City of Iqaluit
Water Licence Monitoring Program

Prepared for:
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1.0 INTRODUCTION

1.1 Background

The City of Iqaluit is located at the south end of Baffin Island, on Frobisher Bay at 64° 31'N latitude and 68° 31'W longitude, in a region of continuous permafrost with a typical arctic climate. The community has only four months when the average monthly temperature is above freezing.

The city has a population of approximately 6,200 with a predicted increase in population to 11,300 in 2022. The infrastructure municipal facilities are currently operated under the Water Licence (File No: 3AM-IQA0611) issued by the Nunavut Water Board (NWB) in 2006. Based on the requirements of the Water Licence, one of the most important responsibilities of the City of Iqaluit is to monitor the quantity and quality of the "water" associated with potable water supply, sewage treatment and solid waste management to protect public health and the environment.

In 2007, the City of Iqaluit retained Earth Tech (Canada), Inc. to provide services for preparing the "water" monitoring plan. The primary purpose of the monitoring plan is to help the City of Iqaluit identify appropriate water quality parameters to be monitored and sampling locations for the collection of representative samples. This monitoring plan will be submitted to the NWB for approval before it is applied for water monitoring in the City.

1.2 Scope and Objectives

It is very important for the City of Iqaluit to comply with the Water Licence for operating and monitoring the municipal facilities (i.e. water treatment, wastewater treatment, landfill etc.) properly. The water monitoring programme, once in place, will provide the appropriate framework for the City to achieve compliance associated with the water sampling requirements in the water licence.

Overall, the primary objective of the project is to develop a cost-effective compliance monitoring plan for:

- Protection against adverse impacts on public health from physical, chemical and biological hazards;
- Environment protection; and Compliance with Water Licence regulation and guidelines.

The Monitoring plan for the City of Iqaluit has been prepared based on the following key tasks:

- Identification of current criteria for water monitoring presented in Water Licence;
- Identification of the gap between the requirements of the Water Licence and the practical needs of Iqaluit for water monitoring;
- Recommendations of appropriate water quality parameters for Iqaluit;
- Confirmation of the sampling points for the recommended monitoring; and
- Preparation of final monitoring plan based upon NWB feedback.
- Organization of the Report.

The remainder of the report has been organized in the following sections:

- Section 2.0: Municipal Facilities and "Water" Characteristics. The treatment process and operation strategy of the drinking water treatment plant (WTP), wastewater treatment plant (WWTP) and solid waste management facility are briefly introduced in this section. In addition, the characteristics of "water", associated with water treatment, sewage disposal and landfill management, are also summarized;

- Section 3.0: Identification of the Water Monitoring Criteria and Locations. This section compares the requirements of the Water Licence applied for the City of Iqaluit with some standards and guidelines published by some organizations or government branches. Also, some suggestions and comments regarding the monitoring criteria required by the Water Licence are discussed.

- Section 4.0: Budget for Sampling. An annual budget for monitoring (sampling and analysis) is presented based on laboratory quotations from several commercial laboratories which the City of Iqaluit could use for sample analysis.

2.0 MUNICIPAL FACILITIES AND "WATER" CHARACTERISTICS

2.1 Water Treatment Facility (WTP)

The City of Iqaluit's water treatment plant (WTP) was initially commissioned in the 1960s, with Lake Geraldine Lake used as the raw water source. Due to the limited treatment capacity, the main treatment process of the WTP was upgraded between 2002 to 2004. After the upgrade, the treatment capacity of the WTP was increased to approximately 9,500 m^3 day^{-1} based on a projected population of 11,300 in 2021.

The upgraded treatment facility consists of the following processes:

- Lake Geraldine dam structure and valve chamber;
- Raw water intake pipeline and tempering system (upgraded in 1999);
- Plant inlet flow control valve;
- Ultraviolet (UV) pre-disinfection (one duty and one standby);
- Flocculation tanks (to be used for flocculation only when coagulation is required in future);
- Dual media rapid gravity filters and filter backwash and "filter to waste" storage tanks;
- Chemical (chlorine gas, zinc orthophosphate, hydrofluorosilicic acid and caustic soda) dosing systems; and
- Treated water clearwells (west clearwell and east clearwell).

Normally, raw water is drawn from the dam on the Geraldine Lake and flows to the WTP through a 250 mm main by gravity. Upon entering the WTP, the raw water is metered and controlled by a flow control valve. The raw water then flows through either of the UV reactors to inactivate pathogens. Downstream of the UV equipment the water flows through a set of flocculation tanks (these tanks will only be required to operate as flocculation tanks in the event that future coagulation is required to meet the final water quality targets), or through a flocculation tank bypass line on to the filters. From the filters the filtered water flows into the contact chamber where chlorine gas (for residual disinfection) is injected to the water along with hydrofluorosilic acid (for fluoridation) and caustic soda (for pH adjustment). The treated flow from the contact chamber can then be diverted to either of the clearwells or into the filter backwash chamber. Zinc orthophosphate (for pipeline corrosion protection) is added before the treated water is delivered to the distribution system or an off-site reservoir. The "filter to waste" storage tank is used for accepting the filter ripening flow, of which the quality is usually above the regulatory requirements, generated by filters after backwash cycles.

This drinking water treatment process is automatically controlled by a Plant Control System (PCS) and requires minimal intervention unless there is an alarm indicated. Monitoring, fine-tuning and scheduled maintenance of the WTP operating systems provide reliability and dependability with reduced system malfunctions and breakdowns.

2.2 Wastewater Treatment Facility (WWTP)

The City of Iqaluit has historically used a primary sewage lagoon for its wastewater treatment. To improve the wastewater treatment efficiency and achieve effluent quality requirements, the City initiated construction of a new WWTP. In 1998, the city awarded a design-build contract for a new WWTP.

The design-build contractor proposed the use of an aerated membrane bioreactor (MBR) process for the wastewater treatment. In this proposed treatment process, the wastewater, after flowing through the preliminary treatment screens, is treated by a MBR system, in which most organic contaminants are degraded by microorganisms, and the treated wastewater and biomass are separated by membranes. Then, the filtrate from the membranes may be discharged to the surface water, and waste sludge generated in the treatment process may be dewatered and transferred to the landfill site for disposal.

However, due to design and construction problems, the MBR wastewater treatment process was never commissioned. In 2002, Earth Tech (Canada), Inc. conducted a detailed investigation of the WWTP, and recommended that the City reconfigure the facility to use a conventional biological wastewater treatment process to replace the MBR process. Following that, CH2M Hill developed a workable conceptual design in 2003 and Earth Tech carried out the conversion and expansion work from 2004 to 2006.

The major treatment facilities of the conventional biological treatment process (phase 1 and phase 2) consist of:

- Wastewater lift station;
- Preliminary treatment headworks (screening and grit removal);
- Primary filter (Salness filter);
- Activated-sludge aeration tanks and aeration systems (phase 2);
- Secondary clarifiers (phase 2);
- Waste sludge dewatering system (phase 2); and
- Others (chemical storage, pH adjustment, disinfection equipment).

The construction and commissioning of the new conventional biological WWTP is being carried out two phases. Phase 1 of the WWTP, the preliminary treatment process, was commissioned in May 2006, and phase 2, the biological treatment process, is scheduled for implementation within the next 5 to 10 years. The major facility equipment in phase 1 was designed for a peak flow of 14,400 m^3 day^{-1} with a service population of 12,000; the remaining equipment in phase 1 were designed for a peak flow of 9,600 m^3 day^1 with a service population of 8,000.

Currently, the raw wastewater enters the plant through an existing 300 mm gravity sewer main into the influent pumping chamber, where a basket screen catches any solids that have a diameter greater than 75 mm. The raw wastewater is then pumped and metered up to the coarse screens by which the particles larger than 5 mm are removed. The wastewater from the coarse screens is further screened to 300 micron particle size by fine screens and then flows by gravity into the retention channel. This primary effluent flows through the retention channel, under an underflow weir (to contain any floatable flammables), then over an overflow weir and finally out through the outfall to the Koojesse Inlet.

The sludge from the screens and the primary filter is compacted and dewatered to a solids content of approximately 20 %, and dropped into a the dump trailer which is periodically emptied at the landfill site. The sludge is dewatered further by freeze-thaw over the course of one winter, and composted at the landfill site.

2.3 Landfill Facility

The City of Iqaluit produces approximately 10,000 m^3 of compacted waste which enters the landfill annually, including residential, commercial and industrial wastes. Recycling is currently limited to the collection and diversion of aluminium cans. The current landfill facility was constructed on the south end of the West 40 Dump Site #3 in 1995 and expanded to the north in 2001. Further construction work in manage the site drainage was completed in 2006.

The waste disposal techniques at the landfill include compaction and covering with wood waste fill. The area method is used for the landfill operation, and includes placing waste above grade against a perimeter berm, compacting the waste using a wheeled loader and covering the waste using a wood waste material. The mulch, developed from wood construction waste, is a 250 to 300 mm layer that is placed over the waste and prevents wind blown material.

The landfill does not have an impermeable liner system to control the subsurface runoff; it relies on the local permafrost regime to provide a low permeability barrier to control the subsurface runoff. To control the surface discharge of runoff from the landfill site to the receiving environment, a surface water control system for both on-site and off-site drainage was completed in 2006.

The landfill surface runoff management system consists of a series of continuous ditches associated primarily with the perimeter berm structure of the landfill facility. The system is used to divert the "off-site" surface runoff and "on-site" surface runoff, essentially keeping the clean "off-site" water "clean" and keeping the potentially contaminated "on-site" surface runoff from leaving the landfill site. The "on-site" surface runoff is collected in several control ponds through the ditches and then pumped to a retention pond. The retention pond is discharged annually after testing and notification to the regulatory authorities.

3.0 IDENTIFICATION OF THE WATER MONITORING CRITERIA

3.1 Drinking Water Monitoring Criteria

3.1.1 Raw Water

Table 3.1 presents the water quality parameters and testing frequency that are required by the Water Licence (File No: 3AM-IQA0611) and recommended by Earth Tech for the raw water supply from Lake Geraldine Reservoir at the City of Iqaluit's WTP prior to treatment.

Table 3.1 Raw Water Monitoring Criteria and Frequency

Parameters Required by Water Licence	Required Frequency by Water Licence	Earth Tech's Recommendation
Routine Parameters		
Acidity	Monthly	Not recommended
Alkalinity	Monthly	Monthly
Bicarbonate	Monthly	Quarterly
Carbonate	Monthly	Quarterly
Chloride	Monthly	Quarterly
Conductivity	Monthly	Monthly
Hardness	Monthly	Quarterly
Hydroxide	Monthly	Quarterly
ORP	Monthly	Not recommended
pH	Monthly	Weekly
Sulphate	Monthly	Quarterly
TDS	Monthly	Monthly
TSS	Monthly	Monthly
TOC	Monthly	Monthly
TIC	Monthly	Not recommend
Temperature	Monthly	Weekly
Turbidity	Monthly	Weekly
Potable Water Parameters		
Fecal coliforms	Monthly	Quarterly
Total ICP metals	Monthly	Quarterly
Dissolved ICP metals	Monthly	Quarterly
Additional Parameters		
UV transmittance	N/A	Monthly
Color	N/A	Quarterly
Total coliforms	N/A	Quarterly
Giardia Lamblia	N/A	Quarterly
Cryptosporidium	N/A	Quarterly

As presented in **Table 3.1**, the Water Licence requires the City to monitor all of these listed parameters monthly. However, from the point view of operation of a WTP, some of these parameters may need to be monitored more frequently and some less frequently. Based on the importance of these parameters specific to the City of Iqaluit's WTP, different monitoring frequencies ranging from daily to annually are recommended as listed in **Table 3.1**. The reasoning behind these recommendations is discussed in the following paragraphs.

Parameters not recommended: Acidity, ORP and TIC.

The acidity of raw water can be directly or indirectly reflected by pH and alkalinity, which are recommended for routine monitoring. ORP monitoring is usually needed for water containing a relatively high concentration of a redox-active species, which may have some adverse effects on pipelines. The water quality of Lake Geraldine is good and there are no such redox-active species observed currently. Since many important parameters related to inorganic components, such as metals, chloride, carbonate, etc., are recommended for routine monitoring, TIC, as an overall index of the inorganic matters present in water, is not necessary. Acidity, ORP and TIC are not recommended during the normal operation of the WTP, although these parameters are to be monitored if some unusual condition arises.

Weekly monitored parameters: pH, Temperature and Turbidity.

These three parameters have significant effects on the performance of the existing water treatment process at the WTP. For example, raw water pH and temperature have great impacts on the chlorine concentration and contact time for the disinfection of treated water. Turbidity is very important for the operation of coagulation, flocculation and filtration. In addition, UV disinfection is also affected significantly by turbidity. The higher the turbidity of water in a UV reactor, the more UV light is attenuated. This means that higher UV doses will be required to achieve reliable disinfection levels when the turbidity is high. Under the current operating conditions, it is recommended to monitor these parameters weekly; if and when the coagulation and flocculation process is applied, it would be better to measure these parameters on a daily basis.

Monthly monitored parameters: Alkalinity, Conductivity, TDS, TSS, TOC and Fecal coliform.

The alkalinity of a water is its ability to neutralize an acid and is due to its CO_3^{2-}, HCO^{3-} and OH^- content. This is an index of the buffering capacity of water and if it is too low, the pH value could be changed significantly during the treatment. TDS and conductivity are used directly or indirectly to estimate the dissolved solids concentration in water. Both of them have certain correlations with the parameter of hardness. Water with high TDS usually tastes bitter, salty or metallic and sometimes, it may have some unpleasant odours. TSS is used to indicate the suspended solids present in water and it can usually affect the performance of some treatment processes, such as UV disinfection, coagulation, flocculation and filtration. TOC, indicating the concentration of organics present in water, is another important parameter for the WTP operator to monitor. In addition, TOC can also be used to estimate the generation of some organic disinfection by-products (DBPs), such as THMs and HAAs. Due to the importance of these parameters to the operation of the WTP, it is recommended to monitor them monthly in the first one or two years after the monitoring program is applied and then, to optimize the monitoring costs, these parameters could be monitored quarterly if the raw water quality, confirmed by the results obtained in the first one or two years, is good enough for the operation of the WTP. The reason that these parameters are recommended to be monitored at least quarterly is that the water quality of Lake Geraldine could have a variation due to the transition between different seasons, such as the runoff in spring. Some of these parameters may need to be monitored more frequently if some unusual condition of the WTP requires doing so.

Quarterly monitored parameters: Hardness, Bicarbonate, Carbonate, Chloride, Hydroxide, Sulphate, Total ICP Metals, Dissolved ICP metals and Fecal Coliforms.

Compared with the parameters discussed above, the focus of this group of parameters is more on the suitability of raw water to be used as a source for the WTP rather than the effects of raw water on the operation of the WTP treatment process. Since the water of Lake Geraldine is characterized to be good for drinking water treatment by the WTP, it is recommended to monitor these parameters (except Fecal Coliforms) quarterly in the first one or two years after the monitoring program is applied. If these parameters are in acceptable ranges and there is no significant contaminant source affecting the water quality of Lake Geraldine, these parameters could be monitored annually. If these parameters are monitored annually, it is recommended to monitor them alternatively in warm seasons and cold seasons. For the fecal coliforms, it is quite important for the public health and safety and it is recommended to monitor this parameter quarterly for the first two years after the monitoring program is applied; the monitoring frequency can then be reduced if the observed results are stable and no significant contamination source is around the drinking water source.

Additional parameters: UVT, Color, Total Coliforms, *Giardia Lamblia*, and *Cryptosporidium*.

Since a UV reactor is used for pre-disinfection at this WTP, the UV transmittance (UVT) of raw water becomes very important for the performance of the UV reactor. The lower the UVT of the raw water, the less effective UV light can get to the target pathogens and therefore, the more pathogens could pass through the UV reactor. To ensure the UV reactor is working under design conditions, it is recommended to monitor the raw water UVT at least monthly. Color is another important parameter for the monitoring of raw water quality and it is usually regulated as an aesthetic parameter by many regulatory authorities. The current treatment process of the WTP has minor capability for the removal of color. Therefore, the raw water color monitoring is recommended at least quarterly in the first one or two years after monitoring program is applied. In warm seasons, the raw water color may need to be monitored more frequently if it has been observed to experience a significant variation during this time. However, if the color is always observed far below the regulatory requirement, it may be monitored annually in the following years for economic purposes. Total coliforms, *Giardia Lamblia* and *Cryptosporidium* are three important biological parameters for any water treatment plant to monitor, to protect the public from biohazards. It is recommended to monitor these three biological parameters quarterly for the first two years after the water monitoring program is applied and then, if these biological parameters are within acceptable ranges, the monitoring frequency may be reduced to annually.

3.1.2 Treated Water

There are no specific requirements for the quality of treated water in the Water Licence. However, it is more important for the protection of public health to monitor the quality of treated water than it is to monitor the quality of raw water. Therefore, some important parameters are recommended hereinafter for the monitoring of treated water quality. The *Guidelines for Canadian Drinking Water Quality* (March 2007) published by Health Canada on behalf of the Federal-Provincial-Territorial Committee on Drinking Water was used as a reference in the following discussion.

Generally speaking, the parameters required for monitoring the quality of treated water can be categorized as microbiological, physical, chemical (inorganic, organic, disinfectant and disinfectant by-products (DBP)) and radiological parameters. Since most drinking water sources have very low radioactive contaminants, the radiological parameters in most WTPs are not monitored in routine operation. Lake Geraldine is recognized as a good drinking water source and no radioactive contamination has been observed. Therefore, to reduce the operation cost, the City of Iqaluit does not need to monitor the radioactive parameters routinely unless such kind of contamination is suspected in Lake Geraldine. The inorganic and organic chemical parameters of treated water to be monitored primarily depend on the raw water quality. The parameters of disinfectant and DBPs are monitored based on the species of disinfectant applied at the WTP and organics present in the raw water. Physical and microbiological parameters are usually monitored in most WTPs to protect the public from aesthetic and pathogenic problems. **Table 3.2** summarizes the microbiological and physical parameters and the guideline limitations required by Health Canada.

Table 3.2 Treated Water (in WTP) Monitoring Parameters and Frequency

	Limitations Required by Health Canada	Recommended Monitoring Frequency
Microbiological Parameters		
Fecal coliforms	0 CFU/100mL	Quarterly
Total coliforms	0 CFU/100mL	Quarterly
Heterotrophic plate count	No numerical guideline[1]	Twice per year
Giardia Lamblia	No numerical guideline[2]	Dependent on the raw water
Cryptosporidium	No numerical guideline[2]	Dependent on the raw water
Enteric viruses	No numerical guideline[3]	Dependent on the raw water
Turbidity	0.3/1.0/0.1 NTU[4]	Weekly
Physical Parameters[5]		
Color	≤ 15 TCU	Quarterly
pH	6.5 – 8.5	Weekly
Temperature	≤ 15 °C	Weekly
Total dissolved solids	≤ 500 mg/L	Monthly
Taste and Odor	Inoffensive	Not recommended
Chemical Parameters		
Free and/or total chlorine		Weekly
THM formation potential	0.08 mg/L[6]	Annually
HAA formation potential	0.06 mg/L[6]	Annually

Note:
1. No MAC is specified for HPC bacteria currently; but increases in HPC concentration above baseline levels are considered undesirable;
2. If the presence of these protozoa is observed or suspected in drinking water sources, the WTP should achieve at least a 3-log reduction in and/or inactivation of cysts and oocysts, unless source water quality requires a greater log reduction and/or inactivation;
3. Where treatment is required, the WTP should achieve at least a 4-log reduction and/or inactivation of viruses;
4. Requirements listed in the table are based on conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration;
5. All limits of physical parameters listed in Table 3.2 are aesthetic objectives or operational guidance values; and,
6. Maximum contaminant levels required by USEPA

3.1.3 Microbiological Parameters

As shown in **Table 3.2**, Health Canada has set relatively stringent requirements on treated water for microbiological parameters. For the treated water produced by the City of Iqaluit's WTP, the parameters of E. *coli*, total coliforms and turbidity should be monitored on a routine schedule. To reduce the operation cost, turbidity of treated water is recommended to be monitored at least weekly (daily measurement is preferred); E. *coli* and total coliforms should be monitored no less frequently than those done in raw water of the WTP (quarterly for the first two years and then annually if possible). Generally speaking, Heterotrophic Plate Count (HPC) does not have health effects; it is an index to reflect the variety of bacteria present in water. The lower the HPC, the better maintained the water system is. Therefore, to monitor the maintenance condition of the water system it would be better to determine the HPC level in treated water twice per year. The threat from *Giardia Lamblia* and *Cryptosporidium* against public health and safety has attracted great attention in North America since several fatal illnesses caused by drinking water contaminated by these protozoa were reported in recent years. Although there are currently no specific MACs required for these protozoa, Health Canada has set strict reduction and/or inactivation requirements for the water treatment process if possible contamination by these protozoa is suspected or known in the drinking water source. According to *the City of Iqaluit Water Treatment Plant Design Report* dated September 2001, the current treatment process at the City's WTP should be able to achieve at least a 3-log removal of *Giardia* and *Cryptosporidium*, which is a minimum requirement for a WTP without source water assessment for these parasites. Therefore, at the moment, it is important for the City's WTP to monitor the *Giardia* and *Cryptosporidium* levels in the raw water; the treatment redundancy for *Giardia* and *Cryptosporidium* can then be determined based on the obtained raw water data. If the City of Iqaluit has watershed protection plan in place it may not be necessary to monitor these protozoa levels in treated water routinely. For enteric viruses, as long as the water treatment facilities, especially filtration and chlorination, are operated properly, it should be able to achieve at least a 4-log removal at this WTP. Therefore, it is more important to monitor the parameters (chlorine residual, contact time, turbidity etc.) which can indicate the operational status of treatment facilities, than to determine the level of enteric viruses present in treated water. Due to this reason, it is not considered necessary to monitor the enteric viruses routinely in treated water.

3.1.4 Physical Parameters

Regarding the physical parameters listed in **Table 3.2**, they do not cause health risks but aesthetic problems for human consumption in most cases. Very similar aesthetic objectives or operational guidance values are regulated by both Health Canada and USEPA. Of these parameters, Odour and Taste are two very subjective parameters and are easy to be detected. So, it is not necessary to collect some specific water samples for odour and taste analysis in normal conditions. However, operators may need to check for these two aesthetic parameters in routine operation, especially in algal blooming period. Temperature and pH are two basic parameters for treated water; they may affect the chlorine disinfection process and cause pipeline corrosion and some aesthetic problems. It is recommended to determine these parameters at least weekly. For TDS and Color in treated water, they should be monitored as frequently as TDS and Color in raw water.

3.1.5 Chemical Parameters

Chemical parameters monitored in treated water can be categorized as inorganic, organic, disinfectant and disinfection by-product (DBP). As described previously, the City of Iqaluit's WTP currently uses UV irradiation for pre-disinfection, and chlorine gas for secondary disinfection and disinfection residual kept in potable water distribution systems. Many academic researchers have indicated that no significant DBPs could be generated by UV disinfection. For chlorination, some harmful DBPs, such as trihalomethanes (THMs) and haloacetic acids (HAAs), can be produced. The following parameters regarding the disinfectant and DBP in treated water are recommended to be monitored:

- Free chlorine concentration or total chlorine concentration in treated water before entering potable water distribution systems at least weekly (daily is preferred);
- THMs formation potential (FP) at least annually; it is recommended to analyze the THMs FP alternatively in warm seasons and cold seasons if it is monitored annually;
- HAAs formation potential (FP) at least annually; it is recommended to analyze the HAAs FP alternatively in warm seasons and cold seasons if it is monitored annually; and
- UV reactors should be checked routinely according to both the operation manual, and the requirements to make sure that reactors are working properly and appropriate UV doses can be delivered to the water.
- Inorganic chemical parameters include metals and anions. All of these parameters are quite important for the public safety and health and Health Canada has strict requirements on these parameters. Since there has been no systematic analysis conducted before for these parameters in treated water at the WTP, it is recommended to:
- Conduct a full metal scan[1] (for total concentrations) quarterly in the first two years of the Water Licence applied; the analysis frequency then can be reduced to annually (alternatively in warm seasons and cold seasons) if the metals are within the regulatory required ranges and the determined metal concentrations do not have significant variations; and
- Conduct a anion scan[2] quarterly in the first two years of the Water Licence applied; the analysis frequency then can be reduced to annually (alternatively in warm seasons and cold seasons) if the anions are within the regulatory required ranges and the determined anion concentrations do not have significant variations.

Generally speaking, the purpose of monitoring the dissolved metals (such as Aluminium, Iron, Calcium, and Manganese) in drinking water is to study the effects of these dissolved ions on the performance of some specific treatment units (such as membrane filtration, softening and coagulation). Therefore, monitoring these dissolved metals does not have significant meaning for the current treatment process at the WTP. If the total concentrations of metals can achieve the regulatory requirements, it may not be necessary to routinely monitor the dissolved metals.

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1 Including Aluminium, Arsenic, Antimony, Barium, Boron, Calcium, Cadmium, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Nickel, Potassium, Silver, Sodium, Zinc, etc.

2 Including Chloride, Cyanides, Fluoride, Nitrates, Nitrites, Phosphates, Sulphates, etc.

3.1.6 Potable Water in Distribution Systems

The Water Licence does not mention the requirements for the monitoring of potable water in potable water distribution systems. Due to the possibility that treated water supplied by the WTP could be contaminated in potable water distribution systems, it is also important to monitor the quality of potable water in distribution systems. The following parameters are suggested to be monitored:

- Temperature and pH. These two basic water quality parameters are usually related to many important reactions of water chemistry. It is recommended to monitor them at least weekly;

- Free chlorine residual and/or total chlorine residual concentration. This is an important parameter indicating the residual disinfection ability of the potable water in distribution systems. It is recommended to monitor this parameter at least weekly;

- THM and HAA concentrations. Sometimes, due to the presence of some organics (TOC) in treated water, significant amounts of THMs and/or HAAs could be generated in distribution systems after a long contact time of the organics with chlorine. It is recommended to monitor the THM and HAA concentrations at least annually;

- Turbidity. It is used to monitor the possibility of potable water in distribution systems contaminated by surface runoff and it is suggested to monitor the potable water turbidity at least weekly; and

- Fecal coliform, total coliform and HPC. These parameters are used to monitor the potable water in distribution systems contaminated by human and animal fecal wastes. Quarterly determination of these parameters is recommended to protect the public from these microbiological threats.

Table 3.3 summarizes the parameters which are recommended to be monitored in potable water distribution systems of the City.

Table 3.3 Treated Water (In Distribution Systems) Monitoring Parameters and Frequency

Recommended Parameters	Recommended Monitoring Frequency
Temperature	Weekly
pH	Weekly
Free and/or total chlorine residual	Weekly
THMs concentration	Annually
HAAs concentration	Annually
Turbidity	Weekly
Fecal coliforms	Quarterly
Total coliforms	Quarterly
HPC	Quarterly

3.2 Wastewater Monitoring Criteria

3.2.1 Influent to the WWTP

Only a primary treatment process is operated at the City of Iqaluit's WWTP currently and domestic sewage is the major wastewater treated at the WWTP. In order to achieve the discharge requirements required by NWB, a secondary biological treatment process may be added to the WWTP in the future. To protect the wastewater treatment process from damage, especially microorganisms in secondary treatment process, and to ensure that contaminants contained in wastewater influent are under the design loading rate of treatment facilities, some important influent parameters are usually monitored in the routine operation of most WWTPs. **Table 3.4** lists the parameters required by the Water Licence and recommended by Earth Tech to be monitored in the influent of the City's WWTP.

Table 3.4 WWTP Influent Monitoring Parameters and Frequency

	Required By Water Licence	Earth Tech's Recommendation
Biological Parameters		
Biochemical oxygen demand	Annually	Quarterly
Total coliforms	Annually	Quarterly
Fecal coliforms	Annually	Quarterly
Nutrient Parameters		
Ammonia nitrogen	Annually	Quarterly
Nitrate nitrogen	Annually	Not recommended
Nitrite nitrogen	Annually	Not recommended
Total phosphorus	Annually	Quarterly
Orthophosphate	Annually	Not recommended
Other Parameters		
Total suspended solids	Annually	Quarterly
Temperature	Annually	Biweekly
Conductivity	Annually	Not recommended
pH	Annually	Biweekly
ICP Parameters		
A full metals scan (total conc.)	Annually	Not recommended
Site Specific Parameters		
Chlorinated paraffins	Annually	Not recommended
LC50 Bioassay	Annually	Not recommended
New Added Parameters		
COD	N/A	Annually
TKN	N/A	Annually

As shown in **Table 3.4**, the Water Licence requires the WWTP to monitor these listed parameters in its influent annually. Based on the current operating condition and future development of the WWTP, the following recommendations, as presented in **Table 3.4**, are suggested for the WWTP:

Parameters not recommended: Nitrate nitrogen, Nitrite nitrogen, Orthophosphate, Conductivity, ICP metals, Chlorinated paraffins and LC50 bioassay.

The concentrations of NO_3-N, NO_2-N and orthophosphate in wastewater are usually used to monitor the nitrification, denitrification and phosphorus removal processes in a microbiological treatment process for nutrient removal. As described previously, it is just a primary treatment process operated at the City's WWTP, and there are no significant microbiological activities expected to occur during this phase. So, currently to monitor these three parameters in wastewater influent has no meaning. However, after the WWTP is upgraded to a secondary treatment process with biological nutrient removal sectors, these parameters may need to be monitored routinely based on some samples collected in relevant microbiological cells. Conductivity in influent usually is not a concern for wastewater treatment and it can be ignored in normal conditions. Metals, especially some heavy metals, have significant adverse effects on microorganisms in secondary biological treatment process. To keep microorganisms healthy and ensure the WWTP is running properly, Environment Canada has regulated the contaminant limits of industrial waste (including various metals) discharged to municipal sewers. In addition, the Department of Sustainable Development, Environmental Protection Service, Nunavut, also published detailed requirements on the industrial wastewater discharged to local sewage systems. However, for the current primary treatment process, it is not essential to routinely monitor the concentrations of various metals in the influent of the WWTP. Similarly, chlorinated paraffins and LC50 bioassay, though they may need to be monitored in the effluent of the WWTP to protect the receiving water from toxic contaminations, do not affect the current treatment process significantly and presently are not recommended for routine monitoring in the influent of the WWTP.

Quarterly monitored parameters: Total coliform, Fecal coliform, BOD5, Ammonia nitrogen, Total phosphorus and TSS.

No regulations specifically limit the numbers of total coliforms or fecal coliforms present in the influent of a WWTP; however, in order to have a basic understanding of the influent quality and performance of the wastewater treatment facilities, it is recommended to monitor these two parameters in the influent routinely at the City's WWTP. Since the numbers of total coliforms and fecal coliforms in wastewater could vary significantly in different seasons, the City of Iqaluit should monitor these parameters quarterly instead of annually. BOD_5, ammonia nitrogen and total phosphorus are some important parameters indicating the organic and nutrient concentrations contained in wastewater; however, they do not have significance for the current primary physical treatment process of the WWTP. In consideration of the future upgrade of the WWTP, it would be better to routinely collect the influent BOD_5, NH_3-N and TP data from now on for the design and operation of future secondary biological treatment process. TSS is another important parameter for the influent quality of WWTP, and it may significantly affect the performance of both primary and secondary treatment processes. Therefore, it is recommended to be monitored quarterly.

Biweekly monitored parameters: Temperature and pH.

These two basic water quality parameters are easy to measure and important to the operation of a WWTP. For example, both temperature and pH can affect the microorganism behaviours in a biological treatment process; also, the wastewater temperature and pH can be significantly related to the corrosion of plumbing fixtures of the primary treatment process. Therefore, it is recommended to monitor these parameters on a biweekly basis.

Other recommended parameters: COD and TKN.

Chemical oxygen demand (COD) is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in an acid solution. Total Kjeldahl nitrogen (TKN) is the total of the organic and ammonia nitrogen in wastewater. Both COD and TKN in the influent wastewater do not have significant meanings for the current primary treatment process. However, the concentration of COD, combined with the influent BOD_5, is usually used to evaluate the possibility of wastewater treatment by biological means; TKN, combined with NH_3-N, usually can be used for the estimation of organic nitrogen loading in wastewater, which is important to biological nutrient removal process. Therefore, it is recommended to monitor these two parameters in the influent wastewater annually for the design and operation of future biological treatment process applied at the WWTP.

3.2.2 Effluent from the WWTP

As indicated by Nunavut Water Board Reasons for Decision including Record of Proceedings dated May 2006, Sewage Treatment Plant Investigation dated December 2002 and City of Iqaluit Wastewater Treatment Plant Completion Study dated October 2003, the effluent of the City's WWTP, with the current primary treatment facilities, is hard-pressed to achieve the limits of discharge quality required by NWB. Also, there is a concern that the WWTP effluent which is being discharged to receiving water may not comply with the Fisheries Act. Based on the requirements of the Water License issued by NWB and the current operating condition of the WWTP, the monitoring parameters and frequency of sampling for the WWTP effluent are recommended and summarized in **Table 3.5**. The reasons for recommendations of these parameters are discussed after the Table.

Table 3.5 WWTP Effluent Monitoring Parameters and Frequency

	Required Frequency by Water Licence	Earth Tech's Recommendation
Biological Parameters		
Biochemical oxygen demand	Bi-monthly	Quarterly
Total coliform	Bi-monthly	Quarterly
Fecal coliform	Bi-monthly	Quarterly
Nutrient Parameters		
Ammonia nitrogen	Bi-monthly	Quarterly
TKN	N/A	Quarterly
Nitrate nitrogen	Bi-monthly	Not recommended
Nitrite nitrogen	Bi-monthly	Not recommended
Total phosphorus	Bi-monthly	Quarterly
Orthophosphate	Bi-monthly	Not recommended
Other Parameters		
Total suspended solids	Bi-monthly	Quarterly
Temperature	Bi-monthly	Quarterly
Conductivity	Bi-monthly	Not recommended
pH	Bi-monthly	Quarterly
ICP Parameters		
A full metals scan (total conc.)	Quarterly	Annually
Site Specific Parameters		
Chlorinated paraffins	Annually	Annually
LC50 Bioassay	Annually	Annually

Quarterly monitored parameters: BOD_5, Total coliforms, Fecal coliforms, Ammonia nitrogen, Total phosphorus, Total suspended solids, Temperature and pH.

The effluent BOD_5 and total suspended solids are two important parameters which are usually required by regulatory authorities to meet certain discharge qualities. Currently, a primary mechanical treatment process is operated at the wastewater treatment facility. Normally, a primary treatment process has a certain capacity to physically remove the influent BOD_5 and TSS and the treatment efficiency is usually very stable under certain operating conditions. So, these two parameters are recommended for monitoring at a quarterly basis. In addition, the existing treatment process is expected to have a minor capacity for the removal of ammonia nitrogen, total phosphorus, fecal coliforms and total coliforms; however, it is necessary to routinely determine these parameters as they provide information on nutrients and pathogens discharged from the WWTP to receiving water bodies. As these parameters in influent have been recommended to be monitored routinely, it is recommended to monitor them in effluent less frequently (quarterly) than bi-monthly required by the Water License.

Temperature and pH are two easily measured and commonly monitored parameters at most wastewater treatment facilities. A WWTP effluent with unacceptable temperature and pH values usually causes adverse effects on the plants and animals in receiving water bodies. To ensure the effluent temperature and pH are in normal ranges, the City should monitor these two parameters quarterly.

Annually monitored parameters: Full metal scan, Chlorinated paraffins and LC50 bioassay.

Some metals, especially heavy metals, may have significant adverse impacts on microorganisms and aquatic organisms. The chlorinated paraffins are classified as toxic to aquatic organisms and have been recognized as a possible carcinogen to humans. An LC50 bioassay is usually used to reflect the toxicity of wastewater to aquatic organisms. As these parameters were not monitored during previous operation of the WWTP, it is absolutely necessary to monitor these parameters to ensure the effluent quality can achieve the requirements of *Fisheries Act*. However, the primary wastewater treated at the WWTP is domestic sewage and under normal conditions, there is low probability that domestic wastewater will contain such high levels of toxic contaminants. Therefore, in this report, these parameters are recommended for monitoring on an annual basis. If there are no significant such toxic contaminants detected in the effluent, the monitoring frequency can be reduced based on a reasonable basis.

Not recommended parameters: Nitrite nitrogen, Nitrate nitrogen, Orthophosphate and Conductivity.

Although these parameters, such as NO_2-N, NO_3-N and PO_4-P, are very important for a biological nutrient removal treatment process, they do not have significant meanings for the currently operated mechanical treatment process at the WWTP. The parameter of conductivity is not a very important parameter for the effluent quality of a WWTP and it is not routinely monitored at most WWTPs. In addition, as a full metal scan of the wastewater effluent is recommended to be conducted on an annual basis, this report does not recommend routine monitoring of the effluent conductivity.

3.3 Landfill Monitoring Criteria

The current Water License only includes some general requirements for the landfill runoff and it does not address specific monitoring parameters and frequency. According to *Nunavut Water Board: Reasons for Decision Including Record of Proceedings* dated May 2006, there was a concern regarding environmental contamination by runoff from the landfill facility. This file documented that the City would propose a weekly sampling frequency for pH, Electrical conductivity, metals, BTEX, and Fractional hydrocarbon analysis and a monthly sampling frequency for phenols, PAHs and PCBs; when the drainage improvements are complete, the sampling frequency would be reduced to monthly for pH, Electrical conductivity, metals, BTEX, and Fractional hydrocarbon analysis and annually for phenols, PAHs and PCBs.

From 2004 to 2007, some samples were collected from the runoff of the landfill site and parameters such as BOD_5, TOC, nutrients, solids, anions, and metals were analyzed. Based on the comparison of these sampling reports (**Appendix X**), it can be concluded that:

Some parameters (BOD_5, TSS, and some metals) of the landfill runoff in detention pond significantly exceed the MWWE guidelines, and the direct discharge into environment from the detention pond may need to be controlled; and

The quality of runoff in retention pond is significantly better than that in detention pond; most of the parameters in retention pond are within the MWWE guidelines except for total iron, manganese and zinc concentrations which slightly exceed the guidelines.

Based on the historical sampling results and NWB's requirements, the monitoring parameters and frequency for the landfill runoff are recommended as shown in **Table 3.6**. The reasons for the monitoring recommendations are discussed in following paragraphs.

3.3.1 Monitoring Parameters In Detention Ponds

According to *Iqaluit Landfill Improvements* dated August 2006, detention ponds of the landfill facility are primarily used to collect the landfill "on-site" runoff and protect the "off-site" runoff from contamination. With a short retention time in detention ponds, the collected "on-site" runoff streams are directed to the retention pond where the wastewater is cleaned by holding for a long retention time. From this point of view, the "on-site" runoff collected in detention ponds is similar to the raw wastewater of a WWTP. Since the waste streams are treated primarily in the retention pond, some basic parameters are recommended for annual monitoring of the "on-site" runoff collected in detention ponds.

3.3.2 Monitoring Parameters In Retention Pond

The wastewater held in the retention pond has been annually discharged to the environment. It is important to ensure the discharge quality of the wastewater is within the regulatory requirements. Therefore, more detailed water quality parameters in the retention pond are recommended for routine monitoring. As BTEX and PCBs are concerns in the leachate of the landfill facility, it is also necessary to routinely monitor these two parameters. It is recommended to monitor these parameters before the discharge of each year. If the wastewater in the retention pond is discharged more than once per year, it is also necessary to monitor these parameters before each discharge.

Table 3.6 Landfill Runoff Monitoring Parameters and Frequency

	Earth Tech's Recommendation
Detention Ponds	
pH	Annually
Turbidity	Annually
Total suspended solids	Annually
BOD_5	Annually
COD	Annually
TOC	Annually
Retention Pond	
pH	Annually
Turbidity	Annually
Total suspended solids	Annually
BOD_5	Annually
COD	Annually
TOC	Annually

	Earth Tech's Recommendation
Ammonia nitrogen	Annually
TKN	Annually
Total phosphorus	Annually
Full Metal Scan + Hg	Annually
Total coliform	Annually
Fecal coliform	Annually
BTEX	Annually
PCBs	Annually

3.3.3 Monitoring Parameters for Sewage Sludge

The current Water License does not include requirements for the sludge monitoring with regard to parameters and frequency. Since sewage sludge treatment is an inherent part of the landfill management, sampling and testing should be required as part of the sludge management plan.

Table 3.7 Sewage Sludge Monitoring Parameters and Frequency

	Earth Tech's Recommendation
pH	Twice during summer
Total solids	Twice during summer
TKN	Annually
Total phosphorus	Annually
Full Metal Scan	Every second year
Total coliforms	Annually
Fecal coliforms	Twice during summer

4.0 BUDGET FOR SAMPLING

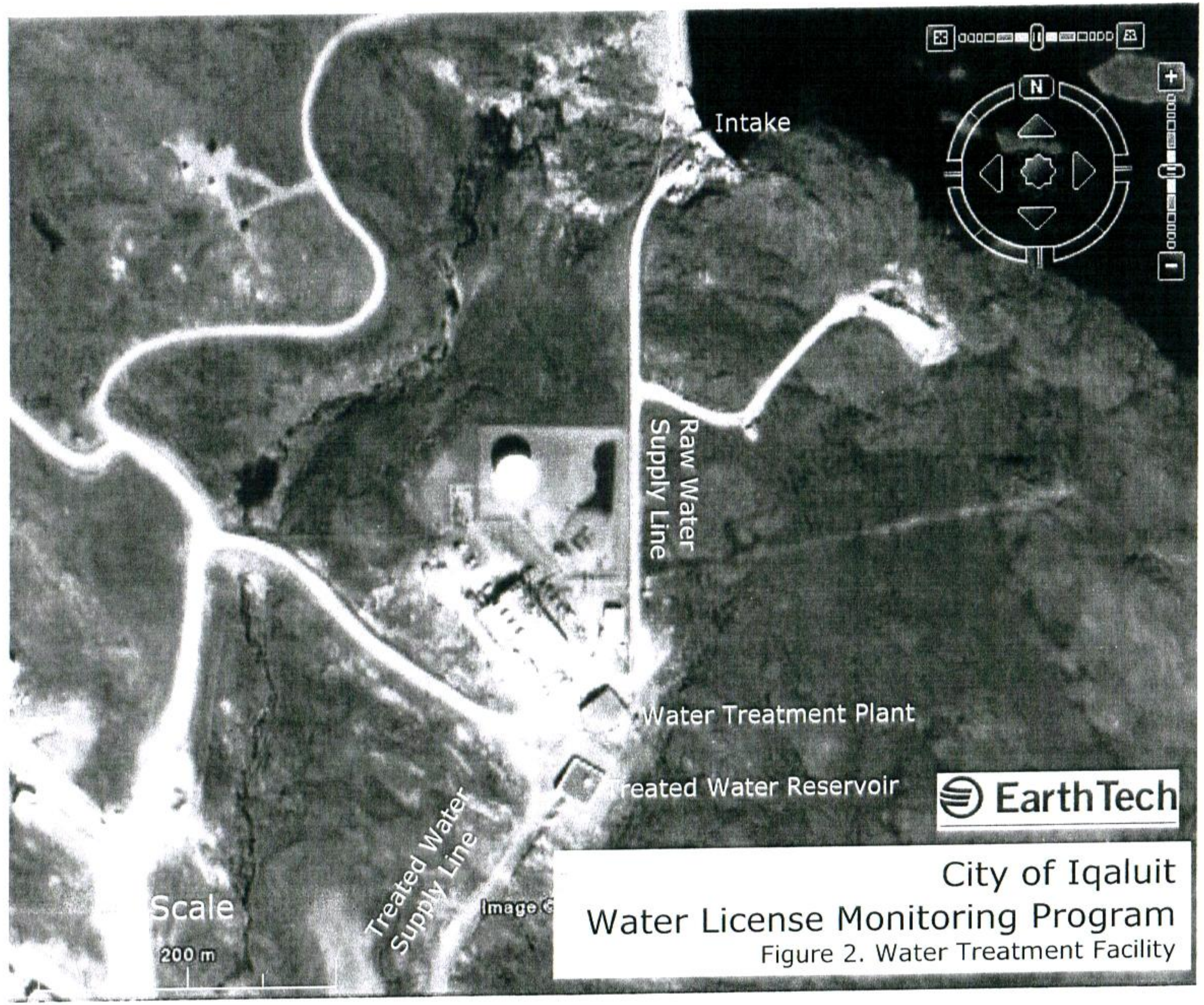
Based on the monitoring parameters and sampling frequency recommended in the previous section, the sampling cost per year is estimated and summarized in **Table 4.1**. It should be noted that:

- The budgetary cost is primarily based on cost information provided by Bodycote Testing Group (Ottawa). Sampling bottles, coolers, freezer packs and forms would be provided at no additional cost;
- "Temperature" of all samples should be determined immediately on-site;
- It is assumed that a total of 100 hours of manpower is required to collect and send all samples every year and $40.00 per hour is used for the estimation of manpower cost; and
- The shipping cost of sampling supplies and samples mainly depends on the weight and/or the volume of the shipment. Due to the variation of the amount of samples collected each time, the shipping cost will also vary significantly; therefore the cost presented is for budgeting purposes only.

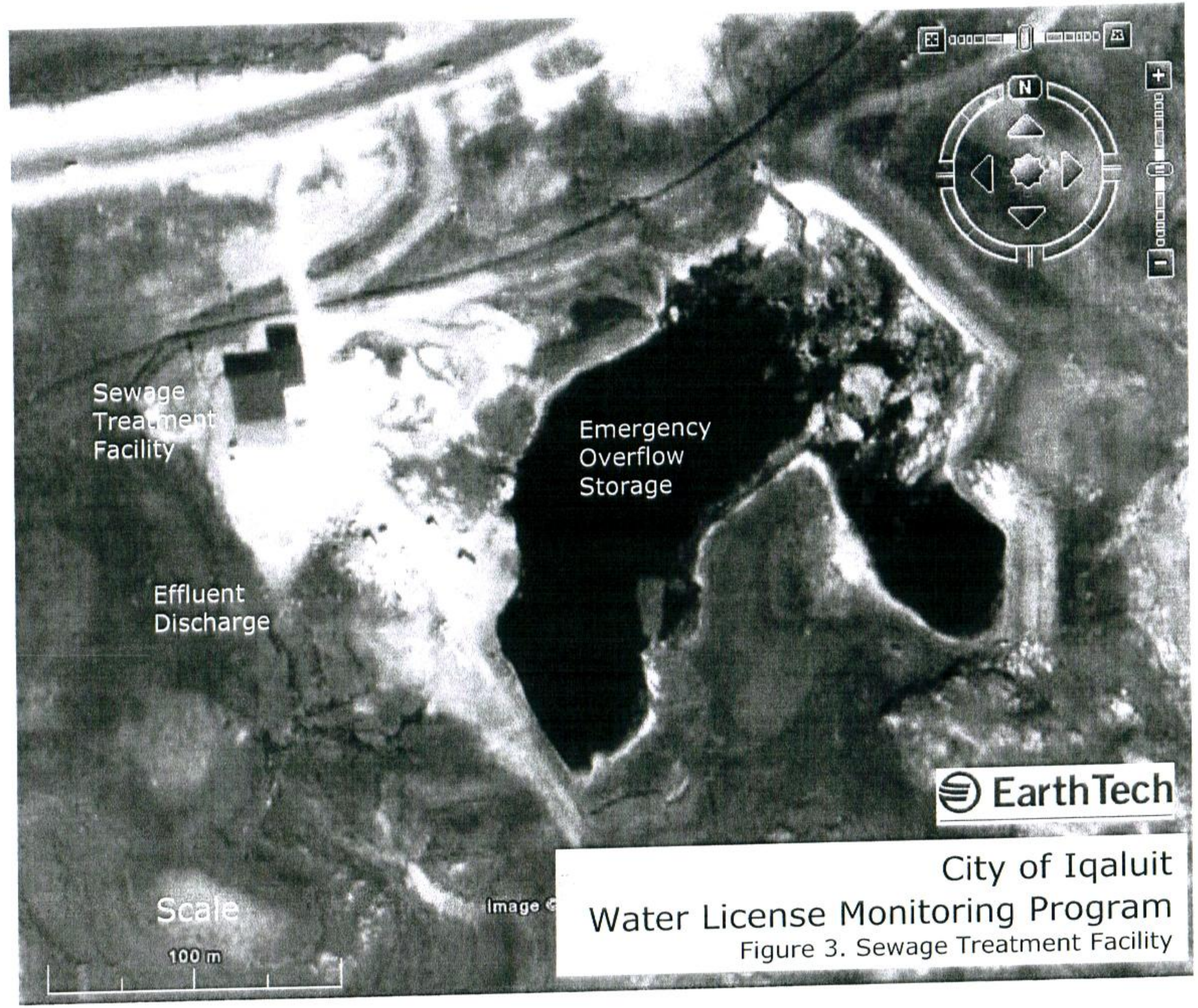
Table 4.1 Budgetary Costs For The Monitoring

			Sampling cost
1.	**Sample Analysis Budget**		
	1.1	Drinking Water	
		WTP Raw water	$ 4,500
		WTP Treated water	$ 3,500
		Distribution system	$ 2,000
		Sub-total	$10,000
	1.2	Wastewater	
		WWTP Influent	$ 1,000
		WWTP Effluent	$ 1,000
		Sub-total	$ 2,000
	1.3	Landfill	
		Detention pond	$ 200
		Retention pond	$ 800
		Sludge	$ 1,000
		Sub-total	$ 2,000
2.	**Other costs**		
	Manpower		$ 4,000
	Sampling supplies		No extra cost
	Shipping		$ 2,000
3.	**Total sampling cost**		$20,000

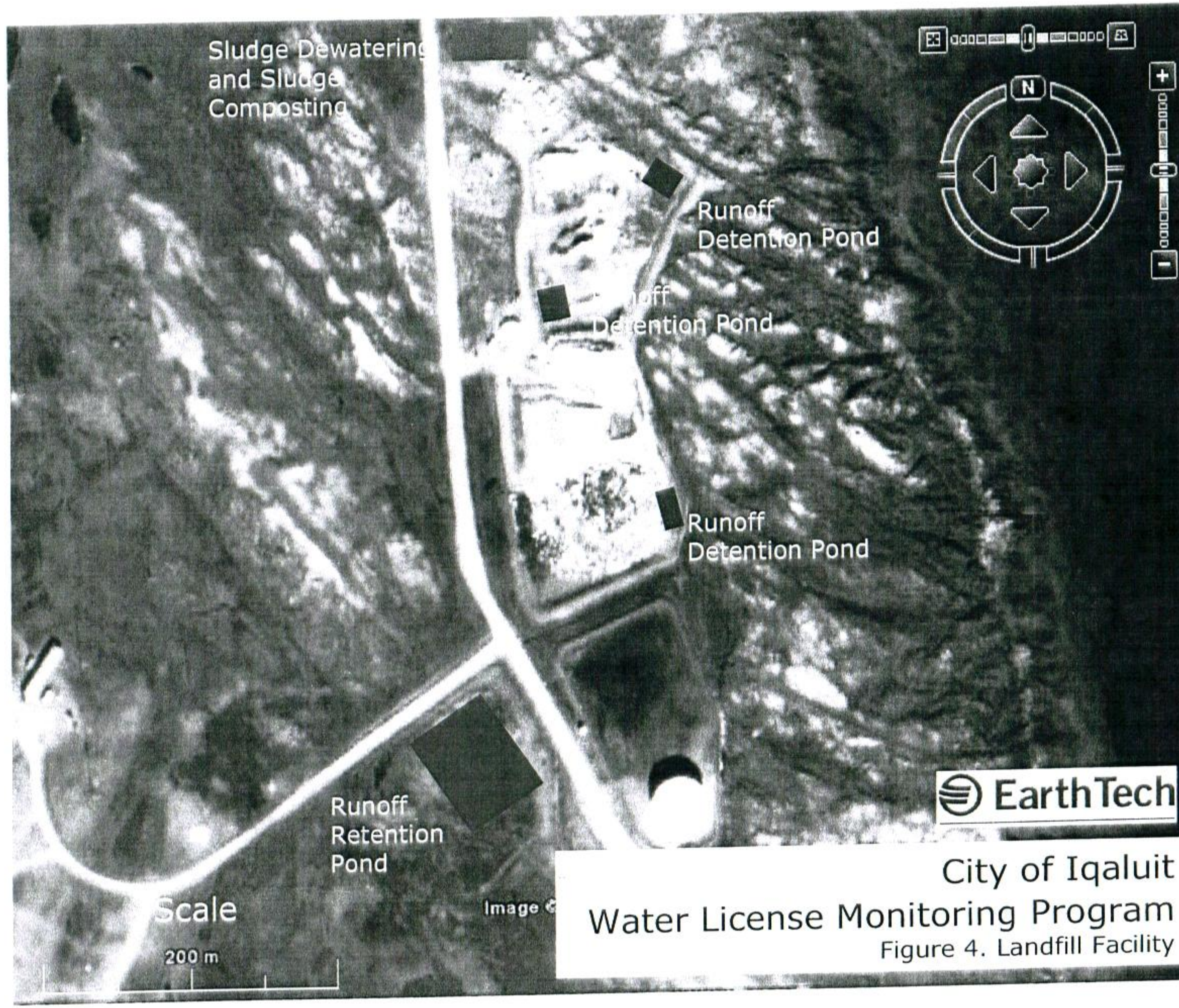
City of Iqaluit
Water License Monitoring Program
Figure 1. Facility Locations



City of Iqaluit
Water License Monitoring Program
Figure 2. Water Treatment Facility



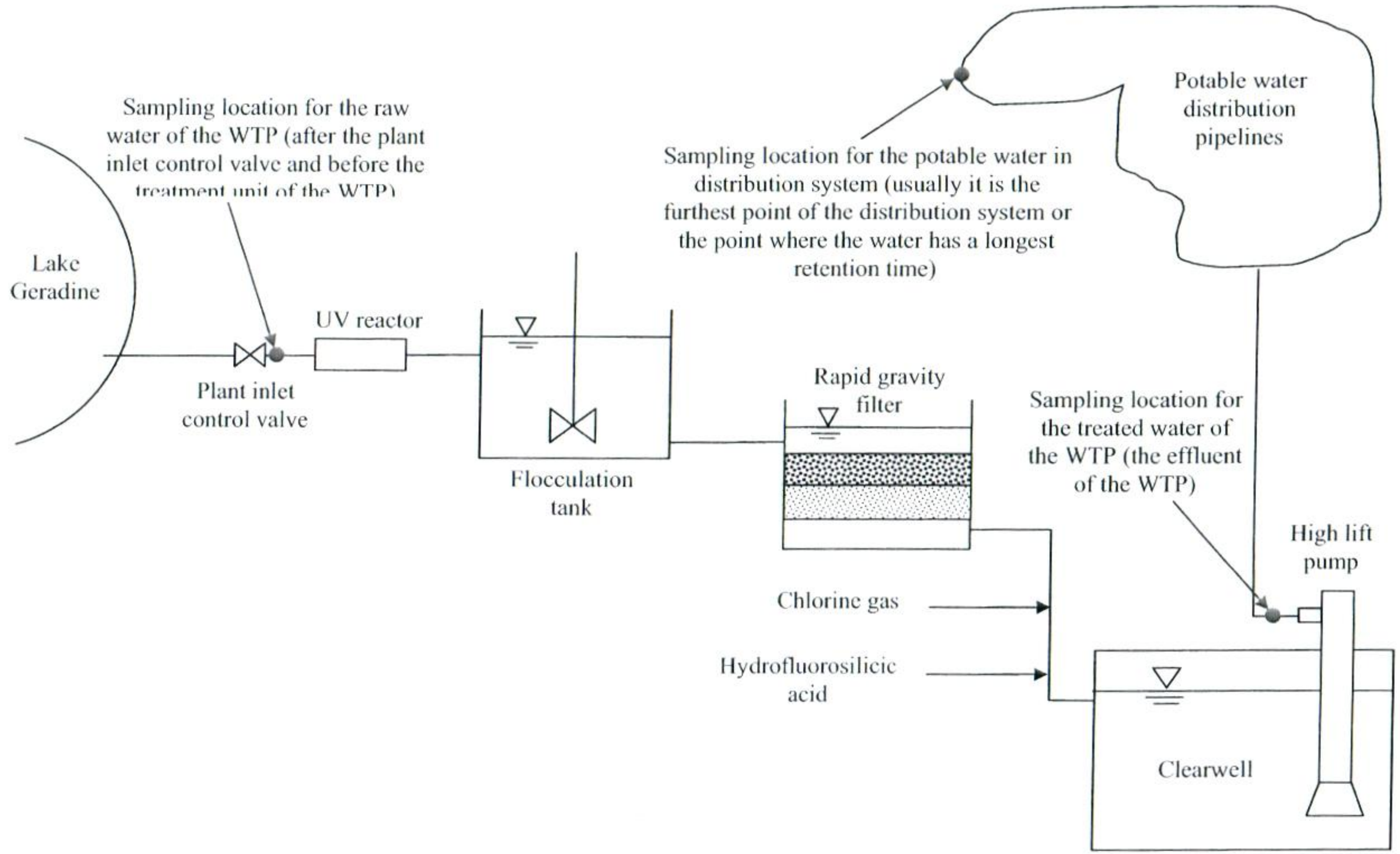
City of Iqaluit
Water License Monitoring Program
Figure 3. Sewage Treatment Facility



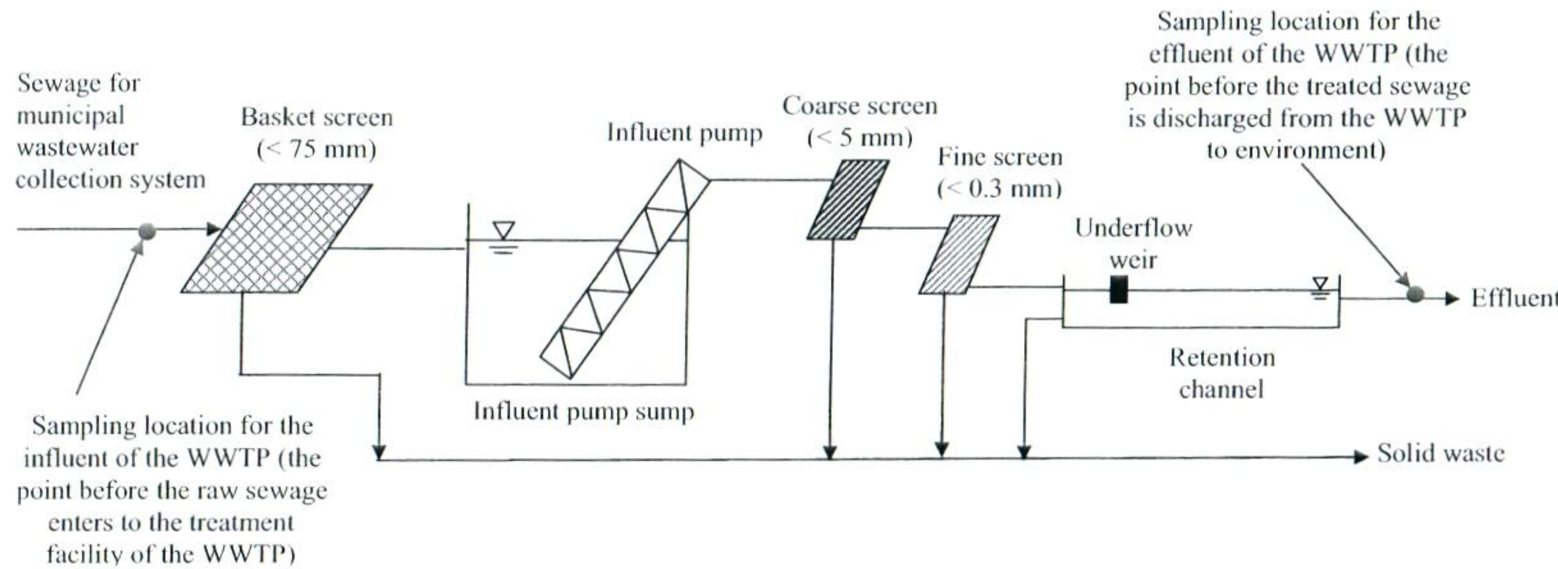
City of Iqaluit
Water License Monitoring Program
Figure 4. Landfill Facility

APPENDICES

Appendix A: Schematic sampling locations for the Water Treatment Facility



Schematic sampling locations for the Sewage Treatment Facility



Schematic sampling locations for the Landfill Facility