December 2016

Study of NWT Waste Management Systems

LANDFILL SITE RISK FACTORS, WASTE GENERATION & MANAGEMENT COSTS IN THE NWT

VOLUME II

Submitted to:
Department of Environment and Natural Resources
Government of the Northwest Territories
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Report Number: 14-1188-0001

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Disclaimer

This report was prepared for information only for the Department of Environment and Natural Resources in December 2016. Information used in this report is current to 2015, however observations from field visits to a number of community landfills were made in 2014.

Department of Environment and Natural Resources
Government of the Northwest Territories
P.O. Box. 1320
Yellowknife, NT X1A 2L9

Attention: Diep Duong, P.Eng.

RE: STUDY OF NWT WASTE MANAGEMENT SYSTEMS
VOLUME 2 Landfill Site Risk Factors, Waste Generation & Management Costs in the NWT

Golder Associates Ltd. is pleased to provide the Northwest Territories (NWT) Government this final report "**Study of NWT Waste Management Systems, Volume 2: Landfill Site Risk Factors, Waste Generation & Management Costs in the NWT**", dated December, 2016. This report should be read in conjunction with the report "**Study of NWT Waste Management Systems Volume 1: Community Waste Management Profiles and Site Inspections", dated December, 2016.**

This report presents the results of our assessment of the current and proposed solid waste management systems in the NWT including practical recommendations for landfill operations, waste diversion and considerations for the development of an appropriate waste management strategy that could be implemented for the NWT. The report represents the culmination of input and collaboration of a number of individual community, government and Golder staff to provide an up to date and consistent approach to future waste management decisions and planning in the Territory.

We trust that the report herein satisfies the requirements of this project. Please do not hesitate to contact the undersigned if there are any questions or comments.

Golder Associates Ltd.

Kevin Rattray P. Eng.
Environmental Engineer

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LIST OF ACRONYMS

Acronym	Definition
AANDC	Aboriginal Affairs and Northern Development Canada
ATV	All-Terrain Vehicles
BCP	Beverage Container Program
CEAA	*Canadian Environmental Assessment Act*
CEPA	*Canadian Environmental Protection Act*
CRD	Construction, Renovation and Demolition (waste)
EA	Environmental Assessment
ELV	End-of-Life Vehicles
ENR	Department of Environment and Natural Resources
EPA	*Environmental Protection Act*
EPR	Extended Producer Responsibility
ERP	Electronic Rewards Program
GIS	Geographic Information System
GNWT	Government of the Northwest Territories
GLWB	Gwich'in Land and Water Board
HHW	Household Hazardous Waste
ICI	Institutional, Commercial and Industrial
IFO	Industry Funding Organization
INAC	Indigenous and Northern Affairs Canada (formerly Indian and Northern Affairs Canada)
ISP	Industry Stewardship Plans
IWB	Inuvialuit Water Board
MACA	Department of Municipal and Community Affairs
MOLO	Manager of Landfill Operations
MSW	Municipal Solid Waste
MVLWB	Mackenzie Valley Land and Water Board
NAPS	National Air Pollution Surveillance Network
NWT	Northwest Territories
NWTWB	Northwest Territories Water Board (now Inuvialuit Water Board)
PCB	Polychlorinated Biphenyls
SAO	Senior Administrative Officer
SLWB	Sahtu Land and Water Board
SNP	Surveillance Network Program
SWANA	Solid Waste Association of North America
WDO	Waste Diversion Ontario
WLWB	Wek'èezhìi Land and Water Board

1.0 INTRODUCTION

Waste management in the Northwest Territories (NWT) is regulated by federal, territorial, and municipal acts, regulations, standards, and guidelines. Through the process of devolution (i.e., the shifting of responsibilities from the federal to the territorial government), increasing onus has been placed on territorial and community governments to manage their waste including municipal solid waste (MSW, also referred to herein as residential waste), institutional, commercial and industrial (ICI) waste, construction, renovation and demolition (CRD) waste, as well as household hazardous and special waste streams (as defined by CCME, 2009) including used oil, antifreeze and batteries. Other waste materials including bulky metals (for example white goods/appliances), end-of-life vehicles (ELV) and tires are also managed at NWT landfill sites.

A Waste Resource Management Strategy is currently being developed by the Government of the Northwest Territories (GNWT). This strategy will provide a framework for the management of waste in the NWT, and will be the foundation for the development of waste management programs and policies. The purpose of this project is to highlight which areas of the existing waste management framework require prioritization for further work by the Departments of Environment and Natural Resources (ENR) and Municipal and Community Affairs (MACA), community governments, land and water boards and NWT residents.

The study involved the following items contained in the two volumes of this report and based on data collected to the end of 2015:

Volume I – Community Waste Management Profiles and Site Visits (Golder, 2016)

- Background summary including community locations, access and the physiography and climate of the NWT;
- Waste regulations and organization of waste management responsibilities in the NWT;
- Summaries of the waste management systems in the 32 communities of the NWT that operate landfill sites;
- Key findings from community surveys and site visits; and
- Site visits to 31 of the communities and summary of current conditions at the landfill sites.

Volume II – NWT Waste System Environmental Risks, Waste Generation Rates and Costs and Planning (this volume)

- Landfill site relative risk factors and recommended operational alternatives;
- Waste generation rates for MSW/ICI and review of capture rates of specific materials;
- Waste system cost including collection and disposal, estimated future system and site assessment costs; and,
- Key findings, challenges and opportunities.

1.1 Communities in the NWT

As outlined in Volume I, the total population of the NWT was 43,623 as of 2014 (Northwest Territories Bureau of Statistics, 2015), distributed over an area of approximately 1.3 million square kilometres. The vast majority (approximately 78%) of the persons in the 33 official communities live in the southern part of the territory, in the North and South Slave and Dehcho Regions (see Figure 1), and almost half (47%) live in the City of Yellowknife. The population of the more northerly parts of the NWT, in the Inuvik and Sahtu regions, represent 16% and 6%, respectively, of the territorial population. The population of these communities is largely permanent; however, significant seasonal changes in population are noted or expected at some communities, particularly those with connections to resource industries, and for some, tourism. Communities including Hay River, Inuvik, Norman Wells, Tuktoyaktuk and Yellowknife are reported or expected to experience increases in population over the summer months in particular. It is also noted that in some of the smaller traditional communities, many residents go out on the land during hunting season.

This report provides a description of the current state of waste management in 32 of the 33 communities in the NWT. N'dilo has been omitted from the community landfill summary in this report as this community accesses solid waste management facilities in Yellowknife. For the purposes of this report, the communities have been generally grouped on the basis of population into small (less than 1,000), medium (1,000 to 4,000) and large (Yellowknife, approximately 19,300) communities. Large and medium sized communities typically contain 50% or more of the total population in their respective regions and act as "hub" communities, in that they provide a greater level of institutional, commercial and transportation services.

Waste in the NWT communities is managed locally, in large part reflecting the relatively large distances between communities and/or limited and seasonal access in many parts of the territory (Figure 2). A number of NWT communities have limited seasonal (ice road) or no road access, which limits their options for accessing external waste management resources. This is particularly the case for communities in the Inuvik Region, which include three communities entirely reliant on ocean shipping for large goods (Paulatuk, Sachs Harbour and Ulukhaktok). Communities in the Sahtu region are reliant on summer barge and winter ice roads for transport of larger goods; these transport routes are interrupted between seasons. It is also noted that in some cases, seasonal conditions on some of the all-weather gravel highways result in significantly slower travel or interrupted access.

Figure 1: Administrative Regions of the NWT and Their Communities

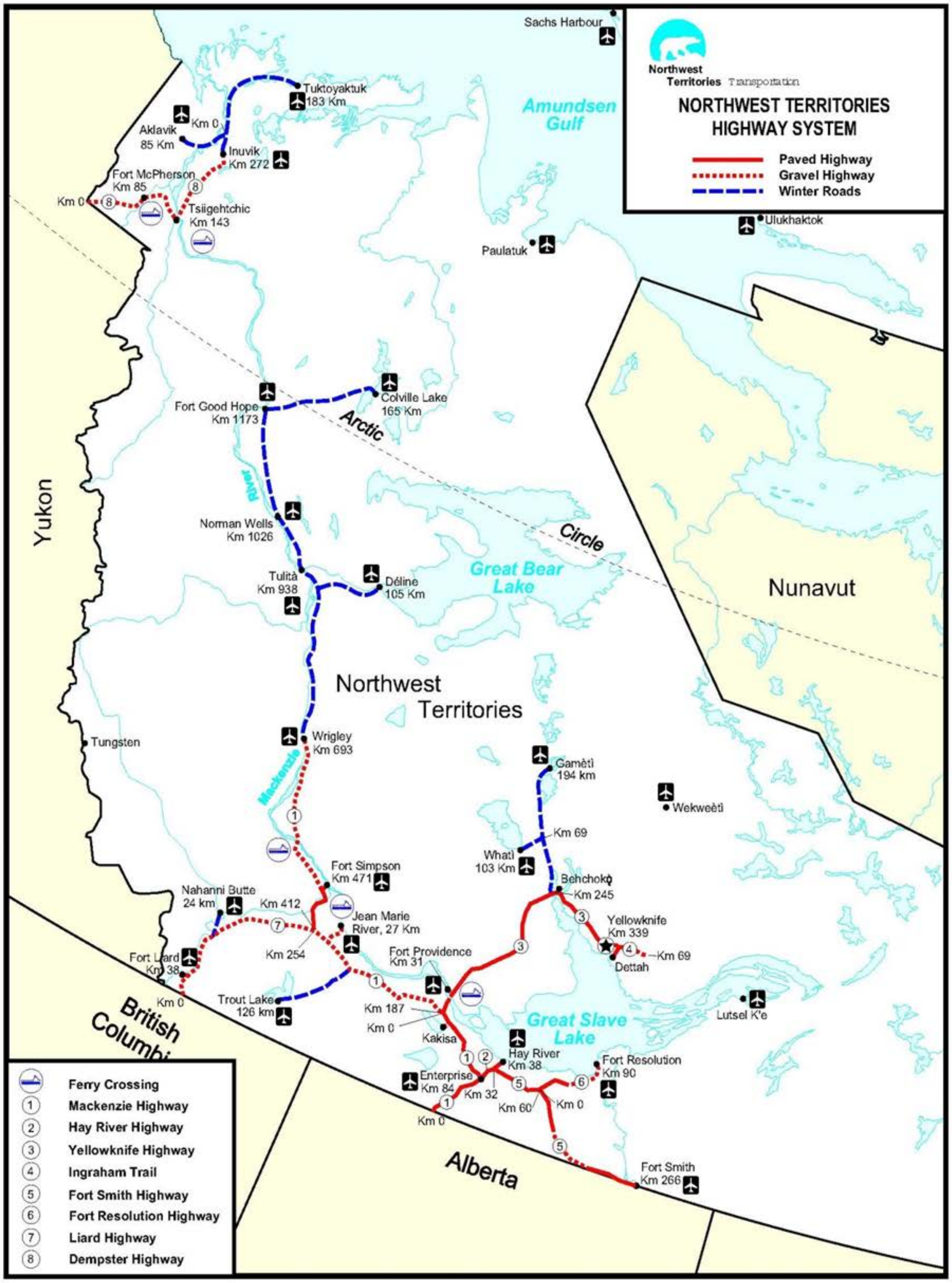

Figure 2: Map of NWT Community Access

2.0 LANDFILL SITE RISK FACTORS

An assessment of the environmental risk factors posed by the operation of landfill sites in NWT communities was completed, based on existing information that was collected through observations of the visible (i.e. current fill) waste and did not involve excavations. A summary of the site specific information, site visit summaries and waste management practices in each NWT community are found in "Volume I: Community Waste Management Profiles" (Golder, 2016).

The GNWT requested the potential risks posed by the operation of community landfills to the communities and the surrounding environment be assessed. This will assist decision-makers in the future development of a relative risk assessment matrix to improve environmental management and to minimize environmental and human risk. A relative risk evaluation will also allow the regulators to prioritize actions to reduce the greatest relative risks.

The approach to assessing risk should consider the principles and guidelines of environmental risk assessment outlined in international, federal and provincial guidance documents from such sources as the United States Environmental Protection Agency (U.S. EPA 1989), Health Canada (2014), and the 1996 and 1999 documents from the Canadian Council of Ministers of the Environment (CCME). Environmental risk has the potential to occur when there is a receptor present, a chemical or risk is present, and there is a pathway by which the receptor may come into contact with the chemical or risk. Each of these factors should be considered when identifying the possible sources and pathways by which receptors may become exposed either directly or indirectly from impacted materials in each landfill.

Once the information collected for each landfill has been input into a risk matrix and the sites of highest priority have been identified, the principles and guidelines in the following Canadian Standards Association (CSA) publications can be used by decision-makers to consider next steps:

- *CAN/CSA-ISO 31000-10 Risk Management – Principles and Guidelines (published 2010; reaffirmed 2015)*
- *CAN/CSA-Q850-97 Risk Management – Guideline for Decision-Makers (published 1997; reaffirmed 2009; withdrawn).*

2.1 Background Information

Information collected as part of this study for use in landfill site risk evaluation included, where available, the design of the landfills, local geological and hydrological (surface water) conditions, typical operation and maintenance procedures, including waste acceptance and storage, landfill size, geology, climatic data, water body location, wildlife interaction and community size and location. This information was obtained from available reporting, a community survey and site visits completed at all community landfill sites in 2014 and 2015, excluding Délı̨nę, which was not visited. These site visits enabled Golder staff to assess the condition of the sites and to confirm and provide additional details on operations based on interviews with the Senior Administrative Officer (SAO) and/or the operator/supervisor of the sites. The information obtained from the above sources was entered into a database, in order to provide a traceable, reproducible and referenced set of information in a consistent format, which can be used to initially populate the data used for the relative risk evaluation process.

The community of Délı̨nę was not visited because a new facility was planned to be constructed. The existing site including the landfill and bulky waste areas for this community will undergo remediation and closure over the next few years. As a result, this community was not included in the study.

The level of risk or risk reduction of the risk factors for each site will vary, both with respect to details of the risk (for example, the volume of hazardous waste stored or the degree of waste covering) and the relative magnitude (for example, the relative risk associated with various types of waste). In cases where a risk mitigation measure is present, but not necessarily used or operational (for example an open landfill site gate or inoperative electric fence), additional weighting should be considered to account for this factor.

2.2 Receptors

Receptors typical to landfill sites in the NWT include the natural environment, wildlife and the public, including community drinking water intakes. Each of these receptors and the pathways by which landfill sites may affect them are described further below.

- **Natural Environment:** Many of the landfill sites are located outside of developed areas, within the natural environment and are often adjacent to wetlands or small surface water bodies, which may be connected to larger water bodies (e.g., rivers and lakes), through surface or subsurface drainage. The primary concern for a natural environment receptor is the presence of leachate impacts that exceed established environmental standards (typically for surface water). These environmental standards are established in order to protect aquatic life (e.g., fish) from the toxic effects of contaminants. Whereas impacts from contaminants sourced from landfills may enter the environment though groundwater, the most typical natural environment end receptor is the surface water, to which groundwater ultimately discharges.

- **Wildlife:** Wildlife, including birds and mammals, live in the environment adjacent to the landfill sites. Wildlife may include but are not limited to large mammals (e.g., bears, wolves), small mammals (e.g., foxes, ground squirrels), large ungulates (e.g., moose, caribou), waterfowl (e.g., gulls, snow geese), scavenging birds (e.g., ravens) and raptors (e.g., eagles). These receptors may also include "Species at Risk". Wildlife may ingest toxic materials (e.g., residential waste, hazardous waste, pesticides) if they are able to gain access to the waste in the landfill. A particular concern is the risk to bears and wolves, for which non-electrified fences are not an adequate barrier to prevent access to a landfill site. The bears and wolves are also at risk if access to landfill sites is not mitigated, due to the development of long-term, generational dependence on waste as a food source and an increase in the danger and nuisance resulting from frequent visits and increasing populations, sometimes culminating in the decision to cull these animals. There is also a risk if animals habituated to this behaviour are suddenly cut off from their food source through the implementation of adequate fencing. These animals may then lose a food source that they have become dependent upon, resulting in rapidly decreased populations and/or the animals may move into nearby communities to search for food, which will most likely result in culling as a result of the increased level of danger to the public in the community.

- **Public:** Members of the public may gain unauthorized access to the landfill site when depositing waste materials or scavenging materials from the bulky waste storage area. Risks to the public include direct contact with waste materials or leachate, sharps, vapours, and interactions with local wildlife (e.g., bears and wolves). Members of the public may also be at risk if landfills are located in the same watershed, or are otherwise upstream of community drinking water intakes or sources.

These receptors and the relevant pathways by which they may be adversely affected by the landfill sites should be considered when identifying the risk factors.

2.3 Development of Risk and Risk Mitigating Factors

The groups of risk and risk mitigating factors that were considered to potentially impact levels of environmental risk at the NWT community landfills are as follows:

Risks

- Waste types accepted (e.g., MSW, ICI waste, CRD waste, hazardous waste);
- Size of the active waste cell;
- Bulk metals storage (e.g., empty waste drums, heating oil fuel tanks, used appliances, end–of-life (ELV) vehicles);
- On-site sewage lagoon;

Risk Controls

- Hazardous waste controls (e.g., hazardous waste storage liner and berm, covered bins);
- Landfill engineering controls (e.g., partial/complete berm or trench, waste lift thickness, cover, liner, leachate collection);
- Site access controls (e.g., attendant, gate, perimeter fence, electric fence);

Other Factors

- Geology;
- Precipitation and temperature;
- Distance to receptors (e.g., water body, community water supply, etc.) and wildlife issues; and,
- Population and distance to landfill.

Within each of these groups, risks, risk controls and other factors can be further subdivided based on observations at each site which would (i) affect the potential generation and type of leachate or release of a contaminant, (ii) control the potential release of leachate or a contaminant or (iii) represent a receptor factor. A negative weighting should be assigned to engineered or site controls which limit environmental risk; however, the overall reduction to the risk weighting from these should be equal to or less than the potential impact factors (i.e., the engineering measures do not outweigh the risks; but rather, offset a part of the risk). For example, if hazardous waste is stored on a site, the assigned risk should be only partially reduced by the use of a lined storage area, which decreases, but does not entirely prevent, a potential impact.

The database developed through the community summaries, surveys and site visits should form the primary source of a risk matrix, in order to provide a consistent, traceable set of factors. The major factors to be considered for a risk matrix are described below.

2.3.1 Waste Type

Waste material types will influence the type of contaminants present in leachate generated from the waste. Hazardous waste materials pose the highest potential risk to the environment, followed by MSW, ICI waste and then CRD waste.

All NWT landfill sites contain a cell for residential waste, which includes material that will generate leachate as a result of infiltration leaching the contaminants from these waste materials. This waste typically only contains small quantities of household hazardous waste (HHW), for example, cleaning products and disposable batteries that are not captured by HHW programs. The waste will also include a component of ICI waste, which is typically greater in larger communities where more services are available.

At some sites, separate CRD waste cells are used. The materials comprising this waste class are considered in most cases to be relatively inert compared to MSW, in terms of the concentration of parameters in leachate generated from the waste materials. The CRD waste at NWT sites is sometimes mixed in with the MSW, occasionally as a rough cover. In the case of demolished housing units and community buildings, which are a common material disposed of at NWT landfills, it is assumed that any hazardous materials in the CRD waste (e.g., asbestos) are removed in the demolition process. In cases where CRD waste is from an unpermitted operation, hazardous waste may be present within the material placed at the landfill.

Hazardous waste is present at most sites, largely in the form of drums or pails of used oil and antifreeze, unused fuel and lead-acid batteries. Uncontrolled releases of hazardous waste from a landfill site, notably from liquid spills, are considered to represent the most significant risk in terms of potential impact to the surrounding environment. Hazardous waste that has been stored at the landfill site for more than a few years without suitable controls is also considered to be a significant risk, in that exposure of the containers to the elements will, in time, degrade them to the point of failure.

Additional risk is associated with waste that is accepted in an uncontrolled mixed fashion (i.e., minimal to no waste segregation) as this can increase the hazardous waste component which enters the MSW/ICI or CRD cells. This risk factor should be considered for sites where all waste (with the exception of used oil, fuel, etc., which are not known to be buried) is buried as a result of poor segregation processes, or burial after segregation, without appropriate cleaning (e.g., empty drums and fuel tanks).

Other materials which may contain hazardous waste include materials normally placed in the bulk storage area, which may be co-disposed with the MSW, and typical household hazardous waste such as vehicle maintenance rags and used oil filters, which may be disposed with MSW.

2.3.2 Cell Size

The size of the active cell influences the potential volume of leachate generation; a larger active cell area is unlikely to be covered seasonally with soil in a manner which promotes runoff and limits infiltration, and thus more leachate generation will occur. Larger cell sizes should therefore be assigned a higher risk ranking.

2.3.3 Bulk Metals Storage

Whereas bulk metals themselves are relatively inert, there is a risk associated with hydrocarbon spills in the bulk metal storage areas due to the risk of fuel drums and tanks being deposited without being properly cleaned and drained. There may also be some risk associated with the metal coatings. Additional risk is associated with the bulk metals storage area where “empty” drums are stored, particularly if there is residual product in the drums. If the drums are stored upright, and notably if the bungs are not installed properly, they may fill with water and overflow. If the drums are stored on their sides (with bung and vent horizontal), this is considered to be a risk control, as it is indicative of good storage practices which minimize the entry of water into the drums.

Bulk metals storage usually includes fuel tanks, used appliances and/or ELV. There are risks associated with these wastes, given that these materials may not have been appropriately drained of fluids and/or had mercury-containing switches removed.

2.3.4 Sewage Lagoon

In many NWT communities, the sewage lagoon is located adjacent to the landfill, often at the same site. The location of a sewage lagoon in close proximity to a landfill represents an environmental risk, as runoff or discharge of leachate from the landfill may enter the sewage lagoon, and then be transported through natural wetlands, and into the surrounding environment. Sewage lagoons can also attract wildlife such as waterfowl, and as a result, increase the level of interaction between wildlife and the landfill site. In addition, it is noted that some wastewater may contain improperly disposed hazardous waste (e.g., paint or other materials cleaned or disposed of in a sink) as well as pharmaceuticals discharged into wastewater.

2.3.5 Hazardous Waste Storage Controls

Controlled storage of hazardous waste (i.e., a berm and liner or covered container/building) reduces the potential risk of environmental impacts through spills, infiltration and leachate flow to surface water. These control measures reduce the risk associated with hazardous waste, but do not completely eliminate the risk; therefore, a net risk remains even with the application of these control measures.

2.3.6 Landfill Engineering Controls

Engineering measures such as landfill cell design, placement of cover over waste, and placement of waste in lifts of appropriate thickness reduce the risks associated with the generation and release of leachate from landfilled waste.

Landfills designed with partial or complete berms and trenches limit the interaction of waste with surface water. Complete berms and trenches are considered to be more effective than partial berms, although it is recognized that infiltration and seepage at the toe of the berms may occur. The placement of landfill cell cover material may occur on an annual basis or as portions of cells are completed, to reduce the potential interactions of waste with both surface water and wildlife. Interim cover placement is considered to be more effective at reducing risk than annual cover, given that interactions are controlled on an ongoing basis rather than once a year or less frequently. More frequent cover may also help to reduce leachate generation and infiltration if the cover is sloped to promote drainage away from the landfill.

Ideally, compacted waste should be placed in lift thickness of 1 to 1.5 metres, and compacted regularly, with appropriate equipment and methods. Thick waste lifts may not compact sufficiently, particularly if equipment with lower ground pressures (e.g., small bulldozers with wide tracks) is used to compact them. Lifts of less than two metres of waste prior to compaction are considered to be an effective control measure to reduce potential leachate perching within the waste, and should be given a negative risk value, whereas lift thicknesses greater than two metres are considered to be associated with some additional risk, and should be given a positive value. Lift thicknesses identified in the site visit summaries have been estimated in many cases, based on the observed landfill design and operations at the time.

Landfill cells that include a liner and leachate collection system greatly limit or prevent the risk of leachate release to the environment through seepage. Use of a liner and collection of landfill leachate also requires access to landfill leachate treatment or disposal options. Currently, only the new cells of the Yellowknife landfill are designed with a landfill liner and leachate collection system.

2.3.7 Site Access Controls

Administrative and physical controls can be put in place to reduce the likelihood that people may gain unauthorized or unsupervised access to the landfill site. The most effective method to discourage unauthorized access is the presence of a site attendant, which reduces unauthorized dumping. The presence of a site attendant also increases waste segregation and adherence to the landfill operations and maintenance manual.

Gating and fencing are also an effective method by which access to the landfill can be limited or prevented. A gate that is closed when the landfill is closed, and/or when the attendant it not present, restricts access to the landfill and reduces unauthorized dumping within the landfill site. Sites with gates that are not used should be assessed a lower remedial measure value. The presence of a perimeter fence not only restricts human access to the landfill, but also reduces wildlife access. A partial fence near the access road to a landfill discourages access by people, however unauthorized dumping may still occur. Electric fencing that is in good working order discourages both people and large wildlife (e.g., bears, wolves) from gaining access to the landfill. Consideration should be given to whether a fence is present fully or partially around the site, if it is electrified, and also if the electrified fence is maintained (i.e., operational).

2.3.8 Geology

The geological materials underlying and adjacent to a landfill site will influence the rate of leachate migration to the underlying groundwater and/or ultimately the rate and of discharge to surface water. Leachate and spills will typically infiltrate more slowly through fine grained soils (e.g., silt, clay, till) than coarse grained soils (e.g., sand and gravel). Regardless of texture, soil will provide some measure of leachate attenuation in comparison to bare rock, which has a relatively high potential infiltration rate given the expectation of a greater proportion of fractures at surface, through which water can flow.

2.3.9 Climate and Permafrost

Groundwater and surface water migration from a landfill are affected by a number of factors including rate of generation and migration path. The factors of precipitation and temperature were assessed relative to their potential effects on leachate generation and migration. A summary of climate in the NWT is provided in Volume I of this report.

The annual total precipitation rate, in the areas of the NWT where communities are present, ranges from approximately 150 mm to 500 mm. Precipitation is lowest in the communities near the arctic coast and it is noted that evapotranspiration in the NWT is typically highest in areas of lower precipitation. Infiltration of precipitation (net of evapotranspiration) through waste results in the generation of leachate. Whereas overall precipitation in the NWT is low compared to many other Canadian jurisdictions, it can be expected that areas of higher precipitation will generate more leachate. The precipitation factor for a risk matrix could be developed based on mean annual total precipitation ranges of (i) less than 200 mm, (ii) between 200 and 300 mm, and (iii) over 300 mm. This information is provided from Environment Canada (2014).

The mean annual temperature within the permanently inhabited parts of the NWT ranges from -5°C to 0°C in the south near Yellowknife, and from -15°C to -10°C on the arctic coast. Permafrost is found in much of the north and central parts of the NWT. Above the permafrost, groundwater is expected to flow through soils in the summer season within the seasonally frozen active layer. It can be expected that leachate flow from a landfill will be greater in areas with warmer climate, where there is less (or no) permafrost and where the shallow soils are frozen for a shorter period of time each year. The temperature factor in the risk matrix could be based on mean annual temperature ranges of (i) less than -10ºC, (ii) -10ºC to -5ºC and (iii) above -5ºC. This information is provided from Natural Resources Canada (2012).

2.3.10 Water

The proximity of potential receptors such as surface water bodies and community water intakes to a landfill site is considered a risk factor. Surface water bodies close to a waste cell have the potential to be adversely affected by leachate or runoff; leachate infiltration can adversely affect water quality and may result in risks to aquatic life such as fish. Surface water bodies within 250 m of a site should be considered to potentially be affected by leachate.

An environmental risk to water should be considered to be present if a leachate seep is visible at the landfill site, or there is documented/monitored impact to groundwater or surface water, as this represents a recognized source of impact.

Some landfills are located in the same watershed as community water intakes or groundwater supply. The exact pathways and degree of attenuation of landfill leachate impacts are not well known at most of these landfill sites. The location of the landfill relative to the community water supply should be considered as a risk factor. It is noted that for the sites visited in this study, where landfill sites were found to be potentially upstream of a water supply source, there was no known direct influence of the landfill on the water supply source.

2.3.11 Wildlife

Wildlife may interact with waste, either directly through contact and/or ingestion at the landfill, or indirectly as a result of windblown litter or migration of impacts off-site. As noted above, the risk of interactions of wildlife with the public are increased when the landfill acts as a regular food source for wildlife.

The presence of wildlife issues, notably the presence of larger animals such as bears and wolves in the active area, are considered to negatively affect both the wildlife and the public.

2.3.12 Population Size and Location

The population of a community typically increases the volume of waste generated. Larger communities, where a greater level of services, including commercial and institutional operations are present, will result in larger volumes of ICI waste generation in a community. This may also increase the use of more hazardous materials associated with these service industries (e.g., local vehicle repair, small industry). As a result, communities with larger populations (i.e., greater than 1,000 persons) should be considered to be associated with higher risk than those with medium (500 to 1000 persons) or small populations (less than 500 persons).

In communities located within 500 m of a landfill, there is a greater potential for the public to access the landfill for the purposes of dumping, scavenging, or viewing wildlife, and should be considered a higher risk.

Communities which support or are located in the vicinity of industrial operations (typically resource development projects) may also receive greater volumes of associated waste. This includes communities such as Fort Smith, Hay River, Inuvik, Norman Wells, Tuktoyaktuk, and Yellowknife, which typically serve as support or material transport hubs for these operations. Increased bulky and hazardous waste storage resulting from these facilities is also often observed.

2.4 Considerations for Site Management to Reduce Risk

Following the inspection of the landfill sites, it is apparent that some key issues related to site operation require improvement in order to reduce the risks posed by the landfill site operations. These include the design and operation of the landfill cells, use of appropriate hazardous waste storage, cover application and site access controls. Of these, the hazardous waste storage at the landfill sites, particularly the larger stockpiles of historical hazardous waste, are considered to likely represent the largest risk and should be prioritized for action. Improved management of incoming hazardous waste is also important, as this will clearly define expectations for dealing with potential impacts of the historical stockpiles of materials while these remain on site.

2.4.1 Landfill Design and Operation

A number of basic landfill design and operation factors are part of standard landfill site operation procedures contained in MACA (2003). In addition to this guidance, Environment and Climate Change Canada is currently developing planning and technical guidance for municipal solid waste facilities in northern and remote communities, and the Mackenzie Valley Land and Water Board, in partnership with ENR and MACA, is developing landfill guidelines for municipal solid waste facilities in the NWT.

Minimizing generation of leachate, and thus risk to the environment, is achieved through the implementation of appropriate compaction and covering of lifts, as well as by minimizing cell size and closing out and capping cells as soon as practical. Ensuring that only residential, ICI and non-contaminated CRD waste is disposed within the landfill is also key to limiting impacts. Efforts to encourage and as needed, enforce, a ban on disposal of hazardous waste disposal in landfills should be implemented as part of future waste management strategy development by the GNWT. This ban should include HHW, which like hazardous waste, should be temporarily stored in a secure area until it is shipped out.

2.4.2 Site Access Controls

Site access controls have been implemented at most sites, usually consisting of at least a gate and a partial fence to prevent entry of non-authorized persons at times when the landfill is closed. Nevertheless, in many cases gates are not used by community landfill operators for various reasons including limiting dumping at the gate, convenience and wildlife issues. It is recommended that the GNWT review the sites where gates are not used and where fencing is ineffective, and work with the community landfill staff to improve access controls.

Control of wildlife (i.e., wolves, bears and other larger scavengers) entry to the landfill sites should be improved in order to minimize the potential for wildlife to become habituated to accessing food from the landfill, and the resultant negative impacts on the community. Where feasible, electric fencing should be installed and maintained in the active areas of the landfills. The GNWT should focus initial efforts on sites where interactions with wildlife are an ongoing issue, which includes Inuvik, Fort Simpson, Norman Wells, Hay River and Aklavik. ENR staff with wildlife expertise may be able to help determine what kind and degree of fencing is necessary, based on local wildlife patterns and other potential deterrents and management options which can be used at a site.

2.4.3 Hazardous Waste

The GNWT and many NWT community governments have recognized that management and shipping out of legacy hazardous waste is needed. Studies completed in 2013 and 2015 (Section 4.0) provide an inventory of hazardous waste at a number of landfill sites in the Inuvik and Sahtu regions of the NWT. Based on the site visits completed by Golder, the liquid containers at a number of these facilities are still present and are decaying (Photo 1), and/or are otherwise evidently compromised as illustrated by bulging or broken drum ends (Photo 2). It was also noted that the batteries stored at these sites are often broken and/or the plastic battery shells are deteriorating as well (Photo 3). It is strongly recommended that the GNWT organize the shipping of these historical materials in the near future. The costs for this have been estimated; however, establishment of the funding mechanisms should be prioritized.

The GNWT is best suited to assess and implement a program for bulk hazardous waste shipment by virtue of having personnel with the necessary experience, as well as the contacts and commercial terms available to this level of government.

Photo 1: Rusted and Decaying Drums (Wrigley)

Photo 2: Bulging Drums (Sachs Harbour)

Photo 3: Deteriorating Batteries (Tulita)

It was noted that in many cases at the landfill sites where hazardous waste is stored, the soils exhibit evident staining from the used oil, typically from overflowing drums with poorly installed or missing bungs, or more commonly from five-gallon pails which have less secure lids (Photo 4). Conversely, where hazardous waste is stored within the community (as opposed to a landfill site), there were few problems noted. Where possible, storage of all new hazardous waste materials should be undertaken in the area of the community garage or other building where staff can manage the materials appropriately. The use of totes (Photo 5) or other larger transportable storage containers for oil should be considered, and long term storage in smaller containers (i.e., pails) should not be allowed.

Photo 4: Five Gallon Pail Storage (Fort McPherson)

Photo 5: Totes used to Consolidate Hazardous Liquids (Whatì)

It was also noted that few landfill sites store the hazardous waste on a lined and bermed pad, or in an approved container (other than the totes noted above). It is recommended that the GNWT encourage and/or enforce the use of appropriate liners (Photo 6) or contained storage that can prevent the release of hazardous waste to the environment in the event of a leak. It is noted that materials stored on a lined area are still required to be stored upright and in sealed containers, which is not the case in the depicted photo. Consideration should be given to providing a standardized liner design for landfills and hazardous waste storage areas that can be readily modified for local needs. The GNWT should also consider standard appropriate containers (Photo 7) sized appropriately to handle more than a years' worth of waste. Typical commercial containers exist which are similar to sea-cans, which for remote sites may suit the need to ship in the containers and move them within the communities. Larger centres could consider purpose-built roofed and fenced structures (Photo 8).

Photo 6: Lined Hazardous Waste Storage Area (Fort Liard)

Photo 7: Commercially Available Hazardous Waste Storage Container

Photo 8: Roofed and Fenced Hazardous Waste Storage

Whereas all water licences require a spill contingency plan, it is recommended that site specific hazardous waste management plans be developed for the waste management portion of each water licence. This should include storage type (liner, building/sea can, bins), location (landfill site or community garage), manifesting and annual reporting.

2.4.4 End-of-Life Vehicles and Bulk Metals

End-of-Life vehicles and used appliances represent potential sources of hazardous waste fluids, lead-acid batteries, ozone-depleting substances and mercury switches. Draining of fluids from ELV is a requirement of acceptance of these units at landfills, as is the removal of the battery, however manifesting of the materials and inspection of these procedures is not common and should be enforced. Development of a standardized manifest and requirement for reporting of this information on an annual basis should be undertaken by the GNWT.

Removal of mercury switches and refrigerants from appliances and vehicles is not a regular practice at community landfills, except where the materials are being prepared for shipping. It is recommended that a program be developed by the GNWT to manage these materials at the landfill sites on a regular basis. It is similarly recommended that these operations be reported in the annual reports submitted to the Land and Water Boards.

As noted in Volume I, the quantity of empty fuel/oil drums at some landfill sites is substantial. These drums take up substantial space in the bulk storage area, and represent an environmental liability as well as a financial liability at closure. Similarly, a large quantity of used home heating oil tanks is present at almost all landfill sites. The GNWT should develop a program to assist communities with cleanup of these empty drum inventories. Consideration should be given to providing a drum crusher on a rotating basis to communities in the NWT with significant quantities of empty drums. Draining and crushing of drums will require some training in order to ensure that they are emptied and cleaned in a manner that limits and manages liquid wastes generated during the process. Considering the current GNWT guidelines (http://www.enr.gov.nt.ca/programs/hazardous-waste/guidelines) for cleaning larger tanks (e.g., home heating tanks), alternative methods would be required for these units, and may also be considered for larger volumes of empty or largely water-filled tanks stored at landfills.

Bulk metals and ELV represent a good opportunity for removal and recovery of some costs for removal, as there is some value in the metal, albeit less at present than in recent years. The GNWT is best suited to assess and implement a program for bulk metal shipment by virtue of the personnel with the necessary experience, as well as the contacts and commercial terms available to this level of government. Programs and reports are available which assess the potential for metal and ELV removal, as described in Section 3.0.

3.0 WASTE GENERATION RATES

An assessment of waste generation in the NWT was completed, to provide information and direction to the Waste Resource Management Strategy currently under development by the GNWT. The objectives of the assessment described in this section are: (i) to review and update earlier estimated waste generation rates for individual NWT communities, (ii) to estimate generation rates for a number of specific waste streams in the NWT based on a review of Extended Producer Responsibility (EPR) and stewardship programs across Canada, and (iii) to estimate the amount of residential household hazardous waste and special waste that would expect to be generated on a per capita basis by NWT residents. It is noted that CRD waste (also referred to in some jurisdictions as C&D waste) is not included in the assessment described below.

Waste generation rates in Canada are measured on the basis of incoming tonnages to landfill sites using weigh scales; rates can also be estimated based on waste audit information and assumed or estimated weights for the audited material. Waste generation data are typically collected to assess federal, provincial/territorial and municipal waste management programs and policies, as well as by various organizations interested in the management and diversion of waste. These data are most commonly collected by municipalities and communities based on commonly accepted classifications of incoming material sources, wherein the waste that is weighed at a facility scale, or as part of a detailed waste audit, have a known origin, be it MSW, CRD waste, institutional, commercial and industrial (ICI) waste, etc.

The most accurate waste generation rates are those that are derived from weigh scale information. Little to no weigh scale data is available for smaller rural and northern municipalities in Canada, which relates to the cost of operating a weigh scale compared to the benefit in gathering data on a relatively small amount of waste generation. This includes communities in the NWT, which do not have scales, with the exception of Yellowknife and recently, Inuvik.

3.1 NWT Waste Generation Rates

Estimates of waste generation in the 32 NWT communities which operate landfill sites, with the exception of Yellowknife, are largely based on the methods outlined in the document "Guidelines for Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the Northwest Territories" (MACA, 2003). The MACA 2003 report provides a description of a method referenced as "MACA (1986)" used to calculate uncompacted waste volume based on an annual residential (i.e., MSW) waste generation rate of 0.015 m^3/day (~5.5 m^3/y) per person and accounts for a proportion of non-residential waste (i.e., small amounts of institutional and commercial waste). The same formula is found in MACA (1991) and is assumed to be developed by the authors of earlier versions of the NWT waste management methods, Gary W. Heinke, Ph.D. and Jeffrey Wong. This formula is not considered to be relevant for the much larger community of Yellowknife.

The calculation of total annual waste generation for residential, institutional and small commercial sources in any one year is undertaken based on the following formula:

$$\textbf{Annual Community Waste Volume (m}^3\textbf{)} = 365\,V * P1\,(1+G)^n + 0.084 * V * (P_1)^2 * (1+G)2^n$$

Where: V = average residential waste volume generation (0.015 m^3/day/person)
P_1 = current population
G = annual population growth rate (persons/year)
n = 1, if determining waste generation rate for the current year

Specific details on the development of the above formula are not available; however, based on descriptions in Crum et. al. (1996), it is considered to include residential and school waste, but excludes bulky waste (e.g., metal, white goods, tires, etc.) and CRD material. The second part of the formula (i.e., $0.084 * V * (P_1)^2 * (1+G)\ 2^n$) corresponds to the estimated school waste generation rate of 0.001 m^3/p/d noted in Crum et. al. (1996). This formula is used by almost all communities in the NWT to provide waste generation values included in annual reports submitted under water licence requirements. These communities do not complete annual surveys of landfill capacity, nor do they have operating scales to measure incoming waste. The City of Yellowknife is an exception, in that they have a scale and complete occasional volume surveys. In 2014, the Town of Inuvik installed a scale at their landfill, however no information on waste tonnages is currently (2015) available. It is reported (Stantec, 2012) that waste in Hay River is periodically weighed, however there is no scale at the landfill site and the reported annual tonnage is stated to be an estimate.

Conversion of waste volume to tonnage in the NWT is typically based on an assumed uncompacted waste density of 99 kg/m^3 (MACA, 2003). It is commonly assumed that operators of small landfills in the NWT can achieve a compaction ratio of 3:1 (MACA, 1990), resulting in a waste density of approximately 300 kg/m^3, which is used to estimate the annual capacity usage of landfills. This is slightly lower than the compaction range of 343 to 476 kg/m^3 reported by Corporations Supporting Recycling (2003). Based on Golder's experience at a number of landfill sites in Ontario and British Columbia, where incoming tonnages and landfill capacity usage is surveyed, the apparent density of waste is typically observed to range from approximately 300 to 500 kg/m^3 at smaller landfill sites. This value includes daily cover, which is commonly required to be placed at a 4:1 waste to cover ratio. As noted earlier in this current study, compaction and placement of daily (or weekly) cover is not commonly carried out at many NWT landfills.

Estimates for waste generation for some communities in the NWT were available from annual reports and the community surveys that were completed as part of this project (e.g., Hay River, Behchokǫ̀). Comparison of these data to the calculated results from the MACA formula, and consideration of the nature of volume or tonnage estimates for these communities, indicated that it was appropriate to rely on the MACA formula results for all data analysis in this study.

Table 1 provides an updated summary of the estimated annual waste generation rates for NWT communities, based on the above MACA formula and the 2011 (Statistics Canada, 2012) populations. Table 1 also provides estimated annual waste diversion rates for each community, based on data from the territorial beverage container program provided by the GNWT and that from Yellowknife. Table 1 does not account for any increase in waste generation rates based on population growth.

As noted in the table, Yellowknife waste generation and diversion estimates are not calculated based on the MACA formula, and instead are based on data collected at the City of Yellowknife landfill weigh scale in 2014. As noted above, use of the MACA formula for the relatively large community of Yellowknife is not considered appropriate. Estimated waste diversion rates for Yellowknife include beverage container program data for the community, as well as the total amount of recyclable materials diverted through the City of Yellowknife municipal recycling program (Yellowknife, 2015).

Based on the weigh scale tonnage information available for Yellowknife in 2014 (Yellowknife, 2015), the total waste generation rate was 28,755 tonnes, of which 12,777 tonnes was CRD waste, asphalt and concrete. The net per capita waste generation for Yellowknife is 1,495 kg/p/y (total), or 831 kg/p/y excluding the CRD, asphalt and concrete. Yellowknife also reports that a total of 11,004 m^3 of airspace was used in 2014 at the MSW bale-fill part of their site. This translates to an apparent waste density of 1,450 kg/m^3, which is higher than that typically reported for other MSW landfills in Canada, and may reflect the use of baling for waste compaction.

The communities of Behchokǫ̀, Inuvik, Hay River / Hay River Reserve (K'atl'odeeche First Nation), Fort Smith, Fort Simpson and Norman Wells have populations of between approximately 1,000 to 4,000 people (excepting Norman Wells, population 727). Based on the MACA formula, the estimated waste generation rates in these medium sized hub communities ranged from 633 to 1,028 kg/p/y.

The remaining small NWT communities have populations of less than 1,000 people. Based on the MACA formula, the average waste generation rate in these communities ranged from 550 to 649 kg/p/y. It is noted that a number of these communities are considered "remote", in that they are not located on an all-season road. Some of these remote communities are accessible by seasonal ice-road, and most are accessible by barge in the summer months.

Table 1: Measured (Yellowknife) and Estimated (NWT Communities) Waste Generation, Diversion and Disposal

Community Name	2011 Population Statistics Canada	Estimated Waste Generation (tonnes/y)	Waste Diversion (tonnes/y)	Estimated Waste Disposal (tonnes/y)	Estimated Annual Waste Generation per Capita (kg/p/y)
Yellowknife	19,234[1]	28,755[1]	4,084[1]	24,671[1]	1,495[1]
Medium Sized or "Hub" Communities					
Behchokǫ̀	1,926	1,507	31	1,476	782
Fort Simpson	1,238	862	55	807	696
Fort Smith	2,450	2,077	77	2,000	848
Hay River / Kátł'odeeche First Nation	3,898	4,008	176	3,832	1,028
Inuvik	3,463	3,373	208	3,165	974
Norman Wells	727	460	31	429	633
Smaller Accessible Communities[2]					
Dettah	210	119	0[3]	119	568
Enterprise	87	48	1	47	553
Fort Liard	536	326	6	320	609
Fort McPherson	792	508	14	494	641
Fort Providence	734	465	16	449	634
Fort Resolution	474	285	9	276	601
Kakisa	45	25	1	34	550
Jean Marie River	64	35	0	25	548
Tsiigehtchic	143	80	0	80	560
Wrigley	133	74	3	71	559
Smaller Remote Communities[2]					
Aklavik	633	393	4	389	621
Colville Lake	149	84	1	83	561

Community Name	2011 Population Statistics Canada	Estimated Waste Generation (tonnes/y)	Waste Diversion (tonnes/y)	Estimated Waste Disposal (tonnes/y)	Estimated Annual Waste Generation per Capita (kg/p/y)
Délı̨nę	472	284	2	282	601
Fort Good Hope	515	312	4	308	606
Gamètì	253	145	1	144	574
Łutsel K'e	295	171	1	170	579
Nahanni Butte	201	114	0	114	567
Paulatuk	313	182	1	181	581
Sachs Harbour	112	62	1	62	556
Trout Lake	92	51	3	48	554
Tuktoyaktuk	854	554	10	544	649
Tulita	478	288	2	286	603
Ulukhaktok	402	238	1	237	592
Wekweètì	141	79	1	78	560
Whatì	492	297	4	293	603
TOTALS (of above)	41,556	46,261	4,747	41,513	

Note:
[1] Measured values obtained from the City of Yellowknife *2014 Annual Water Licence Report* (Yellowknife, 2015)
[2] Smaller communities defined as those with populations under 1,000. Remote communities defined as those which are not accessible by all-season roads. Norman Wells, although under 1,000 population, is defined as a "hub" community.
[3] Dettah utilizes the Yellowknife beverage container depot, waste diversion rate is unknown however is included in the Yellowknife waste diversion total.

In summary the overall waste generation rates for municipal, commercial and institutional waste are as follows:

- Yellowknife: 1,495 kg/p/y total or 831 kg/p/y (excluding CRD);
- Medium Sized "hub communities" (1,000 to 4,000 persons): 633 to 1028 kg/p/y; and,
- Small communities (under 1,000 persons): 550 to 649 kg/p/y.

Waste generation data from other jurisdictions was reviewed compare the tonnages generated by the MACA formula to other available data in Canada. The results of this review are presented below.

3.2 National Waste Generation Rates

At a national level, waste generation rates are calculated every two years by Statistics Canada through data collected in the document "Waste Management Industry Survey: Business and Government Sector" (Statistics Canada, 2013). The national and provincial data include waste generated in the residential sector (i.e., MSW), the ICI sector and the CRD sector. The results of these surveys provide a summary of the physical characteristics (i.e., weight by type) of waste and diverted material. This data provides the most accurate information for waste generation at a national level. Unfortunately, data for the Northwest Territories are not included in the survey results because it does not meet the confidentiality requirements of the Statistics Act. This is similarly the case for Nunavut, Prince Edward Island and Newfoundland and Labrador, which are potential comparators for the NWT.

Whereas it is recognized that waste generation numbers from a national and provincial perspective are influenced by population, services and other factors that are different from the NWT, the data nevertheless provide an overall perspective on the amount of waste generated, disposed and diverted in Canada. Table 2 contains this data, by province and nationally, for 2010. These data illustrate the variability of waste generation rates in Canada, ranging from a low of 670 kg/p/y in Nova Scotia to a high of 1,235 kg/p/y in Alberta; the Canadian average is 965 kg/p/y.

Table 2: Combined Residential and Non-Residential Waste Generation, Diversion and Disposal Rates in Canada

	Population	Waste Generation Rate[1] (kg/p/y)	Waste Diverted[1] (kg/p/y)	Waste Disposed[1] (kg/p/y)
Canada	34,005,300	965	233	729
Nova Scotia	942,100	670	281	389
New Brunswick	753,000	813	183	631
Quebec	7,929,400	1,022	296	733
Ontario	13,135,100	904	208	699
Manitoba	1,220,900	913	144	770
Saskatchewan	1,051,400	1,028	137	897
Alberta	3,732,600	1,235	192	1052
British Columbia	4,465,900	908	322	587

Note: 1 – 2010 Statistics Canada values

Statistics Canada data also provide a breakdown of waste generation from residential and non-residential sources, as shown in Table 3.

Table 3: Residential and Non-Residential Waste Generation, Diversion and Disposal Rates in Canada

Residential[1] (kg/p/y)			Non-Residential[1] (kg/p/y)		
Waste Generated	Waste Diverted	Waste Disposed	Waste Generated	Waste Diverted	Waste Disposed
401	131	270	561	104	457

Note: 1 – 2010 Statistics Canada values

The average annual residential (MSW) waste generation in Canada is 401 kg/p. This represents approximately 42% of the total waste generated by all sectors; the ICI and CRD sectors make up the remaining 58%. The key highlights from the national data are as follows:

- Total waste generation in individual provinces in 2010 ranged from 670 to 1,235 kg/p/y. There are significant differences from province to province;
- Total residential waste generation (MSW) averaged 401 kg/p/y in 2010; and,
- Total non-residential waste generation (ICI and CRD) averaged 561 kg/p/y in 2010.

As can be observed from the data, standard waste generation rates cannot be universally estimated. A number of factors affect waste generation rates; one of the most significant factors influencing waste generation is economic activity. Alberta had the highest waste generation rate in Canada during the reporting period (2008 – 2010), considered to reflect high levels of economic activity in the province. This variation also occurs at a municipal or community level, which makes it unrealistic to specify a single waste generation rate for a jurisdiction. Furthermore, it is recognized that local decisions on classifying some diverted materials (for example contaminated soil classified as cover, not waste) are not universally applied. As a result, a range of per capita waste generation rates, rather than a formula, is considered to be the most appropriate approach to use in communicating national and regional data.

3.3 Waste Generation Rates for Comparative Communities

An examination of available waste generation data in other Canadian communities with similar characteristics to those in the NWT was undertaken to provide a further comparison with the NWT data. These communities were selected based on their locations being relatively far from urban centres, demographic similarities with NWT communities, and small population sizes. Data from smaller, northern communities of British Columbia and Ontario were reviewed along with available data from Newfoundland. It was concluded that the available data from British Columbia and Newfoundland were not directly comparable to the NWT for the following reasons:

- A significant amount of the data was based on estimations rather than weigh scale information;
- Some of the data only represented generation numbers for MSW and excluded ICI waste;
- For some data, it was unclear in the supporting information as to what was included in the estimation (i.e., just MSW, MSW with CRD, etc.);
- It was unclear if waste diversion numbers were included in the data; and,
- The methodology for calculating the generation numbers was not presented.

Waste Diversion Ontario (WDO) data were also reviewed. Information from WDO is based on MSW data from municipalities in Ontario which have active recycling programs. The WDO data includes both recycling and disposal tonnages to arrive at a total waste generation rate. By definition, the waste material from this source largely represents MSW, but is expected to include some small portion of ICI and CRD material entrained within the waste stream.

Comparable communities to those in the NWT (excluding Yellowknife, which has a larger population) are included in Table 4. These data indicate waste generation rates ranging from 307 to 447 kg/p/y, which are lower than those calculated by the MACA formula for the small to medium sized communities in the NWT. In addition, waste generation data from the Rama First Nation (not from WDO) indicate a range of 168 to 328 kg/p/y, also lower than the MACA formula. This latter data was based on waste measured using a “weigh-in-motion” system mounted on a front end loader.

Table 4: Waste Generation Rates for Select Ontario Communities

Municipality or Jurisdiction	Population	Total Annual Waste Generation t/year	Annual Waste Generation Rate kg/p/year	Reference
City of Dryden, ON	8,195	3,669	447	WDO, 2011
Rama First Nation, ON	750	168 - 328	224 – 437	Golder, 2015
Township of Prince, ON	1,031	344	324	WDO, 2011
Town of Spanish, ON	696	232	319	WDO, 2011
Township of Billings, ON	507	250	381	WDO, 2011
Wahnapitae First Nation, ON	102	31	307	WDO, 2011

Waste generation data from regions such as Nunavut and Yukon, where the more remote nature of communities was considered to be similar to that of a number of the communities in the NWT, were also examined. The available data for Nunavut used the MACA formula to calculate waste generation, and were therefore not assessed further. A study completed in 2009 in the Yukon by EBA (2009) included waste generation estimates for a number of the communities, which are presented in Table 5, below.

Table 5: Yukon Waste Generation Data

Municipality	Population	Total Waste Landfilled tonnes/y	Annual Waste Generation Rate kg/p/y
Carmacks	472	343	730
Dawson City	1,923	2,550	1,330
Faro	395	350	890
Haines Junction	848	850	1,000
Mayo	466	600	1,290
Teslin	458	510	1,110
Watson Lake	1,594	1,600	1,000
Whitehorse	25,403	22,500	890

These data from the Yukon indicate an overall typically higher range of waste generation rates than the national average and are also higher than the Ontario data. The data from Whitehorse is somewhat higher than that from Yellowknife; overall, waste generation data from the other Yukon communities is higher than that estimates for NWT communities.

The waste generation estimates for medium-sized hub communities in the NWT (e.g., Inuvik, Fort Smith and Hay River) are similar to the waste generation rates for many provinces, whereas waste generation rates for smaller communities are lower. It should be noted that, overall, the communities in the NWT and Yukon can be considered "closed systems" from the perspective of the options for disposing of residual waste (i.e., waste remaining following diversion or other reduction) generated within the community. As a result, waste disposal rates in the NWT would be expected to be higher compared to jurisdictions where other, typically private, waste disposal or diversion options exist. In southern Canadian jurisdictions, a substantial part of the ICI and CRD waste is often collected and disposed in private waste facilities, which have lower tipping fees than community landfills. As a result, waste generation estimates based solely on municipal collection data for regions with private waste disposal options likely underestimate the total amount of waste being generated in closed systems.

Based on the above analysis it was concluded that accurate data for comparable communities similar to the NWT is not available and could not be directly compared to the NWT to arrive at definitive waste generation rates to project overall waste quantities.

The only absolute waste generation number available in the NWT is for Yellowknife. When weigh scale data is available from the Inuvik landfill, the data from this facility will provide direct measurement of waste generation for a typical medium-sized hub community in the NWT.

For the smaller communities in the NWT, it is recommended that the GNWT work with select communities to implement a program to weigh the incoming waste using a weigh-in-motion system. Similarly to weigh scale data, the communities using this system should separate the incoming material by source type.

Topographic surveys should be completed at the sites where waste weighing is conducted, in order to allow for calculation of apparent waste density. The surveys should be undertaken at sites where the waste disposal over the selected period is able to be contained within a clearly defined area, and can exclude or account for any significant movement of soil (i.e., excavation or berm construction).

3.4 Management of Specific Materials in the NWT Waste Stream

There are a number of specific material streams, many of which are designated as hazardous materials, which are currently managed under product stewardship, extended producer responsibility (EPR) or hybrid programs in many Canadian provinces. These materials include the following: antifreeze (glycol); lead-acid batteries; end-of-life vehicles; large appliances; mercury-containing lamps and equipment; needles/sharps; used oil; oil containers and filters; paint, coatings and their containers; pesticides, fungicides, herbicides, insecticides and their containers; pharmaceuticals; tires and household hazardous waste (HHW).

These specific material streams are currently managed in the NWT as described below.

Used Antifreeze

Used antifreeze is collected from servicing of vehicles and is stored in pails and/or drums. These materials are typically stored with used oil, and sometimes these materials are inter-mixed, which makes recovery of both of these materials difficult. Antifreeze is typically shipped to a hazardous waste receiver for recycling and/or shipment to a registered recycler or disposal facility.

Lead-Acid Batteries

Strong demand for the lead in used batteries drives manufacturers reverse distribution systems aimed at collecting used batteries from commercial vendors. Commercial establishments in Yellowknife (e.g., Canadian Tire, Walmart) accept end-of-life (ELV) car batteries from the public for free and pay new battery customers for exchange of old batteries (sonnevera, 2015). The City of Yellowknife accepts lead-acid batteries from residential and commercial generators for a fee; commercial generators are limited to two batteries per month. The City stores the batteries until there is a sufficient quantity to ship to market in Edmonton.

Local contractors in the Inuvik area collect lead acid batteries from the Inuvik landfill (KBL, 2013b). Hazardous waste inventories for the Inuvik and Sahtu regions reported significantly lower quantities at sites in the Inuvik

Region, where batteries are reported on an individual basis, than in Sahtu, where batteries are reported based on the number of pallets.

Electronics

The GNWT has created the *Electronics Recycling Regulations* under the authority of the *Waste Reduction and Recovery Act*. The regulations, effective as of February 1, 2016, address computers, display devices, printers and peripherals. A second phase addressing a much broader list of electronics such as audio-visual equipment, telephones, answering machines and small appliances is planned to follow within a few years. Environmental handling fees will fund the program; these fees are being collected by distributors and remitted to ENR, which is managing the recycling program. In the ten largest communities existing bottle depots have expanded to collect electronics for recycling. One-day collection events, scheduled at least once every two years, will be held in all other communities. Recovered electronics are being shipped to Alberta for recycling.

End-of-Life Vehicles

End-of-life vehicles (ELV) are stored at most community landfills until a sufficient number are collected to make shipping out by metal recyclers economical. In many communities, ELV have never been removed from the community. Fluids are required to be drained from the vehicles before arrival at the landfill sites; mercury switches and batteries should be removed at the site. Reports from various community waste site operators interviewed by Golder indicate that this is often not the case. At Inuvik, the vehicles are buried with the waste, or used to construct berms at the landfill, however it was reported by the operator that fluids were drained from these vehicles. The majority of the ELV consist of cars and trucks, in addition to some larger construction equipment. In more remote communities, there is a larger proportion of all-terrain vehicles, snowmobiles and boats, as well as boat motors, in comparison to cars and trucks.

A telephone survey completed for a study on scrap metal recovery in northern Alberta and the NWT contacted 12 communities in the NWT including Yellowknife, as well as GNWT transportation (Alberta Recycling Council, 2007). The result indicated 2,651 tonnes of auto hulks (ELV) were present in the NWT. This same study indicated that Yellowknife recycled 2,175 tonnes of auto hulks between 2000 and 2006.

Large Appliances

Large appliances are stored in the bulk metals area of most landfills. This typically includes fridges, freezers, stoves, washers and dryers. As with ELV, these bulk appliances are occasionally shipped out at some sites when a sufficient quantity has been collected to make recycling economically viable; however, this is not the case at many remote sites (i.e., the piles of metals have been at the same sites for a decade or more).

The above noted report completed by Alberta Recycling Council (2007) indicated 68 tonnes of white goods (appliances) were present at the 12 NWT communities. This same study indicated that Yellowknife recycled 966 tonnes of white goods between 2000 and 2006.

Mercury Containing Lamps and Equipment

Mercury containing materials observed at the landfill sites consist primarily of the switches in ELV and appliances. These switches are required to be removed from these items prior to shipping. Mercury-containing lamps and other types of mercury-containing equipment, such as thermostats, are not being segregated and not handled separately at most NWT landfill sites, with the exception of the City of Yellowknife.

Needles / Sharps

There is no NWT program to manage needles / sharps at the current time. Needles and sharps waste from GNWT health facilities are sent for disposal and incinerated in Wainwright, Alberta.

Oil Containers and Filters

Used oil containers and filters are not segregated or managed separately from the residential (i.e., MSW) stream, based on observations at NWT landfill sites.

Paint

Commercial generators of waste paints and coatings (e.g., contractors) in the Yellowknife region use KBL Environmental for waste paint management. Residents in Yellowknife can dispose of paint at City of Yellowknife HHW events, and year-round at the Yellowknife Solid Waste Facility in the HHW collection area or at the KBL transfer station. Residents of other communities can bring waste paint to HHW collection events. In some communities such as Hay River, staff spread leftover paint on CRD waste prior to disposing of the empty paint cans.

Consideration should be given to implementing a paint exchange program similar to that operated by stewardship programs in other provincial jurisdictions. The paint in these programs is made available to the public free of charge and the re-use program is considered to be efficient, as the paint does not require transportation or reprocessing.

Pesticides, Herbicides and Insecticides

There are no specific programs to manage pesticides including herbicides and insecticides or their containers in the NWT, however companies permitted to use these materials are required to dispose of them under the Pesticides Act. Considering differences between the NWT and southern jurisdictions with respect to agricultural and other pest control operations and use of maintained grass cover, it is expected that the use of this class of material will be relatively lower in the NWT.

Pharmaceuticals

There is no specific program to manage discarded pharmaceuticals in the NWT. Pharmaceutical waste from GNWT health facilities is collected by G-M Pearson Biomedical Waste Specialists and incinerated at their facility in Wainwright, Alberta.

Used Oil

Used lubricating oil is one of the most common types of hazardous waste generated in the NWT. There is widespread use of used oil burners in the NWT in commercial and industrial (typically commercial/resource development) operations. A few communities ship used oil to recycling facilities in southern Canada, however there is a significant amount of oil stockpiled at most community landfill sites. KBL Environmental consolidates used lubricating oil received from commercial customers and ships it to recycling facilities in Edmonton. The City of Yellowknife landfill receives used lubricating oil from residential customers for shipment to southern recycling facilities.

Tires

Most communities stockpile tires at their landfill sites; however, few landfills have shipped tires out to a recycling facility in southern Canada. In 2014, the communities of Yellowknife, Hay River and Fort Smith collaborated in a pilot project to shred stockpiles of used tires into tire-derived aggregate. This project was funded through the ENR Waste Reduction and Recycling Initiative. At the time of the project, Yellowknife estimated that it had a stockpile of 20,000 to 25,000 tires, Hay River had 75,000 to 100,000 tires, and Fort Smith had 10,000 to 15,000 tires. Yellowknife plans to use the tire-derived aggregate as a road base material at the landfill. The City of Yellowknife accepts tires at the landfill for a $15 fee from residential and commercial generators.

Hazardous Waste

The generation, storage, transportation and treatment of hazardous waste is administered under the *Environmental Protection Act* (EPA). The EPA provides ENR with the authority to prevent or stop the discharge of contaminants to the environment, and impose remedies. Regulations and guidelines have been established for the management of a variety of hazardous materials and hazardous waste, and for spill containment and reporting, with requirements for generator registration, permitting, manifesting and reporting.

Hazardous waste inventories of ten disposal landfill sites in the Inuvik and Sahtu regions (KBL 2013a; KBL 2013b) indicated that these communities typically store their hazardous waste at their waste management facilities. Hazardous materials stored at landfill sites or community buildings visited by Golder as part of this study typically consisted of used oil, antifreeze and lead-acid batteries. For the most part, other than the inventories provided in KBL, there are no records of the quantities of these materials accepted or stored, however the material is identified in manifests when shipped out of the communities. The amount of hazardous waste shipped is tracked by ENR.

There is one government-licensed hazardous waste management company in Yellowknife (KBL Environmental) that operates a transfer station where customers can dispose of hazardous waste for a fee. The waste is shipped primarily to facilities in Alberta.

Given that information on the amount of hazardous waste generated in the NWT is not well known, as discussed below, it is recommended that a running inventory of all hazardous wastes (as well as bulky materials) accepted and stored at the landfill or community storage area be required as part of all water licences, and that reporting of this information by the community be required as part of the normal annual water licence reporting. This would notably include used oil, antifreeze and lead-acid batteries. Development and management of a database of this information should be undertaken by the GNWT.

Household Hazardous Waste (HHW) materials are defined herein according to the list of household hazardous and special waste found in Appendix F of the Canada-wide Action Plan for Extended Producer Responsibility (CCME, 2009) and include:

- paints and coatings and their containers;
- solvents, such as thinners for paint, lacquer and contact cement, paint strippers and degreasers, and their containers;
- all batteries, including single-use, dry cell batteries (e.g., non-rechargeable);
- batteries that can be easily removed and replaced by the consumer), but excluding lead-acid batteries;
- pressurized containers, such as propane tanks and cylinders;
- fertilizers and their containers;

- pesticides, fungicides, herbicides, insecticides and their containers;
- aerosol containers, such as hair-spray containers;
- portable fire extinguishers;
- pharmaceuticals and sharps, including syringes;
- any product that meets the criteria of the CSA standard for HHW (CSA HHW Z752-03) containing corrosive materials;
- environmentally hazardous materials;
- flammable materials;
- explosives (excluding ammunition); and
- toxic materials.

The GNWT supports and promotes an event-based HHW collection program. Regular events are held in Hay River and Fort Smith; in all other communities, events are scheduled on an ad-hoc basis. Individual communities organize these events, and are responsible for transportation and treatment costs and associated logistical arrangements. The GNWT provides technical assistance and containers to ensure that materials are appropriately sorted, packed and documented. Promotional material prepared by the GNWT indicates that a wide range of HHW materials may be accepted at an event, including but not limited to paint, used lubricating oil, lead acid and consumer batteries and fluorescent bulbs (GNWT, 2010). In Yellowknife HHW is accepted throughout the year at the solid waste facility.

Beverage Container Recycling Program

The GNWT operates a territory-wide beverage container recycling program under the authority of the *Waste Reduction and Recovery Act* and the associated Beverage Container Regulations. The program is managed by ENR and is structured around a refundable deposit and a non-refundable handling fee. The recycling system infrastructure consists of 24 recycling depots and three regional processing centres. These depots are permanent sites, operated under license by private businesses, schools and community groups. The remaining communities are served by temporary, satellite collection events. Depot operators receive monthly financial assistance to help offset operational costs (GNWT, 2014b). Processing centres are located in Yellowknife, Hay River and Inuvik. The modes and routes for transporting recovered containers to market depend on location. In the Inuvik Region, containers are shipped to Inuvik by barge from the high Arctic, or by road or winter (ice) roads from communities in the Mackenzie Delta area. Consolidated loads are transported from the Inuvik processing centre via the Dempster Highway to markets in the south. In the Sahtu Region, containers are shipped to the Hay River processing centre primarily via barge in summer and access road in winter (in the case of Déljnę, containers are backhauled by air). Communities in the North Slave and Dehcho regions use the permanent road and winter road network. South Slave communities use the permanent road network. The beverage container recycling program is important in that it represents a successful territory-wide program that services all regions.

3.5 Estimated Generation Rates for Specific Materials

Most community landfill sites visited by Golder in 2014 and 2015 contain large areas where bulky materials are stored, until they can be shipped out. Most sites also contain areas where hazardous waste is stored, consisting largely of antifreeze and/or lead or alkaline, batteries. In many cases, particularly for the more remote communities in the north, these materials are stored for significant periods of time, and are only occasionally shipped out for recycling and/or disposal. As noted above, these materials are typically manifested only when shipped.

The City of Yellowknife collects data on specific materials accepted at the site. Based on the 2014 Annual Report (Yellowknife, 2015), the following was collected at the Yellowknife landfill site:

Table 6: Special Wastes Received at the Yellowknife Landfill in 2014

Waste Type	Total Units 2014	Approximate Unit Weights (kg)	kg/y	kg/p/y
Automotive batteries (lead-acid)	823	18	14,814	0.7
Tires (regular)	7,101	12	85,212	4.3
Tires (oversized)	763	45	34,335	1.7
Appliance (with Freon)	540	50	27,000	1.4
Appliance (without Freon)	2,290	50	114,500	5.7
ELV vehicles	140	1,500	210,000	10.5
Propane tanks	222	8	1,687	0.08

There is very little data on the volume of hazardous and specific materials generated in the NWT, other than that reported for the City of Yellowknife. Per-capita generation rates for specific material streams were assessed in this report based on information contained in two earlier reports (sonnevera, 2015 and exp, 2012) and from, data collected from EPR and stewardship programs for these materials across Canada and federal summaries of EPR data, contained in a database summarized by Pear (2014).

As discussed in the report "The State of Waste Management in Canada" (Giroux Environmental Consulting, 2014), improved monitoring and reporting of materials for virtually all materials managed through stewardship or EPR organizations in Canada is required, in order to provide consistent data across Canadian jurisdictions. Whereas data is available from these organizations, inconsistencies in how materials are grouped, collected and processed from year-to-year make it difficult to obtain comparable data across Canada to estimate capture rates in the NWT.

Similarly to the recommendation regarding hazardous waste data collection noted above, it is recommended that a running inventory of all bulky materials collected at the landfill sites be required as part of the water licence, and that reporting of this information by the community be required as part of the normal annual water licence reporting. This would include, for example, ELV vehicles, appliances (by type), tires and other materials which are commonly stored at many landfill sites. Development and management of a database of this information should be undertaken by the GNWT.

The following materials were assessed in this study:

Table 7: Materials Assessed in this Current Study

Antifreeze (glycol)	Mercury-containing lamps	Pesticide containers (commercial)
End-of-life vehicles	Needles / sharps	Pharmaceuticals
Lead-acid batteries	Oil filters and oil containers;	Tires
Large appliances (refrigerators, freezers, washing machines, stoves)	Paints and coatings and their containers;	Used oil
Mercury-containing equipment		

Data from Previous Reports

A study completed by exp in 2012 for Environment Canada provided an assessment of the economic viability of waste recovery opportunities in Nunavut and the Northwest Territories (exp, 2012). The study reported on eight potentially recoverable waste streams including fibres, plastics, metals, glass, HHW, electronic waste, wood waste and tires. The quantities of these recoverable materials were estimated from a waste composition model for communities of NWT and Nunavut; the model data was based on waste audits and reports prepared for Natural Resources Canada on the recovery of scrap metal from NWT and Nunavut, data from Environment Canada on end-of-life vehicles and other reports prepared for Environment Canada (Arktis 2010, 2012). Data generated for the Northwest Territories and Nunavut are listed in Table 8, below.

Table 8: Estimated Per Capita Annual Generation of Large Appliances Electronics and End-of-Life Vehicles in Nunavut and Northwest Territories

EPR Category	Northwest Territories[1]	Nunavut[1]
Large Appliances	1.12 kg/y	0.76 kg/y
Electronics	3.36 kg/y	2.32 kg/y
ELV	0.034 units/y	0.008 units/y

Note 1 – Data from exp (2012)

sonnevera (2015) reported on collection rates for some of the materials noted above, for Nunavut, Northwest Territories, Yukon and northern, remote communities in other Canadian provinces. This study focused on electronics, tires, used lubricating oil, antifreeze, lead acid batteries, consumer batteries, fluorescent lights and paints. sonnevera obtained the data from provincial and territorial stewardship programs, EPR organizations, Environment Canada, Natural Resources Canada and other third party studies and data. Per capita collection rates calculated using 2013 population values in the sonnevera report are presented in Appendix A (Table A-1).

Assessment of Data from Canadian Product Stewardship and EPR Programs

Golder gathered the best available data on collection rates for specific materials from other provinces and territories. This was completed using data gathered through previous reports (see above) and by Pear (2014) from a combination of Industry Funding Organizations (IFO) and Industry Steward annual reports, the Statistics Canada Waste Management Industry & Hazardous Waste Survey and the Environment Canada EPR program performance profiles. A list of the primary EPR, IFO and stewardship organization data sources is included in

Appendix A, Table A-2. Quantities of hazardous waste generated were summarized to facilitate comparisons across provinces. A summary of the data collection results is provided in Appendix A, Table A-2.

The data collected includes estimated waste generation rates for antifreeze, lead acid batteries, large appliances (white goods), mercury containing lamps and equipment, needles/sharps, used oil, oil filters and oil containers, paints and their containers, pesticide containers, pharmaceuticals and ELV. Data are provided by province based on those reported by the various organizations. Averages have been calculated following exclusion of obvious outliers (in the case of Quebec white goods data). Notes in Table A-2 provide comments on the data for each material as well as the total number of data points considered to be calculated from the same source (i.e., per capita results are the exact same). In the case of mercury containing lamps, needles/sharps and antifreeze, the data for other provinces is in part considered to be calculated based on a summary of overall data. Data for pesticides was available only for a program to recycle containers for commercial pesticides; information obtained for pesticide collection in BC reported of the collection of this material mixed with other (flammable) material. Data from Yellowknife, as reported above in Table 6, indicate lower rates of collection for tires, lead-acid batteries and ELV than those collected from provincial and national data or similar numbers for large appliances were reported.

The estimated per capita collection rates for specific materials are presented in Table 9:

Table 9: Estimated Per Capita Collection Rates for Specific Materials in the NWT

Material Category	Per Capita Collection Estimate		
	Pear (2014)	sonnevera (2015)	exp (2012)
Large appliances	5.20 kg/y	--	1.12 kg/y
Electronics	--	3.95 kg/y	3.36 kg/y
Tires	10.7 kg/y	0.67 units/y	--
Used oil	10.71 kg/y	14.05 L/y	--
Oil filters		1.22 units/y	--
Oil containers		0.34 kg/y	--
Paints, coatings & their containers	0.75 L/y	0.52 L/y Paint	--
Batteries (lead-acid)	0.38 kg/y	--	--
Mercury-containing lamps	0.03 kg/y	--	--
Mercury-containing equipment	0.00037 units/y	--	--
Pharmaceuticals	0.02 kg/y	--	--
Needles/Sharps	0.016 kg/y	--	--
End-of-life vehicles	0.070 units/y	--	0.034 units/y
Pesticide containers (commercial)	0.052 kg/y	--	--
Antifreeze	0.59 kg/y	0.32 L/y	--

--: no data available

Total amounts of materials collected, as well as the population for each province and territory where the data were collected are listed in both the sonnevera report (summarized in Table A-1) and the data listed in Table A-2. The per capita quantity for each Canadian jurisdiction was calculated by dividing the total quantity generated by the listed population in each data set. An average of the available per capita quantities was calculated for each material. The data sources used to arrive at the generation rates shown in Table 9 represent collected quantities, not available, quantities of each material in the waste stream.

In addition to presenting collected quantities, the sonnevera report outlined estimates on the total quantities of each of the materials available in the waste stream (i.e., generated materials). The report provided estimates of per person generation rates for each of the materials and used these to project the total quantities available of each material in a given year in the NWT, based on a population of 43,623. The information for each of the materials reviewed in the report is provided below in Table 10.

Table 10: Estimates of Specific Material Available for Collection in the NWT

	Kg/p/y	Tonnes/y NWT
Electronics	6.1	266
Tires	11.1	484
Used oil	10.1	440
Antifreeze	1.2	52
Oil filters	0.71	31
Oil containers	0.32	14
Lead acid batteries	6	174
Florescent lamps	0.36	16
Paint	1.1	48
Steel paint cans	0.37	16
Plastic paint cans	0.037	1.6

Household Hazardous Waste

As stated in exp (2012), detailed compositional information of the HHW stream is not available for the NWT. In this exp report, it was estimated that HHW makes up 0.9% of the waste generated in the NWT. This represents an estimated 441,000 kg of material, as outlined in exp (2012).

Information on total HHW collection qualities in other jurisdictions is available from the Provinces of Ontario and of Newfoundland and Labrador. Similarly to other data available in Canada for other materials discussed herein, significant variability and lack of harmonized reporting standards is expected for the reported HHW data.

The Province of Newfoundland and Labrador reported that 1,890,000 kg of HHW was diverted (i.e., sent for processing / recycling) between 2003 and 2013 (Government of Newfoundland and Labrador, 2015). In 2013, 184,000 kg of HHW is reported to have been collected, which converts to a capture rate of 0.35 kg/p/y.

Stewardship Ontario reports that 19,870,000 kg of HHW was collected in the Province of Ontario in 2014 (Stewardship Ontario, 2015). This represents a HHW capture rate of 1.46 kg/p/y (approximately 0.2%). Assuming a similar HHW capture rate, it is estimated that approximately 63,000 kg could be captured in the NWT.

Given that HHW collection is undertaken in three of the larger communities in the NWT (i.e., Fort Smith, Hay River and Yellowknife), it is recommended that this information be processed in order to provide a territory-specific data set.

3.6 Summary and Recommendations

The GNWT is presently developing a Waste Resource Management Strategy and an assessment of waste generation in the NWT was requested, as part of the overall study herein, to provide information and direction to inform this strategy.

The only absolute waste generation values available in the NWT are for Yellowknife. When weigh scale data is available from the Inuvik landfill, the data from this facility can provide direct measurement of waste generation for a typical the medium-sized community in the NWT. The overall waste generation rates as reported for Yellowknife, or calculated by the MACA formula for other NWT communities, are as follow:

- Yellowknife: 1,495 kg/p/year total; 831 kg/p/y excluding CRD;
- Medium Sized "hub communities" (1,000 to 4,000 persons): 633 to 1028 kg/p/y; and,
- Small communities (under 1,000 persons): 550 to 649 kg/p/y.

Based on the analysis of the data collected as part of this study, it is concluded that accurate data for comparable communities in other jurisdictions similar to the NWT is not available. As a result, direct comparisons of the data for other jurisdictions could not be made to the NWT data to arrive at definitive waste generation rates.

The available collected waste generation rates for materials managed under Product Stewardship, IFO and EPR programs is presented in Table 9. This information can be used to project the estimated quantities of materials that could be collected through diversion programs for these materials in the NWT, assuming a similar success rate to the jurisdictions from which the data were collected. Table 10 provides estimates of the total amount of generated materials that may be available in the waste stream in NWT.

Using data from other jurisdictions to estimate capture rates for the NWT can provide an estimate of what may be collected, assuming similar programs, acceptance and success can be achieved. Ideally however, estimates of waste diversion should be based on waste audits sampled from the area in question. It should be recognized that even for provinces such as British Columbia, Ontario and Quebec, which have mature integrated waste management systems, estimating waste generation and recovery is an inexact science. In most instances, estimates of generation are based on modelling exercises that use some combination of steward sales and waste audits. Many jurisdictions do not have reporting systems or programs in place for certain material streams. Variations between jurisdictions on how data is grouped and analyzed limit comparisons with other jurisdictions.

Data for HHW in the province of Ontario and reported generation rates in exp (2012) provide estimated capture and generation rates of 0.2% and 0.9%, respectively, of the total waste generation rate. Provided similar percentages can be assumed for the NWT, it is estimated that up to 441 tonnes of HHW may be generated and that 60 tonnes of this would be captured, assuming capture rates are similar to Ontario.

The following overall recommendations are provided based on the assessment completed herein:

- Waste audits should be conducted in communities within the NWT considered to represent "typical" demographics, size and location, in order to provide information to develop the Waste Resource Management Strategy. This could include, for example, (i) medium-sized (over 1,000 persons) "hub" communities, (ii) smaller (under 1,000 persons) accessible communities and (iii) smaller remote communities;

- The GNWT should work with the community of Inuvik to collect data on the weight and type of waste deposited (i.e., separate residential waste, CRD waste and externally sourced waste);
- For the smaller communities in the NWT, it is recommended that the GNWT work with select communities to implement a program to weigh the incoming waste using a weigh-in-motion system. Similarly to weigh scale data, the communities using this system should separate the incoming material by source type;
- Topographic surveys should be completed at the sites where waste weighing is conducted, in order to allow for calculation of apparent waste density. The surveys should be undertaken at sites where the waste disposal over the selected period is able to be contained within a clearly defined area, and can exclude or account for any significant movement of soil (i.e., excavation or berm construction);
- A running inventory of all hazardous materials, as well as bulky materials should be required as part of the water license. Reporting of this information by the community should be required as part of the normal annual water license reporting. Development and management of a database of this information should be undertaken by the GNWT; and,
- The HHW collection information from collection programs Fort Smith, Hay River and Yellowknife should be processed in order to provide a territory-specific data set. Consideration should be given to implementing a paint exchange program similar to that operated by the Product Care Association in some provinces.

4.0 LANDFILL MANAGEMENT COSTS

Waste management in the NWT is largely funded through the 32 communities that operate landfill sites. A summary of the waste management systems in the NWT and an assessment of the current and estimated near-future cost of managing waste collection, disposal and storage of materials at the community landfill sites is provided herein. These costs relate to the collection and disposal of residential and ICI waste. The costs for disposal of CRD waste are typically included in the overall waste management costs for the communities, however as volumes of these materials are not available, direct assessment of related costs are not included herein. Estimated costs to complete a Phase II/III Environmental Site Assessment at each landfill are provided. The cost to clean up each site (i.e., to remove and/or bury waste as appropriate) cannot be readily estimated for the sites without completion of a Phase II/III. The estimated cost range to complete a closure plan for the community landfills is also provided.

Waste management practices in each NWT community are summarized in Volume I - Community Waste Management Profiles (Golder, 2016). The waste generation rate for MSW and for specific materials in the waste stream including hazardous waste and a number of the bulky waste items stored at NWT landfill sites, is described in Section 3.0.

4.1 Landfill Management Systems and Material Estimates

4.1.1 NWT Waste Management Guidelines

The current standards for the design, operation and management of waste systems and landfill sites in the NWT is provided in the 2003 document "Guidelines for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the Northwest Territories" (MACA, 2003). This document outlines the expected approaches to waste collection, landfill site and cell design, waste placement, compaction, covering, bulky and hazardous waste storage, monitoring, record keeping and reporting, closure and post closure and the regulatory process. Whereas this document pre-dates the construction of a number of the currently active landfills in the NWT, it is generally used to guide the approach to regulation by the Land and Water Boards and other agencies that are involved in the process to approve water licences and associated landfill operations and maintenance reports.

Modified landfilling is described in MACA (2003) as a method of disposing of solid waste on land in a manner that protects human health and the environment. Applying engineering principles, solid waste should be confined to the smallest practical area, reduced to the smallest practical volume and covered routinely with a layer of soil. The stated objectives of solid waste management in the NWT are:

- Public Health and Safety - including minimization of (i) communicable diseases transmitted from human fecal wastes; (ii) uncovered wastes promoting infestations of disease vectors (bacteria, insects, and rodents); and (iii) the release of carcinogens and respiratory irritants from the incomplete combustion of open burning;
- Environmental Protection - as regulated by the *Environmental Protection Act*, waste management operations should minimize the potential impacts to the environment including air, land and surface water and groundwater, and should minimize improperly stored hazardous waste. Guidelines are available for specific substances such as waste solvents, antifreeze, asbestos, lead, lead-based paint, other paint and batteries;
- Costs – waste management operations are under the control of local community governments, which are in part funded by the territorial government (Operations and Maintenance Funding). As with any government funding, management includes balancing regulated activities with the available funds; and,

- Aesthetics – concerned primarily with minimizing the impacts of odours and visual impacts, including litter.

The major activities associated with landfill sites, particularly with respect to those for which cost considerations are required, are further described below.

4.1.2 Waste Management Systems and Activities Summary

The following describes existing waste management systems and activities that are presently utilized in the NWT, based on community surveys and site visits conducted in 2014 and 2015, as well as current waste management guidelines in the NWT. Based on this information, an overarching observation regarding systems and activities is that communities in the NWT could benefit from a hands-on, landfill operator training program, developed and managed by accomplished waste system operators familiar with small to medium landfills in the NWT. Such a program may be developed in concert with the current training offered through the MACA School of Community Government.

Waste Collection and Receiving

Waste collection systems in NWT communities range from small systems consisting of a modified pickup truck (e.g., in Aklavik) to contracted pick-up of residential and commercial waste in bins or large compactor trucks (e.g., Inuvik, Yellowknife). Many communities use a modified container vehicle with a side loading bin, typically capable of picking up approximately 10 to 11 cubic metres of waste per load (Photo 9) in a single stream format (i.e., no separate recyclable stream). With a few exceptions, waste in plastic bags is picked up at individual residences (i.e., MSW or residential waste) and commercial establishments (ICI) once a week, which typically requires collection staff to operate on a frequency of two to three days a week to achieve. Waste collection is usually conducted by municipal staff, however there are a number of communities which contract out this service. The collection system in the City of Yellowknife is typical of that in other Canadian cities of similar size, consisting of larger collection vehicles for residential and commercial pickup, as well as commercial vehicles which self-haul materials to the landfill, including large containers. The community of Inuvik collects waste in bins (4 m^3 and 6 m^3), which are picked up on a regular schedule.

For the most part, the compaction of the waste using the smaller pickup and side loading trucks is minimal. These vehicles are driven to the landfill when full, and usually require multiple daily trips to dispose of the loads. These vehicles are typically operated by two staff, consisting of a driver and a labourer. With the exception of Yellowknife, and recently Inuvik, there are no weigh scales at the landfills and there are no records of the number of weekly or daily trips of the waste vehicles to the sites. The number of days of waste pick-up and the approximate number of trips per day have been estimated based on discussions with community staff. It is not possible to accurately estimate the volume of waste generation using this information; however, it is typically observed that each residence has, on average, two to three bags of waste for pickup on a weekly basis. Individual details of the waste collection are provided in Volume I (Golder, 2016).

The waste is dumped at the landfill, typically in a receiving area directed by the landfill operator, site attendant, or in many cases as outlined by markers (traffic cones, etc.) or the location of the previous load. Full time attendants were not present at most landfill sites, with the exception of larger communities of Fort Simpson, Fort Smith, Hay River, Inuvik, and Yellowknife. In the remainder of the cases, including some larger communities such as Behchokǫ̀, occasional visits to the site by the operator occurred during the day when waste collection was active, or when dumping of sewage (typically a daily occurrence) was active at sites where the sewage lagoon and landfill were proximal. This operator is also responsible for directing the receipt and storage of bulky and hazardous waste and their duties would also include record keeping.

Photo 9: Side Loading Waste Truck

The transportation and disposal of CRD waste at community landfills is typically handled through delivery of the waste materials to the site by external contractors or community staff. At some sites (e.g., Behchokǫ̀, Fort Simpson, Paulatuk, Tuktoyaktuk), the CRD waste is placed in a separate cell or storage area from the MSW, or may be set aside for community use (Ulukhaktok) or later use as alternative cover (e.g., Aklavik). At a few sites (e.g., Colville Lake, Łutsel K'e), all waste is co-disposed in the same cell and little separation is undertaken, with the exception of larger quantities of hazardous waste (antifreeze, lead-acid batteries, oil).

In many communities, a front end loader used on a weekly basis for a few hours a week to push back the incoming waste in the receiving area, or to lift the material into the cell. The loader may also be used, along with an excavator or other equipment, to manage larger materials within the bulky waste area.

Based on the above, costs related to waste collection and receiving would consist of the personnel and equipment (including fuel, maintenance and storage) to collect and dump the waste, an attendant (part- or full-time) to manage the landfill, direct the waste disposal and placement of bulky and hazardous waste and a heavy equipment operator and front end loader to manage the receiving and bulky waste areas.

Waste Compaction and Covering

Waste compaction and covering requirements outlined in MACA (2003) differ somewhat depending on the method of waste filling (area, trench or depression). Whereas it is not stated directly, the timing of compaction of waste is largely based on placement of a 1.5 to 2 metre lift of waste, which is compacted to a thickness of approximately one half to one metre using three to five passes of heavy equipment. The City of Yellowknife compresses MSW in a baling facility and places the bales in a lined collection cell.

The compaction should preferably be undertaken by three to five passes in each of two directions using a bulldozer (or a compactor if available). Almost all communities own or can hire the services of a D-6 or larger bulldozer for this purpose. In addition to maximizing airspace, compaction of the waste can limit the amount of windblown litter, provided that some or alternative cover (e.g., tarp) is applied. For sites where daily soil cover is not applied, consideration should be given to limit the size of the working face and to use a frame and tarp or other alternative daily cover, where appropriate, to limit windblown litter. Crushing or grinding CRD wood waste, where approved for disposal, could provide the added benefit of potentially managing this bulky waste in a more productive and meaningful way. Special procedures for waste disposal are required at many landfills, to deal with animal carcasses and materials such as asbestos. In these cases, separate disposal areas or excavation of a trench, placement of the waste material, followed by loose waste cover and compaction is undertaken. Locations where asbestos-containing materials are stored must be tracked and recorded.

Waste covering is undertaken to limit contact of persons and wildlife with waste and to minimize vectors (i.e., small mammals and birds). Best practices, particularly in larger communities (i.e., with more waste generation) include placement of 0.1 m of soil cover on a regular basis, provided the minimum waste thickness has been achieved. Draft standards currently under preparation for the Mackenzie Valley Land and Water Board (MVLWB) (Tetra Tech, 2015) suggest that this cover be placed every 7 days for medium sized communities (500 to 5,000 persons) and every 21 days for small communities (under 500 persons). Depending on the cell design, the current covering practice recommendation involves placement of 0.3 m of soil over the compacted waste when it has reached the top of the berm in the area fill method (typically 2 m) or one metre for the trench method. Placement of cover prior to winter is also required. Covering of waste in the NWT does not usually occur from approximately November 15 to April 15, as the soil is frozen and cannot be effectively placed. Final capping of a cell with 0.6 m of soil, forming a cover that sheds water, is to be undertaken when the cell is complete.

Material for interim (i.e., daily, weekly, monthly or seasonal) cover is typically sourced from the landfill site area or a nearby borrow source. As it is not required to consist of higher quality (i.e., coarse, clean, well graded) material, the cover soil is more readily available than granular resources used for runway and road construction projects. As a general guide, Class 3 or Class 4 material as defined in GNWT (2015) would be acceptable cover material. Finer grained material is often preferred as final cover; but is not always necessary. Fine-grained material is less suitable for interim or daily cover as it is more difficult to spread and may limit drainage and result in perched leachate within the cell.

Based on the above, waste compaction and covering costs will vary depending on the amount of waste to be managed and the equipment used (typically a D-6 bulldozer). Taking the sizes of the communities into account, it is assumed that compaction and covering would occur at most medium sized sites on a weekly basis, through use of a bulldozer, if the planned guidelines are being followed. Compaction at small sites would occur every three weeks and would also incorporate cover placement. Provided that cover soil is staged by a front end loader as part of weekly activities, this operation is anticipated to take approximately two to three hours. An additional day or two of effort at the end of each season (i.e., November, or earlier depending on climate) is anticipated for a bulldozer and loader, to prepare and cover the sites for winter operation.

Photo 10: Bulk Waste Storage Area, Paulatuk Landfill

Bulky Metals

Bulky metals are stored at most landfill sites, typically separated into piles of white goods, drums, empty tanks, scrap metal, culverts, etc. Some of these may contain halocarbons and mercury switches, which are often not removed. The metals are managed differently, depending on type. Empty barrels should be stored on their sides with caps (bungs) in place to prevent water from collecting in them; some communities crush the empty barrels, which prepare the material for shipping and also maximizes use of the bulky waste storage area. Crushers are not available at many communities (e.g., Aklavik, Paulatuk) where larger quantities of barrels were noted; organization of a drum crushing program, with appropriate containment of residual liquids could be considered to reduce space requirements for these materials and simplify future management. It was noted at a number of sites that a significant part of the metals included culverts, which some operators confirmed was from road work completed by GNWT or others. Options to better manage or reduce the space used by these materials should similarly be considered.

For the most part, the bulky metals remain on site for a significant period of time until shipping for metal recycling can be organized. As a result of the high cost and related transportation issues, most bulky metals remain at NWT community landfill sites until or even beyond closure. There are a few communities that have shipped out bulk metals for recycling, including Yellowknife and Hay River. The significant amount of this material is problematic at some sites relative to the management of new material that is delivered to the site, and represents a long term environmental liability.

Photo 11: Bulk Metals Storage, Hay River

Tires

Tires are usually separated at the landfill sites. The majority of these are from personal automobiles or community vehicles in communities with road access, whereas more remote, northern NWT communities have a higher proportion of all-terrain vehicle (ATV) tires. Some larger tires from heavy equipment are also typically present. There is, at the present time, no program to manage tires in the NWT and in some cases the tires are buried at closure of a landfill site. In 2014, the communities of Fort Smith, Hay River and Yellowknife conducted a pilot project to shred discarded tires and use the tire-derived aggregate at the landfill.

Photo 12: Tire Storage, Fort Simpson

End-of-Life Vehicles

Almost all landfills have an area where ELV are stored. These include cars, trucks, ATV and snowmobiles. For the most part, these vehicles remain on site for quite some time. Some communities have occasionally shipped out vehicles for recycling, however others, such as Inuvik, bury the vehicles on-site. Removal of fluids from these vehicles is a requirement of typical water licences. In the case of Inuvik, it is reported that the vehicles were drained prior to burial. Although not confirmed, it is expected that removal of mercury switches from vehicles is not undertaken other than when these vehicles are shipped out.

Some communities, notably in the southern part of the NWT, ship out ELV irregularly. Programs for ELV vehicle storage, crushing and shipping have been undertaken in other northern jurisdictions. Documents prepared by Recycling Council of Alberta (2007) and Summerhill Impact (2014) provide information and approaches to ELV management in the north. In addition, the City of Yellowknife hires a contractor to manage their ELV; the crushed vehicles are regularly shipped south for recycling.

Hazardous and Special Waste

Hazardous and special waste is stored at many landfill sites, however in some communities (e.g., Behchokǫ̀, Gamètì, Ulukhaktok) these materials are stored at the community maintenance facility. This material is typically stored for a significant period of time prior to shipping out, under manifest, to processing facilities in southern Canada. The significant amount of this material is problematic at some sites, relative to the management of new material that is delivered to the site. These hazardous waste stockpiles represent a long term environmental liability.

Photo 13: Hazardous Waste Storage Compound, Hay River

Electronic Waste (e-waste)

The NWT Electronics Recycling Program was launched February 1, 2016 under the *Electronics Recycling Regulations*. Under the program, environmental handling fees are collected to cover the costs of the program; the fees collected on electronics at the point of sale and remitted to ENR, which manages the recycling program. Permanent electronics recycling depots have been established in the ten largest communities at existing beverage container depots. One-day collection events, scheduled at least every two years, will be held in smaller communities. Recovered electronics are being shipped to Alberta for recycling. A number of landfill sites currently separate e-waste, however it was noted in the site visits completed in this study that some have not yet shipped electronics stockpiles out of the community.

Contaminated Soils

Hydrocarbon contaminated soils are often managed at landfill sites, particularly for spills associated with community operations as well as small residential spills. Contaminated soils associated with other facilities (e.g., airports) are typically transported out of the community by the agency or government responsible. The contaminated soil piles managed on-site at landfills require registration with ENR as a contaminated soils receiver (ENR 1998) in addition to requiring some heavy equipment (front end loader or excavator and bulldozer) to turn over the piles to assist in aeration and degradation of the hydrocarbons. This work is not typically included in the standard waste management tasks, in part as it is not a regular or planned occurrence.

Overall Bulky and Hazardous Waste Management Efforts

Based on our visits to the landfills, a significant amount of effort is expended by community staff in order to segregate and manage bulky and hazardous wastes. This represents two separate activities involving (i) management and segregation of incoming material and (ii) segregation of historical waste materials. The latter activities are often undertaken as the piles become too large, or an expansion of the waste cell requires moving of material. From the perspective of estimating the annual cost for waste management, only those activities from incoming materials should be considered. On an annual basis, approximately two days of effort, including a loader/forklift (if available) is considered to be required to palletize and prepare relevant materials for shipping out of community.

4.1.3 Waste Management System Survey

Information collected in the community surveys included the time spent by community staff on waste management activities (waste collection, compaction and covering, site attendant). The information collected in the community surveys was updated based on discussions with management and operations staff during the site visits. This combined information was helpful to assess the current level of effort for each site and for discussions of the reported cost of waste management for the communities, however the cost of current waste collection and landfill management was typically not well understood or reported.

Waste collection efforts are the easiest to estimate, as collection is undertaken on a scheduled frequency and usually for the entire day. In some cases, where undertaken by a private firm local to the community, the contract cost is available. The frequency of waste collection is defined as the number of days which community or contracted staff work to pick up waste within the community. In most cases, weekly pick-up at each residence was achieved as a result of collection frequencies. In many communities, collection staff work typically two to three days a week, usually for a full day; some communities collect waste once a week, one community collects waste four days per week and others five half-days per week. Collection for three communities (Fort Simpson, Inuvik and Yellowknife) was 5 full days a week.

Site attendants were rarely present at community landfills on a full time basis, with the exceptions of Fort Smith, Hay River, Fort Simpson, Inuvik and Yellowknife; this was a part time activity for most communities, often completed by a supervisor with other activities in the community (water, sewer, roads). Waste management, compaction and covering activities were usually limited to no more than weekly, or even seasonally, at most sites. Where completed more frequently (typically weekly), it is reported that the pushing of waste in the active tipping area and compaction were completed in a half day or less. Compaction at most of the smaller communities is currently reported to be undertaken monthly or seasonally. In these cases, it is typically reported that this activity takes a few days at most.

Table 11 provides the results of the community survey on waste collection and compaction activities, updated based on information provided during the site visits.

Table 11: Community Survey Information

	Waste Collection Frequency (days/week)	Collection Vehicle	Waste Compaction Frequency	Compaction Equipment	Waste Covering Frequency	Cover Materials
Aklavik	3	Pickup truck (3.5 m^3)	Twice in summer	Bulldozer Front End Loader	No regular cover placement	Gravel from west mountains, local brush
Behchokǫ̀	2	Vehicle type unknown	Weekly	D-6 Bulldozer	No regular cover placement	Local fine grained soils
Colville Lake	Varies each month	ATV or Pickup	No compaction undertaken	No compaction undertaken	No regular cover placement	Local sandy soils
Dettah	1	Vehicle type unknown	Twice per year	Contracted	No cover in winter	Gravel; but has not been used in quite some time
Déljnę	3	Garbage truck	Sporadically	Equipment unknown	Regular cover placement	Soil
Enterprise	1	Vehicle type unknown	Sporadically	International Series B bulldozer	Sporadic	Silty sand and gravel
Fort Good Hope	2	11 m^3 vehicle	Monthly	D6 Bulldozer	Annually	Silt/clay
Fort Liard	2	11 m^3 vehicle	Once a year	D8 Bulldozer	Annually	Soil
Fort McPherson	3	Ford F350 (8 m^3)	Twice per summer	D6 Bulldozer	Sporadic	Pit run gravel/dirt
Fort Providence	2	Ford F450 (7 m^3)	Bi-weekly	Loader	Annually	Contaminated soil
Fort Resolution	2	Vehicle type unknown	As required	Bulldozer	Sporadic	Soil
Fort Simpson	5	15 m^3 vehicle	Sporadically	Contracted	No cover	Local sandy soil
Fort Smith	2	19 m^3 garbage truck	As needed	Equipment unknown	Summer as needed	Local quarry soil
Gamètì	3	11 m^3 vehicle	Daily	D4 Bulldozer	Daily	Local sandy soils
Hay River	2	Compaction truck (volume unknown)	Weekly	D-6 Bulldozer and CAT 616B Compactor	Sporadic	Clayey soil from site

	Waste Collection Frequency (days/week)	Collection Vehicle	Waste Compaction Frequency	Compaction Equipment	Waste Covering Frequency	Cover Materials
Inuvik	5	4 m^3 and 6 m^3 bins and 16 m^3 side load	As needed	D6 and D9 Bulldozer	Annually	Fine grained local soil
Jean Marie River	Unknown	Vehicle type unknown	Not compacted	Not compacted	Final cover only	Silt soil from site
Kakisa	2	¾ ton pickup	Not compacted	Not compacted	No cover	No cover material
Łutsel K'e	3	10 m^3 vehicle	Not compacted	Not compacted	Less than every 2 years	Local weathered shale
Nahanni Butte	2	F150	Not compacted	Not compacted	No cover	No cover material
Norman Wells	4	Compaction truck (volume unknown)	Once per week	Bulldozer	2-3 times per week	No information available
Paulatuk	2	11 m^3 side load	Monthly or less frequent	D6 Bulldozer	Cell closure	Local sandy soils
Sachs Harbour	2	Vehicle type unknown	Monthly	D6 Bulldozer	No cover	No cover material available
Trout Lake	3	2 m^3 vehicle	Every few weeks in summer	D4 Bulldozer	No regular cover placement	No cover material
Tsiigehtchic	2	Vehicle type unknown	As needed	Equipment unknown	No cover in winter	No information available
Tuktoyaktuk	3	8 m^3 side load	Every 2 months in summer, monthly in winter	D-6 Bulldozer CAT 938 Loader	No cover until closure	No cover material available
Tulita	2 (summer) 1 (winter)	10 m^3 haul-all	Weekly	D4 Bulldozer	Monthly	No information available
Ulukhaktok	5 half days	11 m^3 haul-all	Once or twice a month in non-frozen months	D-6H, D-6N Bulldozer	Every 2 weeks	Local sand and gravel
Wekweètì	3	11 m^3 haul all	Every 2 weeks	Bulldozer	Daily	No information available

	Waste Collection Frequency (days/week)	Collection Vehicle	Waste Compaction Frequency	Compaction Equipment	Waste Covering Frequency	Cover Materials
Wrigley	3 (summer) 2 (winter)	1 tonne flat deck truck with side rails	Every few weeks	D4 Bulldozer	Every 2 to 3 weeks during summer	No information available
Whatì	5 (half days)	11 m^3 haul-all	3 times a month	Loader	2-3 times annually	No information available
Yellowknife	5	Large waste truck for curbside carts	Daily	MSW compacted at a baling facility	Daily	Chipped wood waste, treated soils

4.1.4 Waste Generation and Cover Material Usage Estimates in NWT

Estimates of waste generation in NWT communities provided in annual reports for water licences are typically based on the methods outlined in MACA (2003), however in some cases reported volumes appear to be significantly different from the MACA approach and are not justified with data (e.g., vehicle volume and tipping counts). The calculated uncompacted volume from the MACA approach and conversion to tonnage based on an uncompacted density of 99 kg/m^3 (MACA, 2003) were used to generate the waste generation tonnages in a consistent approach, as outlined in Section 3.0.

Table 12 provides a summary of the estimated annual waste volumes and waste tonnage generated in each NWT community, based on the above noted method. Tonnages for Yellowknife are based on reported data from the scale. Compacted volumes provided in the table are based on an assumed 3:1 waste compaction rate. The population used to generate the values in Table 12 is based on the Statistics Canada (2012) values for the communities in 2011. These are slightly different than those used in the NWT Waste Cost Model (see below), but are considered to be reasonably similar.

For the purposes of cost estimates provided below, the approximate annual volume of cover for each community was calculated based on standards and practices in other jurisdictions (e.g., Ontario), where it is assumed that a waste to cover ratio of 4:1 will be placed. Given that cover will not be applied in the NWT landfills in the period from November to April, the estimated amount of cover has been reduced accordingly by multiplying the resultant cover volume by 7/12. As Yellowknife uses a baling system to compact their waste, the compacted waste volume and cover ratios are not comparable to the other landfills and have not been included below. The total annual cover used by Yellowknife is not specified in their recent annual report.

Table 12: Estimated Annual Waste Generation and Annual Cover Volume Calculations for NWT Landfills

Community Name	Estimated Annual Waste Generation Uncompacted Volume (m^3)	Estimated Annual Waste Generation Mass (t)	Compacted Waste Volume (m^3) (3:1 Compaction Ratio)	Estimated Volume of Annual Cover Material Required (m^3)
Yellowknife	290,455	28,755		
Medium Sized or "Hub" Communities (typically 1,000 to 4000 persons)				
Behchokǫ̀	15,219	1,507	5,073	592
Fort Simpson	8,709	862	2,903	339
Fort Smith	20,977	2,077	6,992	816
Hay River / Kátł'odeeche First Nation	40,486	4,008	13,495	1,574
Inuvik	34,070	3,373	11,357	1,325
Norman Wells	4,646	460	1,549	181
Smaller Accessible Communities (under 1,000 persons)				
Dettah	1,205	119	402	47
Enterprise	486	48	162	19

Community Name	Estimated Annual Waste Generation Uncompacted Volume (m^3)	Estimated Annual Waste Generation Mass (t)	Compacted Waste Volume (m^3) (3:1 Compaction Ratio)	Estimated Volume of Annual Cover Material Required (m^3)
Fort Liard	3,297	326	1,099	128
Fort McPherson	5,127	508	1,709	199
Fort Providence	4,697	465	1,566	183
Fort Resolution	2,878	285	959	112
Kakisa	249	25	83	10
Jean Marie River	356	35	119	14
Tsiigehtchic	809	80	270	31
Wrigley	750	74	250	29
Smaller Remote Communities (under 1,000 persons)				
Aklavik	3,971	393	1,324	154
Colville Lake	844	84	281	33
Déljnę	2,865	284	955	111
Fort Good Hope	3,154	312	1,051	123
Gamètì	1,466	145	489	57
Łutsel K'e	1,725	171	575	67
Nahanni Butte	1,151	114	384	45
Paulatuk	1,837	182	612	71
Sachs Harbour	629	62	210	24
Trout Lake	514	51	171	20
Tuktoyaktuk	5,595	554	1,865	218
Tulita	2,905	288	968	194
Ulukhaktok	2,405	238	802	160
Wekweèti	797	79	266	53
Whatì	2,999	297	1,000	200

4.2 Waste Management Funding and Costs

4.2.1 Community Funding for Waste Management

At the present time, community landfill operations and maintenance funding is provided by GNWT (through MACA), to all community governments including the City of Yellowknife. The funding provided to the community governments is intended to support operations of municipal services, one of which is waste management.

Whereas some communities did provide waste management cost information through the community survey, discussions with staff during the site visits indicated that for most communities, the costs of waste management have been intertwined with those of other community services. This is considered in large part to be the result of the funding approach for this service, which is not separated from general activities, unlike water and wastewater systems which are specifically funded. Equipment used to complete waste management tasks (e.g., waste compaction), is often primarily used for road maintenance or community construction activities. Waste management funding was not separated from general activities, as was the case for water and wastewater systems. The funding review process that MACA underwent in partnership with community governments identified this concern and a recommendation was made to separate waste management funding from general operations and maintenance funding and include it with the water and wastewater funding. In order to better assess waste management costs, funding of waste management should be allocated based on consistent approved methods of waste management operations. This has the potential to improve the ability of the communities to allocate the necessary funds to better meet NWT landfill operation standards.

Funding to manage the beverage container and planned electronics recycling program is generated through a product stewardship model, where environmental handling fees are placed on these products when they are first distributed or imported into the NWT. The fees are deposited into the Environment Fund and are used to pay for collection and recycling of the products at the end of their life cycle. GNWT consolidated revenue fund is not used to run these programs.

Data on the landfill management costs, as well as for any landfill-related income (i.e., user fees) was requested as part of the community surveys and was further discussed in the site visits. This information is summarized in Table 13, along with calculated per capita costs. Communities that reported charging waste collection fees indicated that this was charged per residence or commercial operation (e.g., community store, hotel) and government operation (e.g., police, airport). Higher fees are typically reported to be charged for commercial and government operations.

Information supplied on costs was limited in the database to a total of 12 of the 32 communities with landfill sites. It is reported by most communities that the income (e.g., taxation or levy for waste collection) is typically calculated based on the total number of residences multiplied by the monthly levy. Based on discussions with community management staff at the time of the site visits, it is expected that the reported costs are an estimate and do not correspond exactly to the costs directly associated with waste collection and landfill management. As a result, the outcomes of the comparisons below should be viewed with caution.

Table 13: Waste Collection and Landfill Costs Reported by NWT Communities

	2011 Population	Waste Collection and Landfill Cost/y	Waste Management Income/y	Waste Collection and Landfill Cost/capita/y[2]
Aklavik	633	$5,000		
Dettah	210	$10,000		$48
Fort McPherson	792		$50,000	
Fort Resolution	474	$100,000		$211
Fort Simpson	1,238	$350,000	$175,000	$283
Fort Smith	2,450	$522,000[1]	$456,000[1]	$213
Gamètì	253	$13,306		$53

	2011 Population	Waste Collection and Landfill Cost/y	Waste Management Income/y	Waste Collection and Landfill Cost/capita/y[2]
Hay River / Kátł'odeeche First Nation	3,898	$489,000	$31,000[1]	$125
Paulatuk	313	$60,000	$30,000	$192
Trout Lake	92	$24,000		$261
Tulita	478	$50,000		$105
Ulukhaktok	402	$69,307	$44,700	$172
Wekweèti	141	$50,000		$355
Yellowknife	19,234	$2,750,000	$2,475,000[1]	$143

[1] Values provided by GNWT (MACA) September 17, 2015

[2] Per capita estimated landfill costs do not take estimated income from landfill activities into consideration.

4.2.2 Provincial Waste Management Costs Comparison

A summary of waste management costs in Canada (Statistics Canada, 2013) was obtained for comparison to reported values in the NWT. The information contained in this summary excludes the territories, as well as Prince Edward Island, due to confidentiality requirements. Figure 3 illustrates the per capita costs for waste management activities in the provinces and nationally in 2010. These costs are reported by Statistics Canada to consist of local government costs. Waste collection and transportation are reported to be the largest of these costs, totalling $36 per person nationally. On a per capita basis, costs for waste collection and transportation in Canadian provinces ranged from approximately $15 to $45, whereas that for operation of waste management facilities (i.e., disposal) ranged from $10 to $40. The estimated total annual cost for these items ranged from $40 to $60 per person.

On a per capita basis, the reported cost for waste management (collection, transportation and disposal) in the NWT ranged from $48 to $355 per person. Some communities (Fort Simpson, Fort Smith and Yellowknife) report relatively higher per capita income from fees or other sources related to waste management than other NWT communities, with the intent of offsetting budgeted costs. The per capita waste management costs for these communities ($143 to $283) is considered to reasonably represent the cost of waste management. It is further noted that some of the reported waste management costs from NWT communities are considered to be lower than the actual cost to conduct waste management operations, based on assessments described below.

The range of reported costs is higher in the NWT than in Canadian provinces, which is not surprising considering the comparatively smaller population in the NWT, as well as other factors including the design and operation techniques for landfills, access to alternative disposal and diversion options. The results of comparison to the other reported jurisdictions should therefore be viewed with caution. Comparison of per capita waste management costs with other similar jurisdictions (e.g., Yukon and Nunavut Territories) was not possible due to lack of data.

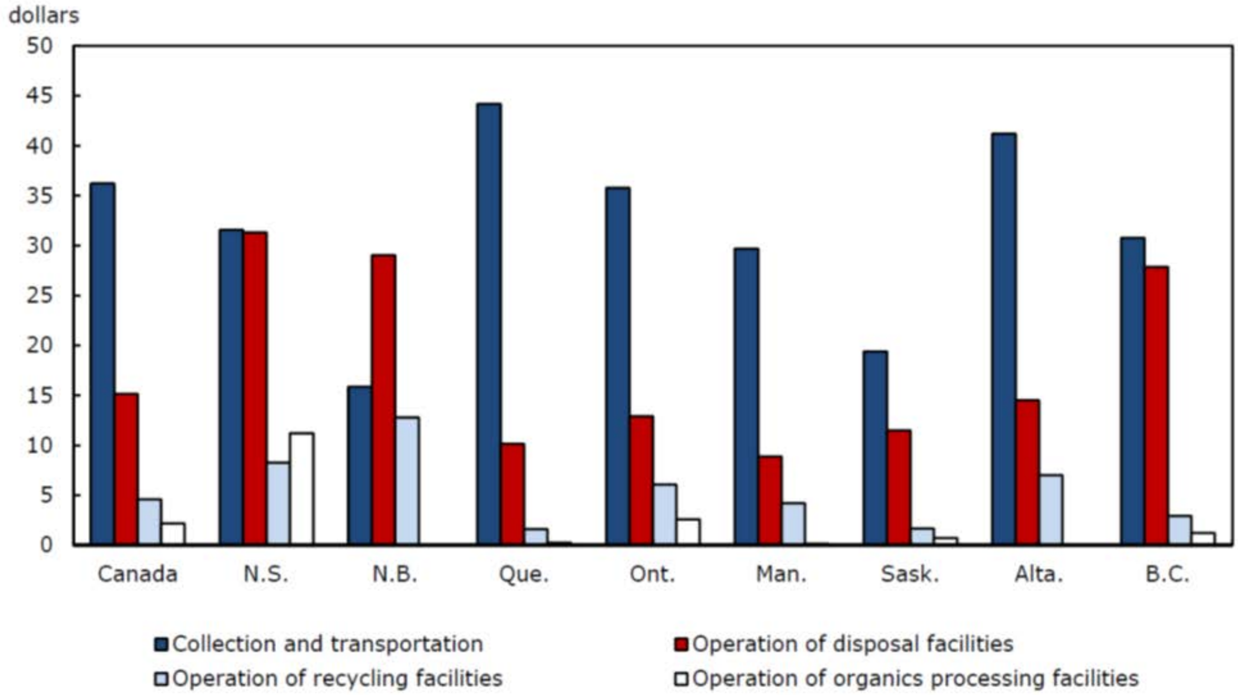

Figure 3: Per Capita Local Government Expenditures Related to Waste Management for Selected Provinces in 2010 (Statistics Canada, 2013)

Figure 4 illustrates the per tonne costs for local governments in the provinces in 2010 for waste collection, transportation and disposal. Costs for waste collection and transportation in Canadian provinces ranged from approximately $10 to $90/tonne/year, typically $20 to $40/tonne/year. The highest costs reported nationally are for jurisdictions where there are more diversion programs (e.g., Nova Scotia) and it is expected that some of the costs of these operations are incorporated into waste collection and site management.

The estimated cost per tonne reported for communities in the NWT was reviewed for comparison with other jurisdictions, however as the tonnage data for all but Yellowknife are calculated values, a direct comparison could not be made. In the case of Yellowknife, the collection and waste management cost of $96 per tonne is slightly higher than the higher end of the provincial range (i.e., Nova Scotia). It is noted that, as a result of the essentially “closed system” (i.e., no alternative waste disposal options), higher waste volumes are disposed at the Yellowknife landfill compared to other similar Canadian jurisdictions. In these other jurisdictions, private waste disposal options typically exist and, as a result, a substantial part of the ICI and CRD waste is often collected and disposed in these private waste facilities. The cost per tonne comparison to other Canadian jurisdictions may therefore not be strictly equivalent, even for Yellowknife. Economies of scale, as well as access to transportation and other waste management alternatives and diversion are also expected to play a significant factor in the cost of waste management in Yellowknife compared to other jurisdictions.

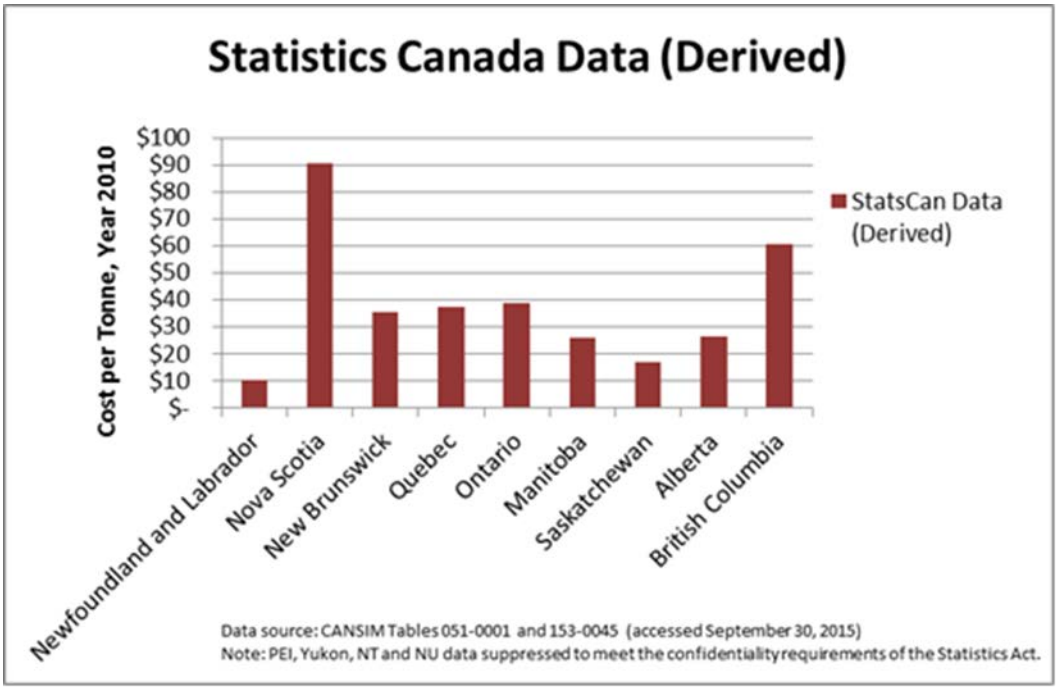

Figure 4: Per Tonne Local Government Expenditures Related to Waste Collection and Disposal for Selected Provinces in 2010 (Derived from data in Statistics Canada, 2013)

As noted in Section 2.0, a significant amount of bulk metals, ELV empty drums and tanks and hazardous waste (antifreeze, leftover fuel, lead-acid batteries and oil) is present at many NWT landfill sites, even at those where the community has shipped out material in the recent past (e.g., Hay River, Ulukhaktok). Additional bulky waste, including tires, is also present in significant quantities. These materials represent an environmental risk from spilled fluids (including from ELV if not drained, and from partially empty fuel/oil drums) as well as taking up increasingly large portions of some of the landfill site storage areas.

Two studies were undertaken in 2013 in the Sahtu and Beaufort Delta - Inuvik regions by KBL for Ecology North (KBL, 2013a) and the GNWT (KBL, 2013b), which involved completion of inventories of the hazardous waste, as well as some of the metals (largely ELV and white goods). Costs to manage, ship and dispose of the hazardous waste were estimated in these studies (Table 14). A third study was completed to update costs for the communities of Paulatuk, Sachs Harbour and Ulukhaktok (KBL, 2015), which identified higher costs related in large part to marine transportation. The costs for the hazardous waste removal identified in the KBL reports ranged from approximately $75,000 to over $795,000 per community and total approximately $3.15 million for the 12 communities assessed in the KBL reports. In addition, a recent cost estimate has been prepared to manage, ship and dispose of the historical hazardous and bulky waste in the community of Délı̨nę (TetraTech, 2014a), which was estimated at approximately $520,000.

Based on observations at the time of the site visits by Golder in 2014 and 2015, the historic hazardous waste is still in place at these communities, as well as at five other community landfills (Enterprise, Fort Providence, Fort Simpson, Fort Smith and Łutsel K'e). The observed waste at these latter communities consists of similar materials to those in the communities assessed by KBL. Assuming the average of the cost estimate for hazardous waste stockpiles at the assessed communities (approximately $150,000 excluding those in the 2015 study), the overall financial liability for the 17 communities is estimated to be on the order of $3.9 million for this historical hazardous waste. It is recognized that communities included in the KBL reports included those which are more remote and were observed by Golder to have proportionally larger quantities of hazardous waste. Most communities in the south ship out these materials more regularly. Nevertheless, the historical material represents a financial liability, which is not captured in annual operating cost estimates.

Table 14: Historical Hazardous Waste Removal Cost Estimates for NWT Communities in the Inuvik and Sahtu Regions

Site	Hazardous Waste Removal Cost Estimate	Reference
Aklavik	$76,154	KBL 2013b
Colville Lake	$111,182	KBL 2013a
Fort Good Hope	$267,655	KBL 2013a
Fort McPherson	$89,723	KBL 2013b
Inuvik	$94,139	KBL 2013b
Norman Wells	$227,844	KBL 2013a
Paulatuk	$557,107	KBL 2015
Sachs Harbour	$795,650	KBL 2015
Tsiigehtchic	$117,127	KBL 2013b
Tuktoyaktuk	$75,091	KBL 2013b
Tulita	$188,800	KBL 2013a
Ulukhaktok	$442,929	KBL 2015

The cost for removal or management of the bulk metals and ELV vehicles, etc. was not included in the studies. Some communities (e.g., Inuvik, Tuktoyaktuk) have buried the metal and ELV vehicles; however the vast majority remains in place above ground. In some cases, consolidation of some materials and reduction of environmental liability may be achieved by crushing empty drums (as noted above) and possibly white goods (following removal of any liquids, ozone-depleting substances and mercury switches). Depending on the metal markets, it may be cost effective to consider tendering removal of metals from a number of communities. As noted above, the feasibility of scrap metal recovery including ELV has been estimated in other reports (e.g., Recycling Council of Alberta, 2007), however this information has not been extensively reviewed as part of this current report.

4.2.3 Landfill Costs with Best Management Practices

Draft estimates of the cost for waste collection and management have been recently prepared by MACA for each NWT community, using a consistent approach and taking into account the variation in equipment and personnel costs across the NWT (MACA, 2015). The costs considered in the “NWT Waste Cost Model” include waste collection staff, the waste collection truck, landfill staff and site equipment maintenance/use, shipping of hazardous waste, program administration and reporting, and can be considered to be equivalent to a Class D cost estimate.

Table 15 provides a summary of these cost estimates.

The cost estimates prepared by MACA take into account the size of the communities in order to account for the per-capita generation of waste, resulting in expected higher costs to manage waste in larger communities. These costs are based on best management practices, in that they provide the resources estimated to be required for operation of the waste collection and landfill management that are within those outlined in MACA (2003).

A per capita cost for each community was estimated based on the populations used by MACA in their calculations. It is reported (MACA, 2015) that the population numbers represent a rolling average of the most recent three years from Northwest Territories Bureau of Statistics.

Table 15: NWT Waste Collection and Management Costs (MACA Model)

	Solid Waste Collection	Solid Waste Management	Administration	Annual Solid Waste Costs	Population	$/capita
Aklavik	**$124,836**	$153,192	$25,023	**$303,051**	660	$459
Behchokǫ̀	**$181,868**	$293,799	$42,810	**$518,477**	2,079	$249
Colville Lake	**$53,994**	$111,123	$14,860	**$179,977**	157	$1,146
Déli̜nę	**$127,219**	$157,247	$25,602	**$310,067**	517	$600
Dettah	**$86,627**	$82,967	$15,264	**$184,858**	241	$767
Enterprise	**$37,517**	$70,058	$9,682	**$117,257**	119	$985
Fort Good Hope	**$130,112**	$158,689	$25,992	**$314,794**	550	$572
Fort Liard	**$109,412**	$123,445	$20,957	**$253,814**	588	$432
Fort McPherson	**$125,732**	$166,715	$26,320	**$318,768**	795	$401
Fort Providence	**$106,864**	$144,017	$22,579	**$273,461**	797	$343
Fort Resolution	**$108,483**	$130,301	$21,491	**$260,275**	500	$521
Fort Simpson	**$2,080**	$308,387	$37,842	**$458,310**	1,237	$371
Fort Smith	**$188,011**	$295,188	$43,488	**$526,687**	2,508	$210
Gamètì	**$102,586**	$100,820	$18,307	**$221,712**	300	$739
Hay River/ Kátł'odeeche First Nation	**$279,118**	$357,668	$57,311	**$694,096**	4,007	$173
Inuvik	**$209,284**	$330,795	$48,607	**$588,686**	3,357	$175

	Solid Waste Collection	Solid Waste Management	Administration	Annual Solid Waste Costs	Population	$/capita
Jean Marie River	**$42,587**	$84,936	$11,477	**$139,000**	69	$2,005
Kakisa	**$37,359**	$59,360	$8,705	**$105,425**	50	$2,095
Łutsel K'e	**$112,505**	$113,934	$20,380	**$246,819**	296	$833
Nahanni Butte	**$45,111**	$88,449	$12,020	**$145,581**	100	$1,456
Norman Wells	**$126,682**	$162,087	$25,989	**$314,759**	793	$397
Paulatuk	**$119,918**	$126,640	$22,190	**$268,749**	316	$851
Sachs Harbour	**$52,387**	$101,612	$13,860	**$167,859**	125	$1,343
Trout Lake	**$47,324**	$91,916	$12,532	**$151,771**	101	$1,508
Tsiigehtchic	**$48,009**	$94,778	$2,851	**$155,638**	150	$1,035
Tuktoyaktuk	**$128,081**	$180,199	$27,745	**$336,025**	932	$361
Tulita	**$127,074**	$151,658	$25,086	**$303,818**	545	$558
Ulukhaktok	**$124,702**	$134,322	$23,312	**$282,336**	453	$623
Wekweètì	**$47,419**	$92,518	$12,594	**$ 152,532**	142	$1,074
Whatì	**$120,527**	$154,014	$24,709	**$299,250**	505	$592
Wrigley	**$43,684**	$85,930	$11,665	**$141,280**	140	$1,007
Yellowknife	**$536,785**	$1,819,672	$212,081	**$2,568,539**	19,997	$128

The following assumptions apply to the NWT waste cost model:

a) The waste collection effort (time) is based on community size, and assumes a range from 0.25 person-years (65 days) to 1 person-year (260) days of effort (for two persons) to collect the waste;

b) With the exception of Yellowknife (three collection vehicles), one collection vehicle is sufficient to collect the waste in all other communities;

c) The annual costs for the collection vehicle are based on 4% to 6% of the purchase and local shipping cost, and include storage, maintenance and fuel costs;

d) Costs for staff involved in landfill site management are based on community size, and assume a range of 0.25 person-years to 3 person years (1,040 days) to manage the landfill site and compact the waste;

e) The costs for the waste management equipment (bulldozer) are based on 2% of the purchase and local shipping cost, as well as the PWS index, and include storage and maintenance costs;

f) Licence requirements costs (i.e., Surveillance Network Program (SNP) sampling, analysis and report) are included, on a sliding scale of $3,750 to $25,000 annually; and,

g) Hazardous waste shipping costs are included, on a sliding scale of $10,000 to $400,000 annually.

Comparison of the estimated costs calculated by the NWT waste cost model (Table 15) for the City of Yellowknife (~$2,568,000) to those stated by the City ($2,750,000), indicate very similar values. Whereas it is recognized that the program provided by the City also includes waste diversion and other factors not included in the model, this suggests a reasonable comparative cost at the higher end of the range. For the community of Fort Simpson, the costs estimated by the NWT waste cost model (~$458,000) are somewhat (30%) higher than those provided by the community ($350,000). Costs provided by the community are reportedly based on the contracted cost for waste collection and management, whereas that of the NWT waste cost model include a number of items (reporting, administration, hazardous waste shipping) not considered in the community estimate. For smaller communities (e.g., Paulatuk, Ulukhaktok, Wekweèti), where annual costs are estimated by the communities to range from $50,000 to $70,000, the model estimates a higher cost (~$152,00 to $282,000), however again, these communities did not likely include costs for reporting, administration and hazardous waste shipping, which account for over $50,000 of the costs in the model calculation.

Overall, based on these comparisons, the waste cost model appears to provide reasonable estimates of costs for larger to medium sized communities, but results in higher costs than are reported for smaller communities. Closer comparisons of the items included in the community budgets may be required, however as noted above, the model accounts for activities not typically considered by the communities, which are part of the overall required waste management program. It can be concluded that, for the smaller communities at least, their estimated costs may be understated, or that their waste management program is less than that assumed in the NWT model.

An alternative unit rate cost assessment was completed by Golder for select communities in order to assess the differences in cost compared to the approach provided by the NWT waste cost model. The unit rate costs were based on hourly rates for waste collection and management staff, as well as for landfill management equipment, as outlined in Section 4.1. The unit rate cost analysis for the community of Fort Simpson is shown in Table 16 below. This approach can also be considered a Class D estimate, and incorporates the best management practices from MACA (2003) as well as recommendations on compaction frequency from the draft landfill management guidelines currently under preparation by the MVLWB, incorporating review and comment by ENR and MACA (Tetra Tech, 2015). Further refinement of the estimate provided below would require more detailed site-specific understanding including typical collection time, travel time, appropriate waste collection vehicles and any site specific community or management needs.

Table 16: Summary of Unit Rate Cost Assessment for the Fort Simpson Landfill

Waste Collection				
Description	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Collection Truck	1	annual	$41,070	$ 41,070
Fuel	6,611	L	$ 1.20	$ 7,933
Driver	2,080	hrs	$40	$ 83,197
Labourer	2,080	hrs	$36	$ 75,653
Total Waste Collection Cost:			**Subtotal:**	**$ 207,853**
Waste Site Management				
Description	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Site Attendant	208	hrs	$40	$ 8,320
Drop off Area Maintenance (FEL)	208	hrs	$250	$ 52,000
Waste Compaction (BD)	104	hrs	$250	$ 26,000
Seasonal Covering (FEL and BD)	16	hrs	$500	$ 8,000
Cover Soil Supply	339	m3	$15	$ 5,085
Bulky Waste Management (EX, FEL)	16	hrs	$500	$ 8,000
Hazardous Waste Management	1	lump sum	$72,000	$ 72,000
Total Landfill Management Cost:			**Subtotal:**	**$ 179,405**
Supervision, Monitoring and Reporting				
Description	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Supervison and Planning		%	9%	$ 34,853
Annual Reporting	1	lump sum	$10,000	$ 10,000
Analytical Costs	2	lump sum	$250	$ 500
Water Licence Renewal allowance	1	Lump Sum	$5,000	$ 5,000
Total Admin and Reporting Cost			**Subtotal:**	**$ 50,353**
Estimated Total Annual Landfill Operation Cost:				**$ 437,611**

Note: FEL - front end loader; BD – bulldozer; EX - excavator

The following assumptions apply to the approach used for Fort Simpson:

a) The waste collection effort (time) is based on reported or estimated time (number of full days per week) required to collect the waste, adjusted based on anticipated hourly collection and travel time to the landfill;

b) The collection vehicle is sole-purposed, with the exception of communities where pickup trucks are used. Larger vehicles (side loader, large waste truck) costs are based on a 15-year depreciation and maintenance cost and smaller (pickup truck) vehicle costs are based on an 8-year depreciation;

c) Costs for landfill site management are based on reported or estimated time for management of the drop-off area, compaction on a weekly (population 500 to 5,000 persons) to every 21 day (under 500 persons) basis and interim covering seasonally;

d) Daily cover costs are based on estimated local charge per load, \$15 per m^3 for nearby sources, \$50 per m^3 for sources within 20 km and \$100 per m^3 for sources remote to the landfills (e.g., Tuktoyaktuk);

e) The costs for the waste management equipment, consisting of a bulldozer (BD), front end loader (FEL), and excavator (EX) are based on estimated rental rates dependent on location and access (i.e., year round roads or remote barge/ice road);

f) Licence requirements costs (i.e., SNP sampling, analysis and report) on a sliding scale of \$3,750 to \$10,000 annually as per the NWT model; and,

g) Hazardous waste shipping costs (annual) for the small to medium sized communities estimated on a sliding scale of \$10,000 to \$60,000 annually as per that for these communities in the NWT model; and,

h) An estimated allowance is carried each year to accumulate for water licence renewal applications and supporting documents.

Based on the assumptions outlined above, the estimated annual waste management cost for the Village of Fort Simpson using the Golder methodology is approximately \$437,600; this is somewhat less than that estimated by the NWT Waste Cost Model (\$458,310), and more than that estimated by the Village (350,000). As noted above, the costs provided by the Village exclude management, reporting and hazardous waste shipping/disposal costs.

A similar comparison was undertaken for select communities, as listed in Table 17, in order to provide an assessment of the GNWT cost model for a cross-section of landfill site locations and operations. The waste collection and landfill operation costs are comparable for most communities, largely within 16%. Whereas the methods differ somewhat in the approach to accounting for cost of equipment, labour and materials, both account for estimated “true” costs of waste management and can therefore be considered reasonable from the perspective of establishing an approach to community budgeting for these operations.

Table 17: Projected Annual Waste Collection and Landfill Operation Cost Comparison for Select NWT Communities

	Unit Rate Cost Assessment (Golder)	GNWT Cost Model
Aklavik	\$347,571	\$303,051
Behchokǫ̀	\$479,254	\$518,477
Fort Liard	\$283,398	\$253,814
Fort Providence	\$285,089	\$273,461
Fort Simpson	\$437,611	\$458,310
Inuvik	\$614,047	\$588,686
Jean Marie River	\$155,681	\$139,000

	Unit Rate Cost Assessment (Golder)	GNWT Cost Model
Norman Wells	$346,044	$314,759
Tuktoyaktuk	$389,045	$336,025
Ulukhaktok	$267,159	$282,336

4.2.4 Potential Use of Transfer Stations in Select Communities

Waste transfer stations represent an alternative means of management of waste disposal in areas where communities are accessible and in sufficiently close proximity to consider a regional approach to landfill site operation. The most comparable jurisdiction to the NWT which has considered transfer stations is Yukon Territory, for which a 2009 study (EBA, 2009) provided information on regional landfill operation. Yukon government unincorporated transfer stations ship sorted and unsorted waste to the City of Whitehorse and pay tipping fees to dispose of household waste. The Village of Teslin operates the only municipal transfer station in the territory, which is a modified transfer station that ships household garbage to Whitehorse (Yukon Community Service, 2013).

Whereas all communities assessed in this study operate waste disposal sites, consideration should be given to completing a cost-benefit analysis of conversion of some of the smaller landfills with all-weather road connections to transfer stations, which would be transported to landfills closer to larger regional "hub" communities. This could include, for example, (i) the communities of Behchokǫ̀ and Dettah going to Yellowknife; (ii) Enterprise, Kakisa, Fort Providence and Fort Resolution to Hay River, (iii) Jean Marie River, Fort Liard and Wrigley to Fort Simpson, and (iv) Fort McPherson and Tsiigehtchic to Inuvik. These groups were selected on a preliminary basis using distances (typically under 200 km) to the hub community and consideration of the presence of an all-weather road and the size and current operation of the smaller sites.

Commercial firms have developed engineered waste storage, transfer and transportation facilities, which are in operation at a number of locations in western Canada. Such transfer stations would ideally be located near the communities in order to provide the necessary oversight and would use community power supply. Cold temperature operation is accommodated through use of oil tank heaters and heat tape to ensure smooth operations at low temperatures. The units are water tight and cannot be opened by wildlife. The frequency of collection from these units is dependent on the volume and type of material collected and would typically be weekly in warmer weather if substantial organic (i.e., putrescible) material is disposed, and less frequently in colder weather, or if the waste material is largely non-putrescible.

Based on discussions with Haul-All Equipment (Lethbridge Alberta), the cost of one 50 cubic-yard "Transtor" waste storage unit is approximately $120,000, whereas a compactor trailer to service multiple waste storage units is approximately $270,000. Additional budget for development of the waste transfer facility, including footings, retaining wall, railing, power, access, etc. would be required. Costs for these items are site-specific and have not been assessed. It is also noted that hazardous waste storage and transfer are not included in the estimates.

4.2.5 Future Landfill Site Completion and Closure Costs

Phase II / III Environmental Assessments and Final Landfill Cover

A Phase II environmental site assessment is used to investigate areas of potential contamination, as well as background concentrations, to verify if contamination is present. A Phase III environmental site assessment is used to calculate the volume of contaminated soil, determine site specific remediation goals, develop feasible remedial options and in the case of landfill sites, develop a closure plan.

Based on a review of some of the typical bulky and hazardous waste storage areas, for example those reported for the community of Délı̨nę (Tetra Tech, 2014a), and observed by Golder, in communities during the 2014/2015 site visits, a “typical” Phase II/III environmental site assessment of a community landfill would consist of the following major activities:

- Review existing reports, interview applicable personnel and conduct a site visit;
- Field confirmation of the visual extent of the waste fill area and the materials stored in the bulky metals area;
- Confirmation of the likely extent of any buried waste trenches and any buried bulky materials based on report reviews;
- Preparation of a geological description of the site including overburden depth, depth to water, nearest receptors, etc.;
- Sampling the material in drums/pails;
- Excavation of shallow test pits in background areas and the areas of the bulky materials and hazardous waste storage, focusing particularly on the hazardous waste, drum storage and vehicle storage areas to test for potential hydrocarbon and metal contamination of the soil;
- Advancing hand auger holes in areas inaccessible for an excavator;
- Sampling of selected test pits and hand auger holes and analysis for metals and hydrocarbons or other identified parameters of concern;
- Estimation of the volume and type of bulky metals, empty drums, hazardous waste, etc., within the bulk storage area, as well as the volume of contaminated soil;
- Installing a minimum of three groundwater monitoring wells and collecting groundwater samples from all three, considered to be a minimum required to establish flow direction and impacts;
- Preparation of a cost estimate for material removal and contaminated soil remediation, as well as any grading required to close the site; and,
- Preparation of a report and cost estimate for the clean-up of the site.

Phase II/III costs for the above activities have been based on the following assumptions:

- One test pit will be excavated per 100 m^2 in areas of potential contamination. Additional hand auger holes will be advanced in areas with limited accessibility;
- Test pits will be excavated to a depth of 2 m below grade using contracted equipment available locally, or rented (with an operator) from the community;
- Two samples will be submitted for analysis of hydrocarbons and metals per test pit/hand auger hole;

- Equipment will be supplied locally and will be sufficient to move material stored in the areas of potential contamination;
- Local transportation will be available for investigation staff in remote areas; and,
- Thirty samples will be collected from material stored in drums/pails on-site.

Table 18 provides a summary of the estimated costs for assessment of a typical landfill (in this case the recently closed Délı̨nę landfill), which has an overall bulky waste area of 17,000 m^2. It is understood that a similar scope to that outlined above was recently (2014) completed for the Délı̨nę landfill, at a cost of approximately $205,000, although it is noted this cost included assessment of the sewage lagoon in addition to the waste areas.

Table 18: Phase II/III Cost Estimate for the Délı̨nę Landfill

Task Description	Total Task Cost
Project Preparation	$15,000
Phase II /III ESA	$140,000
Remediation Planning and Costing	$21,000
Project Total Cost (Exclusive of Applicable Taxes)	**$175,000**

Based on the overall size of the bulk material storage area (including hazardous waste storage) in Délı̨nę and the cost estimates for a Phase II/III assessment ($175,000), the cost for the assessment estimated to be on the order of $10 to $12/m^2. This cost is considered to reasonably represent that for a typical landfill site, where hazardous waste and bulky waste stockpiles are found. The actual costs will depend on the proportion of the bulky materials and particularly the hazardous waste storage area, as well as the degree of impact noted in the initial excavations. Access and transport considerations will increase the cost of the studies in more remote communities, as will the availability of appropriate equipment in the community (e.g., an excavator). Conversely, sites where historical hazardous waste has been removed, are in smaller quantities, stored appropriately and/or stored off-site, will reduce the cost of the assessment, in some cases significantly. Examples of such communities include Gamètì, Wekweèti and Hay River.

The approximate area of the active cell and the bulky waste storage area for the 32 landfill sites was estimated based on the available mapping information from the GNWT Atlas site and observations during the site visits by Golder in 2014 and 2015.

The area of the active landfill cell was used to estimate the costs for placing a 0.6 m thick soil cover over the waste fill area. Costs for completing a Phase II/III investigation were based on the area of bulky and hazardous waste storage (averaging $11/m^2), as noted above. The resultant costs are outlined in Table 19. It is estimated that a basic lower end cost for a Phase II/III ESA investigation will be on the order of $25,000 to $45,000, in order to account for assessment, interview, contractor mobilization, travel and reporting costs. An average minimum cost of $35,000 has been assumed for communities regardless of the size of the bulky storage area. It is also noted that, where required, the rental cost of specialized equipment in remote area such as drilling rigs could potentially increase costs above those stated.

Table 19: Estimated Landfill Cover and Phase II/III Costs for NWT Landfills

Community Name	Landfill Site Area (m^2)	Cover Source at Site	Cover Source within 20 km	Cover Source Remote (>20 km)	Active Cell Area (m^2)	Cover Supply Cost	Bulky Metals Area (m^2)	Phase II/III ESA Cost Estimate
Unit Cost		$15/m³	$50/m³	$100/m³				$11/m²
Aklavik	28,900		x		4,400	$132,000	7,500	$82,500
Behchokǫ̀	48,600		x		14,000	$420,000	7,200	$79,200
Colville Lake	8,400	x			1,000	$9,000	500	$35,000
Délı̨nę [1]			x				17,000	$175,000
Dettah	8,035		x		4,600	$138,000	210	$35,000
Enterprise	21,200	x			1,000	$9,000	1,900	$35,000
Fort Good Hope	56,300	x			5,600	$50,400	4,500	$49,500
Fort Liard	30,800		x		2,200	$66,000	2,650	$35,000
Fort McPherson	75,000	x			300	$2,700	2,000	$35,000
Fort Providence	24,000			x	4,940	$296,400	8,500	$93,500
Fort Resolution	28,750		x		2,800	$84,000	800	$35,000
Fort Simpson	6,700	x			7,200	$64,800	12,000	$132,000
Fort Smith	204,000		x		37,300	$1,119,000	10,100	$111,100
Gamètì	22,500	x			1,300	$11,700	1,800	$35,000
Hay River	76,500	x			15,100	$135,900	8,100	$89,100
Inuvik	62,000	x			41,500	$373,500	5,400	$59,400
Jean Marie River	10,600		x		1,400	$42,000	1,000	$35,000
Kakisa	10,500		x		1,400	$42,000	240	$35,000
Łutsel K'e	21,200	x			5,000	$45,000	3,300	$36,300
Nahanni Butte	2,100		x		100	$3,000	150	$35,000
Norman Wells	56,700	x			13,200	$118,800	6,400	$70,400
Paulatuk	55,000	x			2,400	$21,600	15,000	$165,000
Sachs Harbour	25,000			x	3,700	$222,000	6,500	$71,500
Trout Lake	8,300		x		1,100	$33,000	350	$35,000

[1] Délı̨nę closed landfill in the process of remediation.

Community Name	Landfill Site Area (m²)	Cover Source at Site	Cover Source within 20 km	Cover Source Remote (>20 km)	Active Cell Area (m²)	Cover Supply Cost	Bulky Metals Area (m²)	Phase II/III ESA Cost Estimate
Tsiigehtchic	11,500		x		5,100	$153,000	3,600	$39,600
Tuktoyaktuk	54,400			x	17,600	$1,056,000	6,870	$75,570
Tulita	34,280		x		10,700	$321,000	9,300	$102,300
Ulukhaktok	27,000	x			12,300	$110,700	3,800	$41,800
Wekweèti	17,100	x			6,300	$56,700	3,500	$38,500
Whatì	31,000	x			1,000	$9,000	1,600	$35,000
Wrigley	26,300		x		2,300	$69,000	3,500	$38,500
Yellowknife	139,600		x		22,800	$684,000	26,900	$295,900

Landfill Closure and Remediation Plan Costs

Based on the current requirements (MACA, 2003) and those in the draft guidelines under preparation (Tetra Tech, 2015), a closure and remediation plan for a typical community landfill site will consist of the following basic activities and reporting:

- Description of site visit and interview with local community officials and staff;
- Background information including:
  - Site description including location co-ordinates, distance from community, access route, significant nearby features, borrow areas for cover;
  - Appropriately scaled and oriented maps showing (i) site location relative to community, potential receptors (e.g., water bodies) and (ii) site scale map showing current ground contours, landfill cell location(s), hazardous waste storage location(s), bulky waste piles and site facilities;
  - Subsurface conditions including regional geology, local geology and soil/rock description, local groundwater conditions and site-specific permafrost conditions (if known);
- Update of a site survey as required to accurately calculate areas and volumes (may be completed as part of Phase II/III assessment;
- Recorded location (GPS location) of any asbestos disposal areas at the site, if applicable;
- Phase II/III Environmental site assessment results and recommendations (completed separately);
- Site remediation to be completed (based on Phase II/III assessment), including:

- Remediation of contaminated soil at the site;
- Bulky waste removal or burial;
- Demolition or re-use of infrastructure;
- Hazardous waste removal;
- Cover requirements over bulky waste storage area (if needed); and,
- Removal of fencing and gate and changes to limit site access if required.

- Appropriate engineering drawings outlining:
  - Surface water drainage;
  - Re-grading of existing landfill cells as required to limit leachate seeps, adjust slopes and allow of installation of a cap with slopes designed to prevent erosion and maximize runoff'
  - Cover system design;
- Cover and site re-vegetation plan;
- Post-closure monitoring plan including location map;
- Anticipated or planned future land use;
- Cost to complete the site reclamation and closure activities;
- Calculation of the funds required to be set aside to undertake closure in the future; and,
- Schedule for implementation of closure activities.

Based on recent closure cost assessments for the Fort Simpson and Délı̨nę landfill sites, valued at approximately $45,000 to $60,000, it is estimated that the cost for a typical closure and remediation plan for a landfill will range from $35,000 to $75,000 for most sites. Lower costs would be related to sites where significant information is readily available (e.g., survey, description of historical site development) and/or the site development is relatively simple, whereas the higher range of cost would include sites where little information is available or where overlapping waste cell development and bulky waste storage may require significant assessment, or sites where remediation works are more complex. The assessment and cost for the remediation of the bulky storage area would be addressed in the Phase II/III estimates described above.

4.3 Summary

Operations and maintenance funding is provided by GNWT through MACA, to all community governments including the City of Yellowknife. The costs of waste management have been intertwined with those of other community services in large part as a result of the funding approach for this service. Waste management funding is not separated from general activities, like water and wastewater systems, presumably in part because equipment used to complete waste management tasks is often used for other general community operations. In order to better assess the true cost of managing waste in communities, the planned changes to community funding developed by MACA in partnership with community governments, should be implemented. This approach should also align to costs estimated herein based on approved methods of waste management operations.

On a per capita basis, the reported cost for waste management (collection, transportation and disposal) in the NWT ranged from $48 to $355 per person. Some communities (Fort Simpson, Fort Smith and Yellowknife) report relatively higher per capita income from fees or other sources related to waste management, with the intent of offsetting budgeted costs. Many of the reported waste management fees in NWT communities are considered to be lower than the actual cost to conduct waste management operations. The range of reported waste management costs is higher in the NWT than in Canadian provinces, which is not surprising considering the comparatively smaller population in the NWT, as well as other factors including access to alternative disposal and diversion options. Collection and waste management costs of $96 per tonne estimated for Yellowknife is slightly above the higher end of the national range of waste management costs. Economies of scale, as well as access to transportation and waste management alternatives are expected to play a significant factor in the cost of waste management in Yellowknife compared to other jurisdictions.

Stockpiles of hazardous waste have been assessed in a number of communities in the northern part of the NWT. The overall financial liability for the 17 communities where stockpiles of material is present is estimated to be on the order of $3.9 million and may be higher based on recent informal estimates provided to ENR. It is recognized that communities captured in the above cost estimate represent those which are more remote and have proportionally larger quantities of hazardous waste. Most communities in the south ship out these materials more regularly. Nevertheless, the historical material represents a financial liability, which is not captured in annual operating cost estimates.

Draft estimates of the cost for waste collection and management have been recently prepared by MACA for each community, using a consistent approach and taking into account the variation in equipment and personnel costs across the NWT. The costs considered in the “NWT Waste Cost Model” include waste collection staff, the waste collection truck, landfill staff and site equipment maintenance/use, shipping of hazardous waste, program administration and reporting, and can be considered to be equivalent to a Class D cost estimate. A similar model was completed by Golder for 10 select communities. Comparison of these models indicated similar (within 16%) results for most communities. Overall, based on these comparisons, the waste cost model appears to provide reasonable estimates of costs for larger to medium sized communities, but results in higher costs than are reported for smaller communities. Closer comparisons of the items included in the community budgets may be required, however it is recognized that the model accounts for activities not typically considered by the communities.

The cost for a typical Phase II/III ESA is estimated to be on the order of $\$11/m^2$ for a landfill site where hazardous waste and typical bulky waste stockpiles are found. The actual costs will depend on the coverage of the bulky materials and particularly the hazardous waste storage area, as well as the degree of impact noted in the areas not covered by waste materials. The approximate area of the active cell and the bulky waste storage area for the 32 landfill sites were estimated based on the available mapping information and observations. The Phase II/III costs range from $35,000 for a basic assessment at smaller sites regardless of size, to over $100,000 for larger sites.

It is estimated that the cost for a typical closure and remediation plan for a landfill will range from $35,000 to $75,000 for most sites. Lower costs would be related to sites where significant information is readily available (e.g., survey, description of historical site development) and/or the site development is relatively simple, whereas the higher range of cost would include sites where little information is available or where overlapping waste cell development and bulky waste storage may require significant assessment, or sites where remediation works are more complex. The assessment and cost for the remediation of the bulky storage area would be addressed in the Phase II/III estimates described above.

Some best management practices outlined within this document that can influence cost expectations include:

- The GNWT should consider developing a program to allow a crusher to be regularly placed in remote communities with large number of empty barrels, to maximize space and limit potential for contamination;
- Depending on markets, it may be cost effective to consider tendering removal of bulk waste metals from a number of communities;
- Consideration should be given to use of frame and tarp or other alternative daily cover including uncontaminated CRD waste, where appropriate, to limit windblown litter;
- A NWT specific landfill operator training program should be developed and managed by an accomplished operator;
- In order to better assess waste management costs, funding of waste management should be allocated based on consistent approved methods of waste management operation; and,
- A cost benefit analysis should be completed to assess conversion of the landfills to transfer stations for select smaller communities accessible by all-weather roads.

5.0 KEY FINDINGS, CHALLENGES AND OPPORTUNITIES

The following provides a summary of the key findings, challenges and opportunities based on the results of this study.

5.1 Community Landfill Site Summary

Waste management in the NWT is conducted at 32 communities across the Territory using guidelines developed by the GNWT in 2003 (MACA, 2003). The management of the landfills is typically overseen by the Senior Administrative Officer (SAO) and managed by community works staff. Waste collection is organized and managed locally in the communities and consists of single stream collection of residential and commercial waste. Bulky items and hazardous waste from the community are delivered by the generators or contracted/community staff.

The landfills sites are all (with the exception of Gamètì) located at least 500 m from the community; however a new site had been identified at the time of the inspection and construction underway approximately 4 km from the community. With the exception of Yellowknife, the landfills are all unlined and capped with local soil and control of impacts to the environment is based on natural attenuation. The degree of engineering design of these sites varies, but is largely based on the modified landfill approach outlined in MACA (2003); landfill designs include (i) trench-fill designs excavated into the native soils, (ii) area-fill designs where berms are used to allow waste filling above grade, often above a trench fill landfill, and (iii) depression fill designs, which essentially fill in past the edge of a natural slope.

Monitoring of landfill environmental performance is largely based on limited surface water sampling. Groundwater monitoring is only currently conducted at a few landfills (Fort Smith, Hay River, Yellowknife); however the GNWT is in the process of constructing monitoring wells at a number of landfill sites in the North and South Slave Regions.

Licencing of these facilities is undertaken through the local Land and Water Boards, whereas inspection and regulation is undertaken by the GNWT, largely through ENR. Of the 32 communities surveyed for this report, 24 have approved water licences (as of December 31, 2015). A number of the licenced landfill sites are reported through the most recent inspections to be in non-compliance with some aspects of their licencing requirements. An inconsistent level of detail in the available operation and maintenance manual (where available), absence of site mapping, open site access and lack of training at some sites result in inadequate management of waste compared to the GNWT standards.

It is recommended that the GNWT include more critical aspects of the non-compliance issues noted above in their determination of selected sites for follow up, notably those identified in the risk assessment described in Section 2.0. A standardized and enforced approach to annual reporting for waste management operations, notably including inventories of accepted bulky and hazardous waste items, would be of substantial benefit to development of programs for improved management of materials accepted at the sites.

Many NWT landfills are not fully enclosed by a fence and whereas some landfills have a gate and lock; the gate is often left open in order to limit dumping of waste at the gate after hours. Some communities with fenced sites report that they still experience issues related to wildlife access, including bears climbing or digging under the fence to gain access to the waste. A few waste management sites are surrounded with electrified fencing, however maintenance to keep them in working order is often problematic. The presence of wildlife, notably bears and wolves, represents a risk to the site operators, public users and the wildlife itself, and as a result, increased measures to limit or prevent wildlife from accessing waste as a food source is necessary. It is recommended that, as part of licencing applications for all land and water boards, basic fencing plans be required and implementation of these plans form part of annual compliance reviews.

With a few exceptions, waste deposited at the community landfills is almost entirely sourced from the local community and consists largely of residential and ICI waste from the residents and community services (community administration, school, police, etc.), retail establishments and businesses that largely serve the local community. The landfills also receive a substantial quantity of CRD materials from the demolition of buildings through the NWT Housing Corporation, community buildings (e.g., schools) and some retail or rental establishments, which have become unusable. In addition, the landfill sites receive bulky items including ELV vehicles, used appliances, tires, empty (and occasionally full) fuel barrels, heating oil tanks, etc. from residents and community operations, as well as other material including culverts from regional highway projects completed through the GNWT Department of Transportation. Wood, usually in the form of pallets, brush and some separated CRD material is also stockpiled at many sites, and in many cases is burned.

Hazardous waste is present at most sites, largely in the form of drums or pails of used oil and antifreeze, unused fuel and lead-acid batteries. In some communities, the recently generated hazardous materials are managed at a community facility, typically the community garage. This hazardous material is required to be managed according to established NWT guidelines, however at many facilities, the required storage and handling procedures are not followed, notably for those sites with larger historically derived quantities of these materials. This represents a significant environmental risk and management of this risk should be prioritized by the NWT. Only five communities have a Hazardous Waste Management Plan that is being actively implemented. At the present time, there is inadequate funding to ship hazardous materials or to construct proper infrastructure to store these materials. Management of these hazardous materials should be prioritized by the GNWT, as communities often report they do not have sufficient funds.

Some communities participate in semi-annual HHW collection events (Yellowknife, Hay River and Fort Smith), where items like paint, propane tanks, batteries, household cleaners, aerosols, oils/fuels, fluorescent bulbs, thermostats, pesticides and electronic waste are accepted for proper disposal for free. Few communities were observed to regularly collect and store HHW, which represents an opportunity for increased collection of materials that would otherwise end up in the residential and ICI waste streams deposited in the landfill.

5.1.1 Landfill Site Management, Waste Segregation and Training

At most landfills, waste is typically dropped off at a tipping face, at or next to the active cell, largely by the community waste collection vehicles. This material is placed in the cell by the available heavy equipment. Compaction is completed irregularly at many sites, ranging from weekly to monthly, or even seasonally. Cover is not placed regularly at many landfills, and as a result, windblown litter is present at these sites. It is also evident that many sites operate a larger active face/fill area than is needed, and as a result large areas of waste are uncovered for a period of time, which can lead to greater potential for leachate generation.

Illegal dumping is a problem in many communities, largely consisting of waste left at or near the gates when the landfills are closed or unattended. Given the remote nature of many of the landfill sites and the part time nature of their operation, this issue is expected to continue and is an operational issue which will be dealt with locally and though the implementation of fencing plans in the water licence requirements.

A number of basic landfill design and operation factors described in MACA (2003) are part of standard landfill site operation procedures contained in MACA (2003). Minimizing generation of leachate, and thus risk to the environment, can be improved through the implementation of appropriate compaction and covering of lifts, as well as by minimizing cell size and closing out and capping cells as soon as practical. Ensuring that only MSW, ICI and non-contaminated CRD waste is disposed within the landfill is also key to limiting impacts. Efforts to encourage and as needed, enforce, a ban on hazardous waste including household hazardous waste disposal in landfills should be implemented as part of the Waste Resource Management Strategy being developed by the GNWT.

Waste segregation can be improved at the landfill sites through a combination of (i) education of residents regarding material banned from disposal in the residential waste pick-up, (ii) training of waste collection and landfill supervisors regarding banned waste and the need for diversion, (iii) supervised drop off of waste and (iv) clear signage and well managed piles of material in the bulk storage area. Continued development of educational material and community-based programs supporting the need for proper segregation and waste reduction should be part of ongoing GNWT waste management programs.

Waste management facility operators and waste collection vehicle operators in most NWT communities work on a part-time basis. In many cases, operators work less than three days per week, and in some cases, only a few hours per week. Whereas classroom training is available through organizations such as MACA and SWANA, it is reported by the communities (in the survey completed for this study) that operators from only 10 communities have completed waste management training program offered through MACA. It is often difficult to provide the “hands-on” experience required for operators to understand site management and equipment operations which are needed to meet the expectations of the regulations and to both maximize use of the available landfill capacity and limit issues which increase leachate generation and litter generation. Training, including “hands-on” sessions at an active landfill, or even at each of the community landfills to assist in improving operator understanding and performance, is recommended.

5.1.2 Categorization of Waste Management Systems

With the exception of Yellowknife, which operates a modern collection, recycling and landfill system, the community landfills in the NWT are all designed and operated relatively similarly, as noted above. There are some differences in how communities handle hazardous waste, in that a number of communities store incoming hazardous waste in secure containers located within or near the community, whereas others store these materials at the landfill, usually in unlined areas. All, however, accept these materials from the residents and ICI establishments and ship these materials, some more regularly, to licenced processing facilities in the south.

Taking into consideration the aspects of population, services, transportation routes and accessibility with relation to waste management, the waste management systems used by the communities in the NWT can be grouped in the following four categories based on community size and access.

- Yellowknife has a population of approximately 19,300 (as of 2014), nearly half of the total population of the territory, and is the territorial capital and major regional centre. The supporting institutional, government, industry and retail services are expected to generate a proportionally larger amount of MSW, ICI and CRD waste relative to smaller NWT communities. The City collects waste five days a week using a standardized household container system, operated by a private contractor. Commercial and Institutional waste is collected separately, however both this and the municipal waste are transported to the landfill, where the material is baled and disposed of in a modern lined landfill with a leachate collection system. Recycling is accepted at four depots located within the community, which accept paper, cardboard, glass and metal cans.

HHW from residents is accepted at the landfill site and is also collected twice a year in organized HHW events;

- A number of moderately sized (approximately 800 to 3,600 persons) hub communities (Inuvik, Norman Wells, Hay River, Fort Simpson, Fort Smith, Behchokǫ̀), have moderate service industries to support the local and regional population (e.g., stores, restaurants, repair facilities, service stations, larger institutional operations and support agencies). Semi-annual HHW collection events are undertaken in two of these communities (Fort Smith, Hay River);
- A number of mostly small (less than 1,000 person) communities that are reasonably connected by permanent roads and generate waste largely limited to residential and local institutional/commercial operations (community office, community garage, a school, one or a few stores). This includes, for example, Fort Providence, Kakisa, Enterprise and Tsiigehtchic. Tuktoyaktuk is included in this group, though road access is presently a seasonal ice road; and,
- A number of small communities that are remote and have seasonal winter roads or no roadways and generate waste largely limited to residential and local institutional/commercial operations (community office, community garage, a school, one or a few stores). This includes, for example, Ulukhaktok, Paulatuk, Sachs Harbour, Délįnę, Trout Lake, Gamètì and Łutsel K'e).

With respect to planning and prioritization, the systems defined above can be used to consider the approach to planning from the perspective of the amount of waste generation and the opportunities to transport diverted materials to facilities in the south. From the perspective of prioritization, the differences in the amount and time of storage of hazardous materials, as well as the methods and location of this storage provide useful comparisons for changes to site management.

5.1.3 Coordination of Waste Management Activities

Waste management regulations and guidelines are developed, implemented and enforced by the Environment and Natural Resources (ENR) department of the GNWT. Following devolution, inspection and enforcement activities at municipal disposal facilities continues to be undertaken by Water Resource Officers regarding water licence issues; Environmental Protection Officers deal with issues where a discharge of a contaminant may occur that is not covered by the water licence. Prior to devolution, this enforcement was completed by AANDC (now INAC) inspectors. The department of Municipal and Community Affairs (MACA) also plays a large role in waste management, providing funding and technical support to community governments that are managing waste at the community level. MACA works closely with ENR and the community government officials (e.g., Senior Administrative Officers (SAO).

The Waste Resource Management Strategy should clearly define the licencing, regulatory and management roles in the NWT. This would involve preparing a policy guideline on the expectations on how waste should be managed. There will be a need to develop enabling legislation resulting from the strategy and develop detailed guidance documents for execution of the strategy. The GNWT should establish a Waste Management Group made up of the required expertise to provide guidance on the execution and monitoring of the strategy and should include some key community representatives. Development and delivery of training programs to the communities on landfill operations and other components of the strategy will be required.

Based on the information collected in this study, the community level of government is best suited to manage their facilities from the perspective of their understanding of the local conditions and allocation of funding within their program in order to meet community priorities and GNWT guidelines (i.e., MACA, 2003). Notwithstanding this, it is apparent that there are a number of landfills which are not managed in accordance with expectations outlined in the guidelines. Inspections and enforcement have not, in many cases, resulted in the desired degree of compliance with these guidelines. Given this, it is considered that in some areas, input to management of at least part of the waste operations, notably those relating to higher environmental and human risk and cost implications, should be more closely managed by the territorial level of government. This is in part discussed below in the sections relating to hazardous waste management, as well as those relating to providing manifests of bulky and hazardous waste material and waste generation rates.

In exp (2012), the concept of waste sheds in the NWT is introduced, which identified common areas where waste management (notably diversion) could potentially be co-ordinated on the basis of location and transportation routes. The four waste sheds considered were (i) in the Beaufort-Delta region centred on Inuvik, (ii) in the Yellowknife area (largely consisting of the Tłı̨chǫ communities and Dettah), (iii) Hay River south, including communities on Great Slave Lake (other than those in the Yellowknife waste shed) and (iv) Hay River north, consisting of communities from Wrigley to Colville Lake. From the perspective of hazardous waste management or possibly other material diversion, these areas may be considered in terms of combining materials from smaller communities to a larger regional transportation or processing centre, similar to the approach for the existing BCP. It is understood that the GNWT is considering how to assist in co-ordination of hazardous waste transport from communities in some regions (for example the Beaufort-Delta area); territorial management of hazardous waste is further discussed below.

Whereas all communities operate waste disposal sites, consideration should be given to completing a cost-benefit analysis of conversion of some of the smaller landfills with all-weather road connections to transfer stations, which would be connected to landfills closer to larger regional "hub" communities. This could include, for example, (i) the communities of Behchokǫ̀ and Dettah going to Yellowknife; (ii) Enterprise, Kakisa, Fort Providence and Fort Resolution to Hay River, (iii) Jean Marie River, Fort Liard and Wrigley to Fort Simpson, and (iv) Fort McPherson and Tsiigehtchic to Inuvik. These groups were selected on a preliminary basis using distances (typically under 200 km) and consideration of the presence of an all-weather road and the size and current operation of the smaller sites. Commercially available waste storage, transfer and transportation facilities based on enclosed bins are in operation at a number of locations in less populated areas of provinces including British Columbia, Alberta and Ontario.

5.1.4 Waste Diversion from Residential and Construction/Demolition Waste

Communities in the NWT divert a limited number of materials at the present time, largely through the Beverage Container Program (BCP) and as of February 2016, the Electronics Recycling Program (ERP). Communities currently participate in the BCP through a permanent or satellite depot in their community. The BCP materials are stored in regional centres and shipped out once a significant quantity of material has been processed.

Additional materials are diverted in the City of Yellowknife, which is possible in large part due to the size, resources and location of this community relative to the nearest licenced receivers of diverted materials in the southern part of Canada (typically Alberta or British Columbia). Diverted materials include glass, metal cans, newsprint and paper, as well as HHW. The community of Hay River ships out electronics on a regular basis.

Centralized composting is undertaken in Yellowknife, whereas the communities of Fort Smith and Hay River have implemented programs to encourage residents to purchase and use backyard composters. At some NWT communities, backyard composters are located at their community garden sites. Greater implementation of composting represents an opportunity to increase diversion and at the same time produce material which can be used by communities to grow a portion of their produce requirements.

With the exceptions noted above, very few communities divert material from residential waste out of the community for recycling and/or disposal. Challenges to increasing diversion include limited local infrastructure and regional transportation or long distances, high costs to start EPR programs because of legacy waste and small populations of all communities other than Yellowknife. It is reported (Giroux Environmental Consulting, 2014) that out of territory purchasing patterns translate to comparatively lower surcharge income for stewardship and EPR program operation. The BCP and the EPR programs are good examples of organized waste diversion programs and illustrate the need for management of diversion at the territorial level. Beyond these existing programs, the most readily diverted material from MSW/ICI waste are HHW (above what is already diverted), wood, fibres (paper, cardboard) and metal food containers. The diversion of HHW is described in Section 5.1.7.

At the present time, there is some confusion amongst landfill site operators as to what is allowed to be burned and what cannot, or if any burning of wood, paper and cardboard is allowed. Development of standard guidelines for acceptable management of clean wood, paper and cardboard should therefore be undertaken. Where possible, composting of shredded clean paper and cardboard should be encouraged as a primary means of diverting these wastes. Should burning be the only feasible option, it should be undertaken for clean, untreated or unpainted wood, paper and cardboard in a well-maintained burner with good air flow to reduce the production of pollutants including dioxins and furans. Critically, this vessel should also limit/ prevent the potential for sparks/forest fires. It is recommended that clarification on what is allowed to be burned, and under what conditions/design, be included under the conditions of the water licences.

5.1.5 Bulky Material Management

Some communities have shipped out bulky metals (e.g., used appliances, ELV vehicles, etc.), however significant quantities are still present at many community landfills, notably those in the north with limited and expensive transportation options. The presence of historical bulky and hazardous materials is summarized in Report I (Golder, 2016), as well as in KBL (2013a, 2013b, 2015) and Recycling Council of Alberta (2007). Nevertheless, considering the amount of this type of stockpiled material at community landfills that could be removed, there are opportunities for additional waste diversion. This will likely require considerable financial backing to support these initiatives and would likely also be best managed at the territorial level, at least in part, to be successful.

Construction, Renovation and Demolition Waste

All landfill sites contain a MSW cell, which includes material from residential users and a component of ICI waste, which is typically greater in larger communities where more services are available. At many sites (e.g., Behchokǫ̀ and Fort Simpson), separate CRD waste cells are used. The CRD waste at NWT sites is sometimes mixed in with the MSW, occasionally as a rough cover.

An additional opportunity for diversion could include a requirement that community construction or demolition projects should develop a waste management plan as part of project planning and approvals. This should include a waste minimization plan including a review of minimum materials needed for the project, limiting non-burnable packaging, consideration of cost-effective back-haul options and re-use of existing resources in the design.

Similarly, housing demolition and highways materials that are being disposed of at landfills by GNWT departments should be better managed by requiring quantity estimates and inventory of materials, including an assessment of re-use, separation and volume minimization options.

Cost for construction of new housing should include separation of useful materials for scavenging, clean wood for burning and crushing of the remainder to use as alternative cover where appropriate. Taking apart housing for material re-use should be part of any demolition cost assessment in the construction tender process. Whereas the waste material generated as a result of construction or demolition of housing, service buildings and roads (i.e., culverts) benefits the community, and the goal of cost recovery should not be to increase costs, but rather to minimize waste and unnecessary filling of community landfills.

A formal mechanism should be developed, through which community governments can confirm that hazardous materials, such as lead paint, asbestos, and mercury switches, have been removed from CRD materials before these materials are disposed of in the community landfill. This could include a requirement that project coordinators and/or contractors to provide testing results for materials to be deposited in the landfill, showing that no hazardous materials are present.

End-of-Life Vehicles and Bulk Metals

End-of-Life vehicles (ELV) and used appliances represent potential sources of hazardous waste fluids, lead-acid batteries, mercury switches and refrigerants. Draining of fluids from ELV is a requirement of acceptance of these units at landfills, as is the removal of the battery; however manifesting of the materials and inspection of these procedures is not common and should be enforced. Development of a standardized manifest and requirement for reporting of this information on an annual basis should be undertaken by the GNWT.

With respect to environmental liability of used appliances and ELV, mercury and refrigerant removal is required prior to shipping or burial. Removal of mercury switches and refrigerant from appliances and vehicles at the time of acceptance is not a regular practice at community landfills. It is recommended that the GNWT implement a program to ensure that hazardous materials from ELV are managed appropriately, for example using similar approaches to the Tundra Take Back program (Summerhill Impact, 2014), notably when the ELV and appliances are still in a condition that would allow for such processing. It is similarly recommended that these operations be reported in the annual reports submitted to the land and water boards.

As noted in Volume I (Golder, 2016), the quantity of empty fuel/oil drums at some landfill sites is substantial. These drums take up substantial space in the bulk storage area, and represent an environmental liability as well as a financial liability at closure. Similarly, a large quantity of used home heating oil tanks is present at almost all landfill sites. The GNWT should develop a program to assist communities with cleanup of these empty drum inventories. Consideration should be given to providing a drum crusher on a rotating basis to communities in the NWT with significant quantities of empty drums. Draining and crushing of drums will require some training in order to ensure that they are emptied and cleaned in a manner that does not result in generation of more liquid waste. Considering the current GNWT guidelines (http://www.enr.gov.nt.ca/programs/hazardous-waste/guidelines) for cleaning larger tanks (e.g., home heating tanks), alternative methods would be required for these units.

Bulk metals and ELV represent a good opportunity for removal and recovery of some cost for removal, as there is some value in the metal, albeit less at present than in recent years. The GNWT is best suited to assess and implement a program for bulk metal shipment by virtue of the personnel with the necessary experience, as well as the contacts and commercial terms available to this level of government. Programs and reports are available which assess the potential for metal and ELV removal, as described in Section 4.0.

5.1.6 Hazardous Waste Management

Uncontrolled releases of hazardous waste from a landfill site, notably from liquid waste spills, are considered to represent the most significant risk in terms of potential impact to the surrounding environment. Hazardous waste that has been stored at the landfill site for more than a year or two without suitable controls is also considered to be a significant risk. The hazardous waste storage at the landfill sites, particularly the larger stockpiles of historical hazardous waste, represents the largest environmental risk and should be prioritized for action. Improved management of incoming hazardous waste is also important, as this will clearly define expectations for dealing with potential impacts of the historical stockpiles of materials while these remain on site. This includes improved manifesting, reporting and development of a database of materials accepted for bulky and hazardous waste storage at community landfills or other facilities.

The GNWT has recognized that management and shipping out of legacy hazardous waste is needed. Studies completed in 2013 and 2015 (KBL 2013a, 2013b, 2015) provide an inventory of hazardous waste at a number of the sites in the Beaufort-Delta and Sahtu areas of the NWT as well as Ulukhaktok and Sachs Harbour. Based on the site visits completed by Golder, the liquid containers at a number of these facilities are still present and are decaying, and/or are otherwise evidently compromised, as illustrated for example by bulging or broken drum ends. It was also noted that the batteries stored at these sites are often broken and/or the plastic battery shells are deteriorating as well. It is strongly recommended that the GNWT organize the shipping of these historical materials in the near future. The costs for this have been developed, however establishment of the funding mechanism should be prioritized.

It was noted that in many cases at the landfill sites where hazardous waste is stored, the soils exhibit evident staining from the used oil, typically from overflowing drums with poorly installed or missing bungs, or more commonly from five-gallon pails which have less secure lids. Conversely, where hazardous waste is stored within the community, there were few problems noted. Where possible, storage of all new hazardous waste materials should be undertaken in the area of the community garage or other building where staff can manage the materials appropriately. The use of totes or other larger transportable storage for oil should be considered, and long term storage in smaller containers (i.e., pails) should not be allowed.

It was also noted that few landfill sites store the hazardous waste on a lined and bermed pad, or in an approved container (other than the totes noted above). In the case of landfill sites which use larger transfer tanks (e.g., Fort McPherson), is was also noted that a bermed and lined containment pad is not present. It is recommended that the GNWT encourage and/or enforce the use of appropriate liners or contained storage that can prevent the release of hazardous waste to the environment in the event of a leak. Consideration should be given to providing a standardized liner design for mixed hazardous waste storage that can be readily modified for local needs. The GNWT should also consider standard appropriate containers sized appropriately to handle more than a years' worth of waste. Typical commercial containers exist which are similar to sea-cans, which for remote sites may suit the need to ship in the containers and move them within the communities. Larger centres could consider purpose-built roofed and fenced structures.

With respect to hazardous waste management, these materials are required to be stored and shipped out until quantities sufficient for economic transport have been collected. The maximum allowable period of storage of centralized storage of hazardous waste (i.e., at a landfill or community garage) should follow the appropriate territorial guidelines for management of the materials and the Guideline for the General Management of Hazardous Waste in the NWT (1998). Whereas other jurisdictions often specify maximum storage periods of 90 to 270 days and may specify different storage times based on material type, volume and location of the facility, it is impractical for the more remote communities in the NWT to store hazardous waste for less than one year. In the case of a number of communities visited by Golder as part of this study, it is apparent that historical hazardous waste has been stored at communities for a significant period of time, and that as a result, the storage containers have deteriorated. It is recommended that a maximum storage period of one year be established in the water licences for communities with access to all-weather roads, and that a maximum storage period of two years be established for communities with seasonally limited access. This latter period could be adjusted (through formal approval by the land and water boards) for individual communities based on a set storage volume, material type and condition of the storage facility, and based on inspection by experienced NWT staff.

The GNWT is best suited to assess and implement a program for bulk hazardous waste shipment by virtue of the personnel with the necessary experience, as well as the contacts and commercial terms available to this level of government. Whereas some communities are handling hazardous waste appropriately, the lack of expertise and/or changes in community management, combined with decisions on where to spend limited funds from the general community budget results in poor management at a number of communities. Local resources are needed to manage incoming materials and deal with logistics of storage and transport preparation and loading, although the GNWT has the experience and buying power as well as an ability to co-ordinate shipping and other required logistics. More importantly, the GNWT has the expertise with respect to hazardous waste management and is currently relied upon for advice in this regard.

Models that are currently in use for hazardous waste in the NWT include (i) a full time depot and semi-annual collection for HHW in Yellowknife, (ii) storage of hazardous materials at the landfill site, or (iii) storage of hazardous materials at the community garage. The latter two models may also include infrequent HHW collection events. From the perspective of environmental risk, the model of storage of hazardous waste at the community landfill is least desirable, as the waste is often not well managed and rarely on a lined pad.

Hazardous waste management in most other Canadian jurisdictions involves a combination of commercial and community based programs that collect materials including used oil, antifreeze and batteries though a combination of stewardship initiatives or EPR. The BCP is an example of such programs implemented in the NWT. Given the relatively small size and long distances or limited access to the other communities in the NWT, this commercial method is largely not feasible in these communities. Nevertheless, the GNWT may consider a hybrid commercial approach using a depot in each community that is managed by a commercial operation, either as a stand-alone system, or associated with the existing retail establishments in the community that sell products that are being collected (e.g., oil, gas, antifreeze, batteries).

Some commercial operations in the NWT operate oil burners to manage used oil locally. It is understood from discussions with community staff, that issues relating to equipment maintenance, compliance with current emission regulations and ensuring the oil burned in the units is acceptable, have limited the use of oil burners in most communities where they have existed. Further assessment of this approach has not been conducted as part of this study.

Consolidation of hazardous materials in larger communities (i.e., "regional depots") could be considered, however this would require co-ordination at the territorial level, and/or management of regional depots through a commercially licenced operator.

Whereas all water licences require a spill plan, it is recommended that site specific hazardous waste management plans be developed for the waste management portion of each water licence. This should include storage type (liner, building/sea can, bins), location (landfill site or community garage), manifesting and annual reporting.

It is recommended that the GNWT and community governments improve efforts to prevent the deposit of hazardous waste from the ICI and residential sectors at community though the following:

- Ensure that all community landfills are licenced and that the operations and maintenance plans clearly establish bans for disposal all hazardous waste (including HHW as noted below);
- Reinforce the bans for the ICI sector through direct mail-out of a clear, simple poster required to be posted by the establishments in a prominent place where they store/manage waste. This could be established thought the community governments, who should have a list of current businesses;
- Reinforce the hazardous waste bans for the residential sector through education, notably as part of HHW collection;
- Reinforce the hazardous waste bans with waste collection staff, who are most likely to observe improperly disposed materials; and,
- Consider random inspection of waste from ICI establishments.

5.1.7 Household Hazardous Waste

The MSW, ICI and CRD waste streams in the NWT community landfills were observed to occasionally contain hazardous materials (e.g., batteries, hydrocarbon containers, paint containers, etc.), reflecting the need to improve segregation of these materials from the waste stream at source (i.e., before pick-up). Although generated in small amounts, HHW is a significant concern as these small amounts of these materials can have significant impacts if not managed properly. Management of HHW should be identified as a priority in the planned Waste Resource Management Strategy.

There is very little data on the volumes of HHW generation in the NWT. Section 3.0 provides estimated rates of capture of some HHW materials. It is further estimated (exp, 2012) that on the order of 440 tonnes of HHW is generated in the NWT (based on 2012 populations), of which approximately 60 tonnes could be captured if programs and capture rates similar to other jurisdictions (Stewardship Ontario, 2014) are achieved. These totals represent approximately 0.9% (generated) and 0.2% (captured) of the MSW/ICI waste generated in the NWT. It should be recognized that these values are based on broad estimates and multiple data sources from jurisdictions, which may not be directly comparable to the NWT. Given that HHW collection is undertaken in three of the larger communities in the NWT (i.e., Fort Smith, Hay River and Yellowknife), it is recommended that information from these programs be processed in order to provide a territory-specific data set of HHW capture rates.

Management of HHW in other Canadian jurisdictions is variable depending on size and the maturity of the waste management system. The approach that is undertaken by the GNWT is typical of that elsewhere, in that HHW management programs evolve from a program of education and limited collection events, to semi-annual (spring and fall) collection events. As the programs develop further, scheduled (usually Saturday morning) monthly or even weekly HHW collection is conducted at a depot typically located at the community landfill or at a convenient place in the community or region. This is the model currently undertaken in the Province of Newfoundland and Labrador, where HHW is collected at regional centres, but also at separate collection events.

Co-ordination of HHW collection should involve the establishment of systems that are operated by persons trained in the identification, storage and management of hazardous waste. Both the Province of Newfoundland and Labrador and Yukon Territory (Yukon) operate established HHW collection programs across their jurisdictions. In the case of Newfoundland and Labrador, mobile collection events and existing or planned HHW depots are financed and run by the government through the regional waste management bodies. In the case of the Yukon, these events are sponsored by community organizations, with financial and technical support from the Territory. The Yukon also pays for the organization and shipping of special waste from other non-residential hazardous waste generators, who pay for the disposal cost. In the province of British Columbia, permanent depots for hazardous waste collection are identified on a searchable web site for each community. The approaches in these jurisdictions should be considered for use in the NWT, although those which rely on well- connected transportation will not necessarily be applicable.

In order to divert more HHW materials from disposal, the GNWT should consider establishment of a territory-wide program with the goal of diverting all HHW from the MSW/ICI waste stream. This program could involve the following key components:

- Develop education programs (posters, web site information) regarding HHW items which are banned from the landfills and which can be taken to collection facilities for diversion. This education program can be enhanced as part of HHW collection events;
- Establishment of a regular collection frequency from each of the communities, at least annually and preferably on a more regular basis to encourage changes in habits regarding management of these materials. In this regard, it is noted that similar changes in behaviour are reflected in many communities relative to the beverage container program;
- Strict enforcement of manifesting of all hazardous materials accepted at the landfill site or other location;
- As part of landfill site licencing, require the communities to establish containers for storage of HHW at the community works building (where possible) or at the landfill site;
- Investment in proper HHW storage infrastructure in each of the communities; and,
- Consider approaches or changes to enforcement of requirements of water licensing for landfilling and acts/guidelines relating to hazardous waste in order to increase compliance.

5.1.8 Environmental Risk Management and Design at Landfill Sites

Environmental risk management and design of landfills and waste storage/transfer facilities typically evolves as a result of a number of factors including (i) observed environmental impacts, (ii) increasing volumes of waste and recognition of resultant increased potential for impact, (iii) changing regulations, typically at an upper tier level of government and (iv) consolidation of jurisdictions within a higher tier of government. In Simcoe County (Ontario), for example, the County, an upper tier municipality, took over management of a number of small landfills formerly operated by lower tier municipalities (townships). Following this, they consolidated the landfills and closed smaller sites, developed transfer stations, implemented increased risk reduction actions and improved collection of MSW and hazardous waste through a single operator (i.e., the County). Similar recommendations relative to development of transfer stations in Yukon Territory are contained in EBA (2009).

Challenges and recommended risk mitigation measures related to design and environmental management at landfill sites are described in Section 2.0. Some of the key points outlined in this section include:

- The presence of hazardous waste, particularly where it is not stored in secure, lined areas is the largest risk issue from an environmental standpoint. At many sites, historical hazardous waste stockpiles are a significant and increasingly concerning liability as the containers are deteriorating;
- With the exception of the Yellowknife landfill, the landfill designs in the NWT are natural attenuation (i.e., are not lined nor is leachate collected). Whereas such designs area appropriate considering waste generation rates/landfill size, the implementation (i.e., actual construction) of the designs and the operation of some of the landfills does not follow the guidelines and results in increased environmental risk;
- A number of communities largely operate the sites as they are able based on limited understanding of the guidelines and lack of clearly defined financial resources;
- Uncontrolled access and unsupervised placement of waste, particularly hazardous waste, results in spills and inconsistent application of environmental controls;
- Consistency of personnel responsible for the operation of the landfill sites and systems is an apparent issue at many communities. This is notably the case as the SAO is the person listed as being responsible for the landfills, however turnover of this position in some communities is frequent; and,

Information contained in annual reports for many communities is inconsistent and largely not useful with respect to estimating waste generation and determining site life. Reporting of the quantities of hazardous waste and bulky waste managed by the communities is largely not available, with the exception of Yellowknife.

5.2 Summary of Key Waste Management System Challenges, Opportunities and Priorities for Action

It is estimated that approximately 48,000 tonnes of waste is generated in the NWT annually. Of this approximately 29,000 tonnes (60% of the total) is generated in Yellowknife; the remaining 19,000 tonnes is generated at the remaining 31 communities spread over the territory, many of which are interconnected by seasonal roads and water-based transportation. The numerous communities with large distances between them, and the fact that they individually generating a relatively small amount of waste, are key challenges to the implementation of existing and planned initiatives

According to Giroux Consulting (2014) “there is an opportunity to improve waste management in Canada's Northern Territories by: diverting more waste by requiring segregation (e.g., tires, white goods, vehicles, CRD), storing hazardous materials; stopping open burning; constructing waste facilities to modern standards; ensuring that all disposal sites have controlled access; and requiring disposal monitoring of quantities disposed”.

Based on our review of the current state of waste management in the NWT, segregation of these materials is occurring and there is no open burning of solid waste, largely other than wood and paper. Improving the implementation of design and operation standards of a number of the facilities, and notably the storage methods for hazardous waste, is a key opportunity. Furthermore, manifesting of hazardous waste and some bulky waste (e.g., tires, used appliances, ELV, etc.) and measuring MSW/ICI waste disposal rates at select "typical" landfill sites is a key opportunity to better understand the volumes and types of material accepted at these facilities.

The presence of stockpiles of hazardous waste in a number of communities, notably in the northern part of the NWT, is a key challenge, as described above. This represents both an environmental and financial liability, which is not captured in annual operating cost estimates.

Funding of waste management is not currently separated from that for general activities, unlike water and wastewater systems. This is in part because equipment used to complete waste management tasks is often primarily used for other general community operations. In order to encourage communities to better manage waste collection, disposal and diversion, funding of waste management should be allocated based on an approach similar to that outlined in Section 4.0.

The following items should be prioritized in order to limit the potential environmental impact of the landfills and improve the understanding of waste generation in the NWT:

5.2.1 Hazardous Waste Management

- Improve hazardous waste storage including the use of appropriate liners or containers that can prevent the release of hazardous waste to the environment in the event of a leak of the containers;
- Establish a maximum hazardous waste storage period of one year in the water licences for communities with access to all-weather roads, and two years for communities with seasonally limited access;
- Where possible, store all new hazardous waste materials in the area of the community garage or other building where staff can manage the materials appropriately. The use of totes or other larger transportable storage for oil should be considered, and long term storage in smaller containers (i.e., pails) should not be allowed;
- Prioritize management of historical hazardous waste including determination of a funding mechanism;
- Implement a program to ensure that mercury and refrigerants are removed and managed appropriately from appliances and ELV when they are still in a condition that would allow for removal. Require reporting of these actions in the annual report; and,
- Establish a formal mechanism to confirm that hazardous materials, such as lead paint, asbestos, and mercury switches, have been removed from construction, renovation and demolition (CRD) materials before these materials are disposed of in the community landfill.

5.2.2 Waste Generation and Diversion

- Implement waste weighing and surveys at select landfills in order to develop an improved understanding of waste generation rates in the NWT;
- Minimize generation of leachate through the implementation of appropriate compaction and covering of lifts, as well as by minimizing cell size and closing out and capping cells as soon as practical;
- Develop standard guidelines for acceptable management of clean wood, paper and cardboard and include conditions for management options including burning, within water licences;

- Improve management of bulky materials including crushing of empty drums (i.e., 45 gallon barrels) through a regionally (GNWT) managed program for more remote communities;
- Improve efforts to prevent the deposit of hazardous waste from the ICI and residential sectors though licencing, reinforce education identifying materials banned from landfilling and reinforce training of waste collection and landfill operation staff with regard to these hazardous materials. Conduct random inspections/audits of waste, particularly from ICI establishments;
- Require that community construction or demolition projects develop a waste management plan as part of project planning and approvals, which includes a waste minimization plan. Disposal of housing demolition and highways materials that at landfills by GNWT departments should be better managed by requiring quantity estimates and inventory of materials, including an assessment of re-use, separation and volume minimization options; and,
- Encourage and as needed, enforce, a ban on hazardous waste including household hazardous waste disposal in landfills.

5.2.3 Waste Management Systems and Planning

- The GNWT should establish an overarching waste management strategy that clearly defines the licencing, regulatory and management roles in the NWT. As part of this process, a Waste Management Strategy Group should be established to provide guidance on the execution and monitoring of the Waste Resource Management Strategy and should include some key community representatives;
- Enforce the requirement that all communities with landfill facilities complete an approved water licence application with appropriate supporting documentation/reports;
- Develop a site specific hazardous waste management plan for the waste management portion of each water licence. This should include storage type (liner, building/sea can, bins), location (landfill site or community garage), manifesting and annual reporting;
- Training of waste collection and waste management staff should be undertaken based on an NWT specific program and should include in-field training;
- Improve management of incoming hazardous and bulky waste, including improved manifesting, reporting and development of a database of materials accepted for bulky and hazardous waste storage at community landfills or other facilities. Standardize and enforce approach to annual reporting for these items; and,
- In order to allow communities to better manage waste collection, disposal and diversion, funding of waste management should be allocated based on an approach similar to the MACA financial model described in this report.

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APPENDIX A

Specific Materials Collection Rates Data Tables – A-1 & A-2

Provinces and Territories	Population (2013)	Electronics Collected		Tires Collected (Passenger Tire Equivalents)		Used Oil Recovered		Oil Filters Recovered		Oil Containers Recovered		Paints Recovered		Paint Containers Collected		Batteries (lead-acid)		Antifreeze Recovered	
		Total (tonnes)	Per capita (kg)	Total (units)	Per capita (units)	Total (Litres)	Per capita (Litres)	Total (units)	Per capita (units)	Total (kg)	Per capita (kg)	Total (Litres)	Per capita (Litres)	Total (kg)	Per capita (kg)	Total (tonnes)	Per capita (kg)	Total (Litres)	Per capita (Litres)
Canada	35,134,300																		
NL	528,200			465,000	0.88							161,083	0.30	34,260	0.06				
PEI	145,500	645	4.4	2,509	0.02							63,058	0.43						
NS	942,900	4,736	5.04	1,070,000	1.13														
NB	755,600			1,026,000	1.36							236,749	0.31	59,210	0.08				
QC	8,154,000	10,627	1.3			64,785,138	7.95	7,664,067	0.94	1,850,135	0.23							1,523,638	0.19
ON	13,550,900	76,764	5.67					8,726	0.00064	3,753,000	0.28							3,448,000	0.25
MB	1,265,400	3,026	2.38	14,713	0.01	13,600,000	10.75	1,570,000	1.24	260,000	0.21						6	323,700	0.26
SK	1,106,200	3,288	2.95	799,416	0.72	18,740,000	16.94	2,070,000	1.87	420,000	0.38	954,288	0.86	120,300	0.11				
AB	4,007,200	19,994	4.79			95,012,635	23.71	8,382,660	2.09	2,456,182	0.61	2,380,000	0.59	592,846	0.15				
BC	4,582,600	23,234	5.04	2,693,627	0.59	50,000,000	10.91	5,260,000	1.15	1,626,000	0.35	2,889,357	0.63				3.4	2,630,000	0.57
YK	36,400																		
NT	43,800																		
NU	35,400																		
Notes and Comments		Report estimates 6.1 kg/cap avaiable annually or 266 tonnes in NT.		Report estimates 11.1 kg/cap avaiable or 484 tonnes in NT.		Report estimates 10.1 kg/cap avaiable or 440 tonnes in NT.		Ontario number appears low so excluded from averaging. Report estimates 0.71 kg/cap available or 31 tonnes for NT.		Report estimates 0.32 kg/cap or 14 tonnes avaialable in NT.		Includes both non aerosol and aerosol. Report estimates 1.1 kg/kp available or 48 tonnes for NT.		Including both metal and plastic containers. Report estimates 0.37 kg/cap available for steel cans or 16.1 tonnes in NT. Report estimates 0.037 kg/cap avalable for plastic containers or 1.6 tonnes in NT.		6 kg/y was used as Manitoba better represented weather conditions of North. Estimated 262 tonnes for NT.		Report estimates 1.2kg/cap availble or 52 tonnes in NT.	
Average (excluding Canada data)			**3.95**		**0.67**		**14.05**		**1.22**		**0.34**		**0.52**		**0.10**		**6.00**		**0.32**

Jurisdiction	**Population**	End of Life Vehicles		Tires		Used oil, oil filters and oil containers		Antifreeze		Batteries (Lead-acid)		Large Appliances (White Goods)		Paints and coatings and their containers	
		Total (# of vehicles)	Per capita (# of vehicles)	Total (tonnes)	Per capita (kg)	Total (tonnes)	Per capita (kg)	Total (tonnes)	Per capita (kg)	Total (tonnes)	Per capita (kg)	Total (tonnes)	Per capita (kg)	Total (tonnes)	Per capita (kg)
Newfoundland	512,700	**85,000 EOL Vehicles**	0.166	3,992 T	7.56	x		x		x		4,630 T	9.03	x	
PEI	146,100	x		1,962 T	13.48	x		x		x		x		x	
Nova Scotia	948,700	x		11,296 T	11.96	363 T	0.38	x		x		**2,124 T**	2.24	**353 T**	0.37
New Brunswick	756,000	x		11,466 T	15.17	290 T	0.38	x		x		6,827 T	9.03	**301 T**	0.40
Quebec	8,084,800	360,000 EOL Vehicles	0.045	x	x	**2,415 T**	0.30	4,770 T	0.59	2,726 T	0.34	*274,000 T*	*33.89*	**6,169 T**	0.76
Ontario	13,505,900	**550,000 EOL Vehicles**	0.041	88,211 T	6.51	**3,512 T**	0.26	**7,968 T**	0.59	**7,642 T**	0.57	**12,853 T**	0.95	**22,422 T**	1.66
Manitoba	1,267,000	x		12,972 T	10.25	**248 T**	0.20	747 T	0.59	427 T	0.34	**294 T**	0.23	1,352 T	1.07
Saskatchewan	1,080,000	x		48,462 T	*38.30*	**1,071 T**	0.99	637 T	0.59	x		**2,191 T**	2.03	**566 T**	0.52
Alberta	3,873,700	175,500 EOL Vehicles	0.045	44,223 T	11.04	**3,651 T**	0.94	2,285 T	0.59	1,306 T	0.34	34,979 T	9.03	**2,600 T**	0.67
British Columbia	4,622,600	210,000 EOL Vehicles	0.045	44,432 T	9.70	**1,530 T**	0.33	2,727 T	0.59	1,559 T	0.34	41,742 T	9.03	**2,655 T**	0.57
Canada	34,880,500	x		x	x	x		20,578 T	0.59	13,660 T	0.39	**236,786 T**	6.79	x	
Notes and Comments		Per capita results for QC, AB, BC are all the same		2009 to 2011 data		NS and NB per capita results are the same		Per capita data are all the same		QC, MB, AB and BC per capita results are all the same		Quebec data considered an outlier. NFLD, NB, AB and BC per capita results are all the same and much higher than other provinces			
Range (excluding National data)			0.041 - 0.166				0.20 - 0.99		0.59000		0.34 - 0.57		0.23 - 9.03		0.37 - 1.66
Total data points in average			*5*		*8*		*8*		*8*		*5*		*8*		*8*
Common data points			*3*		*0*		*2*		*7*		*3*		*4*		*0*
Provincial Average			0.103		10.71		0.43		0.59		0.57		1.36		0.71
Provincial Average including common values			0.084		10.71		0.57		0.59		0.62		2.90		0.75

Bolded Values Represent individual data
Italicized data considered anomalouos

Select Reference Sources Agencies and Organizations:

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Atlantic Used Oil Management Association
British Columbia Used Oil Management Association
Call2Recycle, Inc.
Canadian Association of Tire Recycling Agencies. *National Data*
Canadian Association of Tire Recycling Agencies. *Provincial Data*
Canadian Battery Association
Eco-Peinture
Health Products Stewardship Association
Interstate Battery System of Canada
LightRecycle
Manitoba Association for Resource Recovery Corp.
Manitoba Medications Return Program
Manitoba Waste and Recycling
Product Care Association
Recyc-Québec
Saskatchewan Association for Resource Recovery Corp
Société de Gestion des Huiles Usagées
Stewardship Ontario

Jurisdiction	Population	Pesticides		Mercury Containing Lamps		Mercury Containing Equipment		Pharmaceuticals		Needles/Sharps	
		Total (tonnes)	Per capita (kg)	Total (tonnes)	Per capita (kg)	Total (units)	Per capita (units)	Total (tonnes)	Per capita (kg)	Total (tonnes)	Per capita (kg)
Newfoundland	512,700	x		x		x		11 T	0.021	x	
PEI	146,100	x		x		x		**3 T**	0.019	x	
Nova Scotia	948,700	x		x		x		20 T	0.021	15 T	0.02
New Brunswick	756,000	x		x		x		16 T	0.021	x	
Quebec	8,084,800	391 T	0.05	235 T	0.03	x		170 T	0.021	127 T	0.02
Ontario	13,505,900	**1,200 T**	0.09	**392 T**	0.03	**5,000 T**	0.000370209	**331 T**	0.025	**212 T**	0.02
Manitoba	1,267,000	x		37 T	0.03	x		**8 T**	0.006	x	
Saskatchewan	1,080,000	x		x		x		23 T	0.021	x	
Alberta	3,873,700	x		x		x		81 T	0.021	x	
British Columbia	4,622,600	**83 T**	0.02	134 T	0.03	x		**69 T**	0.015	73 T	0.02
Canada	34,880,500	**1,283 T**	0.04	1,012 T	0.03	**322,600 T**	0.009248721	734 T	0.021	548 T	0.02
Notes and Comments				Per capita data are all the same		Limited data		Per capita data are all the same except PEI, ON, MB and BC			
Range (excluding National data)			0.02 - 0.09		0.03		0.00037		0.015 - 0.025		0.020
Total data points in average			*3*		*4*		*1*		*10*		*4*
Common data points			*0*		*3*		*1*		*6*		*3*
Provincial Average			0.05		0.03		0.00037		0.016		0.02
Provincial Average including common valu			0.05		0.03		0.00037		0.017		0.02

Bolded Values Represent individual dat
Italicized data considered anomalouos

Select Reference Sources Agencies and Organi

Alberta Recycling Management Authority
Alberta Used Oil Management Association
Atlantic Used Oil Management Association
British Columbia Used Oil Management Associ
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