Abandonment and Restoration of Sewage Lagoons in Nunavut

Draft Review Report

Prepared for:

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1. REPORT GOALS AND OBJECTIVES

1.1 GENERAL

Lagoons are the predominate form of sewage treatment in northern communities. Lagoons, especially in combination with wetlands have been shown to be the most cost-effective treatment process, and one of a few processes capable of meeting the general conditions of the *Fisheries Act.* The primary disadvantage is the size of the land parcel required, not only for the process itself, but also including the public health set-back requirements.

Many communities are locked between a body of water, and the airport. Pressure for land sees these communities encroach on areas previously used for waste disposal, such as lagoons. If abandonment and reclamation is undertaken properly, there is potential for use of these former sites for development and occupation by the community. In order to do so, a "clean closure[1]" is required.

The Department of Indian Affairs and Northern Development (DIAND) undertook both a review of the Best Available Technology for Sewage Treatment in the North and an in-situ study of wetland sewage treatment performance in Hall Beach, Nunavut in 2003. From these studies, DIAND recognized that existing sewage treatment systems are gradually being replaced with new facilities and/or treatment processes, either for the reason of pressure for land or for other reasons. There arose the need to provide clean closure and long-term management of former sewage containment sites.

Municipalities in Nunavut are currently required, as a condition for their Water Licence to provide plans for sewage lagoon abandonment and reclamation a minimum of six months prior to closure.

This project is to provide a comprehensive reference document that will outline all of the available technologies for undertaking lagoon closure, the regulatory regimes under which lagoon closure occurs and what is entailed technologically, environmentally and financially with various identified closure options. The project segments include:

- Comprehensive review of literature on available sewage lagoon abandonment and reclamation technology options and regulations. This results in a Draft Lagoon A & R Review Document.
- Share the Draft Review Document with stakeholders to engage them in discussion on available options and seek direction on the development of the Lagoon A & R Guidance/Framework Document.

[1] A clean closure allows for the unrestricted use of the land, free from continuing monitoring and reporting to regulatory agencies

- Complete the Final Lagoon A & R Review Document and compile the Draft Lagoon A & R Guidance/Framework Document.

This present report is the Draft Lagoon A & R Review Document including information on the goals and objectives of Lagoon A & R reclamation, technical practices, regulatory requirements in northern and southern communities, identification and financial quantification (using class D cost estimates) of the available reclamation options.

Other details reviewed include management of sludge, sludge facilities and infrastructure, management of lagoon and associated infrastructure, reversible lagoon closures, long-term site monitoring and related issues.

Several agencies in Canada and the United States have published guidelines for the remediation of contaminated sites, and there are various guidelines for the use and disposal of sludge, however, no agency has published a guideline specific to lagoon abandonment and reclamation[2].

Many problems exist with the application of published guidelines and so-called "Southern" technologies in cold climates. Cool ambient temperatures, short warm weather seasons, and the presence of permafrost complicate treatment technologies in the north. Lack of soil and the high cost of transportation increase reclamation costs. Secure storage of large quantities of contaminants is not available in most communities.

For these reasons, there is a need for guidelines which address abandonment and reclamation of sewage lagoons, which this document will address.

1.2 Report Goals and Objectives

The primary goal of this project is to develop a reference document, "Sewage Lagoon Abandonment and Reclamation Guidelines for Nunavut" that will ensure that lagoon abandonment and reclamation in Nunavut takes place in a manner that protects:

- The public's health;
- The environment; and
- The public's purse.

This "Draft Review Report" presents a comprehensive review of the available technology options and regulations for sewage lagoon abandonment and reclamation. The report includes the review of existing lagoon closure practices in northern and southern climates, closure related concepts, evaluation and Class D cost analysis of the available options.

[2] In this document, "reclamation" is synonymous with "restoration".

The draft report provides a basis for further consultation with stakeholders to discuss the available options and seek direction on the development of the Lagoon A & R Guidance/Framework Document to be called "Sewage Lagoon Abandonment and Reclamation Guidelines for Nunavut", a reference document to provide guidance in undertaken Lagoon A & R practices in the Territory of Nunavut.

1.3 TERMINOLOGIES

Sewage sludge is a by-product of a wastewater treatment system consisting of every waste material and bacteria that settle out from the sewage in the process of treatment. It is a very large problem requiring the treatment and disposal of millions of tonnes each year. One of the most economical ways to dispose of sludge is to incorporate it into the land. This has been done for millennia in other countries. However, in industrialized countries, industrial waste is also mixed with domestic sewage. Such a mixture concentrates contaminants in the sewage treatment process.

To improve the public acceptability of this economical form of disposal, in North America sewage sludge has been more recently renamed as, *"biosolids"* or, *"bioresiduals"*. This new terminology suggests that sewage sludge comes mainly from organic matter that is readily treated to compost and applied to land. Sludge from domestic sewage treatment may contain mainly organic matter (human urine and faeces and domestic easily degradable substances, but sludge from industrial sewage may contain additional substances such as heavy metals, radionuclides, PCB's, dioxin and a host of industrial chemicals.

Compost refers to a stabilized organic matter resulting from composting. According to CCME definition, compost is *"A solid mature product resulting from composting, which is a managed process of bio-oxidation of a solid heterogeneous organic substrate including a thermophilic phase."*

1.4 DISCLAIMER

There has been little research on the abandonment and reclamation of sewage lagoons in cold climates. The guidelines and treatment alternatives presented in this document represent the best judgment of the authors based upon the available information. Those using this document as a reference should exercise good engineering judgment in its application. It is expected that these guidelines will be updated from time to time as experience with Nunavut lagoons increases.

2. CLOSURE TECHNICAL PRACTICES AND REGULATIONS

This section produces a review of the sewage lagoon and reclamation technical practices and applicable regulatory regimes in northern and southern climates. Available information are presented below for some Canadian Provinces and Territories, United States and environmental regulatory bodies.

2.1 GOVERNMENT OF CANADA

2.1.1 INDIAN AND NORTHERN AFFAIRS CANADA (DIAND)

DIAND issues land use permits and leases on crown lands to people. It is a requirement by DIAND that individuals manage their sewage residuals according to conditions or standards stipulated by DIAND.

2.2 CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT (CCME)

The Canadian Council of Ministers of the Environment (CCME) assists to coordinate provincial and territorial initiatives wherever possible. The CCME published the "Guideline for Compost Quality, 1996, stipulating the acceptable qualities of different parameters in final compost. At this time, this guideline is being revised and remains unavailable to the public until after the revision. It is not expected that the revision will substantially change the guidelines' requirements. One thing the revision will surely do is to provide guidelines for further trace elements not included in the old guideline. The 1996 CCME guideline is believed to still be relevant in this study.

CCME Guideline classifies compost as Class A or B based on trace element concentrations. Category A compost can be used for all types of applications: on agricultural lands, in residential gardens, in horticultural operations, in nurseries or other enterprises. Category A criteria for trace elements are achievable using source separated municipal solid waste feedstock.

Category B compost has restricted use. Its use may be controlled under provincial or territorial regulations. This compost may require authorization (control) when judged necessary by the provinces or the territories. For Category B compost, the provinces could develop sub-categories according to regional needs.

In CCME guideline, compost quality is determined based on four criteria: maturity, foreign matter, trace elements and pathogens.

Maturity
The maturity of compost is an important characteristic to be considered when evaluating compost quality; immature compost has harmful effects on plant growth. If the product of the composting process is not mature, the term "compost" cannot be used. This is why the term "mature" is included in the definition of compost as it is defined in the normative document. The CCME guideline suggests compost is considered matured if two of the three following criteria are met:

- a C/N ratio < *25;*
- an oxygen uptake < *150* mg O_2/kg volatile solids per hour; and
- a germination and growth test using cress *(Lepidium sativum)* seeds and radish *(Raphanus sativus)* seeds, which demonstrates an absence of phytotoxic effects.

OR

- Compost will not reheat upon standing to greater than 20 ^{0}C above ambient temperature; and
- Compost must be allowed to mature for at least 21 days after the thermophilic phase is completed.

OR

- Reduction of organic matter must be 60 percent by weight; and
- Compost must be allowed to mature for at least 21 days after the thermophilic phase is completed.

OR

- If no other determination of maturity is made, the compost must be cured for a six month period. The state of the curing pile must be conducive to aerobic biological activity. The curing stage begins when the pathogen reduction process is complete and the compost no longer reheats to thermophilic temperatures.

Foreign Matter
In CCME guideline, mineral soils, sand, rocks and wood are not considered to be foreign matter. Both Category A and Category B compost must be virtually free of foreign matter that may cause nuisance, damage or injury to humans, plants or animals, during or resulting from intended use. The compost must not contain any sharp foreign matter measuring over 3 mm in any dimension or any foreign matter greater than *25* mm in any dimension.

Trace Elements
A "trace element" is defined as "*a chemical element present in compost at a very low concentration.*" The CCME guideline identify trace elements that are essential to plant growth in addition to identifying heavy metals which, depending on their concentration in the soil, could be harmful to human health and the environment.

CCME guideline classifies compost to Category A and B based on trace element concentration. Category A trace element concentrations come from the maximum background concentrations derived from the arithmetic mean plus 3 standard deviations of rural and agricultural soils from Alberta, Ontario and Quebec, and from limits established through the British Columbia best achievable approach.

Other issues include the following:

- cumulative application limits ultimately affect long-term soil trace element levels more than product quality standards;
- the no-net degradation and best achievable approach for the product quality are not based on risk assessment; and
- both the no-net degradation and best-achievable criteria ultimately lead to the source- separation on MSW.

The maximum trace element limits in category A and B composts and the maximum cumulative metal additions to soil proposed by the CCME are given in the table below:

The maximum trace element limits in category A and B composts (Source: CCME "Guidelines for Compost Quality", 1996)

Trace Elements*	Category A compost (mg/kg, air-dried mass)	Category B compost (mg/kg, air-dried mass)
Arsenic (As)	13	75
Cadmium (Cd)	3	20
Cobalt (Co)	34	150
Chromium (Cr)	**	**
Copper (Cu)	**	**
Mercury (Hg)	0.8	5
Molybdenum (Mo)	5	20
Nickel (Ni)	62	180
Lead (Pb)	150	500
Selenium (Se)	2	14
Zinc (Zn)	500	1,850

* Other elements, such as boron, manganese, aluminum and iron, may eventually be regulated in certain provinces to accomodate regional and national concerns.
** Chromium and copper are not stated.

The Maximum Cumulative Metal Additions to Soil (**Source: CCME "Guidelines for Compost Quality", 1996)**

Trace Elements*	**(kg/ha)**
Arsenic (As)	15
Cadmium (Cd)	4
Chromium (Cr)	**
Copper (Cu)	**
Mercury (Hg)	1
Molybdenum (Mo)	4
Nickel (Ni)	36
Lead (Pb)	100
Selenium (Se)	2.8
Zinc (Zn)	370

*Other elements, such as boron, maganese, aluminum and iron, may be eventually be regulated in certain provinces to accomodate regional and national concerns.
** Chromium and copper are not stated.

Pathogens
Pathogenic organisms are sometimes present in the feedstocks used to make compost. As a result, the compost may also contain pathogens. To reduce any potential health concerns, treatment processes as well as biological specifications have been identified.

The pathogenic organism content must not exceed the following limits:

- the quantity of faecal coliforms must be < 1,000 Most Probable Number (MPN)/g of total solids calculated on a dry weight basis; and
- there can be no salmonellae present (< 3 MPN/4g total solids).

The CCME has also identified additional process guidelines to be followed to meet pathogen limits. The process choice reflects both the feedstock in addition to the composting method being used.

2.3 NUNAVUT WATER BOARD

The guidelines for the Discharge of Domestic Wastewater in Nunavut[3] provide some guidance on the proper treatment, management, and disposal of sewage sludge. Extracts from the guideline is given below:

General

Sewage sludge may be disposed on the land by incorporating it into the soil, taking into consideration the future land use of the disposal site. Generally, this means compliance with the Guidelines published by Canadian Council of Ministers of the Environment (CCME).
Sewage sludge may not be disposed on the surface of the land.

If unsuitable or undesirable, sewage sludge may be disposed in special cells at the solid waste site, or incinerated.

Only stabilized sludge may be disposed on the land. Stabilized sludge is defined as having a Volatile Suspended Solids to Total Suspended Solids (VSS/TSS) ratio less than 0.6. Sludge may be stabilized by treatment in a landfarm, or other process approved by the Water Board, prior to soil incorporation.

Prohibitions

Sewage sludge may not be disposed on the land:

- if it contains 100 mg/L or higher of any of the substances:

Ammonia sulphide	Maleic anhydride
Benzidine	Methylamine
Benzyl chloride	Potassium Permanganate
Diethylamine	Quinoline
Ethylamine	Strychnine
Ethylenediamine	Tetrachloroethanes

or any of the following substances in a concentration greater than 0.001 mg/L:

- hexachloro-dibenzo-p-dioxins
- pentachloro-dibenzo-p-dioxins
- dichlorobenzodioxinstetrachloro-dibenzo-p-dioxins
- hexachloro-dibenzofuranspentachloro-dibenzofurans

[3] The guidelines for the Discharge of Domestic Wastewater in Nunavut, 2000

- tetrachloro-dibenzofurans

Sewage sludge may be treated to meet these requirements, or held in special cells. Other options may be considered.

Microbiological requirements for Applying Sewage Sludge to the Land

Sewage sludge must meet the following microbiological criteria before it may be land applied: Type1 Sludge may applied to the land for immediate residential / parkland use, or public contact with some restrictions described in Section 7.5.

Type 1 Sludge

Organism	**Maximum Acceptance Concentration**
Faecal Coliform	1000 CFU / gram Total Dry Solids
Salmonella	3 MPN / 4 grams Total Dry Solids
Viruses	1 PFU / 4 grams Total Dry Solids
Helminth ova	1 ova / 4 grams Total Dry Solids

Type 2 Sludge is the minimum level of microbiological reduction for land application. Type 2 sludge is acceptable for immediate use on commercial / industrial land, with some restrictions as described in Section 7.6.

Type 2 Sludge

Organism	**Maximum Acceptance Concentration**
Faecal Coliform	2,000,000 CFU / gram Total Dry Solids

Type 3 Sludge is sewage sludge that does not qualify as Type 1 or Type 2 Sludge and cannot be land applied. Type 3 Sludge may be placed in a solid waste site or landfarm approved by the Water Board.

Application Restrictions for all Land Applied Sewage Sludge

Sewage sludge is not to be applied to flooded, frozen, or snow-covered ground so that the sewage sludge enters wetlands or other waters unless authorized by the Water Board.
Sewage sludge is not to be disposed of on the surface of the land. Sewage sludge must be incorporated into the soil.

Sewage sludge applied to open land shall not be applied at rates above agronomic rates, with the exception of reclamation projects approved by the Water Board.

Sewage sludge shall not be applied if likely to adversely affect a threatened or endangered species. Sewage sludge shall not be applied less than 30 meters from the normal high water mark of any waters, unless otherwise approved the Water Board.

Sewage sludge sold or given away in a bag or other container for application to the land should have either a label affixed to the bag/container, or an information sheet should be provided to the person who receives the sewage sludge. Such an information sheet should provide information on proper use, including the annual whole sludge application rate that does not cause any contamination loading to be exceeded.

Additional Application Restrictions for Type 2 Sludge

Animals shall not graze on a site for 30 days after sewage sludge application.
Public access to land with high potential for public exposure shall be restricted for 1 year after sewage sludge application.

Public access to land with a low potential for public exposure shall be restricted for 30 days after sewage sludge application.

For land which may become residential / parkland or where home gardening or vegetable producing may be practiced, Type 2 sludge shall not be applied to such soils within a ten (10) year period unless microbiological testing shows that Type 1 sludge conditions and all other regulatory requirements are met.

2.4 GOVERNMENT OF NUNAVUT

2.4.1 DEPARTMENT OF ENVIRONMENT

The DOE has no published standards for lagoon A&R. Past practice has been to apply CCME guidelines, in the absence of published Nunavut standards.

2.4.2 DEPARTMENT OF HEALTH AND SOCIAL SERVICES

H&SS has no published standards for lagoon A&R. Every sewage lagoon requires a 450 metre setback in compliance with the *Public Health Regulations*. The Chief Medical Health Officer must approve any relaxation of setback and subsequent land occupancy.

For water quality, the Department relies on the Guidelines for Canadian Recreational Water Quality[4]. These guidelines describe the data collection and acceptance requirements for:

- General requirements;
- Microbiological characteristics
- Nuisance Organisms
- Physical and chemical parameters
- Microbiological Sampling and analysis; and
- Posting of recreational waters

Of interest is the risk (environment health) assessment methodology outlined by these guidelines. While specific criteria are recommended by the guidelines, the extent of information still requires significant professional judgment by the health professions prior to approval. The determination of risk is based on a number of factors, including:

Environmental health assessments

These assessments, which should be undertaken annually, consider:

- The risk of inadequately treated sewage, fecal matter, or chemical substances entering waters, from either a discharge or a spill;
- Knowledge of outfalls which may contain sewage, storm water, or agricultural waste or runoff;
- Physical hazards;
- Seasonal variability of hazards, density of bathers, water temperature, frequency of change or circulation of the water, changes in water depth, and occurrence of algal blooms;
- Fluctuation of water quality with rainfall (wet and dry conditions); and
- A reporting mechanism to ensure that health authorities are informed of any malfunction or change to a municipal, private, or industrial waste treatment facility that may cause deterioration of the water quality of a bathing area.

Epidemiological Evidence

Surveillance for bather illness or injuries should be established, along with a reporting mechanism to inform health authorities. Surveillance should be increased if there are reports of suspected illness or injury. The water quality may be considered impaired as a result of such surveillance.

[4] Guidelines for Canadian Recreational Water Quality, Health and Welfare Canada, 1992.

Indicator Organism Limits

An indicator organism should be chosen by the local health authority in consultation with the laboratory microbiologists for each area. The following organisms are used for routine fresh water monitoring: Escherichia coli, (faecal coliform).

Presence of Pathogens

Tests for pathogenic organisms may be undertaken where there have been reports of illnesses of specific etiology, where there have been illnesses of an undetermined cause, or when levels of an indicator organism demonstrate a continuous suspected hazard. In general, however, the guidelines do not stipulate maximum limits for pathogens.

2.5 GOVERNMENT OF THE NORTHWEST TERRITORIES

2.5.1 MACKENZIE VALLEY LAND AND WATER BOARD (MVLWB)

The MVLWB has no formal data requirements or acceptance standards for lagoon A&R. Until guidelines are developed, the water licence standard clauses would be used to collect data on A&R plans submitted by licence holders. Acceptance standards would be developed on a site-specific basis in consultation with other stakeholders. In making any A&R decision, the MVLWB would rely on current codes of practice, current published standards, and the advise of experts.

2.5.2 MUNICIPAL AND COMMUNITY AFFAIRS (MACA) -- LANDS

MACA Lands division requires that the land is returned to its original condition acceptable to the Commissioner. MACA makes such a broad statement to prevent loopholes in A&R plans and, although this statement is primarily intended toward industrial sites, MACA believes it should apply to sewage sites as well. The broad statement also obviates the requirement for publishing a list of data requirements and allows MACA to request addition information at any time. In accepting any A&R plan, MACA Lands would rely on the advise of experts from RWED, H&SS and the MACA engineers.

2.5.3 DEPARTMENT OF HEALTH AND SOCIAL SERVICES.

Every sewage lagoon requires a 450 metre setback in compliance with the *Public Health Regulations*. While Regional interests are managed by the various Health Boards through their respective Environmental Health Officer, the Chief Medical Health Officer must approve any relaxation of setback and subsequent land occupancy. Currently, the Chief Medical Health Officer is with the Department of Health and Social Services.

For water quality, the Department relies on the Guidelines for Canadian Recreational Water Quality[5]. These guidelines describe the data collection and acceptance requirements for:

- General requirements;
- Microbiological characteristics
- Nuisance Organisms
- Physical and chemical parameters
- Microbiological Sampling and analysis; and
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Of interest is the risk (environment health) assessment methodology outlined by these guidelines. While specific criteria are recommended by the guidelines, the extent of information still requires significant professional judgment by the health professions prior to approval. The determination of risk is based on a number of factors, including:

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These assessments, which should be undertaken annually, consider:

- The risk of inadequately treated sewage, fecal matter, or chemical substances entering waters, from either a discharge or a spill;
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- Seasonal variability of hazards, density of bathers, water temperature, frequency of change or circulation of the water, changes in water depth, and occurrence of algal blooms;
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Presence of Pathogens

Tests for pathogenic organisms may be undertaken where there have been reports of illnesses of specific etiology, where there have been illnesses of an undetermined cause, or when levels of an indicator organism demonstrate a continuous suspected hazard. In general, however, the guidelines do not stipulate maximum limits for pathogens.

2.5.4 DEPARTMENT OF RESOURCES, WILDLIFE AND ECONOMIC DEVELOPMENT (RWED)

RWED, Environmental Protection Service provides the following:

- The intended future land use should be first determined;
- For soil, sewage outfall plains, and wetlands RWED's and CCME Guidelines apply;
- If the site is abandoned without remediation, then RWED still considered it to be a contaminated site;
- Capping without remediation does not constitute remediation;
- There is no distinction between surface and subsurface soils;
- Water bodies are referred to EC, DFO and DIAND;
- Public consultation is a pre-requisite prior to implementation.

RWED's Guideline for Contaminated Sites Remediation provides the following definitions:

Contaminated Site: "Areas of land, water, groundwater, or sediments that have levels of contaminants above the remediation criteria"; and

Remediation: "The management of the contaminant at a site so as to prevent, minimize, or mitigate damage to human health, property, or the environment. Remediation is a broader term than clean-up in that remediation options can include physical actions such as removal, destruction, and containment, as well as the use of institutional controls such as zoning designations or orders".

2.6 GOVERNMENT OF ONTARIO

2.6.1 THE MINISTRY OF ENVIRONMENT AND ENERGY (MINISTRY)

The Ministry of Environment and Energy (ministry) prepared "Guideline for Use at Contaminated Sites in Ontario" June 1996 (revised in February 1997; Appendix revised September 1998) for property owners cleaning up and/or redeveloping contaminated property. Ministry Engineers advise this guideline would apply to sewage lagoons.

The ministry has also prepared three accompanying documents which provide property owners and consultants with additional detailed information on parts of the revised guideline. Following is information taken from the Executive Summary of the guideline.

The Guideline for Use at Contaminated Sites, June 1996, (guideline) replaces the Guidelines for the Decommissioning and Clean-up of Sites in Ontario, February 1989 and the Interim Guidelines for the Assessment and Management of Petroleum Contaminated Sites in Ontario, August 1993 issued by the Ministry of the Environment. The guideline does not change the legislative powers or the regulatory mandate of the ministry. The ministry has a mandate to deal with situations where there is an adverse effect, or the likelihood of an adverse effect, associated with the presence or discharge of a contaminant.

This responsibility stems primarily from administering the Environmental Protection Act (R.S.O. 1990) and the Ontario Water Resources Act (R.S.O. 1990).
The guideline provides advice and information to property owners and consultants to use when assessing the environmental condition of a property, when determining whether or not restoration is required, and in determining the kind of restoration needed to allow continued use or reuse of the site.

The ministry has provided the guideline, along with its supporting documentation, to assist landowners in making decisions on soil and/or groundwater quality for proposed or existing property uses.

Public communication is incorporated into the site restoration process, particularly when a change in land use is involved. The method(s) of public communication will depend on the complexity of the situation and the range of issues involved. The guideline suggests different levels of communication for the range of site restoration approaches.

Approaches to Site Restoration

Three approaches for responding to site contamination are described. These approaches may be used when a decision has been made to remediate or restore a contaminated property. The approaches are: background, generic and site specific risk assessment.

Background approach

The background approach involves use of soil quality criteria to restore the site to ambient or naturally occurring "background" conditions. These background criteria were developed from an Ontario-wide sampling program at rural and urban parks unaffected by local point sources of pollution. If necessary, a proponent may develop background criteria to reflect local conditions by completing a sampling program as outlined in the guideline.

Generic approach

The generic approach involves use of soil and groundwater quality criteria which have been developed to provide protection against the potential for adverse effects to human health, ecological health and the natural environment. The criteria may be applied to agricultural, residential/parkland and industrial/commercial land uses. Criteria are also provided for potable and non-potable groundwater use. The potable criteria ensure that groundwater may be used as a source of drinking water. The non-potable criteria offers protection against vapours from groundwater and to aquatic life in receiving surface water.

Generic soil criteria are provided for two depths of soil restoration and for two soil textures. Full depth restoration involves use of the same generic criteria to the full extent of contamination. When contamination extends deeper than 1.5 m from the surface a stratified restoration using different generic criteria below 1.5 m is an option. The texture of the subsurface material can influence the numerical value of the criteria and criteria values are provided for coarse and fine textured materials for many of the parameters.

Soil and groundwater criteria are provided for an extensive list of parameters. Analysis for all the criteria may not be necessary in all instances. Likewise, soil and groundwater analysis may sometimes be required for parameters not listed in the guideline. The decisions involved in site investigation and parameters for sample analysis are always based on consideration of the specific factors at each property. The generic soil and groundwater criteria may be modified to reflect particular site conditions. This is done through modification of relevant variables in the models and process used to develop the generic criteria. If appropriate, criteria from another jurisdiction may be proposed for use, or new generic criteria may be developed if criteria are not provided for a particular contaminant.

There may be sites where the physical site characteristics, or the ecological characteristics (plants and animals) are very different from those considered in the development of the generic criteria. For example, a potentially sensitive site is one where there may be a rare or endangered species which was not considered in the development of the generic criteria, but which may be affected by site contamination. In such a case, the generic criteria are inappropriate for use and more protective criteria will be needed. There is a range of conditions/situations for which a site may be considered potentially sensitive and an ecological risk assessment may be used to establish protective criteria.

In some cases consultation with other agencies such as the Ministry of Natural Resources or local conservation authority will be required in determining whether the site is a sensitive site.

Site specific risk assessment approach

Site specific risk assessment (SSRA) and risk management are approaches which may be used instead of the background or generic approaches. The SSRA approach does not involve use of existing soil or groundwater quality criteria; rather this approach may be used to establish criteria for a site or a risk-based level of exposure protection. Risk assessment is a scientific technique which estimates the health risk posed to humans, plants, wildlife and the natural environment from exposure to a contaminant.

The principles of risk assessment were used in developing the generic soil and groundwater criteria. Because site specific characteristics are incorporated in a risk assessment, there will be numerical differences between the generic criteria which may apply at a site and those developed through SSRA. The level of health protection provided, however, remains the same as that provided by the generic criteria. Risk management decisions may be made using the results of an SSRA. These decisions may lead to use of equipment or construction techniques to manage, control the movement of, or reduce the concentrations of contaminants over time, independent of or in conjunction with site reuse. When risk management decisions involve use of engineered measures to reduce the levels of risk at a site, the type of monitoring and maintenance required for the technique(s) used and the responsibility for ensuring that it/they continue(s) to operate as designed must be outlined in a risk management plan.

There may be sites where the physical site characteristics, or the ecological characteristics (plants and animals) are very different from those considered in the development of the generic criteria. For example, a potentially sensitive site is one where there may be a rare or endangered species which was not considered in the development of the generic criteria, but which may be affected by site contamination. In such a case, the generic criteria are inappropriate for use and more protective criteria will be needed. There is a range of conditions/situations for which a site may be considered potentially sensitive and an ecological risk assessment may be used to establish protective criteria.

In some cases consultation with other agencies such as the Ministry of Natural Resources or local conservation authority will be required in determining whether the site is a sensitive site.

Ontario uses the *Guidance on Site Specific Risk Assessment for Use at Contaminated Sites in Ontario*[6]. This document applies to all contaminated sites, and can be applied to sewage lagoons. The document has been prepared for the purpose of giving general guidance on conducting both

[6] *Guidance on Site Specific Risk Assessment for Use at Contaminated Sites in Ontario*, published by the Ontario Ministry of Environment and Energy, Standards Development Branch, May, 1996

human health and ecological risk assessments for site clean-ups in Ontario. The document is organized into three parts.

Part 1 is a general introduction to the process of risk assessment. It describes the purpose of this document and the role of risk assessment in the site remediation decision making process often followed in Ontario. It also provides guidance for the selection of a qualified individual or group of individuals for the conduct of site specific risk assessment, and formulates MOEE requirements regarding third party review.

Part 2 provides some general guidance for conducting human health risk assessment for the remediation of contaminated sites in Ontario. It was not intended to be an exhaustive guideline or protocol, but a statement of basic principles and general requirements for Human Health Risk Assessment.

Part 3 provides a basic framework for conducting site specific ecological risk assessments for the remediation of contaminated sites in Ontario. As per Part 2, it is not an exhaustive protocol or methodology, but a statement of principles and direction. Reference is made at the end of Part 3 to sources that give more detailed methodologies for the field user. This document uses concepts and terminology that are consistent with the framework for conducting ecological risk assessments that has been developed by the Canadian Council of Ministers of the Environment (CCME) (CCME, 1996a).

The appendices include:
APPENDIX A Chemical Selection Criteria
APPENDIX B MOEE Human Health Based Toxicity Values
APPENDIX C Calculation of Weighted Average Chronic Daily Intake (CDI)
APPENDIX D Numerical Adjustments for Absorption and Bioavailability
APPENDIX E Upper Concentration Limits for Soil and Water
APPENDIX F Checklist for Reviewers

Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario

This document provides guidance on a wide range of topics related to site assessment, sampling and analytical methods for use in site clean-ups in Ontario.
1. INTRODUCTION AND PURPOSE
2. PHASE 1 ENVIRONMENTAL SITE ASSESSMENTS
3. PHASE 2 ENVIRONMENTAL SITE ASSESSMENTS
4 VERIFICATION
5. SAMPLING METHODS

2.6.2 ONTARIO BIOSOLIDS (SLUDGE) GUIDELINES

The purpose of this document [7] is to facilitate the use of biosolids and other waste materials on agricultural land, while protecting environmental quality, consumer and animal health, food quality and the productivity of the land. These Guidelines are intended to supplement Ontario Regulation 347 under the Environmental Protection Act. The document outlines criteria which must be met before biosolids or other waste materials can be considered for use on agricultural land. In essence, these materials must be of benefit to crop production or soil health and not degrade the natural environment, before approval for use will be given by the Ministry of Environment (MOE). The materials should supply essential plant nutrients and/or organic matter, or other constituents that will maintain crop production or soil health.

Ontario uses the term sewage biosolids to refer to stabilized municipal "sewage sludge" as included in Processed Organic Waste, in Ontario Regulation 347. Hauled sewage (septage) is not included in this category. The term "other wastes" includes materials not defined as sewage biosolids, septage or agricultural waste in Ontario Regulation 347. The term "waste materials" is used frequently in this document and refers to both sewage biosolids and other wastes.

Producers of potentially usable waste materials must obtain approval to spread or apply the material on agricultural land. Once the waste material is judged suitable for land application, a specific site must be approved and receive a Certificate of Approval from the Ministry of Environment for an "Organic Soil Conditioning Site", before the waste material can be spread. The Certificate of Approval allows agricultural land application of waste materials for crop production or ground cover growth. No waste materials within the scope of this document are allowed to be applied to agricultural land unless a Certificate of Approval has been issued.

Before applying any waste to agricultural land, it must be treated in such a manner as to minimize the odour potential and reduce the number of pathogenic organisms and other potentially harmful constituents to an acceptable level.

Sewage Biosolids

All sewage biosolids must be "stabilized" before being spread on agricultural land. MOE approved municipal anaerobic and aerobic digestion processes provide appropriate stabilization. Other stabilization methods will be reviewed on an individual basis. The review will determine the acceptability of the treatment method for use on waste materials intended for land application.

All wastes other than sewage biosolids applied to agricultural land must have an acceptably low potential to generate odours and must contain acceptably low concentrations of organisms pathogenic

[7] Guidelines For The Utilization Of Biosolids And Other Wastes On Agricultural Land March 1996 Ministry of Ministry of Environment Agriculture, Food and Rural Affairs

to humans or animals. As with sewage biosolids, anaerobic and aerobic digestion may be used to stabilize waste and possibly control odours and pathogenic organisms. In general, wastes may be considered as appropriately stabilized, if:

a. Odours after spreading are no more objectionable than those produced from normal farming practices; and

b. The pathogenic content of the wastes is no greater than that of digested sewage biosolids.

Separation Distances

The separation distances required for waste material spreading operations are provided in Table 4 and 5. If lesser distances are approved, these will be specified in the Conditions attached to Certificates of Approval for the site.

Separation From Surface Watercourses

For the purposes of these Guidelines, a surface watercourse is defined as a natural or established watercourse or an open municipal drain along which water flows on a continuous or intermittent basis. In addition, ponds, lakes, springs and wetlands and points of direct access (such as catch-basins for drainage tiles or municipal drains) should be treated as watercourses for purposes of determining separation distance. The minimum distance between the spreading site and a surface watercourse is listed in Table 5. These distances were developed taking into account land slope and soil permeability. When sewage biosolids are applied by methods other than irrigation, the MOE may approve a reduction in separation distances. For example, separation distances may be reduced when:

a. waste materials are injected directly into the soil;
b. materials are spread by surface irrigation and are incorporated when dry and within 24 hours;
c. materials are spread on soils which are described in soil survey reports as "well drained";
d. materials are spread when there are crop residues which will prevent or inhibit precipitation from washing biosolid residues into watercourses;
e. application, soil tillage, and/or cropping patterns follow land contours;
f. there are other local or site factors which inhibit or prevent the transfer of waste material residues into watercourses.

Waste materials should never be applied within 10 metres of any watercourse or body of water. Ministry of Environment staff can advise on separation distances from bodies of water or drainage channels other than surface watercourses as defined above.

Separation From Groundwater

The groundwater table should be greater than 0.9 metres from the soil surface at the time of biosolids or other waste application.

Separation From Bedrock

Sewage and other biosolids may be applied to soils greater than 1.5 metres deep. Shallow soils (1.5 m or less over bedrock) will be evaluated on a case-by-case basis.

Separation From Residences

When sewage biosolids are applied to land close to residences, concerns may arise because of the potential for odours, air-borne drift of particles and surface run-off. The level of concern will depend upon the application method and land slope. Guidance is provided for slopes.

The minimum distances between the spreading site and a residence in a residential area is normally 450 metres. For an individual residence not in a residential area the minimum separation distance is 90 metres. However, when liquid wastes are injected into the soil, or when it is spread by surface irrigation and is incorporated within twenty-four hours, distances may be reduced. In addition, the distance may be reduced by the farmer when he or she is the owner and occupier of the individual residence.

The applicant must provide technical justification for any reduction in the separation distance before the local MOE will render a decision to allow the reduction. The absolute minimum distances for waste material application in all cases are 50 metres from a residence in a residential area, and 25 metres from an individual residence.

Separation From Water Wells

The minimum separation distance between the spreading sites and water wells shall be 15 metres for drilled wells more than 15 metres deep and 90 metres for all other wells, including dug wells.

Biosolids Blending

Two or more batches of sewage biosolids with unacceptable nitrogen to metal ratios or metals content may be blended to form an acceptable sewage biosolid mixture. In such circumstances, proper mixing is essential and periodic testing is required to verify uniform blending.

Criteria for Metal Content in Sewage Biosolids

1	2	3	4	5
	Metals Anaerobic Biosolids		Aerobic, Dewatered and Dried Biosolids and Other Wastes	
	Minimum Ammonium + Nitrate Nitrogen (NH4 + - N + NO3 - - N) to Metal Ratios		Maximum Permissible Metal Concentrations (mg/kg of solids)	
	Present Requirements	Long-term Targets	Present Requirements	Long-term Targets
ARSENIC	100	480	170	35
CADMIUM	500	4200	34	4
COBALT	50	220	340	77
CHROMIUM	6	32	2800	530
COPPER	10	45	1700	380
MERCURY	1500	8400	11	1.4
MOLYBDENUM	180	1700	94	1.2
NICKEL	40	210	420	80
LEAD	15	75	1100	220
SELENIUM	500	2800	34	6
ZINC	4	20	4200	840

a. *Acceptability of biosolids will be judged on the basis of the average concentrations of nitrogen, metals and solids during the preceding 12 months.*
b. All dewatered and dried biosolids must meet the appropriate biosolid criteria before dewatering and drying.
c. The long term targets are based on the assumption that metal additions to soil from waste materials is undesirable and that application rates of metals should be reduced in the future.

Criteria for Metal Content in Soils

1	2	3	4	5	6
Metal	Mean Metal Content in Uncontaminated Ontario Soils a (mg/kg)	Maximum Permissible Metal Content in Soils Receiving Waste Materials a (mg/kg)	Maximum Permissible Metal Addition to Uncontaminated Soil b (kg/ha)	Maximum Permissible Metal Application per 5 years d (kg/ha)	Minimum Number of Years to Reach Max. Recommended Metal Content in Soil b&c
ARSENIC	7	14	14	1.4	50
CADMIUM	0.8	1.6	1.6	0.27	30
COBALT	5	20	30	2.70	55
CHROMIUM	15	120	210	23.3	45
COPPER	25	100	150	13.6	55
MERCURY	0.1	0.5	0.8	0.09	45
MOLYBDENUM	2 4	4	4	0.8	25
NICKEL	16	32	32	3.56	45
LEAD	15	60	90	9.0	50
SELENIUM	0.4	1.6	2.4	0.27	45
ZINC	55	220	330	33.0	50

a. Based on dry weight at 105 o C.
b. Columns 4 and 6 take into account the mean metal content of uncontaminated soils (see column 2). These numbers are examples because most soils are unlikely to have exactly the mean metal contents listed in column 2.
c. Based on anaerobic biosolid applications providing 135 kg/ha of ammonium plus nitrate nitrogen, or aerobic biosolid applications providing 8 tonnes of dry solids per hectare per 5 years, as outlined in these Guidelines. The number of years is rounded to the nearest five. See sample calculation in Figure 4
d. Column 4 divided by column 6 will give metal application for one year. To obtain the figures in column 5 the yearly metal application figures are multiplied by 5.

Sodium Criteria

SUGGESTED ANNUAL SODIUM ADDITION TO ONTARIO SOILS	
Soil Texture	Annual Maximum Sodium Addition (kg/ha)
Sands, sandy loams Organic soils, loams, clay loams and clays	200 500

Note: Higher additions may be acceptable under some conditions.

Separation Distances

Feature	Distance (metres)	Notes
Water Table	0.9	Measured vertically
Bedrock	1.5	Measured vertically
Drilled Wells more than 15 m deep	15	Measured horizontally
All other wells including dug wells	90	Measured horizontally
Individual residences	90	Measured horizontally
Residential areas	450	Measured horizontally

Minimum Separation Distances of Spreading Sites from Watercourses

Maximum Sustained Slope	Soil Permeability	Distance (metres)
0 - 3 %	Rapid to Moderately Rapid	50
	Moderate to Slow	100
3 - 6 %	Rapid to Moderately Rapid	100
	Moderate to Slow	200
6 - 9 %	Rapid to Moderately Rapid	150
	Moderate to Slow	Not Permitted
> 9 %	All Permeabilities	Not Permitted

Notes:
a. Determine soil permeability in accordance with OMAFRA's Drainage Guide for Ontario. Determine the soil type from County Soil Maps, also available from OMAFRA.
b. Spreading must be suspended when run-off is expected. The spreading of fluid waste is not normally permitted when soils are frozen.

Spreading Restrictions Related to Public Health and Pathogens

Crop	Waiting Period After Application
Hay and Haylage	3 weeks before harvest
Pasture for horses, beef or dairy cattle	2 months before grazing
Pasture for swine, sheep or goats	6 months before grazing
Commercial Sod	12 months before harvest
Small fruits	15 months before harvest
Tree Fruits and grapes	3 months before harvest
Vegetables	12 months before harvest
Tobacco	Application not recommended
Home lawns and gardens	Application not recommended
Golf Courses and recreational land	Application recommended only if stabilization additional to digestion is used to reduce pathogenic content.
Some of these restrictions may be lifted for those wastes not containing pathogens. However, wastes other than sewage biosolids will be evaluated on a case-by-case basis.	

2.7 GOVERNMENT OF ALBERTA

2.7.1 ALBERTA ENVIRONMENT – LAND RECLAMATION

Alberta does not have any abandonment and reclamation guidelines specific to sewage lagoons. The Land Reclamation Division, Field Operation Manual, 1990, does provide some guidance: The basic reclamation procedure is called surface spreading and involves bringing the organic matter or sludge from the bottom of the lagoon to the surface where it is incorporated into the upper most 0.3 metres of soil. This process circumvents some of the problems encountered in burying sludge, such as subsidence and the generation of noxious gases.

The first step is to determine if the water meets the minimum requirements for discharge. If the water meets the requirements the contents are discharged using the existing mechanism. Any water remaining could be pumped out or the berm breached. The lagoon must be emptied without releasing any of the sludge…

The reclamation procedure may change if heavy metals or organics are found in the sludge. The sump is then squeezed to remove the water and the sludge allowed to dry. Once dry it is incorporated into the top layer of soil, and re-seeded.

2.7.2 APPLICATION OF MUNICIPAL WASTEWATER SLUDGES TO AGRICULTURAL LANDS GUIDELINES

Alberta's regulatory expectation of land treatment[8] is maintenance, and preferably enhancement, of the quality of the soil-plant system with minimal risk to human health and other environmental receptors. The intent of land treatment of sludges (biosolids) is to use the soil-plant system to degrade, assimilate, and immobilize waste constituents and waste transformational products. Although unstated as such, Alberta uses a mass balance approach along with crop use and other factors to determine the appropriate application rates. Acceptable criteria are provided in following tables.

Sludge application is restricted to lands intended for the production of forages, oil seed, small grains, dried legumes, trees, and commercial sod. Direct grazing is not recommended for three years following application. Sludge should not be applied to lands that may be grazed by dairy cattle or used to grow roots crops or crops that may be eaten raw.

Minimum Acceptable Ratios of Nitrogen and Phosphorus to Metals

	Cd	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Nitrogen (Organic + Nitrate + Ammonium)	1,500	20	15	3,000	100	20	10
Or[1]							
Phosphorus (Total)	600	8.0	6.0	1,100	40	8.0	4.0

[1] Biosolids is unacceptable if either nitrogen or phosphorus criterion is not met. Spiking biosolids with nitrogen or phosphorus to achieve these results is not permitted.

[8] Alberta Environment(b). Guidelines for the application of municipal wastewater sludges to agricultural lands, December, 2001.

Additional Application Restrictions

FEATURE	MINIMUM DISTANCE[1] (m)	
	Surface Application	Subsurface Injection
Rivers[2], Canals[2], Creeks[2], Intermittent Drainage Courses, Lakes, Sloughs, Dugouts	30	10
Water Wells	20	20
Areas Zoned Residential or Devoted to Urban Use	500	165
Occupied Dwellings	60	20
Public building Perimeters	10	3
Public Buildings	60	20
School Yard Boundaries (School in Session – September to June, inclusive)	200	66
School Yard Boundaries (School not in sessions – most of July and August)	20	7
Cemeteries, Playgrounds, Parks, Campgrounds	200	66

[1] Greater separation distances may be required based on local topographic and climactic conditions.
[2] Distances required are from the major break in slope.

2.8 USA (USEPA)

The U.S. Environmental Protection Agency has been in the process of developing comprehensive federal sewage sludge (biosolids) use and disposal regulations for many years. The proposed regulation was published for public comment on February 6, 1989, and in final form in the Federal Register on February 19, 1993 (58 FR [32]:9248-9415).

The final regulation is organized into the following subparts: general provisions; land application; surface disposal; pathogens and vector attraction reduction; and incineration.

Subparts addressing standards for land application, surface disposal and incineration practices consist of sections covering: applicability and special definitions; general requirements; pollutant limits; operational standards; management practices; frequency of monitoring, recordkeeping, and reporting requirements.

2.8.1 EPA Regulations Concerning the Disposal and Use of Biosolids[9]

The Office of Wastewater Management's (OWM's) National Biosolids Management Program promotes the beneficial recycling of biosolids and regulates biosolids that are used or disposed of through land application, surface disposal, or incineration. Wastewater residuals (formerly sewage sludge) would not be known as biosolids unless they have been treated so that they can be beneficially used.

> The long term practice of recycling biosolids has been subjected to more than 30 years of intensive careful study. As a result of research and practice showing the safety of biosolids recycling, the U.S. Department of Agriculture, the Food and Drug Administration and EPA issued a joint policy statement in 1981 that endorsed the use of biosolids on land for producing fruits and vegetables.
>
> Then, in 1984, EPA issued a policy statement in the Federal Register that encouraged and endorsed the recycling of biosolids. And again in 1991, EPA was a co-endorser of an Interagency Policy placed in the Federal Register regarding the benefits of using biosolids. The Federal rule that governs the use of biosolids today is based upon comprehensive science- based risk assessments and many rounds of extensive review and took seven years to complete.
>
> Additional confirmation of the validity of the Federal biosolids rule and the Federal policy that promotes the beneficial recycling of biosolids is the careful three-year review of by the prestigious National Research Council of the National Academy of Science which took place after the promulgation of the rule. The NCR concluded in their 1996 report that the use of biosolids in accordance with existing Federal guidelines and regulations, presents negligible risk to the consumer, to crop production, and to the environment.

General Requirements

The regulation establishes two levels of sewage sludge quality with respect to heavy metal concentrations--pollutant Ceiling Concentrations and Pollutant Concentrations ("high quality" sewage sludge); and two levels of quality with respect to pathogen densities--Class A and Class B; and two types of approaches for meeting vector attraction reduction--sewage sludge processing or the use of physical barriers. Under the Part 503 regulation, fewer restrictions are imposed on the use of higher quality sewage sludge.

To qualify for land application, sewage sludge or material derived from sewage sludge must meet at least the pollutant Ceiling Concentrations, Class B requirements for pathogens and vector attraction

[9] EPA, Biosolids Management Handbook - Summary Of 40 Cfr Part 503 Standards For The Use Or Disposal Of Sewage Sludge, 1999

reduction requirements. Cumulative Pollutant Loading Rates are imposed on sewage sludge that meet the pollutant Ceiling Concentrations but not the Pollutant Concentrations. A number of general requirements and management practices apply to sewage sludge that is land applied unless it meets three criteria for "Exceptional Quality"--sewage sludge or derived material which meet the Pollutant Concentration limits, Class A pathogen requirements, and vector attraction reduction sewage sludge processing. However, in all cases the minimum frequency of monitoring, record keeping, and reporting requirements must be met.

Pollutant Limits for Land Application

Land Application Pollutant Limits (all limits are on dry weight basis)

Table in 503 Rule	Table #1	Table #2	Table #3	Table #4
Pollutant	Ceiling Concentration Limits* (mg/kg)	Cumulative Pollutant Loading Rates (kg/ha)	"High Quality" Pollutant Concentration Limits** (mg/kg)	Annual Pollutant Loading Rates (kg/ha/yr)
Arsenic	75	41	41	2.0
Cadmium	85	39	39	1.9
Copper	4,300	1,500	1,500	75
Lead	840	300	300	15
Mercury	57	17	17	0.85
Molybdenum	75	—	—	—
Nickel	420	420	420	21
Selenium	100	100	100	5.0
Zinc	7,500	2,800	2,800	140

* absolute values
** monthly averages

To be land applied, bulk sewage sludge must meet the pollutant Ceiling Concentrations <u>and</u> Cumulative Pollutant Loading Rates <u>or</u> Pollutant Concentration limits. Note that these requirements are based on a mass balance approach using the assimilative capacity of the land and the crop material.

Bulk sewage sludge applied to lawns and home gardens must meet the Pollutant Concentration limits. Sewage sludge sold or given away in bags or other containers must meet the Pollutant Concentration limits <u>or</u> meet the Ceiling Concentrations and be applied at an annual sewage sludge product application rate that is based on the Annual Pollutant Loading Rates.

Microbiological Considerations

During the research for this project, none of the provincial agencies had microbiological standards. Health Canada was contacted for guidance and recommended using the EPA guidelines. Agriculture Canada, and Environment Canada did not provide further guidance.

The Class A Sludge applied to land for residential use, public contact or agricultural are:

Class A Sludge

Organism	Maximum Acceptance Concentration
Faecal Coliform	1000 CFU / grams Total Dry Solids
Salmonella	3 MPN / 4 grams Total Dry Solids
Viruses	1 PFU / 4 grams Total Dry Solids
Helminth ova	1 ova / 4 grams Total Dry Solids

Class B is the minimum level of pathogen reduction for land application and surface disposal. The only exception to achieving at least Class B occurs when sewage sludge is placed in a surface disposal unit that is covered daily.

Class B Sludge

Organism	Maximum Acceptance Concentration
Faecal Coliform	2,000,000 CFU / gram Total Dry Solids

Sewage sludge that does not qualify as Class B cannot be land applied.

2.8.2 EPA MANAGEMENT PRACTICES

Bulk sewage sludge shall not be applied to flooded, frozen or snow-covered ground so that the sewage sludge enters wetlands or other waters of the U.S. unless authorized by the permitting authority.

1) Bulk sewage sludge shall not be applied at rates above agronomic rates, with the exception of reclamation projects when authorized by the permitting authority.
2) Bulk sewage sludge shall not be applied if likely to adversely affect a threatened or endangered species.
3) Bulk sewage sludge shall not be applied less than **10 meters** from waters of the U.S., unless authorized by the permitting authority.

4) Sewage sludge sold or given away in a bag or other container shall have either a label affixed to the bag/ container, or an information sheet shall be provided to the person who receives the sewage sludge for application to the land that provides information on proper use, including the annual whole sludge application rate that does not cause any of the annual pollutant loading rates to be exceeded.

Furthermore, when sewage sludge that meets Class B pathogen reduction requirements, but not Class A, is applied to the land, the following site restrictions have to be met:

1) Food crops with harvested parts that touch the sewage sludge/soil mixture (such as melons, cucumbers, squash, etc.) shall not be harvested for **14 months** after application.
2) Food crops with harvested parts below the soil surface (root crops such as potatoes, carrots, radishes) shall not be harvested for **20 months** after application if the sewage sludge is not incorporated for at least 4 months.
3) Food crops with harvested parts below the soil surface (root corps such as potatoes, carrots, radishes) shall not be harvested for **38 months** after application if the sewage sludge is incorporated in less than 4 months.
4) Food crops, feed crops, and fiber crops shall not be harvested for **30 days** after sewage sludge application.
5) Animals shall not be grazed on a site for **30 days** after sewage sludge application.
6) Turf shall not be harvested for **1 year** after sewage sludge application if the turf is placed on land with a high potential for public exposure or a lawn, unless otherwise specified by the permitting authority.
7) Public access to land with high potential for public exposure shall be restricted for **1 year** after sewage sludge application.
8) Public access to land with a low potential for public exposure shall be restricted for **30 days** after sewage sludge application.

2.8.3 THE STATE OF ALASKA

The available information on Alaska[10] suggests that there is not any guidance specific to the abandonment and restoration of sewage lagoons. It is a site specific issue. There is no current updates to the technical practices.

Previously at a DEW Line site that apparently had not been operated for the past 5 years the following was approved:

- A general permit to pump out the wastewater and dispose of it to the tundra.
- Samples required for faecals and hydrocarbons.

[10] McGee, Peter, Dec. 17, 1998. Pers. Com. Alaska Environment

- Remove the sludge and dispose of it properly. Land filling with lime treatment if pathogens appear to be a concern;
- The disposal of the sludge could probably take place in the lagoon itself, but as this one was on a gravel pad, the sludge was removed. Then the dikes were pushed in, the cell leveled and a little topsoil added and then re-seeded.

Nutrients were not considered to be a problem for a summer time tundra discharge. In 1993 the Department of Health and Human Services provided guidance as follows:

- If the waste is organic domestic waste created by a small community, a natural process will reduce the waste to an inert debris over a period of time. The lagoon input needs to be stopped and the site isolated for a few years. Inert solids (plastics) may remain or be removed as desired. In time the lagoon could be returned to a natural lake or component of a park with some normal precautions on water contact.
- If the initial evaluation indicates that the lagoon contains chemical, industrial, or hazardous wastes, a different approach is required to the disposal of the facility. Procedures are available to encapsulate, or remove these wastes for disposal at a prepared facility. Future use of the site depends on the wastes encountered and the degree of clean up completed. The USEPA Super Fund Program provides guidance on this approach.
- For Honey Bay wastes – these wastes will be substantially treated by natural decomposition and could then either be removed or encapsulated. Permafrost aggradations may be a consideration in encapsulation.

3. LAGOON RECALAMATION OPTIONS

3.1 GENERAL

The processes involved in full scale Sewage Lagoon Reclamation include:

- Abandonment
- Pumping out (emptying) the lagoon content
- Biosolids Handling (Preparation) and Disposal
- Site Restoration

These processes must comply with all existing regulations regarding sewage lagoon abandonment and reclamation, biosolids quality requirements for intended future use of the in-situ or the ex-situ site and other applicable land regulations.

A reclamation strategy could be *in-situ* – all processes taken place on site or *ex-situ*- some of the processes (e.g. biosolids handling and disposal) taken place off-site.

This section discusses procedures for abandonment and available reclamation technologies. Some of the remediation technologies (particularly ex-situ) focus mainly on biosolids management aspect. A more detailed discussion on biosolids management is contained in section 5.0.

Reclamation options in common use in Canadian provinces and territories and United States are discussed under section 3.3.

3.2 ABANDONMENT

3.2.1 GENERAL

The *Public Health Act* requires a 450 metre set-back from all sewage treatment sites. Soil quality criteria dictate land uses categories.

Webster's Dictionary defines "abandon" as: *v.t.*-- give up; leave; forsake; or cast away.
An unremediated sewage lagoon provides an on-going source of pollution and represents a contaminated site. As such, no government regulatory agency would permit an owner to simply "walk away" from an unremediated sewage lagoon; set-backs and land use restrictions would still apply.

Webster's also defines abandon as: *n.* -- freedom from restraint. In achieving "freedom from restraint", an owner abandoning a sewage lagoon would be seeking relaxation and/or removal of the *Public Health* set-back, and/or unrestricted land use options. In order to achieve such a condition, the owner would have to prove to the appropriate regulatory agencies that the site no longer posed and environmental or public health risk.

There are thee basic scenarios which provide some freedom from restraint:

The *Public Health* set-back is relaxed, the lagoon remains;
The *Public Health* set-back is removed, the lagoon reclaimed; and
The *Public Health* set-back is removed, the lagoon is removed or in-filled to a desired land use category.

3.2.2 THE LAGOON REMAINS, THE PUBLIC HEALTH SET-BACK IS RELAXED

In this case, the lagoon may have undergone some reclamation activity; however, it is not fully reclaimed. The following conditions may exist:

- The sludge remains and is stable but unacceptably contaminated. However, it is not a point source of downstream pollution;
- The sludge remains but does not pose a significant risk to the public's health with respect to microbiological considerations. Perhaps casual contact may be permissible;
- Surface water discharges meet acceptable criteria for contact recreation;
- Adjacent land is of acceptable quality for the desired land use; and/or
- The site has some redeeming ecological characteristics, such as a site where rare birds may be found.

If the adjacent land is of acceptable quality, regulatory authorities may relax the set-back to allow for occupation of the land. Depending on the quality of the remaining sewage lagoon, barriers and signage may be required.

3.2.3 THE LAGOON IS RECLAIMED, THE PUBLIC HEALTH SET-BACK IS REMOVED

In this case the lagoon has been reclaimed through some method. The following conditions should exist:

- The sludge remains and is stable, or has been removed from the site;
- The lagoon bottom sediments meet appropriate soil quality criteria for the intended land use;
- The lagoon bottom sediments do not pose a risk to the public's health with respect to microbiological considerations. Recreational contact is permissible; and
- Surface water discharges meet acceptable criteria for contact recreation; and
- Adjacent lands are of an acceptable quality for the intended use.

If these conditions are met, notwithstanding any other required by the regulators or as a result of public consultation, regulatory authorities should remove the set-back to allow for occupation of the land and contact recreation. Depending on the situation, public health signage may be still required.

3.2.4 THE LAGOON IS REMOVED OR IN-FILLED TO A DESIRED LAND USE CATEGORY, THE PUBLIC HEALTH SET-BACK IS REMOVED.

In this case the lagoon has been reclaimed through some method. The following conditions should exist:

- The sludge remains and is stable, or has been removed from the site;
- The lagoon bottom sediments meet appropriate soil quality criteria for the intended land use;
- The lagoon bottom sediments do not pose a risk to the public's health with respect to microbiological considerations. Recreational contact is permissible; and
- Surface water discharges meet acceptable criteria for contact recreation; and
- Adjacent lands are of an acceptable quality for the intended use.

If these conditions are met, notwithstanding any other required by the regulators or as a result of public consultation, regulatory authorities should remove the set-back to allow for in-filling of the property and its subsequent occupation.

3.3 LAGOON RECLAMATION

3.3.1 GENERAL

Webster's Dictionary defines "reclamation" as *noun-*

--- T*he act or process of reclaiming (recall from wrong or improper conduct; rescue from an undesirable state; make available for human use by changing natural conditions; obtain from a waste product or by-product*).

--- *Restoration to use*

--- *Rehabilitation*

--- *Reformation*

Sewage Lagoon Reclamation is therefore the act or process of reclaiming, rehabilitating or restoring to use a land property that have previously been used for sewage treatment and is now abandoned. An abandoned sewage lagoon left unremediated constitutes an on-going source of pollution and represents a contaminated site.

3.3.2 RECLAMATION PLANNING

Reclamation planning should follow a process shown in Figure 3.1.

First, public consultation and land use planning determine the future requirement for the land. At the same time the sewage lagoon and, where a wetland, overland flow, or drainage channel is used, its discharge area is assessed and characterized. Future land use requirements and the site assimilative capacity will dictate the selection of reclamation criteria. Other factors including wildlife interactions should be included in this analysis.

The selection of reclamation criteria then determines the selection of reclamation technology. Although it could take place at any point throughout the process, regulatory consultation must take place at this point to obtain the necessary and appropriate approvals.

During the reclamation process which follows, monitoring is undertaken to ensure that the reclamation is obtaining the desired results; that contaminants are not be mobilized during the process to migrate off-site; and that the reclamation activities are not causing damage. Regulatory reporting may be a component of the monitoring program.

Prior to the relaxation or removal of public health setbacks, and the approval from the appropriate regulatory agencies for the new use of the reclaimed area, a report detailing the reclamation activities and an environmental assessment which verifies the quality of the property must be prepared. The report must be provided to the regulatory agency and also remain with the property to facilitate future property transfers.

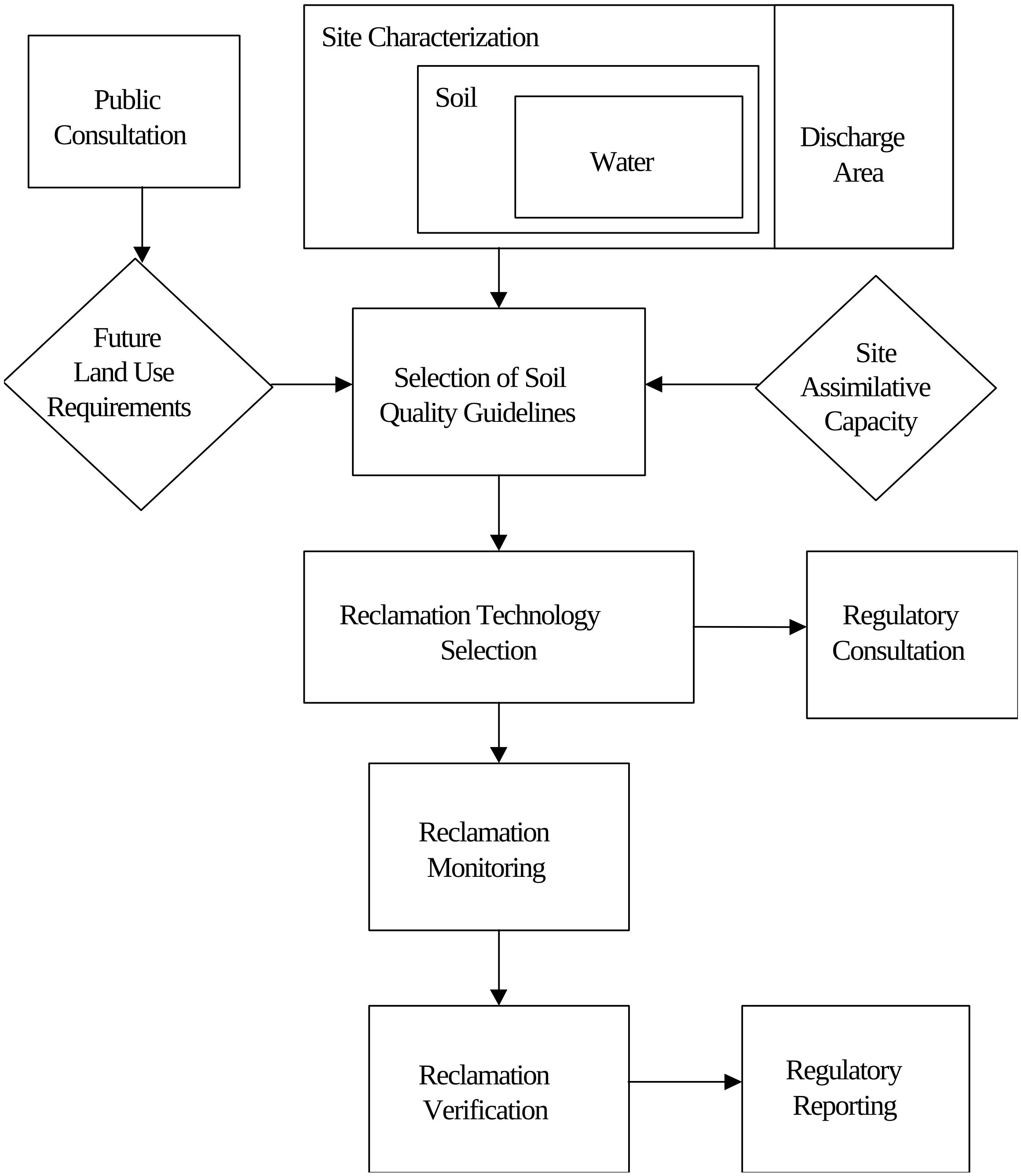

Figure 3.1 - Reclamation Planning Flowchart

3.4 AVAILABLE RECLAMATION OPTIONS

3.4.1 NATURAL PROCESSES

Permafrost Encapsulation

Depending on the depth of soil, and the location of the lagoon, once water is no longer introduced to, or moves through a site, ground temperature fluctuations may stabilize. In permafrost regions, permafrost may aggrade into the site, encapsulating the waste. This is not a treatment process, but one of risk management, as the site remains contaminated. Permafrost encapsulation may only be appropriate for contaminated soils below the active layer. Sewage lagoons may not provide such a site.

Natural Biological Degradation

In the NWT, natural biological degradation is primarily limited by temperature. Lagoon sludges tend to accumulate in lagoons, therefore, natural biological activity is not conducive to natural remediation. Unless brought to the surface and exposed to a warm environment, lagoon sludges tend to remain with low biological activity and retain a high organic content. Heavy metal, and most organic contaminants are not treated and may become concentrated in the stabilization process.

A high organic content in the sludge provides the potential for pH fluctuations, thus, increasing the potential for mobilizing metals. Natural processes will, over time, reduce pathogenic organisms to acceptable levels. Depending on the type and extent of contamination, natural processes should be considered primarily for risk management.

3.4.2 MECHANICALLY ASSISTED PROCESSES

Landfarming (Composting)

Landfarming, the spreading of sludge on land and incorporation into the upper soil horizon, is a method for the disposal of sludges of appropriate quality. The reader is referred to Ontario, Alberta, and USEPA regulatory information in Section 4 for information on acceptable treatment and disposal. The NWT does not have criteria for landfarming sludges.

Freeze Thaw Conditioning[11,12]

Freeze-thaw conditioning is a sludge treatment process where the liquid sludge is placed on sand drying beds and allowed to freeze. The process conditions the sludge to produce a one that is readily dewaterable and of a reduced volume (a result of the lost water from the matrix).

The process is appropriate for sludges that are to be removed to an alternate site for further treatment and disposal. It is also appropriate for dewatering stabilized sludges from mechanical treatment processes.

Freeze-thaw conditioning will occur naturally where soils are landfarmed. To use this process in suitable locations in the NWT, lagoon effluent should be discharged and the water excluded from the site. The sludge would freeze and could be left over the winter and removed either the next summer, or the next winter once it froze again.

Variables in the process are the depth of volume to be frozen and the ambient and ground temperature. The freeze-thaw conditioning does not provide pathogen destruction. The filtrate quality from the sludge is three to six times poorer than raw wastewater and must be treated and disinfected.

Incineration

Sludge incineration is widely practiced. Considerations would include access to an incinerator, fuel costs, stack gas emissions, clinker disposal. This is unlikely to be an appropriate method in the NWT in the near future.

Other thermal methods are available for soil treatment but not applicable to sewage sludges include:

- Fluidized Bed;
- Rotary Kiln;
- Infrared;
- Pyrolysis.

Biological Oxidation by Aeration

Mechanical surface aerators, or subsurface bubblers, could be used to suspend sludges in the water column for biological treatment. The process can be used on-site, and is appropriate for biodegradable organic compounds. It will stabilize the sludge, thus, reducing the potential for

[11] Rush, R. J. and A. R. Stickney. Natural freeze-thaw sewage sludge conditioning and dewatering. Training and Technology Division (Water), Environmental Protection Service. Environment Canada, Ottawa, Ontario. Project No. EPS 4-wp-70-1.
[12] Schneiter, R. W., E. J. Middlebrooks, R. S. Sletten, and S. W. Reed. Accumulation , characterization, and stabiliztion of sludges for cold regions. US Army Corps of Engineers, Special Report 84-4, April 1984.

remobilization of metals. Such process has been piloted successfully in the NWT[13], and used widely elsewhere.

The process is temperature dependant, and limited to the water temperatures above 5^{o}C. It may take several seasons to successful treat all the sludge in a lagoon. Electrical costs will be a consideration in the selection of this process. Odours and noxious gases may be produced during the first stages of remediation.

Biological Oxidation by Oxygen Aeration and Injection of Aerobic Bacteria (Enzyme Addition)

This method is similar to the previous except that specialized aerobic bacteria are introduced and a continuous source of oxygen is provided to the bacteria. The reaction rates are relatively fast and production of odour and noxious gasses is minimized.

The reduced time for such an alternative would have to be considered against the extra cost.

Biological Oxidation by Anoxic Bacteria

Specialized anoxic bacteria could be introduced into the sludges which would reduce the organic matter by oxidation. The bacteria would flourish as long as sufficient food in the form of organic sludges was available.

The process is temperature dependant and would not be effective as an on-site treatment method in the NWT. Sludges would have to be removed to a treatment facility where appropriate temperatures could be maintained. Odour, noxious gas, and methane gas generation would be a consideration. Heavy metals would be further concentrated.

Aquatic and Emergent Vegetation for Sludge Treatment

Aquatic and emergent plant growth during summer months will result in an uptake of organic matter and heavy metals from the lake bed sludges. As the plants die and decompose in the fall the organic matter and metals will be re-deposited in the lagoon resulting in the same general chemistry parameters as found in the lake bed in the spring.

It may be possible to use the aquatic growth to reduce the organic content of the lakebed by harvesting the plants in the early fall over a number of seasons. The process may be lengthy. Costs may be offset by using the harvested materials as animal feed.

Mechanical harvesting of the plants will be a consideration. The level of organic material reduction or metals removal cannot be predicted with any degree of accuracy. The plant material may become toxic requiring special handling and disposal.

Other Mechanically Assisted Methods

Other methods are available for soil treatment but not applicable to sewage sludges include:

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[13] Niven Lake Pilot Restoration Study, FSC, 1991.

- Cement solidification;
- Glassification/vitrification;
- Lime solidification;
- Thermoplastic microencapsulation.

3.4.3 CHEMICAL PROCESSES

Remediation of soils using chemical processes is a complex and extensive subject. There are potentially thousands of chemicals which could constitute a contaminant and many potential treatment trains. Technology in this area is evolving rapidly, as the number of new chemicals which are produced grows.

Oxidation by Injection of Hydrogen Peroxide

Oxidation of the organic sludges and heavy metals can be induced by the injection of hydrogen peroxide within the organic sludge blanket. This could result in stabilization of the sludges and heavy metals, disinfection of pathogenic organisms, and may also result in the destruction of some forms of organic contaminants. This is an unlikely on-site process.

This method may not be appropriate in the NWT as there is insufficient data at this time to determine injection rates and long term stability of the sludges. There are significant cost implications.

Soil Flushing

Soil flushing is an on-site treatment method for the removal of volatile organics and toxic metals. Soil is flushed with the use of water, steam, or solvents. The process requires the collection and containment of leachate and groundwater to prevent down stream contamination. The method appears inappropriate for the NWT at first glance, however, if there is no other way to abandon and reclaim a required area, it must be considered.

Soil Washing

Soil washing is a method for the treatment of hydrocarbon and insoluble chemical contaminated soils. Soil washing may be only method currently available to treat inorganic contaminates. This method involves the treatment of contaminated soils by chemical means, such as a surfactant, in conjunction with mechanical agitation. The concept involves literally washing the contaminates from the soil using specially designed equipment. Of concern is disposal of the concentrated residuals.

As with soil flushing, the method appears inappropriate for the NWT at first glance, however, if there is no other way to abandon and reclaim a required area, it must be considered.

Other Chemical Methods

Other methods are available for soil treatment but not applicable to sewage sludges due to the high organic carbon content include:

- Low temperature thermal stripping;
- Glycolate dechlorination;
- Neutralization;
- Photolysis;
- Precipitation;
- Reduction;
- Carbon adsorption;
- Ion exchange.

3.4.4 SUMMARY OF TREATMENT METHODS

Method	Characteristics	Limitations	Application
Permafrost Encapsulation	**Location:** On-site **Function:** Storage of sludge **Possible Residuals/ Transformation Products:** None	Depth of permafrost Frequency of permafrost Depth of active layer	Soils Risk Management
Natural Biological Degradation	**Location:** On-site **Function:** Treatment of water and soils for organic carbon, some hydrocarbons. Sludge stabilization. **resideals/ Transformation Products:** concentration of toxic metals and organics (eg. PCB)	Temperature dependant: may only occur in most southerly regions.	Water, Soils Generic, Background, Risk Management
Landfarming	**Location:** on-site or off site **Function:** Treatment of soils for organic carbon, some hydrocarbons. Sludge stabilization. Plant uptake will reduce nutrient concentrations. **Residuals/Transformation Products:** none	Temperature dependant. Highly permeable soils may be subject to groundwater contamination.	Soils Generic, Background, Risk Management
Freeze Thaw Conditioning	**Location:** on-site **Function:** sludge volume reduction **Residuals/Transformation Products:** none	Liquids generated during the freeze-thaw process require treatment and disinfection	Soils Risk Management
Incineration	**Location:** off-site (in plant) **Function:** sludge treatment and volume reduction **Residuals/Transformation Products:** toxic metals in clinker and stack gas	Access to an incinerator, fuel costs, stack gas emissions, clinker disposal. Water in matrix raises costs.	Soils Generic, Background.
Biological Oxidation by Aeration	**Location:** on-site **Function:** Treatment of water and soils for organic carbon, some hydrocarbons. Sludge stabilization. Nutrient reduction. **Residuals/Transformation Products:** Gases	Capital costs, electrical costs. Temperature dependant. May not occur in one season. Odours and noxious gases may be produced during the first stages of remediation.	Water, Soils Generic, Background, Risk Management
Biological Oxidation by Oxygen Aeration and Injection of Aerobic Bacteria	**Location:** on-site **Function:** Treatment of water and soils for organic carbon, some hydrocarbons. Sludge stabilization **Residuals/Transformation Products:** gases	Capital costs, electrical costs. Temperature dependant. May not occur in one season. Odours and noxious gases may be produced during the first stages of remediation.	Water, Soils Generic, Background, Risk Management

Biological Oxidation by Anoxic Bacteria	**Location:** on-site or off-site **Function:** Treatment of soils for organic carbon, some hydrocarbons. Sludge stabilization **Possible Residuals/ Transformation Products:** H_2S, CH_4	Capital costs, electrical costs. Temperature dependant. May not occur in one season. Odours and noxious gases will be produced.	Soils Generic, Background, Risk Management
Aquatic and Emergent Vegetation for Sludge Treatment	**Location:** on-site **Function:** Treatment of soils for organic carbon, some hydrocarbons. Sludge stabilization, metals uptake. **Possible Residuals/ Transformation Products:** none	Plant harvesting, disposal of vegetation, unknown kinetics, potential phytotoxicity	Soils Generic, Background, Risk Management
Oxidation by Injection of Hydrogen Peroxide	**Location:** on-site **Function:** Treatment of water and soils for organic carbon, hydrocarbons, microbiological considerations. **Possible Residuals/ Transformation Products:** some oxidized organics many be toxic	Soil permeability, requires containment of leachate and groundwater. Costs a factor. Does not stabilize sludge. High organic soils may be unsuitable.	Water, Soils Generic, Background, Risk Management
Soil Flushing	**Location:** on-site **Function:** Treatment of soils for hydrocarbons and metals. **Possible Residuals/ Transformation Products:** extracted materials, flushing mix.	Soil permeability, requires containment of leachate and groundwater. Costs a factor. Does not stabilize sludge. High organic soils may be unsuitable.	Soils Generic, Background, Risk Management
Soil Washing	**Location:** off-site **Function:** Treatment of soils for hydrocarbons and metals. **Possible Residuals/ Transformation Products:** extracted materials, flushing mix.	Requires treatment train, poor treatability of washing fluid, high toxicity of washing fluid. Costs a factor. Does not stabilize sludge. High organic soils may be unsuitable.	Soils Generic, Background, Risk Management

3.5 COMMON SLUDGE DISPOSAL PRACTCES IN CANADIAN PROVINCES

Some of the sludge disposal options in common use in Canadian provinces and Territories and the United States are:

- Land Farming
- Landfilling
- Surface Spreading
- Sludge Preparation + Incineration

3.5.1 LANDFARMING

Land farming is a full-scale bioremediation technology in which contaminated soils, sediments, or sludges are turned over (i.e., tilled) and allowed to interact with the soil and climate at the site. The waste, soil, climate, and biological activity interact dynamically as a system to degrade, transform, and immobilize waste constituents. Wastes are periodically tilled to aerate the waste.

Soil conditions are often controlled to optimize the rate of contaminant degradation. Conditions normally controlled include:

- Moisture content (usually by irrigation or spraying).
- Aeration (by tilling the soil at a predetermined frequency, the soil is mixed and aerated).
- pH (buffered near neutral pH by adding crushed limestone or agricultural lime).
- Other amendments (e.g., Soil bulking agents, nutrients, etc.).

A Landfarming site must be managed properly to prevent both on-site and off-site problems with ground water, surface water, air, or food chain contamination. Adequate monitoring and environmental safeguards are required.

Landfarming is a medium- to long-term technology.

Factors that may limit the applicability and effectiveness of Landfarming technique include:

- A large amount of space is required.
- Conditions affecting biological degradation of contaminants (e.g., temperature, rain fall) are largely uncontrolled, which increases the length of time to complete remediation.
- Inorganic contaminants will not be biodegraded.
- Volatile contaminants, such as solvents, must be pretreated because they would evaporate into the atmosphere, causing air pollution.

- Dust control is an important consideration, especially during tilling and other material handling operations.
- Presence of metal ions may be toxic to the microbes and possibly leach from the contaminated soil into the ground.
- Runoff collection facilities must be constructed and monitored.
- Topography, erosion, climate, soil stratigraphy, and permeability of the soil at the site must be evaluated to determine the optimum design of facility.
- Waste constitutes may be subject to "Land-ban" regulation and thus may not be applied to soil for treatment by land treatment (e.g., some petroleum sludges).

Adopting Landfarming as a sewage lagoon A & R method will involve the following:

- Sampling and analysis for faecals, hydrocarbons and nutrients prior to disposal.
- Release/Pump out the wastewater (if it meets effluent quality requirements) and dispose of it to the tundra or any other approved discharge water body. Nutrients should not be problem for a summer time tundra discharge.
- Remove the sludge and haul to Landfarming treatment site. The sludge treatment could be done in-situ as well.
- Push the dikes in, level the lagoon cell, add topsoil and then re-seed.

3.5.2 LANDFILLING

Landfilling is a method of disposing solid waste on land in a manner that protects human health and the environment. Applying engineering principles, solid waste is confined to the smallest practical area, reduced to the smallest practical volume and covered routinely with a cost-effective layer of earth.

To minimize public health and environmental hazards a solid waste landfill is used for land disposal of refuse. This is done by periodically spreading the refuse into thin layers, compacting the refuse by driving over it a few times, and then applying a granular cover material. A *sanitary landfill* requires daily cover of compacted refuse. A *modified landfill* increases the interval between covering operations to once a month or even once a year.

Design and operation is intended to ensure that final landfill form is domed to promote the rapid runoff of surface water.

In northern climates where covering of refuse daily is impractical due to severe winter weather and in small communities that do not have staff and equipment dedicated to disposal operations, a modified landfill operation is the generally accepted standard.

In permafrost regions where ground temperatures are low, biodegradation of solid waste is so slow that it can be considered negligible.

Adopting Landfilling as a sewage lagoon A & R method will involve the following:

- Sampling of faecals, hydrocarbons and nutrients prior to disposal.
- Release/Pump out the wastewater (effluent) and dispose of it to the tundra or any other approved discharge water body. Nutrients should not be problem for a summer time tundra discharge.
- Remove the sludge and haul to an approved Landfill site.
- Push the dikes in, level the lagoon cell, add topsoil and then re-seed.

3.5.3 Surface Spreading

Spreading or injecting waste is usually the most affordable and appropriate method for use and disposal of manure, sludge, septage, and food processing waste. When undertaken with care through testing, calibration and timing of application, surface spreading of waste can add plant nutrients and organic matter to the soil while limiting odors and protecting surface and ground water quality.

Tractor-pulled or truck-mounted box spreaders are used to spread wastes that contain 20% or more solids. The box must be watertight for road transport. Spreaders are equipped with paddles, flails, or augers to spread the waste evenly over the land area. Feed aprons, moving front-end gates, augers or conveyors are used to move the waste to the spreader. Large spreaders can reduce the number of trips to the field, but may increase soil compaction

Tank wagons or tank trucks are used to haul and spread liquid waste. The waste is either loaded or pumped into the tank through a top hatch, or drawn into the tank with a vacuum. Liquid wastes (up to 4% solids) can be pumped into spreading equipment. Waste with a higher percentage of solids (up to 15% solids) can also be pumped with special equipment. Bedding, hair and feed must be chopped up or separated out of the waste material to avoid clogging pumps, pipes and nozzles. Large tanks should be baffled to avoid inertia problems with starting, stopping and cornering. Once in the tank, the waste should be agitated to prevent settling.

Waste is discharged from a tank using a pump, flail, spinner or deflector plate. Most systems rely on gravity to empty the load, which results in a decrease in the discharge rate as the tank empties. Pump systems provide more uniform discharge.

When spreading liquid manure it is important to limit each application to bring the soil moisture just up to field capacity. If too much liquid is applied at one time it can run off or move directly into drainage tile, which may result in stream pollution. The available soil moisture capacity for different soils can be found in the Ohio Irrigation Guide. Limit the application of liquid waste to the water-holding capacity in the top 24 inches of the soil profile.

Adopting Surface Spreading as a sewage lagoon A & R method will involve the following:

- Sampling and analysis of sewage for faecals, hydrocarbons and nutrients prior to disposal.
- Release/Pump out the wastewater (if it meets effluent quality requirements) and dispose of it to the tundra or any other approved discharge water body. Nutrients should not be problem for a summer time tundra discharge.
- Spread and dry the sludge (or mix with berm soil to dry)
- Push dried sludge and lagoon berms back into lagoon pit. The dried sludge could be hauled to a farmland and spread on the soil surface or injected into the soil.
- Cover with available topsoil.
- Seed to grass/legume mix

3.5.4 INCINERATION

Incineration is an environmentally and technically superior method of waste disposal, offering reliability, safety and efficiency

At the same time, it is highly controversial and expensive. In previous decades, landfills were primarily used for waste disposal, allowing nature to take its course, eventually reducing the end volume toxicity of the wastes. However, because of increasingly stringent environmental regulations concerning air quality, landfills, and groundwater contamination, along with the decreasing availability of land for the encapsulation of wastes, incineration has become a disposal method option for many municipalities and industries.

Incineration thermally decomposes matter through oxidation, thereby reducing and minimizing the wastes, and destroying their toxicity. It can be applied to industrial, municipal, and hazardous wastes, provided that they contain organic material since it is primarily organic substances that can undergo and sustain thermal degradation.

After incineration, wastes are converted to CO, CO2, water and ash

Depending on the composition of the initial waste, compounds containing halogens, metals, nitrogen, and sulfur may be produced. These compounds, along with CO, are deleterious to the atmosphere and highly regulated. Presently, the destruction efficiency for these hazardous wastes must be 99.9999%.

Adopting incineration as a sewage lagoon A & R method will involve the following:

- Sampling and analysis of sewage for faecals, hydrocarbons and nutrients prior to disposal.
- Release/Pump out the wastewater (effluent) and dispose of it to the tundra or any other approved discharge water body. Nutrients should not be problem for a summer time decant.
- Remove the sludge and haul to an Incinerator. Sludge drying could be done prior to incineration.
- Push the dikes in, level the lagoon cell, add topsoil and then re-seed.

3.6 RISK MANAGEMENT

Risk management is a practice that allows a certain risk to remain, but be managed in such a manner that risk is reduced to essentially negligible. Environment Canada[14] and the CCME[15, 16] describe methods for such practices.

More recently, a procedure[17] was developed for the Con Mine and Rycon Trailer Courts in Yellowknife, NT. Here, soils were contaminated in some locations in excess of 1000 mg/kg total arsenic. CCME recommends 13 mg/kg total arsenic for residential/parkland; the GNWT and City of Yellowknife have adopted 160 mg/kg.

The procedure approved by the GNWT would see 300 mm of clean soil placed over the contaminated areas, or roads paved, to reduce exposure.

Therefore, FSC considers that such a practice could be extended to other Northern communities.

[14] A Risk Management Framework for Contaminated Sites, A Discussion Paper, First Draft, Environment Canada, 1997.

[15] A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines, CCME, 1996.

[16] Guidance Manual for Developing Site-Specific Soil Quality Remediation Objectives for Contaminated Sites in Canada, CCME, 1996.

[17] Arsenic Remediation and Risk Management Strategies for the Con and Rycon Trailer Courts, Yellowknife, NT. Risklogic Scientific Services Inc., February 13, 2004.

4. BACKGROUND REVIEW OF CLOSURE RELATED CONCEPTS

4.1 SLUDGE MANAGEMENT

Sludge management involves the handling, preparation for disposal and/or the disposal of wastewater sludge in an environmentally acceptable manner. Management practices vary from municipality to municipality depending on size, regulations, public perception, social, economic, and political factors. A sludge management program comprises of the following key elements:

- Regulatory framework;
- Source control;
- Thickening;
- Solids stabilization;
- Dewatering;
- Storage;
- Transportation;
- Sludge disposal;
- Odour control;
- Contingency planning;
- Quality management programs;
- Program delivery options; and
- Public participation/communications programs.

A sludge management program is required to comply with relevant regulatory framework. The regulations govern sludge accumulation, treatment, disposal and monitoring.

Depending on the size and circumstances, some elements may be less applicable. Source control, for instance, may not be necessary in a small rural community without industries. Elements should not, however, be deleted merely because of size; the issue of public acceptance is important irrespective of size, but the extent of the communication strategy can be tailored.

A sludge management planning study should not be just a process to evaluate available technologies and select the one with the best life cycle costs. The study must review and assess the available technologies and consider how best to arrange the different components to provide an overall system that addresses the protection of the environment and public health, public concerns, reliability, flexibility, regulatory compliance, and cost. Available sludge management technologies have been discussed in Section 3.0 of this report.

4.2 ANALYSIS REQUIREMENTS

Biosolids quality requirements are assist in understanding the levels of quality during development or modification of the biosolids management programs, and in selection of processes and end uses that are desirable or applicable to a particular case.

There are different levels to which biosolids can be processed depending on end use. Different jurisdictions adopt different regulations to guide in determining biosolids quality. The U.S. Environmental Protection Agency (EPA), in its Part 503 Rule, has defined several categories: the most commonly referenced ones being Class A, Class B, and Exceptional Quality (EQ). In Canada, the CCME Compost Quality Guideline and the Fertilizer Act are the only national regulations that make reference to biosolids, since biosolids as with all environmental legislation is under provincial jurisdiction. More and more provinces are adopting the CCME guideline. The quality criteria of the CCME guideline has been discussed in section 2.7.

For the purpose of this report, it was decided to refer to the CCME standards: Category A, Category B. Category A is for restricted use, while Category B is for unrestricted use. These quality levels are defined in section 2.0. The quality levels are currently under review by the CCME; the revisions would be made available to the public in the spring of year 2005.

The maximum trace element limits in category A and B composts (Source: CCME "Guidelines for Compost Quality", 1996)

Trace Elements*	Category A compost (mg/kg, air-dried mass)	Category B compost (mg/kg, air-dried mass)
Arsenic (As)	13	75
Cadmium (Cd)	3	20
Cobalt (Co)	34	150
Chromium (Cr)	**	**
Copper (Cu)	**	**
Mercury (Hg)	0.8	5
Molybdenum (Mo)	5	20
Nickel (Ni)	62	180
Lead (Pb)	150	500
Selenium (Se)	2	14
Zinc (Zn)	500	1,850

* Other elements, such as boron, manganese, aluminum and iron, may eventually be regulated in certain provinces to accomodate regional and national concerns.
** Chromium and copper are not stated.

4.3 SLUDGE TREATMENT TECHNOLOGIES AND INFRASTRUCTURE

The following are the basic descriptions of various sludge treatment technologies and end uses.

4.3.1 MESOPHILIC ANAEROBIC DIGESTION

Mesophilic anaerobic digestion is the natural breakdown of organic matter by bacteria in the absence of air and in a digester whose temperature is controlled at 35°C to 38°C. Sludge is continuously or intermittently introduced into the reactor while digested solids, lower in organic and pathogenic content, are also withdrawn continuously or intermittently. Detention time of the sludge usually occurs for15 to 30 days. The sludge is biologically degraded in the digester through three stages: hydrolysis, acidogenesis, and methanogenesis. During this last stage, methane gas, a beneficial by-product, is generated and can be converted into heat and/or energy. The digested solids can also be dried or dewatered and then used as a nutrient rich soil conditioner for land application.

4.3.2 THERMOPHILIC ANAEROBIC DIGESTION

Thermophilic anaerobic digestion is the anaerobic digestion of sludge at an induced temperature range between 49°C and 57°C. At this higher temperature range, (thermophilic) digestion occurs much faster than mesophilic digestion as biochemical reaction rates increase with temperature, doubling with every 10°C rise in temperature. The residence time is typically 12 to 14 days. Besides the advantage of increased biochemical reaction rates, and consequent lower HRT and tankage volume, thermophilic digestion also increases the sludge processing capability, improves the sludge dewatering, and increases bacterial destruction. However, the disadvantages of thermophilic digestion includes higher energy requirements to maintain the temperature necessary for heating, poor quality of supernatant which contains larger quantities of dissolved solids, increased odour potential, and less process stability.

4.3.3 DUAL DIGESTION (TWO-STAGE AEROBIC-ANAEROBIC)

Dual digestion consists of two stages, the first is an aerobic reactor followed by an anaerobic reactor. The aerobic reactor is fed with oxygen instead of air, thus producing an exothermic bioreactor. The sludge is naturally heated by the oxidation of the volatile solids, and no additional heat is required when the sludge is directed into the anaerobic reactor, which operates at mesophilic temperature.

Dual digestion requires smaller anaerobic digesters and eliminates the need for an external heat source. However, the disadvantages of dual digestion include odour problems in the aerobic stage, foaming in the aerobic and anaerobic stages, and the temperature of sludge entering anaerobic reactor must be closely monitored.

4.3.4 STAGED MESOPHILIC

Staged mesophilic is a multistage anaerobic digestion process at mesophilic temperatures. Both stages are heated and mixed, providing a sufficient SRT in the first reactor for methane production. The staged mesophilic digestion generates lower offensive odours and the biosolids produced seem to be slightly easier to dewater.

4.3.5 STAGED THERMOPHILIC

Staged thermophilic digestion is a multistage anaerobic digestion at thermophilic temperatures. Unlike staged mesophilic digestion, all reactors in the staged thermophilic anaerobic digestion operate as methane reactors (to eliminate shortcircuiting). The flow from reactors is continuous flow, not batch flow.

4.3.6 TEMPERATURE PHASED ANAEROBIC DIGESTION (TPAD)

Temperature phased anaerobic digestion (TPAD) is a two-staged reactor system. The first reactor operates at thermophilic temperatures and the second reactor operates in the mesophilic temperature. By using this twostaged system, the shortfalls of the individual technologies when operated alone are eliminated while the advantages of both systems are realized.

The thermophilic anaerobic digestion alone can achieve higher volatile solids and pathogen destruction, with little foaming, but the process offers poor process stability and can produce offensive odours and poor dewaterability.

4.3.7 HEAT DRYING

Heat drying is mechanical drying partially using the heat of wet sludge. This generates a dried biosolid product such as pellets. Solids concentration of the dried product can be 90 to 95 percent. Mechanical processes that have been used for drying sludge include flash dryers, spray dryers, rotary dryers, multiple hearth dryers, fluid-bed dryers, and multiple effect evaporation. Burners and autonomous recycling can also be used.

4.3.8 COMPOSTING

Composting is a process used to put organic material through a biological degradation process to generate a stable end product. Temperatures of 50°C to 70°C are reached as a consequence of bacteriologic activities during this process. Three types of micro-organisms are mainly responsible for the degradation of the organic material: bacteria, actinomycetes, and fungi. The process is very reliable depending on operating conditions.

Historically, biosolids have been directly applied to agricultural land as a soil amendment on a seasonal basis and/or delivered to private operators for use as compost feedstock. Composting is a preferred method of recycling biosolids, because the finished product quality is high, finished material handling risks are low, seasonal storage logistics are reduced, and a marketing value can be realized. Storage and handling of digested or lime-stabilized and otherwise uncomposted biosolids involves odour problems.

4.3.9 IN-VESSEL COMPOSTING

In-vessel composting is composting within an enclosed container or vessel. The benefits of this are easier process and odour control, faster throughput, lower labour costs, and smaller land area requirements. In-vessel composting is typically a plug flow or dynamic (agitated bed) system. The initial carbon to nitrogen (C:N) ratio should be from 25:1 to 35:1 by weight. Mixing and turning of the material is carried out on a regular basis to prevent drying, caking, and air channelling. The composting time normally lasts for 10 to 21 days followed by a 12 to 16-week unaerated curing period.

4.3.10 OPEN COMPOSTING

Compost is naturally heated and under this pasteurizing effect enteric pathogenic organisms are destroyed. Most composting operations will consist of the following steps:

- Mixing dewatered sludge with an amendment and /or bulking agent (usually wood chips, straw, or sawdust);
- Aerating the compost pile either by the addition of air or by mechanical turning, or both;
- Recovery of the bulking agent (if practical);
- Further curing and storage; and
- Final end use.

The open composting consists of a mixture of biosolids, bulking agents, and finished compost to achieve solids content of 40 to 50 percent, which improves the structural integrity of the mixture. The main objection to open composting is the offensive odours usually generated. Precipitation also creates difficulties with the operation by slowing down the degradation process of organics due to excessive moisture and evaporative cooling.

Generally, there are two types of open composting: aerated static pile and windrow composts. Aerated static pile is a mixture of dewatered sludge and bulking agent, which has been placed over exhaust piping or a grid of aeration pipes. The material is usually left to compost for 21 to 28 days and then is typically cured for another 30 days. A layer of screened compost is usually placed on top of the compost for insulation. Aerated static piles are not mixed.

Windrow composting consists of long parallel piles called windrows, which are turned/mixed periodically during the compost period. During this turning operation, odours are generated. Compost time ranges from three to four weeks up to several months before the compost is cured. Curing time depends on the stability required for the end use of the compost.

4.3.11 PYROLYSIS

Pyrolysis is the splitting of organic substances into gaseous, liquid, and solid fractions in an oxygen-free atmosphere. The resulting components of this process are a gas stream (primarily hydrogen, methane, carbon monoxide, and various other gases depending on the material pyrolyzed), a tar and/or oil stream (liquid at room temperature containing chemicals, such as acetic acid, acetone, and methanol), and a solid stream (a char consisting of almost pure carbon plus inert material that may have entered the process).

4.4 DRAINAGE, OUTFALL AND WETLAND AREAS

4.4.1 DRAINAGE

The lagoon site requires an effective drainage system. The drainage system should be included in the routine maintenance checklist. Detailed site survey and topographic mapping required to determine the appropriate drainage facility.

4.4.2 OUTFALL

The purpose of an outfall is to introduce the effluent stream into its receiving water in a place and manner chosen to achieve efficient mixing, and maintenance of receiving water quality objectives outside the mixing zone. If winter discharge is permitted, wintertime conditions probably will control hydraulic design. Neither sewage sludge nor excess solids are to be discharged through outfalls[18].

Outfalls for disposal of effluent shall maintain contact recreation water quality at the beach.

On beaches where marine mammals are landed for harvesting, background water quality is to be maintained.

For discharges to fresh water, [permanent] outfalls are to extend below the lowest water level that may reasonably be anticipated. This would generally refer to the lowest under-ice water level during the winter season.

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[18] Nunavut Water Board

Outfalls are to ensure contact recreation water quality is maintained at the beach. Approval of shoreline discharges is subject to site-specific considerations.

Both marine and fresh water outfalls should be located and designed to make optimal use of the mixing and dilution characteristics of the receiving water.

Discharges that do not meet these general considerations are to be upgraded.

Designers should consider the effects of ice scour in all settings.

Signs are to indicate the location of outfalls, of treatment and disposal areas on land, and of all mixing zones.

A temporary outfall is defined as one generally associated with the construction phase of a project and employed for a fixed period of time generally less than 5 years.

The Water Board may consider a temporary outfall that may not meet all the general design considerations of these guidelines.

If approved, such a discharge will be by special permit and Water Board may apply all associated requirements.

4.4.3 WETLAND AREAS

Wetlands are widely used as secondary /tertiary wastewater treatment system in the north.

The solid components of sewage should be reduced/removed prior to discharge to wetlands. The sewage discharge to the wetland must meet established guidelines for Nutrients and other parameters.

Sludge disposal should be prohibited in wetlands or unstable areas.

4.5 MANAGEMENT OF LAGOON AND ASSOCIATED INFRASTRUCTURE

Management of sewage lagoon and associated infrastructure should be done in a way to optimize lagoon performance such that the lagoon effluent complies with the discharge requirements and the sludge quality meets applicable regulatory regimes.

Effective management of lagoon and associated infrastructure involves:

4.5.1 ADMINISTRATIVE DECISION / PROTOCOL

The following are the administrative decision/protocol management tools the lagoon owner should establish to ensure effective lagoon and associated structure management:

- Making policy decisions regarding the lagoon operation;
- Engaging operators who are conscientious, competent, and capable of operating and maintaining the treatment plant. The operators must be provided with proper instruction and orientation;
- Providing a replacement for an operator who ceases to be available for that position. The Replacement should be adequately trained to ensure there is no deficiency in their competency;
- Facilitating through protocol a safe working environment;
- Providing a working environment that facilitates retention of trained and experienced personnel;
- Encouraging operators to attend meetings and training courses to increase their technical knowledge;
- Ensuring compliance with relevant Acts and Regulations;
- Obtaining relevant permits and information for the operation of the plant and locating copies of these items at the plant for referencing by operators.

4.5.2 PLANNING AND DESIGN

Planning and design approaches adopted for lagoon and associated infrastructure should ensure lagoon efficiency and take into account environmental issues associated with sewage lagoons (odour, vector attraction etc). These management roles are the responsibilities of the owner or owner's representative.

4.5.3 OPERATION AND MAINTENANCE - OPERATOR'S RESPONSIBILITIES

Routine operations and maintenance by operators, for lagoon management include:

? Frequent site walk-through (minimum weekly)
? Control of emergent vegetation
? Control of floating sludge mats
? Removal of non-degradable wastes
? Addressing odour problems.
? Removing water weeds
? Determining sludge build up
? Observation of lagoon appearance and weather conditions
? In-field testing
? Sampling regime.

4.6 LONG-TERM SITE MONITORING

4.6.1 GENERAL

Long term care of the decommissioned lagoon is important so that the impacts to the surrounding environment are minimized.

For every site, cover material should be allowed to settle and re-graded as necessary. Any cave-ins should be filled in to prevent standing water. Vegetation should be monitored to ensure that it continues to grow. There should be on-going maintenance of drainage pathways and the like.

4.6.2 INSPECTIONS

A post closure inspection checklist should be filed with the appropriate regulatory body. The checklist should include:

- Inspection frequency;
- Items to be inspected; and
- Compliance requirements.

4.6.3 POST CLOSURE MONITORING

Operational monitoring shall be continued into the post-closure period until one or more of the following conditions apply:

- It can be demonstrated that the site is no longer releasing contaminants; or
- It can be demonstrated that the site has reached an equilibrium state in which contaminant release poses no unacceptable risk to the environment.

Proponents should submit a report to the appropriate regulatory body which justifies the cessation of monitoring. Disputes or uncertainties should be resolved by a qualified scientist.

4.6.4 REGULATORY REQUIREMENTS

All land and water boards will require routine reporting. Generally, the requirements will be outlined in a licence.

4.7 INTERIM/REVERSIBLE LAGOON CLOSURES

Interim or reversible lagoon closure refers to a condition of temporary abandonment of a sewage lagoon (e.g. for the purpose of trying some other sewage treatment methods, or a temporary mine closure). The key requirements of an interim lagoon closure are:

- Communicating interim closure notice
- Hydraulic integrity
- Access control
- Care and Maintenance Monitoring
- Baseline study after start up

4.7.1 COMMUNICATING INTERIM CLOSURE NOTICE

Prior to closure all land and water boards and other appropriate regulatory agencies should be notified of the pending interim closure

Lagoon users must be notified by letter if they are municipalities or contract haulers, or by published announcement if private sewage deposition to the lagoon is allowed.

4.7.2 HYDRAULIC INTEGRITY

During the period of interim closure, there should be proper control of water flow in and around the lagoon. The site topographic plan should be reconfirmed and a proper site drainage system installed.

Outfall structure(s) must be constructed to ensure the lagoon does not overflow its limits and cause the lagoon content flooding the surrounding area.

4.7.3 SITE ACCESS CONTROL

Fences or other appropriate structures must be built to limit access to the lagoon site. Signs indicating site closure and alternative sewage treatment system must be posted at locations close by the site and conspicuous to the public.

4.7.4 CARE AND MAINTENANCE MONITORING

Routine care and maintenance monitoring program need to be put in place for the period of interim closure of the site. Regular walk through the site should be carried out to ensure the site condition does not degrade to affect the environment. Some of the regular routines required are:

- Site drainage system
- Surface and groundwater monitoring

4.7.5 BASELINE STUDY

If it is decided to re-open the lagoon, a baseline environment study should be carried out prior to re-opening. The baseline study is required to establish the current state of the lagoon and its suitability for continuing discharge and treatment of sewage.

The level of sludge in the lagoon at reopening should be evaluated to determine whether or not the sludge should be removed at this stage.

5. CASE STUDY OF A FICTITIOUS COMMUNITY – HAMLET OF TUFLUK

5.1 DESCRIPTION OF THE FICTITIOUS COMMUNITY - THE HAMLET OF TUFLUK

The Hamlet of Tufluk has salt water access for sea lift and is accessible by aircraft.

The projected population for the population of Tufluk in the year 2009 is 920 persons.

Sewage is treated in a 19,500 m^3 single-cell sewage lagoon located approximately 600 m. from the shore, and which is now approximately 500 m from a residential area. Wastewater is discharged during the open water season over the foreshore. The lagoon was built by the community using a consultant's design but there are no as-built drawings.

The volume of sewage generated by the community for the year 2004 is 32,000 m^3, which approximately equals annual water use. In 2009, the annual volume of sewage generated by the Hamlet of Tufluk will be 37,000 m^3. All sewage is trucked.

Sewage is primarily domestic in nature, with some commercial (the Co-op) and institutional (Nursing station and school) sources, however, it is unregulated and untested. Other sources include: the Hamlet garage, and firehall.

The sewage lagoon has been in operation for approximately 25 years and is now much too small to accommodate winter storage. The community plans to reclaim the area for new housing. A new site has been chosen and construction begins next spring. It has been estimated by modeling that the lagoon contains approximately 270 m^3 of sludge.

5.2 RECLAMATION OF TUFLUK SEWAGE LAGOON

Using the available information on Tufluk community, the volume of sewage generated in 2004 was 32,000 m^3, whereas the capacity of the single-cell lagoon treatment unit is 19, 500 m^3. The existing treatment facility does not meet the present sewage treatment needs of the community. It has also been projected that the sewage generation rate from Tufluk will be 37,000 m^3 per annum in 2009. It is required to reclaim the existing sewage lagoon and build another lagoon that meets the current and future sewage generation needs of Tufluk.

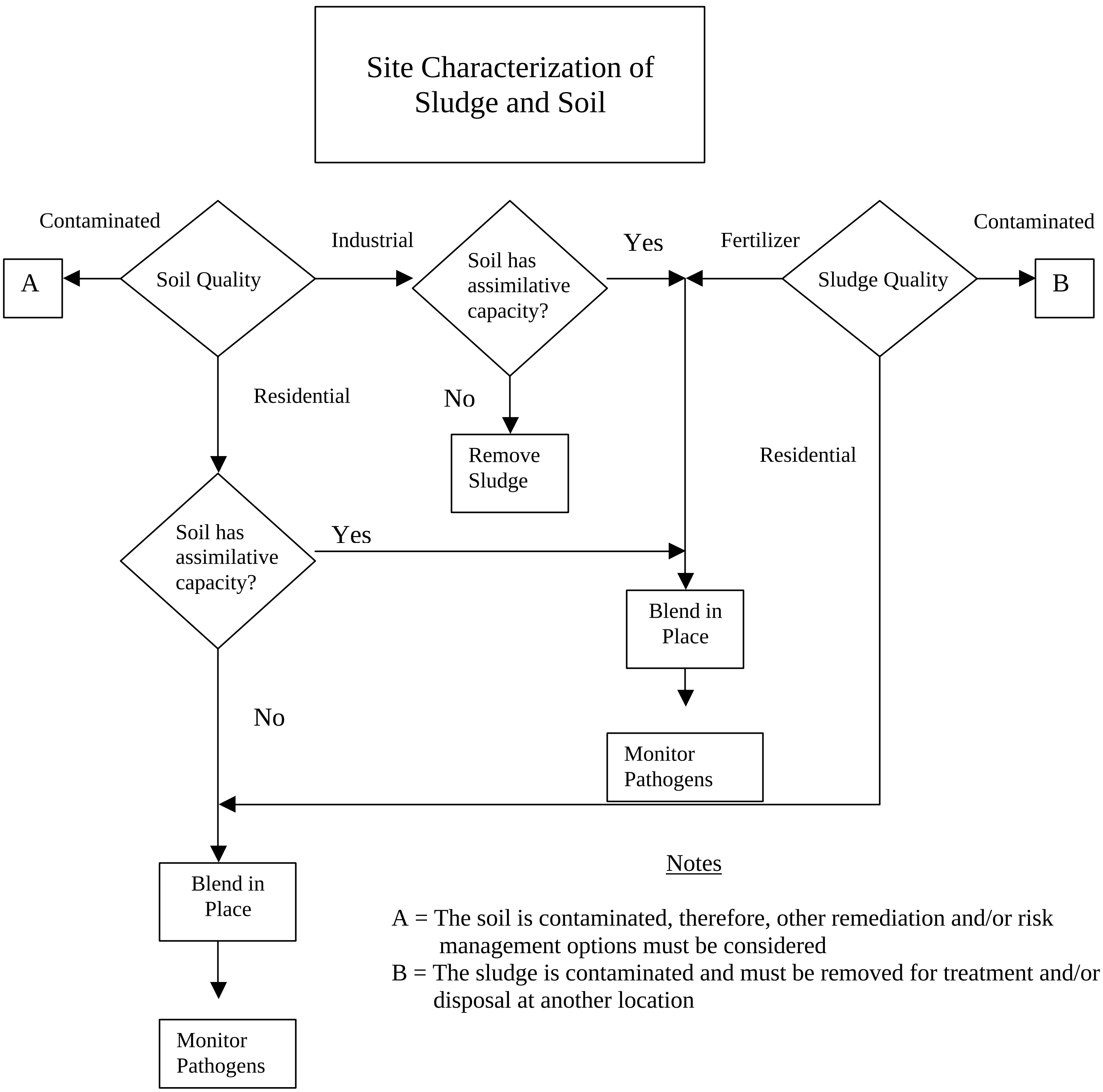
For the purpose of this study, we will only look at the requirements for reclaiming the 19, 500 m^3 capacity lagoon. The reclamation components are:

- Site Preparation for closure (topographic, drainage plan etc)
- Sewage decant

- Sludge treatment – on-site treatment/disposal; off-site treatment/disposal
- Land Reclamation

Based on the sewage treatment components identified above, the evaluation of treatment options for the lagoon is illustrated in the following flowchart:

Figure 5.1: Decision Flowhcart



<u>Notes</u>

A = The soil is contaminated, therefore, other remediation and/or risk management options must be considered
B = The sludge is contaminated and must be removed for treatment and/or disposal at another location

5.3 EVALUATION OF RELEVANT RECLAMATION OPTIONS

5.3.1 RECLAMATION END PRODUCT

Consultation with the community suggests that the community wishes to expand their residential area into the setback and area currently occupied by the lagoon. The goal, therefore, is to provide a reclamation project where the site meets CCME residential/parkland guidelines and Nunavut Water Board guidelines.

5.3.2 DETERMINING ALTERNATIVES

The description of the Hamlet of Tufluk models an average northern community. From the review of the remediation technologies, Figure 5.1 shows options that would be appropriate for the reclamation of Tufluk's sewage lagoon, depending on what is found in place. Several scenarios exist. For the purpose of this exercise three scenarios are as follows:

1. The soil in the bottom of the lagoon, the berms and surrounding area meets CCME guidelines. The sludge also meets CCME and NWB guidelines.

2. The soil in the bottom of the lagoon, the berms and surrounding area meets CCME and NWB guidelines. The sludge is contaminated with heavy metals.

3. The soil in the bottom of the lagoon, the berms and surrounding area is contaminated with heavy metals. The sludge is contaminated with heavy metals.

Some assumptions applied to this exercise include:

- The lagoon was built on the land, therefore, the only backfilling required is to replace the soil removed with the sludge;
- The site can be brought to grade with equipment existing in the Hamlet; and
- The site will not be re-seeded.

Costs are an important concern in waste disposal and play an important part in deciding between appropriate methods. Class D cost estimate analyses of these options have been carried out for the purpose of cost comparison of the techniques. The cost estimates include the capital and O& M costs.

5.3.2.1 Reclamation Project for Scenario 1

Since the soil and the sludge meet all applicable guidelines, the berms will be pushed in, the sludge blended into the soil and the site graded to positive drainage.

Class D cost estimate analyses of scenario 1 is illustrated in Table 5.1

Table 5.1: Class D Cost Estimate for Scenario 1

Capital Component	Unit Cost	Unit	Quantity	Extension
Spreading on the land	$10	m^3	12000	$120,000
Engineering and contingencies @ 15%				$18,000
Total				**$138,000**
O&M Component	**Unit Cost**	**Unit**	**Quantity**	**Extension**
Total				**$0**

Total Scenario 1 Cost: $138,000

5.3.2.2 Reclamation Project for Scenario 2

The sludge will be removed to a constructed cell at the landfill. Clean soil will be returned to replace the sludge, the berms will be pushed in, and the site graded to positive drainage.

Class D cost estimate analyses of scenario 2 is illustrated in Table 5.2

Table 5.2: Class D Cost Estimate for Scenario 2

Capital Component	Unit Cost	Unit	Quantity	Extension
Excavation of sludge	$25	m^3	270	$6,750
Backfilling of clean soil	$60	m^3	270	$16,200
Spreading on the land	$10	m^3	12000	$120,000
Landfill cost to take sludge	$8	m^3	270	$2,160
Sub-total				$145,110
Engineering and contingencies @ 15%				$21,760
Total				**$166,870**
O&M Componenet	**Unit Cost**	**Unit**	**Quantity**	**Extension**
Environmental Monitoring	lump			$10,000
Contingencies @ 15%				$1,500
Total				**$11,500**

Capital Component (Constructed landfill cell)	Unit Cost	Unit	Quantity	Extension
300mm top soil cell cover	$60	m^3	120	$7200
Grading	$10	m^3	390	$3900
Signs	$500	lump	1	$500
Sub-total				$11,600
Engineering and contingencies @ 15%				$1,740
Total				**$13,340**
O&M Component	**Unit Cost**	**Unit**	**Quantity**	**Extension**
Environmental monitoring	$10,000	lump	1	$10,000
Contingencies @ 15%				$1,500
Total				**$11,500**

Total Scenario 2 Cost: $203,010

5.3.2.3 Reclamation Project for Scenario 3

The sludge will be removed to a constructed cell at the landfill. The berms will be pushed in and graded to positive drainage. Clean soil will be returned to replace the sludge, and an additional 300mm of clean soil will be placed and packed over the entire site, and the site graded to positive drainage.

Class D cost estimate analyses of scenario 3 is illustrated in Table 5.3

Table 5.3: Class D Cost Estimate for Scenario 3

Capital Component	Unit Cost	Unit	Quantity	Extension
Excavation of sludge	$25	m^3	270	$6,750
Backfilling of soil	$60	m^3	270	$16,200
Spreading on the land	$10	m^3	15000	$150,000
300mm top clean soil	$60	m^3	3000	$180,000
Landfill cost to take sludge	$8	m^3	270	$2,160
Sub-total				$355,110
Engineering and contingencies @ 15%				$53,270
Total				**$408,380**
O&M Component	**Unit Cost**	**Unit**	**Quantity**	**Extension**
Environmental monitoring	$20,000	lump	1	$20,000
Contingencies @ 15%				$3,000
Total				**$23,000**

Capital Component (Constructed landfill cell)	Unit Cost	Unit	Quantity	Extension
300mm top soil cell cover	$60	m^3	120	$7200
Grading	$10	m^3	390	$3900
Signs	$500	lump	1	$500
Sub-total				$11,600
Engineering and contingencies @ 15%				$1,740
Total				**$13,340**
O&M Component	**Unit Cost**	**Unit**	**Quantity**	**Extension**
Environmental monitoring	$10,000	lump	1	$10,000
Contingencies @ 15%				$1,500
Total				**$11,500**

Total Scenario 3 Cost: $456,220