Town of Inuvik

Sewage Disposal Facility O&M Manual

2019 Update

Prepared by:

AECOM Canada Ltd.
101 – 18817 Stony Plain Road NW
Edmonton, AB T5S 0C2
Canada

T: 780 486 7000
F: 780 486 7070
www.aecom.com

Prepared for:

Town of Inuvik
P.O. Box 1160
2 Firth Street
Inuvik, NT X0E 0T0

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Project #: 60600398

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Revision History

Rev #	Date	Revised By:	Revision Description
2019	June 27, 2019	L. Wang	Updated to match content requirements in O&M Manual Template
2020	March 31, 2020	L. Wang	Report finalized and signed, no changes made.

AECOM Canada Ltd.
101 – 18817 Stony Plain Road NW
Edmonton, AB T5S 0C2
Canada

T: 780 486 7000
F: 780 486 7070
www.aecom.com

March 31, 2020

Project #
60600398

Rick Campbell
Director of Public Services
Town of Inuvik
P.O. Box 1160
2 Firth Street
Inuvik, NT X0E 0T0

Dear Mr. Campbell:

Subject: Town of Inuvik Sewage Disposal Facility O&M Manual 2019 Update

AECOM is pleased to submit the final Sewage Disposal Facility O&M Manual to fulfill the requirements of water Licence No. G17L3-001. The draft version of this document was approved by the Gwich'in Land and Water Board on November 22, 2019. The final version of the same report included signatures from the authors.

Please feel free to contact me should there be any questions or concerns. I can be reached at 780-732-9465, or through email.

Sincerely,
AECOM Canada Ltd.

Jordan Hoffart

Jordan Hoffart, P. Eng., PMP
Project Manager
Jordan.hoffart@aecom.com

JH:lw
Encl. (1)

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AECOM: 2015-04-13

Author

Report Prepared By:

Li Wang, P.Eng. (AB)
Project Engineer

Report Reviewed By:

Jordan Hoffart, P. Eng. (NT), PMP
Project Manager

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1. Site Description

Inuvik treats municipal sewage in a three-cell engineered lagoon system, located at coordinate 68° 21' 58" N, 133° 45' 5" W, immediately northwest of the developed townsite area. The receiving water is the Outlet Creek, which empties into the East Channel of the Mackenzie River. Continuous permafrost is the predominate ground condition. Figure 1 shows the location of the lagoon.

The sewage treatment facility was first constructed as a one-cell system in 1957. A pre-existing brush-filled slough was enclosed on three sides by dikes, to form a single large, shallow cell, 1,000 m long by about 200 to 250 m wide. Inuvik's trunk sewer discharged into the lagoon's south end. The lagoon's level was controlled by a stop logged outlet built into its north dike. The outlet discharged into a small creek, which runs 370 m westerly to East Channel.

The lagoon system's two primary cells were built in 1982, by partitioning the southern portion of the existing lagoon with several dikes. In total, the 1982 project included building new dikes within the original lagoon's southern end to form two new sludge holding cells and two new primary cells; extending the trunk sewer pipe along the new sludge cells' median dike to reach the new primary cells; installing structures within the new primary cells' median dike to control flow into and through the new cells; raising and widening the entire lagoon system's north and west dikes; replacing the outlet weir structure at the original lagoon's north end; and addition of a sewage truck discharge station at its south end. Associated Engineering Services Ltd (AESL) of Edmonton, Alberta provided engineering services including construction oversight; Goodbrand Construction Ltd. of Whitehorse was the builder, under a contract with Water and Sanitation Section, Town Planning and Lands Division, Department of Local Government, Government of the Northwest Territories.

Figure 2 shows the lagoon system's longitudinal cross section and hydraulic profile. As Built drawings are attached in Appendix A.

2. SDF Staff

The following staff consists of the primary contact for the Lagoon:

Table 1. Town of Inuvik Administration Contact Information

Staff Name	Role / responsibility	Phone	Email
Rick Campbell	Director of Public Works	867-678-5388	rcampbell@inuvik.ca
Grant Hood	Senior Administrative Officer	867-777-8608	sao@inuvik.ca
-	Utilidor 24 Hour On Call	867-678-5384	-

3. Security and Control

Gates and "No Trespassing" signs are provided at normal access points to discourage public access to the facility. "Danger - Thin Ice" signs are provided by the Town of Inuvik at appropriate locations. All SNP sites are also identified by proper signage.

4. Wastewater Generation and Conveyance

Wastewater in the Town of Inuvik and area is collected through the above ground utilidor system, along with trucked flows. There are no lift stations nor forcemains within the Town of Inuvik. The estimated volume of wastewater collected in the utilidor system is 538,500 m^3 in 2018.

4.1 Truck Discharge

The truck discharge facility provides a 100 mm/4” diameter camlock for disposal of sewage from tank trucks.

The truck discharge facility is open 24/7 and should only be used by authorized tank truck operators. Care should be exercised in using the facility to ensure no spillage occurs.

The lagoon is designed to receive domestic sewage only. Absolutely no oil or petroleum products or toxic chemicals should be discharged into the lagoon at any time.

Several private businesses have private vacuum trucks that provide sewage collection and disposal services within the Town. It is estimated between 30 m^3 to 50 m^3 of sewage are discharged at the truck discharge point per day. The Town of Inuvik does not offer trucked sewage collection and disposal services.

4.2 Valve House

The "valve house" predated the 1982 project, although redundant, was not modified. It does not contain valves. Rather, it is the point at which two trunk sewers converge. The combined flow is discharged through the trunk sewer line, to the primary cells.

4.3 Trunk Sewer Line

The trunk sewer line extends from the valve house to the inlet structure. It consists of 400 mm diameter steel pipe with flanged joints, covered with 50 mm of insulation and banded-on sheets steel jacketing. The insulated, jacketed pipe rests on steel piles.

4.4 Primary Cells Inlet Structure

The primary cells inlet structure contains slide gates which allow the operator to direct sewage into the east primary cell, the west primary cell, or into both primary cells at the same time. Under usual operation both gates are open.

4.5 Primary Cells Crossflow Structure

The primary cells crossflow structure connects the two primary cells mid-way between the primary cells' inlet structure and the primary cells outlet structure. The crossflow structure contains a slide gate which allows the operator to stop crossflow.

The crossflow structure has never been used and has no foreseen use. It was not re-built to design elevation along with restoration of the lagoon interior dikes in 2006 but could be restored if in future a need for it should arise.

4.6 Primary Cells Outlet Structure

The primary cells outlet structure contains slide gates which allow the operator to direct flow from either or both primary cells to the large secondary cell.

In operational experience the slide gates in the outlet structure have never been used and there is no foreseen need for them. The outlet structure was not re-built to design elevation along with restoration of the lagoon interior dikes in 2006, but it could be restored if in future a use for it should arise.

4.7 Other Hazardous Wastes

Honeybags are not accepted at the lagoon. All honeybags are disposed of in the solid waste facility (landfill), located south of the Town. Other hazardous wastes are also not allowed to be disposed in the lagoon. Hazardous waste collection events are held in the Town and collected wastes are disposed in the solid waste facility.

5. Influent Wastewater Quality

Influent wastewater is not tested prior to entering the sewage lagoon.

6. System Capacity and Design Data

The average rate of outflow from the outlet control structure will, in general, be about equal to the average rate of water consumption and sewage generation within Inuvik. (Uses of water which are independent of sewers, such as lawn care, are minor in Inuvik. Also, minor inflow of runoff to the lagoon, and evaporation losses from the lagoon, are neglected.) The monthly design flow through the lagoon system is 99,200 m^3, the annual design flow is 1,168,000 m^3.

If it is necessary to draw down the level in the system, then the stoplogs in the outlet structures should be removed one at a time to maintain a moderate flow. Rapid discharge is likely to wash away the bedding around the outlet culverts.

No information is available on the design effluent quality criteria at the sewage disposal facility.

7. Effluent Discharge

The primary cells are designed to be operated in parallel; that is, with the slide gates in the inlet, crossflow and outlet structures all fully open.

Under Inuvik's current (2017-2027) Water Licence, the system is to be operated as a flow through, continuous discharge facility throughout the year. Seasonal drawdowns are not part of the planned operating regime.
It is intended that all cells be operated at the planned HWL of 5.95 m throughout the year. The tops of the piles in the outlet structure are at elevation 6.95 m, 1.00 m above planned HWL.

The average discharge flow rate is 1,480 m^3/day. Discharged effluent is sampled at SNP Station 0036-3, located near the outlet of the secondary cell. The lagoon outlet weir structure includes a stop logged weir which allows the operator to control the liquid level in the large secondary cell (and in the two primary cells if the level is above 4.95 m). Currently there are four stoplogs in the structure.

Effluent is discharged to the Outlet Creek, which then empties into the East Channel of the Mackenzie River. The average annual flow rate of the outlet creek is unknown. The average annual flow rate for the East Channel is 137 m^3/s. Currently there are no available information on the quality of the water upstream of the discharge point.

8. Sludge Management

When the accumulation of sludge in the primary cells approaches the design volume, it should be removed from the primary cells and disposed of.

In 1993, 13,500 m^3 of sludge was transferred from the primary cells to the sludge cells; the first such operation since the primary cells were commissioned. The work was done by Marathon Waterworks Ltd. of Hay River, N.W.T., using a "Watermaster" equipped with a cutter suction dredge. The operation took about ten days to complete and caused surprisingly little in the way of odours or other noticeable effects.

Since the 1993 sludge transfer operation, the rate of sludge accumulation has been much less. The change is attributed to enzyme addition, commenced not long after. Possible increase in primary cells' winter temperatures since Inuvik's 1998 change to residual heat for raw water tempering may also be a factor. Nevertheless, sludge accumulation needs to be monitored, by survey every two or three years.

The primary cells are dosed with "Acti-zyme" according to the following schedule:

- The three weeks immediately following melt of ice cover: one 50 lb bucket per cell per week.
- Remainder of open water season: 25 lb (one half bucket) per cell per week.

Acti-zyme is supplied by the Acti-zyme Products Ltd, based in Vancouver, BC, in 5 lb soluble bags. Bags are thrown from cell dikes, spread out to achieve good distribution.

Sludge are to be removed from the two primary cells into the two sludge cells immediately south. Dried and tested sludge are disposed of in the Town of Inuvik Landfill, located approximately 3 km SE of the Town, along Highway 8.

9. Surface Water Management

The sludge cells tend to trap runoff water. Since there are no perimeter ditches, during spring run-off, a large amount of water will enter the east sludge area. Water should be pumped into the primary cells for disposal to prevent it from overtopping the dikes and causing erosion of the dikes. The distance to the nearest fish bearing water body (Each Channel of the Mackenzie River) is approximately 130 m.

10. Record Keeping

The following information are documented in the Annual Reports and are kept within the Town's office and on MVLWB's website at mvlwb.com:

- Monthly and annual quantity of all wastewater discharged to lagoon (estimated based on water production rates)
- Summary of volumes of effluent discharge to the environment (estimated based on water production rates)
- Summary of volume of sludge removed from the system
- Summary of modification and/or major maintenance work carried out on the lagoon, including all associated structures
- A list of spills and unauthorized discharges
- Summary of any closure and reclamation work completed during the year and outline of work anticipated for next year
- Summary of any study requested by MVLWB that relates to waste disposal or reclamation, and a brief description of any future studies planned
- Outline of any spill training and communication exercises carried out
- List of Repairs
- List of Upgrades

11. Water Quality Monitoring

As previously mentioned, the sewage lagoon at Inuvik utilizes an engineered berm with built in outlet structure. Stoplogs are positioned in the outlet structure to control the water level within the secondary cell. The coordinate of the final discharge point is at latitude 68° 22' 21" N and longitude 133° 45' 38" W.

The receiving environment for the lagoon flow is the Outlet Creek, north of the lagoon discharge point. This creek is approximately 5 meters wide and runs for 370 meters before reaching the Each Channel of the Mackenzie River.

In the Outlet Creek, aquatic plants, shrubs, and trees are observed.

A report titled Town of Inuvik Assessment of Sewage Treatment Options (AECOM. 2013.) was prepared reviewing the performance of the existing wastewater lagoon relative to the existing wastewater effluent quality standards within the Water License. This report is attached in Appendix A.

Sampling of the effluent quality are performed according to the requirements of the Water License. Up to date effluent quality results can be found with the Water License Annual Reports.

12. Treatment System Design

This section summarizes the system design information. As built drawings can be found in Appendix B.

12.1 Treatment Process

Treatment processes and treatment performance are described briefly below:

1. The primary cells retain settleable solids and floatables (oil, grease, plastics, etc.). Settled material accumulates in a dedicated storage volume in the lower part of each cell. Because "digestion" of sludge proceeds quite slowly in cold climates, sludge accumulations need to be removed (transferred to the sludge cells) at intervals of five to ten years.
2. The secondary cell provides an environment where biological processes break down and stabilize dissolved organic matter, and where natural ultra-violet light and natural predation can eliminate pathogenic (disease-causing) micro-organisms. Since these processes are dependent on warm temperatures and sunlight, the secondary cell's efficiency is good in summer but poor in winter. Under ice cover it achieves only minor additional settlement of solid material.

12.2 Basins

The system has five basins: the east and west sludge cells; the east and west primary cells, and the secondary cell. In the 1982 construction program all basin dikes were constructed or raised to a crest elevation of 6.95 m (Geodetic). Planned freeboard in the lagoon cells is 1.0 m, yielding a planned high water level (HWL) of 5.95 m. The sludge cells can be operated with a freeboard as little as 0.5 m, and possibly less, yielding an HWL of 6.5 m or higher. Currently there are the five basins are lined with the clay layer, as part of the clay berm.

12.2.1 Sludge Cells

The layout of the sludge cells is shown in Figure 3.

The sludge cells were surveyed by Reid Crowther and Partners Ltd (RCPL) in October 1992 to determine available capacity, in preparation for a transfer of sludge from the primary cells to the sludge cells which took place in the summer of 1993. Capacity data are reported in Table 2.

Table 2. Sludge Cell Volumes and Sludge Volumes

Description	Depth (m)		Cell Volume (m^3)		Total Volume (m^3)
	From	To	East	West	
Freeboard	5.95	6.95	11,118	4,906	16,024
Storage	Varies	5.95	9,005	5,197	14,202
Water & Ice	Varies	Varies	2,542	761	3,303
Sludge	Varies	Varies	3,564	1,758	5,322
Total	Floor	6.95	26,229	12,622	38,851
Available to HWL	Sludge	5.95	11,547	5,958	17,505
Freeboard	5.95	6.95	11,118	4,906	16,024
Total Capacity	Sludge	6.95	22,665	10,864	33,529

At the time of the survey, water levels were 4.75 m in the east cell and 4.30 m in the west cell. Water levels rise to top-of-dike height in the east cell, and sometimes in the west cell, during spring runoff.

The volume of sludge transferred in 1993 totaled about 13,500 m^3. Over time this volume will be reduced by freeze-thaw de-watering, consolidation, and biological digestion.

12.2.2 Primary Cells

The layout of the primary cells is shown in Figure 3.

The original Operations and Maintenance Manual for the lagoon system (O & M Manual) (AESL, 1982) indicates that the primary cells are designed to provide a minimum of five days retention [using combined capacity] at design flow. This is a normal design objective for primary cells.

The following key elevations are from AESL's construction drawings. [Elevations were converted from LAND datum to geodetic.]

- Top of dike 6.95 m.
- High water level (HWL) 5.95 m, controlled by the maximum height of stoplogs in the secondary cell's outlet structure.
- Low water level (LWL) 4.95 m, controlled by the invert level of the outlets from the primary cells to the secondary cell. (Obviously, level in the primary cells is controlled by level in the secondary cell whenever the secondary cell is above LWL.)

- Cell bottom level 3.95 m approximately. (Bottom levels were measured by RCPL in October 1992 and July 1994, to average about 2.5 m in the east cell and about 1.7 m in the west one.) Therefore, the actual volumes and retention capacities of both cells are somewhat greater than designed.
- Maximum sludge level 1.0 m above an assumed bottom elevation of 3.95 m; therefore, 4.95 m.

RCPL's surveys (1992 and 1994) indicate that the primary cells total volumes below HWL are: east, 21,250 m^3; west, 29,340 m^3; total, 50,590 m^3.

The allocation of available primary cell volume between ice allowance, fluid fraction and sludge storage were reviewed by RCPL in 1992. The design conditions adopted were:

- Five-day retention at current peak day flow, 3.2 ML/d, with 25 percent allowance for growth; total 20 ML.
- Lagoon level at HWL.
- Ice cover 0.8 m (average).

The ice cover allowance may seem small, considering the thickness of 2 m or more common to northern lakes. However, it is noted that maximum wastewater flow, which occurs in January or February, does not coincide with maximum ice thickness, which in natural lakes around Inuvik occurs in April. More importantly, sewage carries a lot of heat into the primary cells, and loss of heat to atmosphere is resisted by ice and snow cover. Actual thickness could be confirmed through field measurements taken in late winter.

The allocation of primary cell volumes recommended by RCPL is shown in Table 3.

Table 3. Recommended Allocation of Primary Cell Volumes

Description	Depth (m)		Cell Volume (m^3)		Total Volume (m^3)
	From	To	East	West	
Floor to HWL	Varies	5.95	21,249	29,338	50,587
Ice	5.15	5.95	6,996	8,020	15,016
Fluid	Varies	5.15	8,014	11,986	20,000
Sludge, Maximum	Varies	Varies	6,239	9,332	15,571

12.2.3 Secondary Cell

The secondary cell is about 770 m long by 180 m wide, on average. At HWL 5.95 m it has a surface area of 14.0 ha, and a total volume of 225,000 m^3. Maximum ice thickness is estimated to be 1.5 m and maximum ice volume is estimated to be about 155,000 m^3; leaving a minimum effective volume at HWL of 70,000 m^3.

12.3 Dikes

All dikes have a minimum top width of 4 meters, side slopes of 3 to 1 (H:V) and are construction to elevation 6.95 m Geodetic Datum. Surfacing gravel was placed on selected portions of the dikes to allow all-weather vehicular access. There are no liners separating the dike from the sewage. The dikes are built with clay and topped with gravel for vehicle access.

13. Maintenance of Facility

A sewage treatment facility of this type has low daily maintenance requirements. <u>Frequent routine inspection of the facility is, however, of prime importance.</u>

13.1 Routine Inspection

It is recommended that the system be inspected twice weekly (or daily) during the summer and daily during the winter. Obviously, any problems discovered on an inspection trip should be rectified as soon as possible. Routine inspection should cover:

- conditions at and around the sewage truck discharge station; spills.
- signs of unauthorized entry or willful damage at gates; and around structures.
- dike settlement or erosion.
- condition of control structures.
- flow problems; differences in levels between lagoon cells; possible blockages of flow structures; possible freezing.
- floating sludge "islands" (which need to be removed from primary cells from time to time).
- position of stoplogs in outlet structure; operating level.
- proper flow through outlet structure and channel (needed to prevent freezing in winter).
- outlet channel and culverts to East Channel clear of blockages and flowing freely (especially during winter).
- all other matters of interest.

13.2 Other Maintenance Requirements

13.2.1 Surface Drainage

The sludge cells tend to trap runoff water. Since there are no perimeter ditches, during spring run-off, a large amount of water will enter the east sludge area. Water should be pumped into the primary cells for disposal to prevent it from overtopping the dikes and causing erosion of the dikes.

13.2.2 Dikes

Some settlement can be anticipated in the dikes; however, the magnitude of settlement is not predictable from available information. Until the dikes and foundation soils adjust to a fully stable configuration, they should be built up periodically to original elevation to prevent overtopping during spring run-off or normal operation.

Surfacing gravel should be added to the dike crests as and where required to maintain all-weather vehicular access. Regrading should be carried out as required.

Dikes should be inspected annually by a qualified civil or geotechnical engineer to confirm general condition and stability. (This is also a Water License requirement: Condition D8, 2017 Water Licence.)

13.2.3 Trunk Sewer Line: Maintenance of Grade

Some settlement and movement are to be expected in the timber supports of the trunk sewer line. Supports should be inspected annually in the summer and wedges or other means should be used to raise the supports so that full support of the pipe is maintained.

13.2.4 Trunk Sewer Line: Maintenance of Flow

In recent years there has been a tendency for gravel to accumulate in the section of the trunk sewer downstream from the truck discharge, the suspected source being hydro-vac trucks used alternately for sewage trucking and ground excavation. Gravel needs to be flushed out each summer or more often, to avoid blockages.

13.2.5 Primary Cell Control Structures

Gravel washed or flushed down from the truck discharge station needs to be removed from the primary cells' inlet structure and the pipes leading to the primary cells. Check monthly during the summer.

Build-up of sludge around the ends of the pipes leading to the primary cells needs to be removed each summer, using a backhoe. This is also a good opportunity to remove any sludge mats floating within the primary cells. Material removed is deposited in the sludge holding cells. While this is routine annual maintenance it does involve transfer of a small amount of sludge transfer; hence it is prudent to advise the Water Board in advance.

Prior to freeze-up, it is essential to ensure that there are no blockages in the flow channels in the primary cells' inlet and outlet structures. Clean the pipes using a hydro-vac, if not already done earlier in the summer. The frost covers should be properly positioned to protect the structures.

The heat in the incoming sewage should be sufficient to keep the flow channels in these structures open through the winter. However, if freezing is discovered during the daily winter inspections, some appropriate action can be taken. It should not be necessary to remove the frost covers to see if there are problems as flow restrictions make themselves apparent in other ways. For example, the liquid level in the primary cells will increase if there is no flow into the secondary cell.

13.2.6 Secondary Cell Outlet

The outfall structure (gate with stop log) is built into the north engineered berm of the secondary cell.

The outlet structure depends on frozen-in-place steel piles for stability, structural integrity and water tightness. In the 1982 Construction Report, Thurber Consultants Ltd. recommended that piles be monitored by annual survey for signs of settlement or heaving of piles.

13.2.7 Outlet Creek to East Channel

Effluent are discharge to the Outlet Creek located north of the lagoon. This creek is roughly 5 m wide and flows mainly west for roughly 370 m before discharging into the East Channel of the Mackenzie River. The flow rate of the East Channel is measured to be 137 m^3/s.

Ensure that the creek bed and culvert are free flowing and clear of blockages in the fall. The creek froze off in the winter of 1991-92, backing up and resulting in a freeze-up in the outlet structure. Snow insulation over the flow channel probably helps to prevent freezing.

13.2.8 Sludge

Sludge are to be removed from the two primary cells into the two sludge cells immediately south. Dried and tested sludge are disposed of in the Town of Inuvik Landfill.

13.2.9 Fencing

To discourage and limit public access, the fence should be kept in good repair and the no trespassing signs should always be highly visible.

14. Water License Requirements

Inuvik's lagoon is operated under a Water License issued by the Gwich'in Land and Water Board (GLWB). Water license requirements relevant to normal lagoon O&M not covered elsewhere in this Manual are summarized here. Consult the actual license for precise wording. Also, consult the actual license for topics not included here, such as conditions pursuant to modifications of the facility; detailed requirements for routine reports; among others.

Inuvik's current water licence (2017) runs from July 1, 2017 to June 30, 2027. It is important to note that standards and requirements set out in the license are subject to change by the Water Board, upon issuance of a new licence or at any other time.

14.1 Water License Lagoon Operating Standards

Dike freeboard is to be maintained at 1.0 m. Inuvik is to advise the Inspector 10 days before initiating a "batch decant" (lowering of lagoon water level).

14.2 Mandatory Routine Lagoon Performance Monitoring

Inuvik's water license sets monitoring requirements for effluent quality and dike integrity (the "Surveillance Network Program", or SNP). Samples are taken from designated sampling stations at stated intervals. Samples are analyzed for specified parameters, and results are reported o the water board in routine quarterly and annual reports.

Sampling stations related to the lagoon system are listed below:

- Station SNP 0036-3. Lagoon (secondary cell) outlet. Used to monitor effluent quality for compliance to the Water Licence.
- Station SNP 0036-3a. Emergency Decant Structure. Monitor and sample in the event of an emergency decant.
- Station SNP 0036-6. Pond just outside the lagoon system's west dike, near the entry gate adjacent to the truck discharge station ("Gate Pond"). Used to monitor pond for possible sewage contaminants, as a warning of possible leakage through the dike.
- Station SNP 0036-7. Pond just outside the lagoon system's west dike, 800 m northwest of Gate Pond ("Far Pond"). Used to monitor pond for possible sewage contaminants, as a warning of possible leakage through the dike.
- Station SNP 0036-8. Twin Lakes at Happy Valley, west basin. Used as a background reference against which to compare results from Gate Pond and Far Pond.

Station locations are to be marked by signs, so that sampling locations remain consistent.

14.3 Routine Effluent Monitoring and Performance Standards

Effluent (Station 0036-3) is sampled monthly. Parameters monitored and quality limits according to the current water licence are:

Table 4: Water License Quality Limits

Parameter	Approved Maximum Amount	Unit
Suspended Solids (SS)	70	mg/L
$CBOD_5$	135	mg/L
Faecal Coliforms	1×10^6	CFU/100mL
Oil and Grease	5	mg/L
pH	6-9	-
Ammonia	N/A	-

Limits (except for pH) apply to average concentration of four consecutive SNP results. Means for $CBOD_5$ and SS are arithmetic, and for FC geometric. pH is not averaged. Ammonia currently does not have an approved maximum limit.

14.4 Batch Decant

In the event of a batch decant (lowering of water level in the secondary cell or all cells) effluent is to be sampled and tested, at SNP Station 0036-3a, for the usual parameters 10 days before the start, at the start, in the middle, and at the end.

14.5 Pond Surveillance

Ponds (Stations 0036-6, 7 and 8) are sampled annually, in September. The parameters tested for are the same as for Station 0036-3, except for Oil and Grease The water board may order additional tests.

14.6 Spills, Unauthorized Discharges

It is a requirement of the water license (and legislation) that any spill be reported to the 24-hour spill report line, 867-920-8130 or via email at spills@gov.nt.ca.

14.7 Other Requirements

The water license requires an annual review and updating of the O&M manual for the lagoon. Updating can be done by issue of errata where issue of an entirely new edition is not warranted.

Inuvik is required to advise the water board at least 60 days in advance of any planned modifications to the sewage treatment facility.

The water license requires submission of an annual report covering many aspects of lagoon (and water use and solid waste site) operations, etc. Specific requirements are detailed in the water license (SNP, Section D). An engineer's certification of lagoon dyke stability is required annually (License, D8).

A special report is required following completion of a batch decant.

Signs identifying each SNP station are also installed near each SNP station's the sample collection location.

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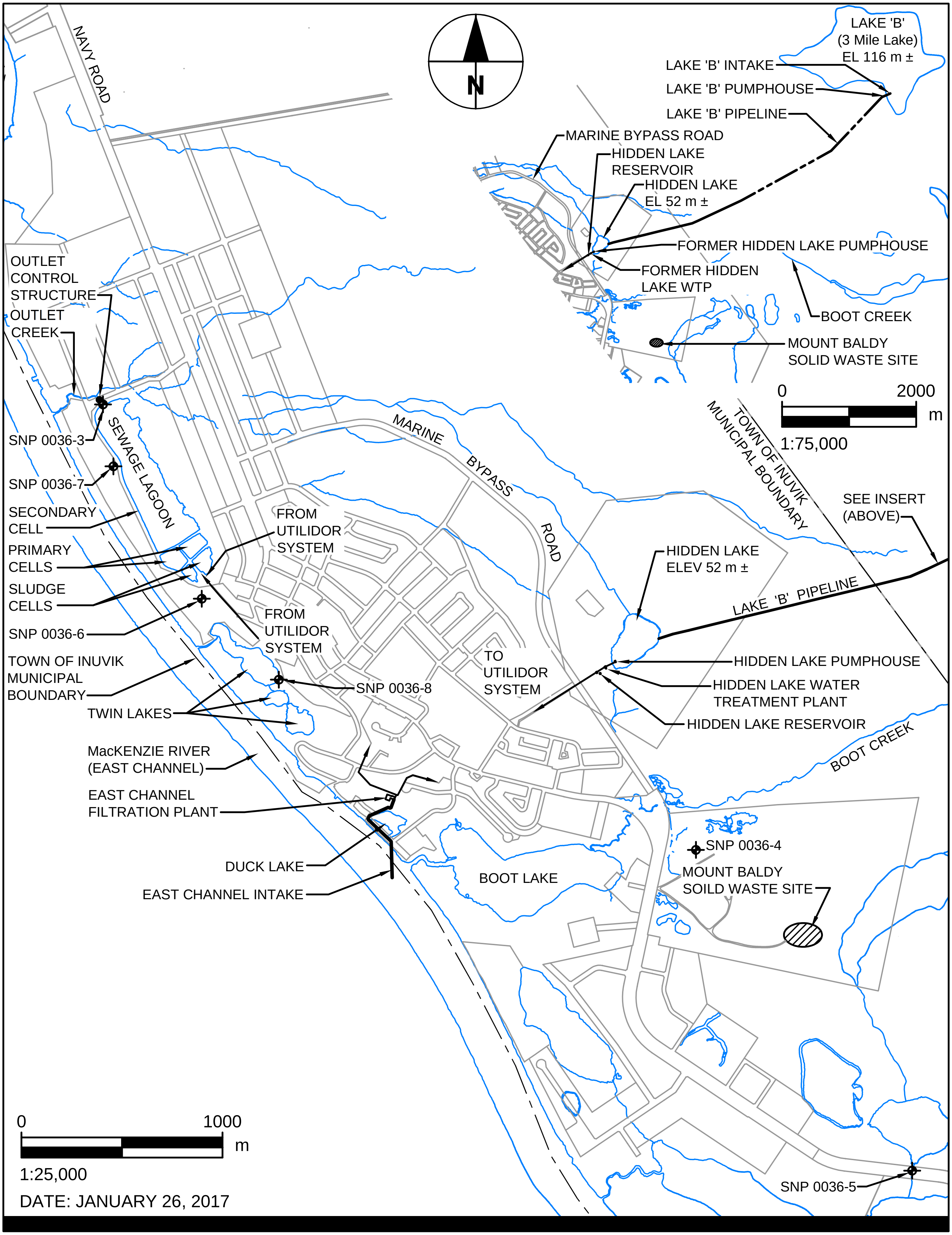
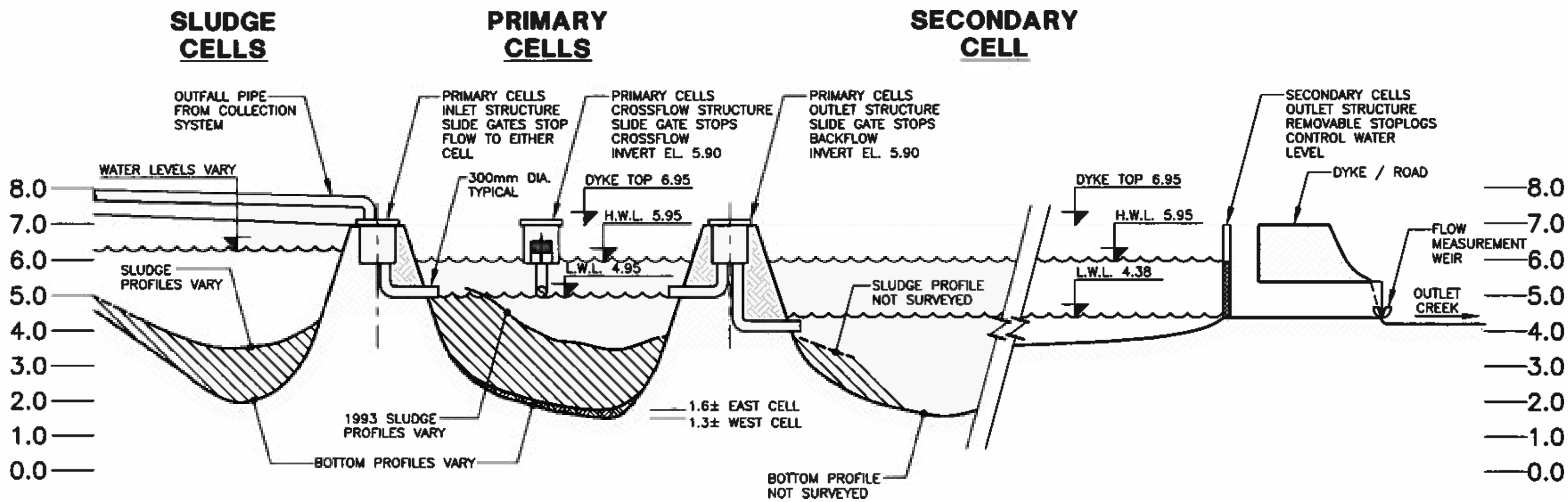


APPLICATION FOR RENEWAL OF WATER LICENSE N3L4-0036
TOWN OF INUVIK, N.W.T.

MAIN WATER AND SEWAGE FACILITIES LOCATION PLAN

AECOM

Figure 1



Note:

SYSTEM NORMALLY IS OPERATED AT H.W.L.
L.W.L. APPLIES IF LEVEL IS DRAWN DOWN FOR MAINTENANCE WORK. COMPLETE RE-FILLING AFTER TOTAL DRAW DOWN MAY TAKE SEVERAL SEASONS.

0 1 2 3 4 5 6 7m

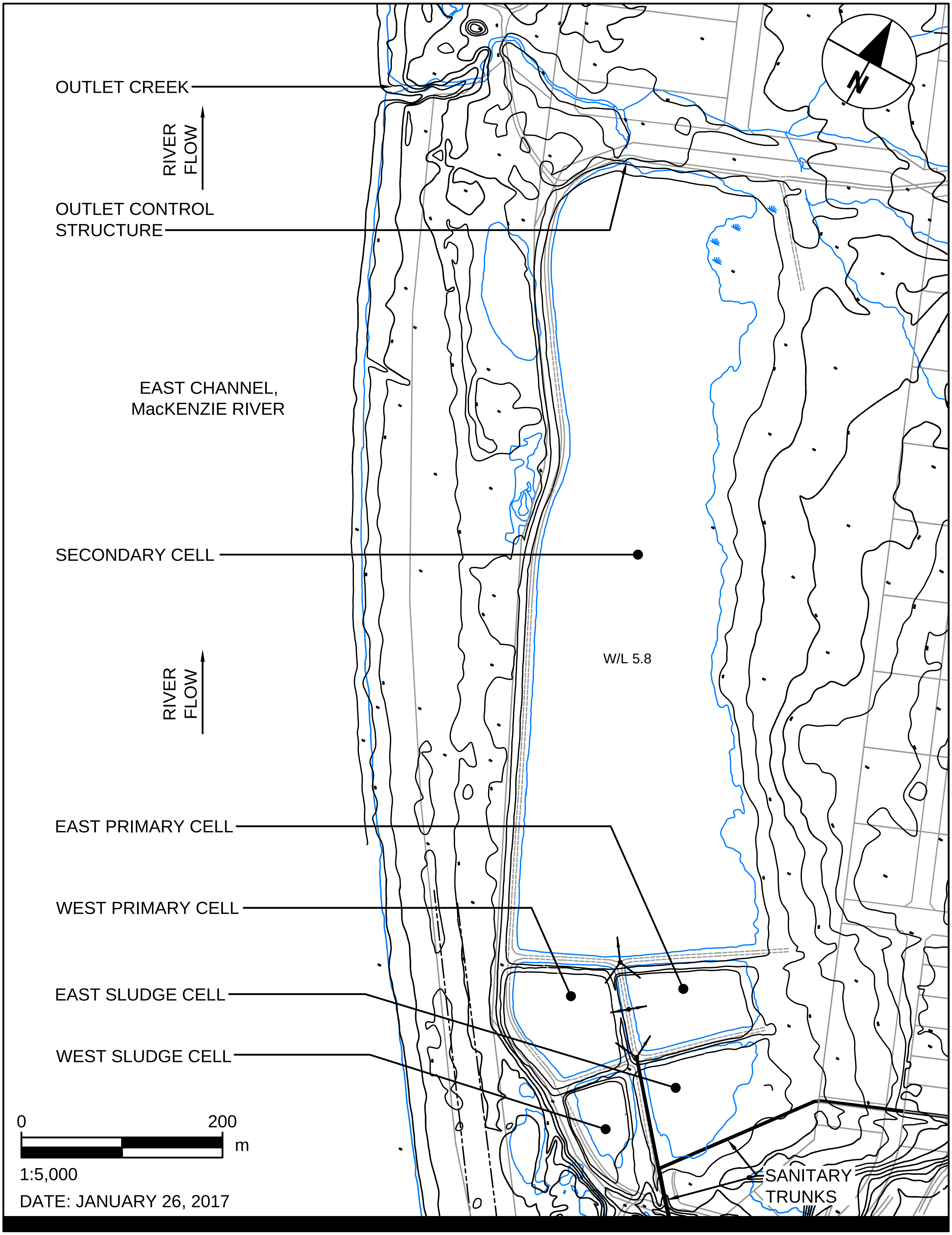
Scale: Horiz. Not To Scale
Scale: Vert. 1:125

Date: FEB. 16, 2010

AECOM

Town of Inuvik, N.W.T.
Sewage Treatment O & M Manual
LAGOON HYDRAULIC PROFILE DIAGRAM

Figure 2



APPLICATION FOR RENEWAL OF WATER LICENSE N3L4-0036
TOWN OF INUVIK, N.W.T.

SEWAGE TREATMENT SYSTEM LAYOUT PLAN

AECOM

Figure 3

Appendix A

Town of Inuvik Assessment of Sewage Treatment Options (AECOM. 2013)

Water

Town of Inuvik

Assessment of Sewage Treatment Options

Prepared by:

AECOM
17203 103 Avenue NW 780 488 6800 tel
Edmonton, AB, Canada T5S 1J4 780 488 2121 fax
www.aecom.com

Project Number:

60240928

Date:

August 2013

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- may be based on information provided to Consultant which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
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- was prepared for the specific purposes described in the Report and the Agreement; and
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AECOM: 2012-01-06

AECOM
17203 103 Avenue NW
Edmonton, AB, Canada T5S 1J4
www.aecom.com

780 488 6800 tel
780 488 2121 fax

August 12, 2013

Town of Inuvik,
Box 1160, #2 Firth Street,
Inuvik, NT, X0E 0T0

Attn: Mr. Rick Campbell
Director of Public Services

Dear Mr. Campbell,

Project No: 60240928

Regarding: **Assessment of Sewage Treatment Options**

Please find the attached referenced report to fulfill Condition B-10 of the Town of Inuvik's municipal Water Licence G06L3-01.

Please forward to the Gwich'in Land and Water Board and the Inspector at your earliest convenience to complete the requirements of Condition B-10.

Sincerely,
AECOM Canada Ltd.

M.C. Maltais

Michael Maltais, P.Eng.
Project Engineer
michael.maltais@aecom.com

MM:jc

cc: David Lycon, AECOM (email only)
Michel Lanteigne, (AECOM) (email only)

Distribution List

# of Hard Copies	PDF Required	Association / Company Name
1	Yes	Town of Inuvik

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
0	Jason Casault	August 12, 2013	Final Report

AECOM Signatures

Report Prepared By:

Jason Casault, E.I.T.
Water / Wastewater Treatment Engineer

Report Reviewed By:

Arvid Pederson, P. Eng.
Senior Project Manager, Water

REGISTERED PROFESSIONAL ENGINEER
A.H. PEDERSON
LICENSEE
NWT/NU
Aug 12, 2013

PERMIT TO PRACTICE
AECOM Canada Ltd.
Signature
Date Aug 12, 2013.
PERMIT NUMBER: P 639
The Association of Professional Engineers and Geophysicists of the NWT/NU.

Executive Summary

This report is written for the purpose of fulfilling condition B-10 of the Town of Inuvik's (Town) municipal Water Licence G06L3-01.

The performance of the existing wastewater lagoon was reviewed relative to the existing wastewater effluent quality standards within water licence G06L3-01. The existing lagoon system produces an effluent well within the current regulatory standards listed in the Town's water licence yet displays significant seasonal performance variation between the summer/fall months (June through November) and the winter/spring months (December through May).

The performance of the existing wastewater lagoon was also reviewed relative to the recently introduced Department of Fisheries and Oceans (DFO) Wastewater Systems Effluent Regulations (Wastewater Regulations) – though these new regulations exempt the Northwest Territories, Nunavut and those areas north of the 54th parallel in Quebec and Newfoundland and Labrador (the Far North). From a possible planning perspective, the DFO Wastewater Regulations for the rest of Canada likely represent the most stringent standards that the Canadian Council of Ministers of the Environment (CCME) would contemplate for communities in the Far North (i.e. remove the exemption). The DFO Wastewater Regulation limits are significantly lower than the current licence requirements for the lagoon. Should these regulations be modified to include the Far North, the lagoon effluent quality would not meet the standard for cBOD (carbonaceous BOD) on an annual average basis due to the poor performance during the winter and spring months; it would comply with all other aspects of these regulations.

The investigation of options to improve the effluent quality focused on improvements to the existing lagoon system and implementing an entirely new mechanical system. The lagoon improvements considered were lagoon expansion and lagoon enhancement. The mechanical systems considered were sequencing batch reactor (SBR), moving bed biofilm reactor (MBBR), and deep shaft aeration (DSA). These options represent process technologies that are currently being applied in, or were considered for, cold regions.

The key findings for each alternative are presented in Table ES 1.

Table ES 1 Wastewater Treatment Option Highlights

Alternative	Meet DFO Regulated Standards?	Level of Skill Required for Operator	Estimated Annual O&M Cost	Estimated Capital Cost	Estimated 20 Year Life Cycle Cost
Lagoon Expansion: Conversion to Annual Discharge	Yes	Basic	$115,000	$ 18,000,000	$ 13,000,000
Lagoon Enhancement	Yes	Basic	$260,000	$ 6,500,000	$ 12,000,000
SBR	Yes	Trained	$695,000	$ 18,500,000	$ 26,300,000
MBBR	Yes	Trained	$695,000	$ 17,000,000	$ 25,000,000
DSA	Yes	Trained	$530,000	$ 25,500,000	$ 29,800,000

The capital costs represent a major capital investment, which would require a funding contribution from a senior government source. The operation and maintenance costs for all of the mechanical treatment options represent a level of funding that may not be sustainable by the community. As well, the level of skill for operating the mechanical treatment options would be challenging for the hiring and retention of appropriately trained individuals.

If Inuvik is required to upgrade their wastewater treatment system at some point in the future to meet new Federal guidelines, the most appropriate option in consideration of capital and life cycle costs, as well as operational training requirements, would be a lagoon enhancement.

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1. Introduction

This report is prepared for the Town of Inuvik (Town) with the purpose of fulfilling Condition B-10 of the Town's water use licence G06L-3-001 which reads as follows:

> *The Licensee shall, by July 1, 2009, submit to the Board an assessment of potential sewage treatment options. The assessment shall identify sewage treatment options suitable to allow the Licensee to meet territorial and federal guidelines for the discharge of municipal wastewater. A copy of this assessment shall also be forwarded to the Inspector.*

The existing continuous discharge lagoon system currently meets all of the regulatory requirements of the water licence, as well as all applicable federal guidelines.

Two previous field studies[1] have found that the effluent discharge from the existing Inuvik lagoon has a very limited impact on the aquatic environment in the East Channel, which is consistent with calculated receiving water parameter concentrations after mixing.

It has been assumed for the purposes of this report that the sewage treatment options being assessed would enhance the treatment performance of the current lagoon system even though the current system meets all current licence requirements and federal guidelines.

One option for improving the quality of the wastewater effluent is expanding the current lagoon and converting the lagoon system to an annual discharge system. The Alberta Environment and Sustainable Resource Development (AESRD) *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems (Part 3, 2013)* have been used for general sizing requirements for this option.

Another option for improving the quality of the wastewater effluent is enhancing the current lagoon while maintaining a similar footprint. The Town commissioned the services of Nelson Environmental Inc. (NEI) to conduct a site visit and present upgrade possibilities to the existing sewage lagoon system. NEI has extensive experience in converting existing lagoons into aerated lagoons, as well as applying a proprietary Submerged Attached Growth Reactor (SAGR) treatment process that has proven to be very successful in polishing cold weather lagoon effluents. NEI's findings are summarized in this report; NEI's report is included as Appendix A.

To assess the potential of improving the quality of the wastewater effluent from the perspective of new treatment processes, project information was gathered from several recent (2006 to the present) mechanical treatment design-build submissions in the Yukon Territory. It should be noted that this design-build information is confidential and therefore this report should not be widely circulated.

1.1 Regulatory Framework

The lagoon currently operates under the terms of Inuvik's municipal water use licence G06L-3-001 from the Gwich'in Land and Water Board. The specific effluent requirements listed in the licence are listed below in Table 1-1. The average concentrations listed for suspended solids and BOD_5 are arithmetic average of any four consecutive monthly measurements; the fecal coliform average listed is the geometric mean of any four consecutive monthly measurements.

---

[1] *Town of Inuvik, Lagoon Effluent Impact Assessment, AECOM (Reid Crowthers & Partners Ltd.), 1994 & Inuvik Sewage Plume Study, Department of Indian Affairs and Northern Development (DIAND), 1998.*

Table 1-1 Existing Inuvik Lagoon Effluent Licence Requirements

Parameter	Units	Maximum Average Concentration	Maximum Concentration
Suspended Solids	mg/L	70	n/a
BOD_5	mg/L	150	150
Fecal Coliforms	CFU/100 mL	10^6	n/a

The Department of Fisheries and Oceans (DFO) enacted Wastewater Systems Effluent Regulations (Wastewater Regulations) in June of 2012, based on recommendations developed by the Canadian Council of Ministers of the Environment (CCME). Under the new DFO Wastewater Regulations, the Northwest Territories, Nunavut and the areas of Quebec and Newfoundland and Labrador north of the 54th parallel (collectively referred to as the Far North) are currently exempt. The exemption was based on the understanding that meeting the new regulations in the Far North may impose an unreasonable burden on communities with extreme climactic conditions and limited economic resources. CCME is reviewing existing technologies and performance of wastewater treatment systems in the Far North, and is expected to develop new effluent criteria for the Far North within the next five years. The current DFO Wastewater Regulations in effect for the remainder of Canada are presented in Table 1-2; the limits come into force January 1, 2015.

Table 1-2 Current National Wastewater Effluent Regulations (excluding the Far North)

Parameter	Standard	Type
Carbonaceous Biochemical Oxygen Demand (cBOD)	≤ 25 mg/L	average
Total Suspended Solids (TSS)	≤ 25 mg/L	average
Residual Chlorine	≤ 0.2 mg/L	average
Un-Ionized Ammonia (Ammonia – N)	≤ 1.25 mg/L	maximum
Acute Lethality Testing Requirements		

The calculation period to determine the average value varies depending on the volumes released and the type of discharge (intermittent or continuous); average values may need to be calculated annually, quarterly, or monthly.

Carbonaceous biochemical oxygen demand (cBOD) is replacing Biochemical Oxygen Demand (BOD), which is listed in the current water licence, as the preferred measurement parameter for treatment of organic waste. cBOD measures only the carbon fraction of BOD. Most cBOD and BOD measurements diverge significantly somewhere between 6 and 10 days as carbon sources (readily available organic wastes) are exhausted and nitrifying bacteria populations have developed sufficiently to exert significant oxygen demand. As a rule of thumb, cBOD is normally 80 to 90 percent of BOD.

With respect to the average residual chlorine standard, chlorine disinfection is not practiced in Canada's Far North and is not expected to impact operations in the region. Residual chlorine concentrations are not of concern for Inuvik and will not be discussed further in this report.

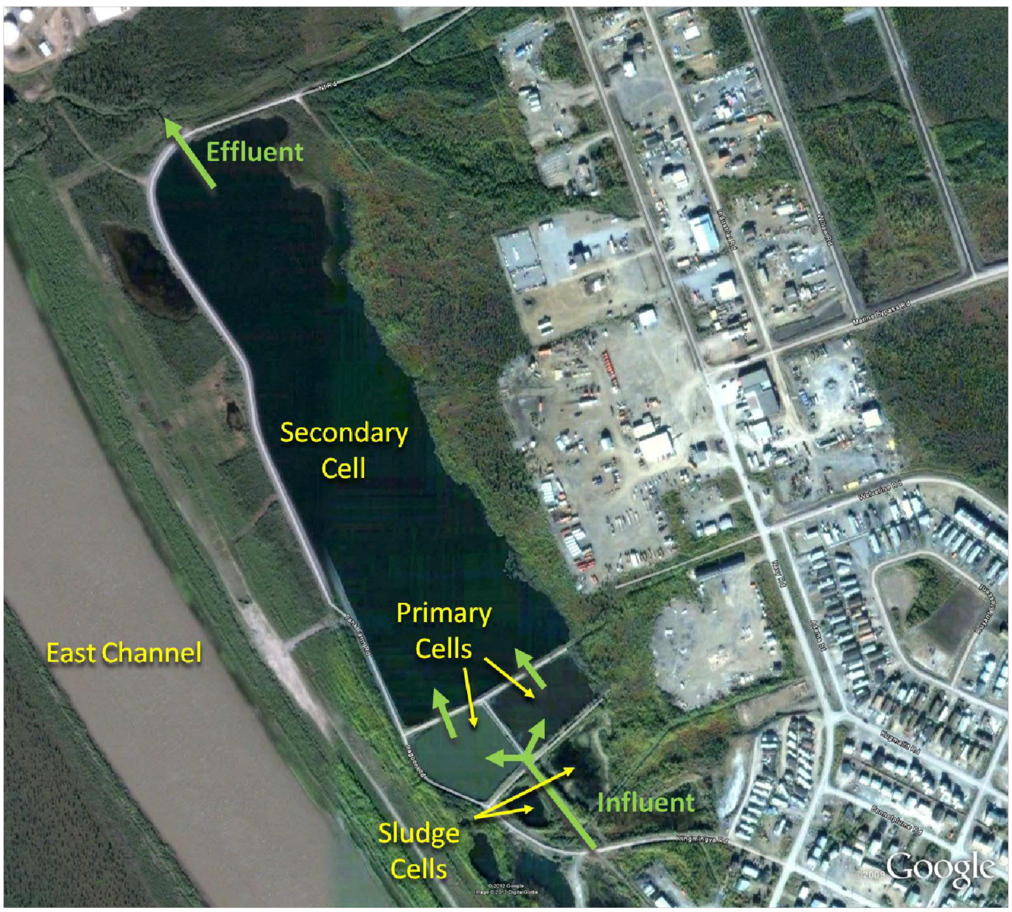
The acute lethality testing requirements only apply to wastewater systems with daily volumes exceeding 2500 m^3/day, meaning a limited number of wastewater facilities in the Far North (likely only the territorial capitals) would fall into this category. Since the Town of Inuvik's daily volume (≈ 1700 m^3/day) is significantly less than this number, acute lethality testing requirements will not be discussed further in this report.

1.2 History of Inuvik's Lagoon Facility

The lagoon facility has been in operation since 1957. Initial construction involved enclosing three sides of an existing slough to form one large and shallow cell approximately 1000 m long by 200 to 250 m wide. The last significant upgrade was in 1982, where the southern portion of the lagoon was partitioned with new dikes to add four new cells; bringing the facility to its current 5-cell facultative lagoon system.

Of the five cells, there are two primary cells and one large secondary cell. The remaining two cells are closed cells for long-term retention of sludge that is periodically removed from the primary cells. The lagoon is operated on a continuous discharge basis, with a hydraulic retention time of approximately 5 months. An image of the existing lagoon from Google Earth is presented in Figure 1-1.

Figure 1-1: Inuvik Lagoon



2. Existing Lagoon Assessment

2.1 Serviced Population

The lagoon serves the current population of approximately 3500[2]. This population number is more or less unchanged from the 2006 number of 3354 used in previous reports[3]. The Government of the Northwest Territories (GNWT) statistics presents an Inuvik population of 3571 in 2003, 3651 in 2006, and 3504 in 2011, which suggests that the population in Inuvik has remained relatively stable since 2003. The *Unit Cost of Water, 2006* report, *AECOM 2008* (Unit Cost Report) stated that the average per capita water demand was 365 L and that there were no future anticipated changes in this number, only fluctuations in the population[4]. Though the current flows into the lagoon are approximately 620 ML/yr[5], the relatively stable population suggests that the loading (amount of waste) on the lagoon system would be relatively constant (i.e. concentrations have decreased proportionately).

For the purpose of this report, the peak wastewater generation rate of 700 Megaliters per year (ML/yr) presented in the *Assessment of Wastewater Management Facilities, AECOM 2004* (Assessment Report), was selected as a conservative process flow.

2.2 Lagoon Performance

Overall performance of the lagoon system is very good in the summer and fall, but poor in the winter and spring.

During the open water season, conditions for bacteria and algae populations improve significantly as winds provide mixing, and the sun provides heat. The long retention times (approximately 170 days[6]), flourishing bacteriological and algal populations, and natural treatment by the sun produce an effluent that rivals mechanical treatment during the summer and fall.

Ice cover and cold temperatures severely limit the treatment performance during the winter and spring months. Retention time is reduced to approximately 50 days during the winter due to the thick ice cover and shallow depth of the secondary cell; biological activity is essentially reduced to zero. The Assessment Report concluded that treatment within the lagoon system during the coldest parts of the year was reduced to primary treatment (settling) only.

A full analysis of the lagoon performance was prepared in the Assessment Report, utilizing effluent data from 1996, 2000, and 2003. A summary of the performance parameters and data from that report is presented over the next few sections. Since the Inuvik population has remained stable since 2003, it is reasonable to assume that the performance of the lagoon has remained stable.

If the DFO Wastewater Regulations were applied to the Far North, Inuvik's wastewater system would be classified as a continuous discharge system with a hydraulic retention time of more than 5 days discharging less than 2500 m^3 average daily volume, meaning the average calculations requirement would be annual.

---

[2] Statistics Canada 2011 Census number is 3403, GNWT population number in 2011 for Inuvik was 3504

[3] Though this number is referenced in previous AECOM reports as well as the recently completed NEI report, GNWT population number for Inuvik in 2006 was 3651, while Canada Census number for 2006 was 3484.

[4] The total water use for the year was 502 ML as taken from the Town's water meters and assuming 100% water to wastewater generation – the estimated population was 3765; actual Census Canada population in 2006 was 3484 putting daily per capita use at 395 L.

[5] Based on Water Licence Annual Report for 2012.

[6] Retention times were calculated in the Assessment Report based on sewage generation rates of 525 ML/yr.

BOD/cBOD

Biochemical Oxygen Demand (BOD) is a measure of the organic pollution in a wastewater effluent, and is frequently used as a measure of effectiveness of treatment. The subscript indicates the number of days that BOD was incubated and measured at (e.g. BOD_5 = sample was incubated for five days and dissolved oxygen was measured initially and at the end of incubation). A high BOD_5 in wastewater effluent will exert excessive demand on the dissolved oxygen in the receiving body, affecting fish and other oxygen users in the ecosystem. The larger the receiving stream is relative to the effluent stream, the less of an impact BOD_5 concentrations will have on the downstream environment.

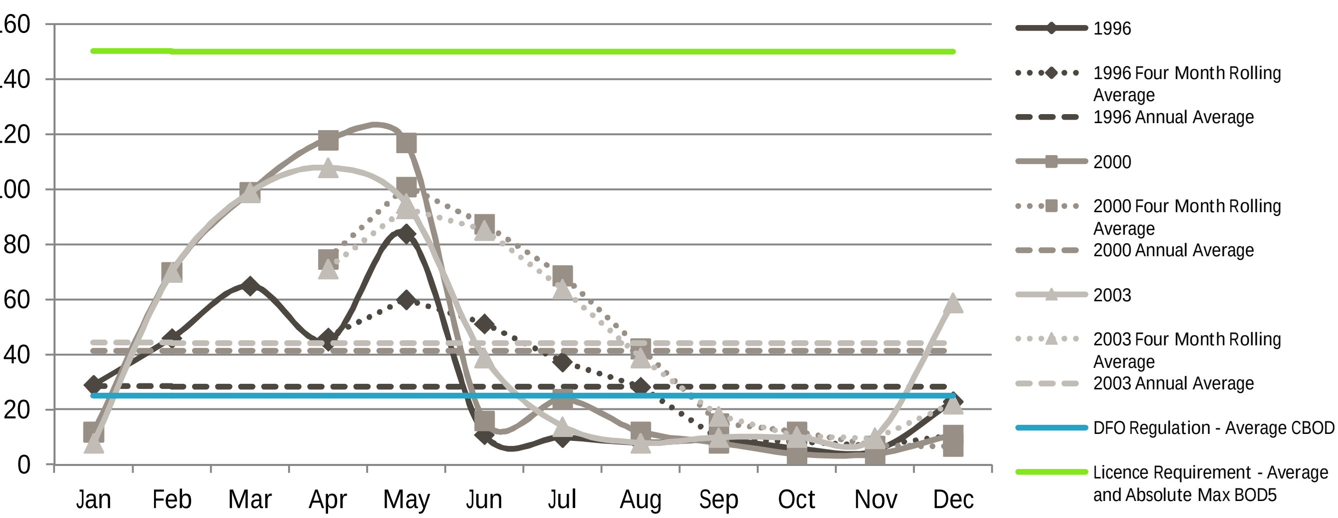
While BOD_5 has been used for years as the primary measurement for treatment effectiveness, more commonly a new parameter, carbonaceous biochemical oxygen demand (cBOD), is becoming the parameter of choice for regulators. The cBOD in a wastewater sample is reflective of the readily available organic biodegradable material in the wastewater, whereas BOD includes both carbonaceous and nitrogenous components.

The new DFO requirement is for an average cBOD measurement at 5 days with nitrification inhibited. In a typical municipal wastewater without significant industrial component, like Inuvik's, cBOD and BOD will only begin to diverge significantly once the carbonaceous sources have been depleted, usually between days 6 and 10. After this point (unseeded) nitrification processes would have a significant impact on oxygen demand.

The test results reported in the Assessment Report are for BOD_5, but given that there is likely minimal nitrogenous oxygen demand in the 5 day test, the existing measurements of BOD_5 are considered a reasonable approximation of the current lagoon's cBOD concentrations at 5 days and therefore can be compared to the new DFO limit.

For much of the year, the lagoon produces results significantly lower than the DFO limit of 25 mg/L average cBOD. The results of the Assessment Report are re-presented in Figure 2-1. The highest reported value of BOD_5 from the Assessment Report data is 118 mg/L which occurred in the early spring of 2000; low values of 4 mg/L were reported in the fall of 2000. The data clearly shows the trend of BOD_5 rising significantly as influent entering the lagoon in the coldest part of the winter reaches the effluent discharge point, and dropping significantly after several weeks of open water. While the average BOD_5 is lower than the requirements of the water licence, if the DFO regulation for cBOD was the regulatory requirement, all three annual BOD_5 averages would exceed the regulatory requirement for cBOD.

Figure 2-1: Measured BOD_5 in Lagoon Effluent (mg/L)



Ammonia

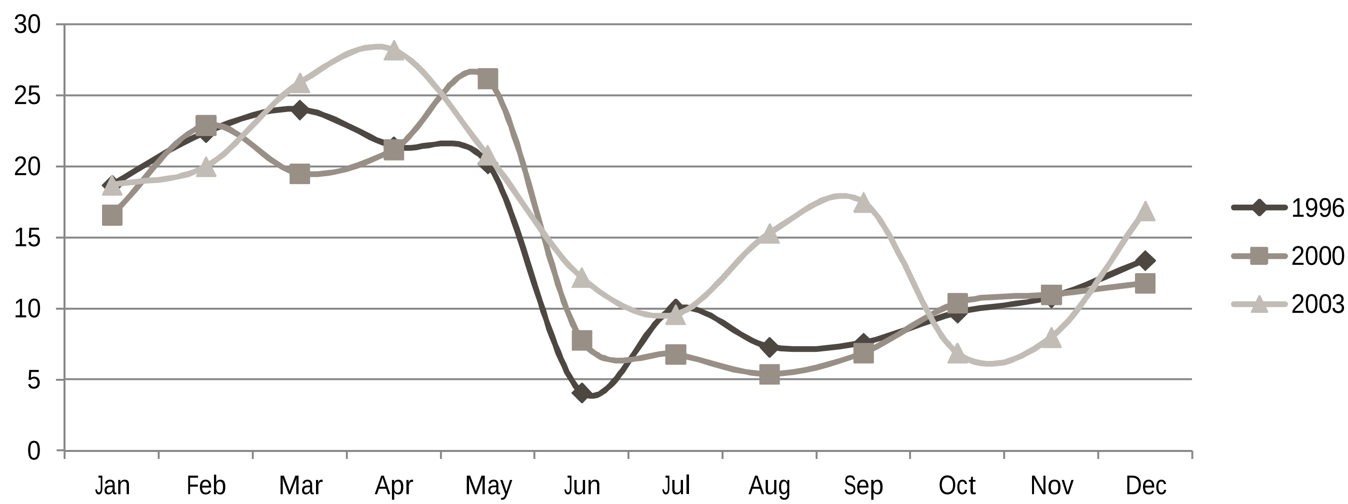
Ammonia is an important by-product of the breakdown of organic material, carried in wastewater effluent, and is a natural part of the nitrogen cycle.

The biological processes in lagoons in general are not reliable for treating ammonia. Where mechanical treatment plants will generally treat ammonia by maintaining an environment where nitrifying bacteria (which convert ammonia to nitrite, and then nitrate) thrive, lagoon system environments generally will not support the growth of significant sustained populations of nitrifying bacteria. In Inuvik, this is particularly true given the susceptibility of nitrifying bacteria to low temperatures.

Total ammonia nitrogen (Ammonia-N) results from the lagoon effluent ranged from 4.1 to 28.2 mg/L, and again show a general, though less defined, tendency to have lower levels through the summer and fall.

The results included in the Assessment Report for ammonia-N are re-presented in Figure 2-2 below.

Figure 2-2: Measured Total Ammonia-N in Lagoon Effluent (mg/L)



Ammonia is very soluble in water and will react with water according to the following equilibrium equation[7], which heavily favours the products at neutral water pH:

$$NH_3 + H_20 \leftrightarrow NH_4^+ + OH^- \quad (\mathrm{p}K_b = 4.74)$$

Even relatively small ammonia concentrations can be toxic depending on pH levels and temperatures of the receiving bodies, and the dilution ratio. At higher pH and temperature, more ammonia tends to remain un-ionized (NH_3). Un-ionized ammonia is known to be more toxic[8] than the ammonium ion (NH_4^+).

The DFO Wastewater Regulations did not define a limit for ammonia-N, but have instead defined a limit for un-ionized ammonia (NH_3). The maximum effluent concentration for un-ionized ammonia in the DFO regulations is 1.25 mg/L expressed as nitrogen (N).

---

[7] *Health Canada – Guidelines for Canadian Drinking Water Quality: Ammonia Technical Document (1987)*

[8] *Canadian Water Quality Guidelines for the Protection of Aquatic Life – Ammonia, CCME 1999, revised 2010*

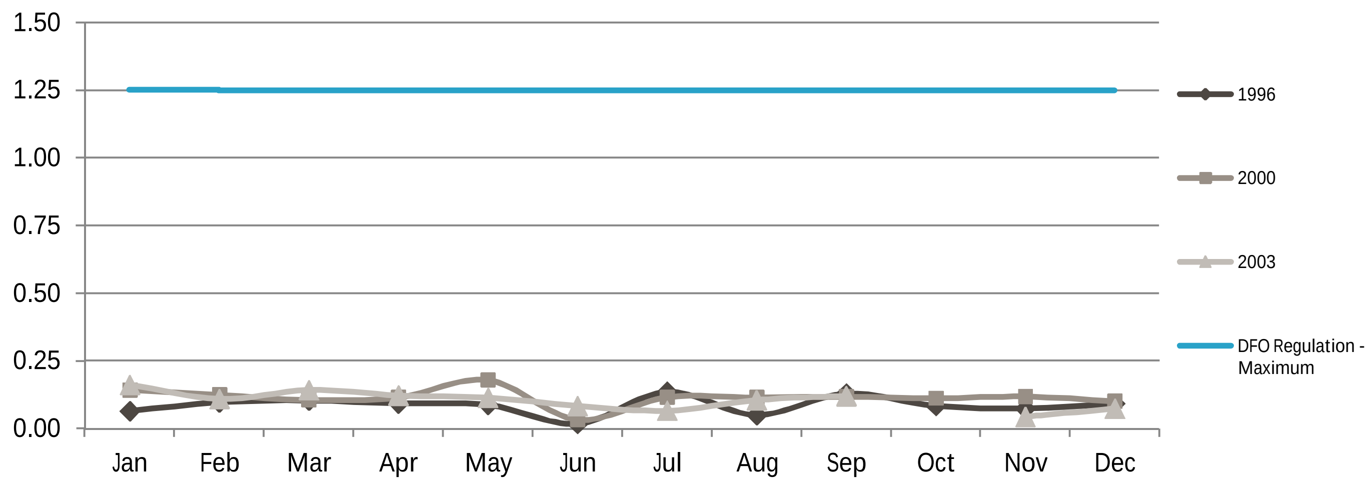
To determine the concentration of un-ionized ammonia-N, the following equation must be used:

$$(Total\ Ammonia - N)\ \times 1/(1 + 10^{9.56-pH})$$

The pH used in the above equation should be adjusted to 15°C ± 1°C, and determined from a portion of the same sample tested for ammonia-N.

To compare the previous ammonia-N readings relative to the new DFO standard, the recorded pH measurements have been adjusted assuming a temperature during pH sample reading of 25°C (i.e. at the lab)[9] and un-ionized ammonia-N has been calculated using the above equation. The recorded pH values ranged from 6.9 to 7.7 (adjusted values used for un-ionized ammonia calculations ranged from 7.1 to 7.9). The estimated un-ionized ammonia-N concentrations are presented in Figure 2-3 and are significantly lower than the DFO regulated maximum to be applied in the rest of Canada.

Figure 2-3: Estimated Un-ionized Ammonia-N (mg/L)



As an alternative method of evaluating the un-ionized ammonia concentrations, it is possible to look at the concentration of un-ionized ammonia-N outside of the mixing zone. The CCME Canadian Water Quality (CWQ) Guideline for the Protection of Aquatic Life for un-ionized ammonia-N is 0.016 mg/L (0.019 mg/L un-ionized ammonia). The Assessment Report presented a projection scenario where peak wastewater generation was 700 ML/yr with unchanged ammonia-N concentrations. Using the monthly flows for this peak projection (Table 4.2 in the Assessment Report) and the monthly flow data from the Water Survey of Canada Station 10LC002 (East Channel near Inuvik), the average dilution ratio for the effluent for the winter/spring and summer/fall would be approximately 1:1,280 and 1:10,370, respectively. Using the available data from the Assessment Report, un-ionized ammonia-N would still be well below the freshwater CWQ Guidelines and are estimated conservatively[10] in Table 2-1.

[9] Lagoon staff measure pH with a hand device regularly, since pH decreases as temperature increases, it is conservative to assume the higher temperature during pH measurement and adjust by adding back 0.2 pH units, rather than the alternative.

[10] Assumes maximum recorded pH in the East Channel and pH increases for temperature,

Table 2-1 Un-ionized Ammonia Concentrations in the East Channel Outside of Mixing Zone

	Winter (November – April)	Summer (May-October)
Average Dilution Ration (700 ML/yr)	1:1,280	1:10,370
***Lowest Dilution Ratio (700 ML/yr)**	1: 110	1:2660
Assumed pH in East Channel	8.2	8.2
Average Concentration outside of Mixing Zone (mg/L un-ionized ammonia-N)	0.000284	0.000015
***Maximum Concentration outside of Mixing Zone (mg/L un-ionized ammonia-N)**	0.00334	0.00113
‡CCME CWQ Guideline (mg/L un-ionized ammonia-N)	0.016	0.016

*** Lowest Dilution Ratios & Maximum Concentrations were calculated for winter/spring (November to April) and summer/fall (May-October) by using the 0.5th Percentile for average monthly flow for the periods, i.e., 2 months out of 230 recorded winter/spring months had average flows lower than 2.59 m^3/s and 2 months out of 231 recorded summer/fall months had average flows lower than 63.95 m^3.**

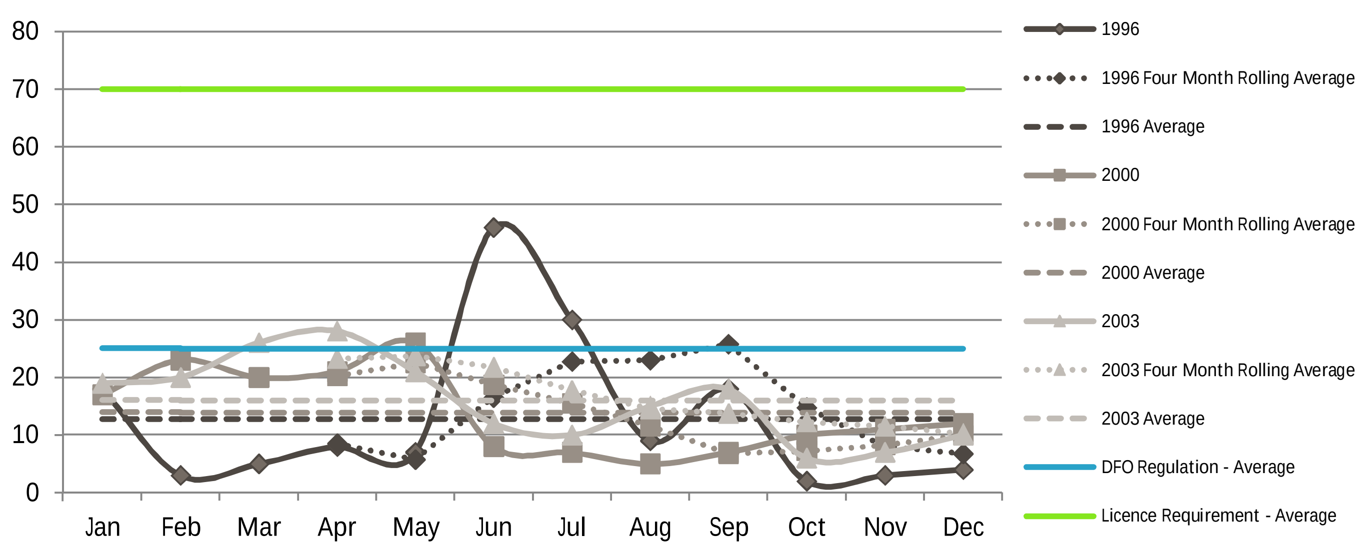
‡CCME CWQ Guideline is 0.019 mg/L Un-ionized Ammonia – or 0.016 mg/L Un-ionized Ammonia-N.

Total Suspended Solids (TSS)

Suspended Solids are a measure of the particulate matter that has not settled out during the course of treatment. Total suspended solids (TSS) is an aggregate measure, reflective of all solids remaining in the effluent, whether the solids are inert or untreated sewage. TSS results are used routinely to assess the performance of the treatment system, and for regulatory control.

The TSS results, with the exception of a spike in summer of 1996, show again a general tendency toward more complete settling and, by inference, more complete treatment, in the warmer latter half of the year. The results from the 2004 report are re-presented below in Figure 2-4, along with the DFO regulated average of 25 mg/L. The average for all data points is 14 mg/L, which would be well below the new standard if applied in the Far North.

Figure 2-4: Measured TSS in Lagoon Effluent (mg/L)



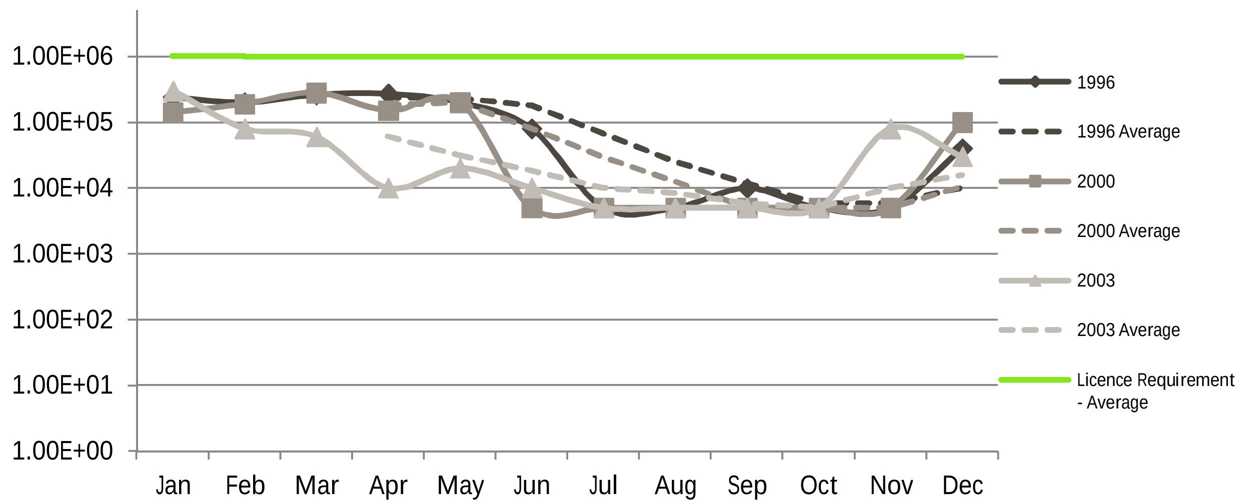
Fecal Coliforms

Fecal coliform measurements use fecal coliform counts as a rough indicator of the levels of pathogenic microorganisms that may be present within the effluent streams. Inuvik's existing water licence limits fecal coliforms to 1×10^6 (1,000,000) colony-forming units (CFU)/100 mL (geometric mean of any four consecutive months) in the wastewater effluent; the lagoon consistently is below this limit as fecal coliforms in the lagoon effluent vary between less than 5,000 to 300,000 CFU/100 mL.

No current DFO or proposed CCME regulation exists for effluent fecal coliform counts, but the Northwest Territories Water Board's *Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories (1992)* limit fecal coliform counts to 100 CFU/100 mL in the receiving waters outside of the mixing zone. AECOM projects a dilution ratio in the order of 1:1300 at peak lagoon flow in the winter. At this dilution ratio it is possible that the NWT's water quality objectives would be exceeded. The *Lagoon Effluent Impact Assessment* report, *AECOM, 1994* (Effluent Impact Report) concluded that risk is low since exposure is mitigated almost entirely by the thick ice cover and recommended practice of treating all surface waters for downstream potable water applications.

As with the previously mentioned parameters, the lagoon's performance improves in the summer and fall compared to the winter and spring. The results from the 2004 report are re-presented in Figure 2-5.

Figure 2-5: Measured Fecal Coliforms in Lagoon Effluent (CFU/100 mL)



The average summer dilution is projected to be on the order of 1:10,000. The high dilution ratio, coupled with the significant reduction in effluent fecal coliform counts in the summer, suggest that it is unlikely that coliform counts in the receiving waters outside of the mixing zone would exceed the NWT's water quality objectives in the summer.

2.3 Lagoon Performance Summary

The existing lagoon is meeting all requirements listed in the current water licence. If the DFO Wastewater Regulations were to be applied in the Far North, the current lagoon would meet all performance standards with the exception of cBOD, where the average for the year would exceed the standard because of the poor treatment performance in the winter and spring when cold temperatures and thick ice cover limit treatment to essentially primary treatment.

A higher cBOD in the wastewater effluent during the winter and spring means that there is additional demand on the dissolved oxygen in the river which fish and other organisms depend on. Despite the higher BOD_5/cBOD in the wastewater effluent in the winter and spring, the Effluent Impact Report and the *Inuvik Sewage Plume Study*, *Department of Indian Affairs and Northern Development, 1998* (DIAND Report) both concluded that impacts on the receiving waters were minimal. During winter conditions the rate of BOD exertion slows significantly and the water in the East Channel upstream of the effluent discharge is oxygen saturated in under ice conditions.

Should the DFO Wastewater Regulations be applied to the Far North at a future date, the lagoon's winter and spring treatment would need to be improved to bring the cBOD values down from its peaks of over 100 mg/L to values below 25 mg/L to ensure that the lagoon would meet the annual average requirements for the cBOD.

Though fecal coliform counts in the wastewater effluent do not exceed the water licence requirements, a reduction of fecal coliforms during the winter and spring would ensure that the coliform counts in the receiving waters would never exceed the NWT's water quality objectives which may currently be occurring for short durations when flows in the East Channel are very low in the winter or spring.

3. Process Options for Improvements to Wastewater Treatment

3.1 Lagoon Expansion – Conversion to Annual Discharge

One option to improve effluent quality is to expand the existing lagoon facility to increase the retention time within the lagoon system and convert the system from continuous discharge to annual discharge. The possible areas for expansion are presented below in Figure 3-1; the percentage of the area required for expansion would depend on the depth of the cells.

Figure 3-1: Lagoon Expansion

Currently there are no defined standards for an annual discharge lagoon in the Northwest Territories. AESRD defines standards for annual discharge lagoons based on average design flow, which if applied to the Inuvik lagoon would require 4 anaerobic cells each with a minimum of 2 days retention, a facultative cell with 60 days retention and a storage cell with 1 year of retention.

From AESRD's standards[11]:

> "*The purpose of storage is to provide additional wastewater treatment (including nutrient removal) under facultative conditions, and to reduce the environmental impact on the receiving drainage course by facilitating the annual discharge of high quality effluent wastewater."*

Since additional treatment occurs in the storage cell, the net effect is that all wastewater, regardless of when it entered the system, will receive facultative treatment, whether in the facultative cell or the storage cell. Since the existing lagoon system's performance is very good during the summer months, converting the system to an annual discharge system – so that all wastewater was treated during the summer – would significantly enhance treatment and produce an effluent that would meet the DFO regulated standards as well as NWT's objectives for coliforms in the receiving waters. Despite increased effluent flows during discharge, dilution ratios are estimated to be a minimum of 1:130 and average 1:500.

At peak wastewater generation, the Assessment Report estimated the ice free retention would be 20 days in the primary cells, and 130 days in the secondary pond. The minimum depth required by the AESRD standards for anaerobic cells is 3 m. It is feasible that additional berms could be constructed to divide the two existing primary cells into 4 anaerobic cells and the bottoms dredged to give the cells an operating depth of 3 m. With these improvements the smallest of the four cells would have a retention time of 3.9 days. An additional berm could be constructed through the secondary cell to allow the southern portion to become the facultative cell (≈ 63 days retention), while the northern portion would become a portion (≈ 51 days retention) of the one year storage. An additional 315 days of average water use storage (605 ML) would be required to be constructed to obtain the full year of storage. These could be constructed in two additional cells within the available area, as presented in Figure 3-2. The northern portion of the existing lagoon and the two new cells would all be operated as one cell and drained annually during a three week period late in the open water season. The cells presented in Figure 3-2 are based on a 2 m depth.

[11] *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems Part 3, AESRD, 2013*

Figure 3-2: Lagoon Expansion - Additional Storage Cells

There are a number of potential problems with expanding the lagoon north. First, an expansion north would create significant land use conflicts – a number of pipeline right of ways exist in this industrial area – which would require resolution before the expansion could be advanced. Though east and east-northeast winds dominate, odour concerns would also be an issue since west-northwest and northwest winds are prevalent and would carry odours back towards the Town.

For lagoon expansion, an extensive geotechnical investigation would be required to determine the existing soil conditions and ice content; a thaw bulb under the new lagoon and potential settlement due to permafrost degradation may cause significant slope stability issues for a lagoon expansion.

Also of concern for this option is the potential for some, or all, of the site to be flooded since the Mackenzie Delta floods every May.

3.2 Lagoon Enhancements (Nelson Environmental Report)

Nelson Environmental Inc. (NEI) completed a site visit and prepared a report on potential enhancements to the existing Inuvik lagoon system. A brief summary of the report and its findings is presented in this section; the complete NEI report is included as Appendix A.

NEI explored three options with regard to lagoon enhancement. An excerpt from their report describes the upgrade options:

Option 1*: Convert two existing facultative lagoons to aerated lagoons*

The proposed lagoon upgrade would consist of converting two (2) of the existing facultative lagoons (NEI is referring to the Primary cells shown in Figure 1-1) *to partial mix aerated cells followed by a facultative cell for secondary treatment, settling, and polishing.*

Option 2*: Existing Facultative lagoon with SAGR (Submerged Attached Growth Reactor)*

The proposed lagoon upgrade would consist of two existing (2) facultative primary treatment cells and the existing facultative secondary treatment cell, followed by a SAGR for BOD_5 *polishing and TSS removal, as well as nitrification (ammonia reduction).*

Option 3*: Convert two existing facultative cells to aerated lagoons, and implement a SAGR*

The proposed lagoon upgrade would consist of converting two (2) of the existing facultative lagoons to partial mix aerated cells followed by a facultative cell for secondary treatment, settling, and polishing. The facultative lagoon system would be followed by a SAGR for BOD_5 *polishing and TSS removal, as well as nitrification (ammonia reduction).*

The conversion of existing primary cells to partial mix aerated cells would involve adding blowers and pipework to enable increased oxygen flow and dissolved oxygen into the existing primary cells. With increased available dissolved oxygen, microbial activity would increase, allowing for more degradation of BOD_5/cBOD.

The implementation of SAGR treatment would involve construction of two small new cells north of the existing secondary cell. These cells would be filled with uniform gravel and would be equipped with blowers and pipework to allow dissolved oxygen levels to be maintained. The gravel acts as a medium for biofilms (attached growth) to develop, which not only further treats BOD_5 /cBOD, but allows for nitrification (ammonia reduction or conversion to nitrate) and total and fecal coliform reduction.

The microbes attached to the gravel medium of the SAGR cells will produce heat and therefore, with the addition of insulation around the SAGR cells, will have some freeze protection. This technology can (and has proven to) perform well even in extremely cold climates.

NEI's recommended upgrade was Option 2, adding SAGR treatment to the existing effluent. NEI suggested that the additional capital and operational costs associated with converting the existing primary cells to partially mixed aerated cells in Option 3 were not justified given the estimated marginal improvement in effluent quality over Option 2 alone. In NEI's opinion, Option 1 would only provide marginal effluent quality improvement that would likely not comply with future regulatory requirements.

As with the lagoon expansion option, the potential for flooding would also need to be addressed with regard to the current lagoon system and the additional required infrastructure.

3.3 Mechanical Treatment Processes

The performance of lagoon systems is inherently variable with respect to effluent quality because their performance is ultimately dependent upon the seasonal variations in the climate, and there is limited opportunity to control the operating parameters. Mechanical treatment, on the other hand, has the ability to produce a consistent effluent quality because the process is generally sheltered from the seasonal variations in the climate and there is a significant opportunity to control the operating parameters within the system (e.g. increase dissolved oxygen, adjust sludge retention times, etc.).

Mechanical treatment requires skilled and qualified operators, which are challenging for small and remote communities to find and retain.

In general, mechanical treatment will have significantly higher capital costs, and significantly higher annual operating and maintenance costs than lagoons. All of the mechanical treatment processes presented will produce an effluent that conforms to the DFO Wastewater Regulations when operated correctly.

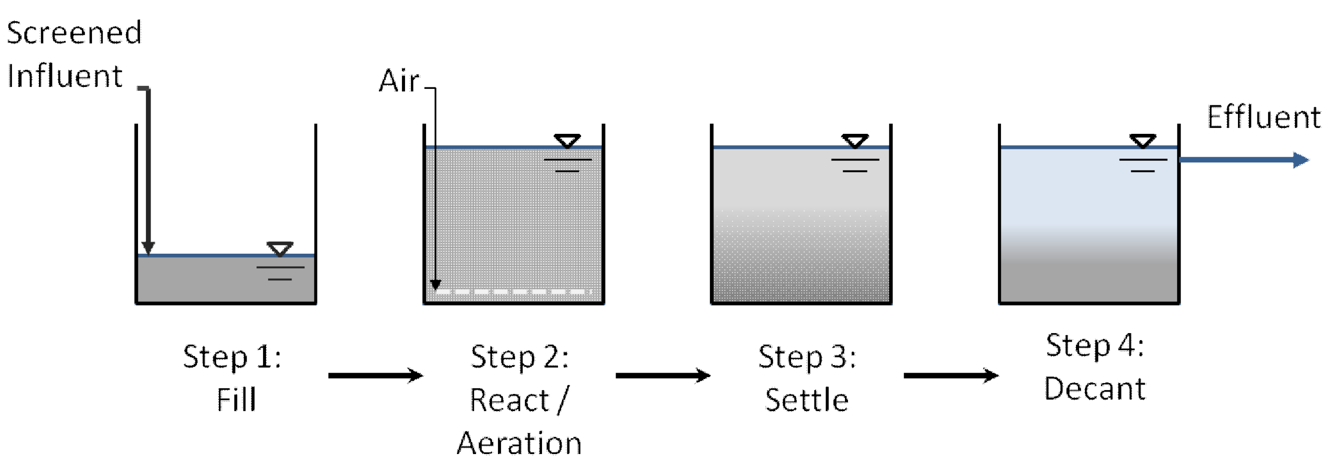
Mechanical treatment, in general, would also require UV disinfection prior to discharge to limit coliforms in the receiving stream, which represents significant power requirements; power costs are quite high in Inuvik.

The same flooding concerns would require that a mechanical treatment plant would be constructed above the flood levels and the current wastewater collection system would need to be rerouted (and possibly pumped) to the plant's location.

3.3.1 Sequencing Batch Reactor (SBR) Process

The sequencing batch reactor (SBR) process generally utilizes a single fill-and-draw reactor, which allows complete mixing during the filling, followed by a sequence of aeration and clarification (settling) occurring in the tank.[12] Once settling has occurred, effluent is drawn from the reactor and the process repeats. In a traditional SBR treatment facility, at least 2 vessels are required so that one vessel can fill while the other is reacting and settling. Continuous flow SBRs which have smaller footprints than traditional SBR facilities are also available. Figure 3-3, presented below, shows a typical schematic for an SBR.

Figure 3-3: SBR Schematic



Unlike lagoons, SBRs can produce and maintain significant quantities of nitrifying bacteria, so they are effective for biological ammonia reduction as well as BOD_5/cBOD and TSS removal. Nitrification occurs in Step 2 (Figure 3-2) along with most of the BOD_5/cBOD removal.

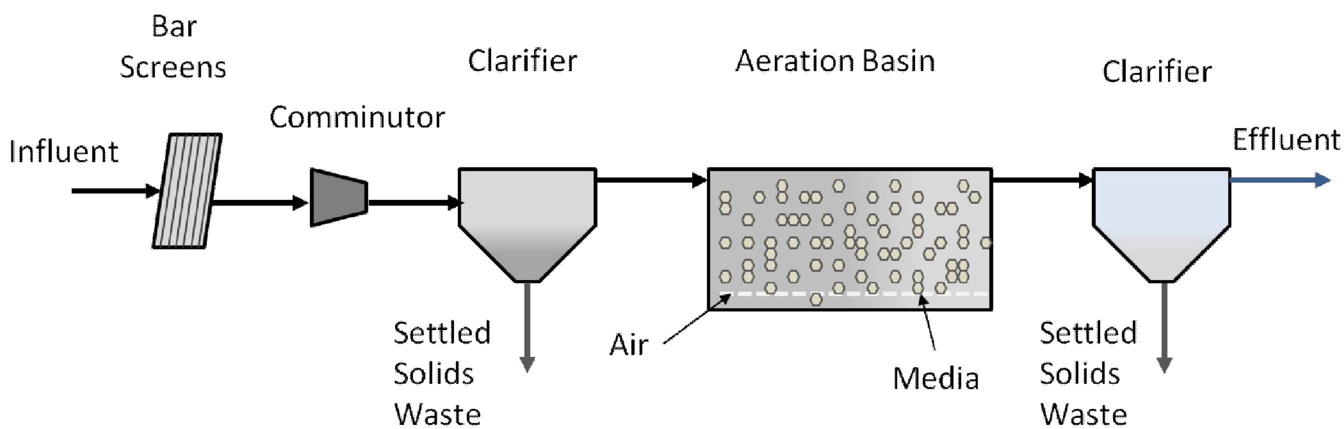
[12] *Wastewater Engineering, Treatment and Reuse, Metcalf & Eddy, 4th Ed.,2003.*

SBR's have been effectively utilized in a variety of wastewater applications, including Northern applications, and are well suited for smaller communities. SBRs are generally relatively simple to operate and would be able to meet all expected DFO and CCME wastewater effluent regulations for the Far North.

3.3.2 Moving Bed Biofilm Reactors (MBBR)

Conventional Activated Sludge (AS) processes employ a reactor in which microbial populations (biomass) are kept suspended and aerated, along with the appropriate systems for solids removal and sludge return. Attached growth treatment processes employ a reactor where treatment occurs as wastewater passes by microbial populations growing in layers of film (biofilms) on stationary or moving objects. Moving bed biofilm reactor (MBBR) plants use conventional AS suspension and aeration techniques, but do not utilize sludge return and increase the biomass in the aeration basin by adding media (or synthetic packing material) for biofilms to develop. Because there is more active biomass within the aeration basin, the size of the basin or reactor can be smaller. Figure 3-4, shows a typical MBBR schematic.

Figure 3-4: MBBR Schematic



Significant nitrifying and denitrifying (converting nitrate to nitrogen gas) bacteria populations develop in MBBR systems, allowing them to be effective for ammonia and total nitrogen removal. Total nitrogen requirements are not expected with the updated CCME effluent guidelines at this time, but the MBBR system would meet the DFO Wastewater Regulations in force in the rest of Canada.

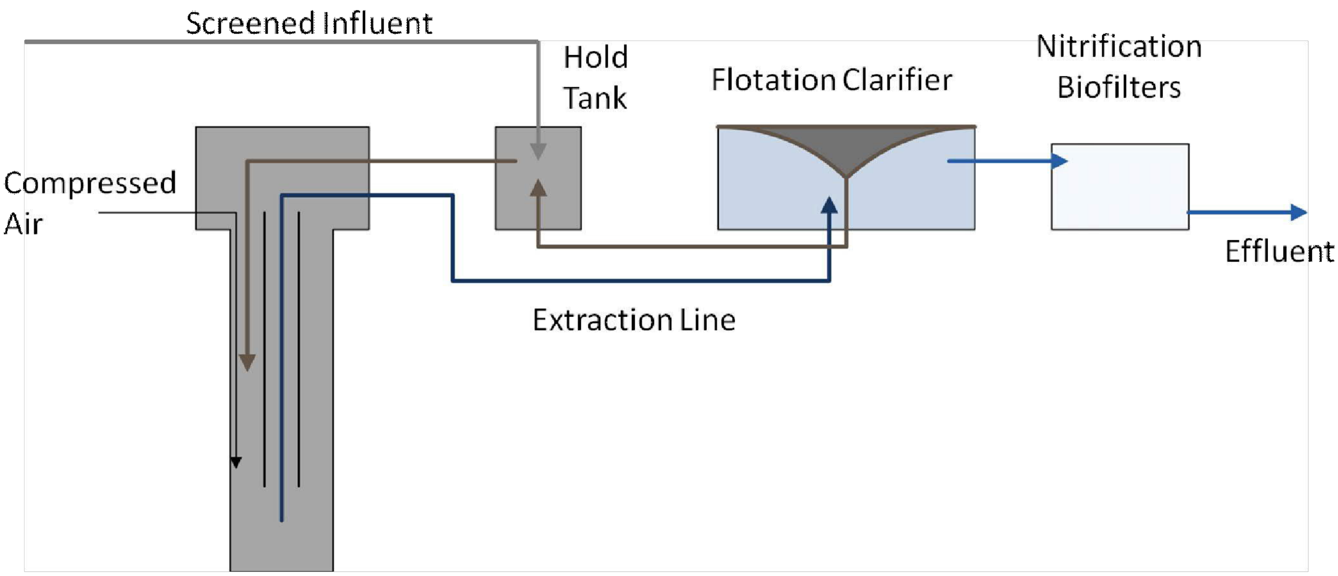
MBBR systems have power consumption costs lower than conventional AS systems along with smaller footprints, are generally easy to operate, and produce excellent effluent quality. Additionally, the higher concentration of biomass allows for good resiliency to loading shocks.

Numerous MBBR systems are performing well in cold climates around the world.

3.3.3 Deep Shaft Aeration (DSA)

Another modification of conventional AS wastewater treatment is deep shaft aeration (DSA). In DSA, rather than a conventional aeration basin, deep shafts (75m to 110 m deep) are the bioreactors. Compressors provide the process air for this type of system. The compressed air enters the shaft near the bottom, where the hydrostatic pressure allows for significantly higher levels of oxygen to be dissolved into the wastewater. Additionally, tiny bubbles provide the mixing action within the shaft. Figure 3-5 shows a schematic of a typical DSA schematic.

Figure 3-5: DSA Schematic



DSA is a high rate process with a small footprint, but requires additional steps of treatment for full ammonia removal (the Nitrification Biofilters in Figure 3-5). However, the reduction of ammonia in the system due to cell metabolism would likely be sufficient to create a low enough un-ionized ammonia concentration. The capital costs for DSA systems are very high, as deep shaft construction is an expensive undertaking. The increased aeration efficiency and natural freeze protection due to the shafts, means that some operating costs are minimized in cold climates. DSA is, however, the most complex system to operate of the mechanical treatment options presented.

4. Discussion on Options for Improvements for Wastewater Treatment

4.1 Regulatory Requirements

CCME released their Canada-wide Strategy for the Management of Municipal Wastewater Effluent in 2009. The Strategy "focuses on improving protection for human health and environmental protection, and regulatory clarity in the management of wastewater."[13] Within this document are timelines for various actions, including the development of performance standards for Canada's Far North by 2013. Subsequent correspondence from AANDC officials suggest this timeline has been pushed back until at least 2014.

The Department of Fisheries and Oceans adopted the CCME's recommended effluent standards for all regions of Canada excluding the Far North under the Fisheries Act; these standards now comprise the Wastewater Systems Effluent Regulations (presented previously in Table 1.2).

In advancing the stakeholder consultation on the national standards, CCME realized there was an absence of technical information upon which to make informed and realistic decisions with regards to the performance capability of wastewater treatment systems in the Far North. The distance to testing services for remote communities and other issues means that most communities do not have a significant base of knowledge from which to predict process performance. Additionally, most wastewater treatment technologies do not have performance data in climactic and geographic conditions similar to those experienced in Canada's Far North.

Given this reality, CCME made a concession for the Far North within their Strategy document to accommodate a specific period for the collection and review of performance, which will ultimately provide a basis for moving forward with standards for wastewater treatment facilities in the Far North region. Ultimately, the wastewater effluent standards that CCME develops for the Far North may be adjusted from the standards proposed for the rest of the country, given the economic and technological constraints in the region.

4.2 Discussion Basis

The conservative approach for wastewater treatment facilities in the Far North (in the absence of defined regulatory requirements and some uncertainty in direction for how the regulatory requirements may unfold) is to adopt the Wastewater Systems Effluent Regulations as the requirements that could be expected in the future for the Far North.

The basis of the discussion could change significantly should CCME develop different effluent limits for Canada's Far North than those adopted in the DFO Wastewater Regulations.

4.3 Options

4.3.1 Lagoon Expansion – Conversion to Annual Discharge

As presented in Section 3.1, expanding the lagoon to provide 12 months retention would likely provide improved cBOD removal, as the measured BOD_5 for the lagoon is below the DFO regulated standard of 25 mg/L for 6 to 8 months every year. The additional storage cells would allow wastewater entering the lagoon in the coldest part of the years to receive facultative treatment in the storage cells after breakup and prior to the annual discharge.

[13] *Canada-wide Strategy for the Management of Municipal Wastewater Effluent, CCME 2009*

Though not a DFO regulation, fecal coliform counts would likely be significantly reduced in Inuvik's nearly 2 months of continuous sunlight during the summer prior to the annual discharge of the storage cells.

Given that the current lagoon system meets the TSS regulations, TSS is not likely to be a concern in an expanded lagoon system with annual discharge, but caution and timing would be required to ensure that the algal populations did not increase effluent TSS during the annual discharge.

Similarly, since the lagoon system currently meets the DFO regulation for un-ionized ammonia, lagoon expansion may further enhance ammonia treatment, but ammonia treatment would not be of significant concern.

4.3.2 Lagoon Enhancement

NEI's recommended option of installing SAGR cells for tertiary treatment, ammonia and coliform reduction would provide a significant upgrade to the quality of the wastewater effluent. Removal of cBOD would occur on a year-round basis through biological processes within the SAGR cells and would produce an effluent significantly lower than the DFO regulated standard on a consistent basis.

As with the lagoon expansion option, TSS would not be of concern for lagoon enhancement as the current lagoon already meets the proposed TSS standards, though TSS removal would be enhanced. Additional ammonia (though currently not a concern) and coliform removal (a potential concern) would further enhance the effluent quality.

4.3.3 Mechanical Treatment

Each of the three mechanical treatment options presented in Section 3.3 has the potential to produce wastewater effluent in compliance with the DFO Wastewater Regulations.

Disinfection would probably be required for all of the mechanical treatment options. The most commonly used disinfection process is ultraviolet (UV). UV disinfection is power intensive, which is a significant factor in Inuvik, where the cost of power is very high.

5. Capital Costs for Improvements to Wastewater Treatment

Capital cost estimates for the various alternatives in this section are strictly "order of magnitude" estimates and are presented over the following sections for comparative purposes only.

To estimate the capital costs for mechanical treatment, actual capital costs or actual design / build proposal costs for northern locations were used as the basis. To account for the differences in inflation and design flow, inflation and capacity multiplication factors (see Section 5.3) were used to adjust the these costs. The actual capital costs for a given alternative will ultimately depend upon a number of factors relating specifically to Inuvik's remote location; more in-depth cost estimation should be completed before proceeding with any option presented in this report. The estimated capital costs are presented in Table 5-1.

Costs do not consider flood mitigation requirements for any of the options.

Table 5-1 Summary of Capital Cost Estimates

Alternative	Original Estimate / Bid Price or Cost	Year	Inflation Multiplication Factor	Capacity Multiplication Factor	Estimated Capital Cost
Lagoon Expansion: Conversion to Annual Discharge	$ 18,000,000	2013	1	1	$ 18,000,000
Lagoon Enhancement*	$ 6,200,000	2012	1.02	1	$ 6,500,000
SBR	$ 6,000,000	2005	1.15	2.63	$ 18,500,000
MBBR	$ 16,500,000	2009	1.07	0.94	$ 17,000,000
DSA	$ 26,500,000	2013	1	0.94	$ 25,500,000

*NEI quote for lagoon enhancement *excluding* civil works was $ 1,975,000 in 2011. Civil works, engineering and contingency were estimated separately in 2012 – the total estimate for lagoon enhancement is the sum of the NEI quote plus the civil works, engineering and contingency.

5.1 Lagoon Expansion – Conversion to Annual Discharge

Lagoon Expansion and conversion to a once per year discharge lagoon system compliant with AESRD standards would involve excavation of over 600,000 m^3 of soil (at $25/$m^3$) and is based on having an appropriate in-situ liner for cell bottoms and berms where possible. The cost is estimated as $18,000,000, but could balloon to $26,000,000 if a polymeric membrane liner is required for the cell bottoms and even higher should geotechnical investigations indicate unfavourable soil conditions.

5.2 Lagoon Enhancement

NEI provided quotes within their report for the various lagoon enhancement options. NEI's estimate only included the engineering work and equipment for the SAGR process, but did include a list of various civil works and materials that would be required for construction. Using that list and the NEI estimate of approximately $2,000,000, in 2011, a preliminary capital cost estimate for the SAGR implementation with the current lagoon is $6,500,000 (see appendix A).

5.3 Mechanical Treatment

As mentioned above, mechanical treatment costs were estimated using actual capital costs or actual design / build proposal costs for similar remote northern mechanical treatment plants as benchmark projects. To account for rising costs, inflation multiplication factors were based on the Canadian Consumer Price Index (CPI) for the reference project relative to the current CPI.

To account for the differences in design flow a log-log linear model was derived from small wastewater treatment plant cost data presented in the United States Environmental Protection Agency (USEPA)'s *Biological Nutrient removal Processes and Costs (2007)*; this model was then used to interpolate or extrapolate costs for systems at the reference project and Inuvik design flows. The capacity multiplication factors are based on the relative costs predicted by the model.

The location and accessibility of a given project is always a significant factor in a given project. As mentioned above, the actual capital costs for a given alternative will ultimately depend upon a number of factors relating specifically to Inuvik's remote location; more in-depth cost estimation should be completed before proceeding with any option presented in this report.

5.3.1 SBR

The design and build bid price for the SBR benchmark mechanical treatment facility was approximately $6,000,000 in 2005. The Average Daily Design flow (ADD) for the benchmark SBR was 104 m^3/d; Inuvik's required ADD is 1920 m^3/d. Cost multiplication factors of 1.15 for inflation and 2.63 for capacity were applied to the benchmark estimate to provide an estimated capital cost in Inuvik.

A preliminary capital cost estimate for an SBR mechanical treatment plant is $18,500,000.

5.3.2 MBBR

The design and build bid price for the MBBR benchmark mechanical treatment facility was approximately $16,500,000 in 2009. The ADD for the benchmark MBBR was 2250 m^3/d; Inuvik's required ADD is 1920 m^3/d. Cost multiplication factors of 1.07 for inflation and 0.94 for capacity were applied to the benchmark estimate to provide an estimated capital cost in Inuvik. The slightly smaller capacity required for Inuvik compared to benchmark nearly offsets inflation in this case.

A preliminary capital cost estimate for an MBBR mechanical treatment plant is $17,000,000.

5.3.3 DSA

The actual cost for the DSA benchmark mechanical treatment facility was approximately $26,500,000. The final costs for this project were totalled earlier this year so no inflation has been added. The capacity multiplication factor for the DSA benchmark is the same as the MBBR multiplication factors (0.94) since the ADD is the same.

A preliminary capital cost estimate for a DSA mechanical treatment plant is $25,500,000.

6. Operations and Maintenance Requirements for Improvements

6.1 Operation and Maintenance (O&M) Costs

Estimates presented in this section are strictly “order of magnitude” estimates based on previous submittals, general assumptions and guidelines. Actual costs are highly sensitive to the actual operating practices of the facility, and local factors such as electricity and fuel costs, and labour; more in-depth cost estimation should be completed before proceeding with any option presented in this report. The estimated O&M costs at Average Daily Design (ADD) flow are presented below in Table 6-1.

Assumptions and bases for the estimates are presented throughout the next few sections.

Table 6-1 Summary of O&M Cost Estimates (ADD)

Alternative	Labour Including Overhead	Treatment Power	Routine Maintenance, Includes: Parts, Materials, Installation, etc	Miscellaneous Includes: Facility Utilities, Insurance, Vehicle, Testing, Consumables, etc.	Total Estimated O&M Cost (ADD)
Lagoon Expansion: Conversion to Annual Discharge	$70,000	$ -	$15,000	$30,000	$115,000
Lagoon Enhancement	$70,000	$140,000	$20,000	$30,000	$260,000
SBR	$130,000	$335,000	$30,000	$200,000	$695,000
MBBR	$130,000	$335,000	$30,000	$200,000	$695,000
DSA	$130,000	$200,000	$30,000	$170,000	$530,000

6.1.1 Lagoon Expansion – Conversion to Annual Discharge

Operations and maintenance costs for an expanded lagoon with annual discharge would be comparable to current costs. A large portion of the costs are associated with the wages and burden for an operator. Allowances of $15,000 for routine maintenance and $30,000 for miscellaneous expenses (which include costs associated with a vehicle, laboratory testing, water licence reporting and other smaller expenses) comprise the remainder of the estimated costs.

6.1.2 Lagoon Enhancement

Under the NEI recommended option, operations and maintenance requirements are still relatively low. Costs would generally consist of wages and burden for an operator, costs for the operations of the SAGR blowers, an allowance for routine maintenance, and an allowance for miscellaneous expenses which include costs associated with a vehicle, laboratory testing, water licence reporting and other smaller expenses. Based on the NEI O&M estimate (adjusted for a power rate of 60.6¢/kWh including demand charges), the annual O&M cost for an enhanced lagoon is estimated at $260,000. This includes $70,000 for labour, $140,000 for blower power, and allowances of $20,000 for routine maintenance and $30,000 for miscellaneous expenses.

6.1.3 Mechanical Treatment

Operations and maintenance costs for mechanical treatment would be considerably higher than a lagoon based system. Costs would include wages and burden for more than one operator, treatment power costs, routine maintenance, and miscellaneous expenses. Treatment power costs would be associated with blowers, compressors, pumps, screening equipment, sludge handling and disinfection. Miscellaneous costs would include facility utilities (including heating), insurance, and consumables (including chemicals if required and UV bulb replacement if required) along with the other miscellaneous expenses applicable to the lagoon enhancement option above.

For the purposes of this report, it is assumed that mechanical treatment, regardless of the process, will have comparable labour. An allowance of $130,000 has been estimated to cover wages and burden for operators for all three mechanical treatment alternatives.

Treatment power requirements in most mechanical treatment facilities of the same size will generally be similar since most often it is the oxygen requirements of the biological processes that dictate the aeration required, which is the single largest component of treatment power. DSA is different from an aeration standpoint since the transfer efficiency is increased considerably, meaning that the aeration requirements, and subsequent treatment power costs, are reduced relative to other mechanical treatment plants of the same size.

To estimate the treatment power costs for mechanical treatment, actual treatment power use or design / build estimated uses have been linearly adjusted for ADD and estimated using a power cost of 60.6 ¢/kWh (including demand charges). It has been assumed that SBR and MBBR treatment power costs would be the same.

The miscellaneous costs have been estimated using actual / projected costs from a benchmark facility in operation, and adjusted to account for the differences in the cost of heating which is the single largest cost in this category. Like power costs, DSA would be expected to require less heating; miscellaneous costs are estimated to be slightly lower for DSA than for SBR or MBBR.

6.1.3.1 SBR

The annual O&M cost for an SBR mechanical treatment plant in Inuvik is estimated at $695,000 per year, which includes $130,000 for operators, $335,000 for treatment power costs, $30,000 for routine maintenance, and $200,000 for miscellaneous costs.

6.1.3.2 MBBR

The annual O&M cost for an MBBR mechanical treatment plant in Inuvik is estimated at $695,000 per year, which includes $130,000 for operators, $335,000 for treatment power costs, $30,000 for routine maintenance, and $200,000 for miscellaneous costs.

6.1.3.3 DSA

The annual O&M costs for a DSA mechanical treatment plant in Inuvik is estimated at $530,000 per year, which includes $130,000 for operators, $200,000 for treatment power costs, $30,000 for routine maintenance, and $170,000 for miscellaneous costs.

6.2 Operations and Maintenance Training

Although there is no currently legislated operator classification system for wastewater facilities in the Northwest Territories, it is expected that the mechanical treatment systems discussed will require a higher level of knowledge and skill from the operators. As an example, the new DSA treatment plant in Dawson City, YT requires a Level II Operator as certified by British Columbia's Environmental Operators Certification Program (EOCP).

A new mechanical treatment system would probably require an operator with an EOCP Level II Operator certification, or an equivalent designation from a different province (e.g. Level II Alberta Water and Wastewater Operator) to operate, and maintain the systems.

There is a shortage of certified operators in Western Canada, and finding and retaining higher levels of operators is challenging for less remote locations than Inuvik.

Conversely, a lagoon system, even with the proposed SAGR enhancements requires significantly less operator input, so training at the level currently offered by the GNWT School of Community Government would be appropriate.

7. Life Cycle Cost Estimates

A 20 Year Life Cycle Cost (LCC) estimate has been prepared for each alternative. Estimates presented in this section are strictly “order of magnitude” estimates based on previous submittals, general assumptions and guidelines. Actual life cycle costs are highly sensitive to the actual capital costs, operating practices of the facility, and local factors such as electricity, fuel costs, and labour. More in-depth cost estimation should be completed before proceeding with any option presented in this report.

The key assumptions for the LCC estimates are:

- Real discount rate of 3%
- A linear increase in flow from 620 ML/yr (current) to 700 ML/yr (ADD) in year 20
- 'Labour', 'Routine Maintenance' and $30K from 'Miscellaneous' are fixed over the 20 year period
- 'Treatment Power', and 'Miscellaneous’ (less $30K) are scaled based on the flow in current year relative to ADD
- For alternatives that continue to utilize the existing lagoon system, the current lagoon infrastructure has been given a value of $10,000,000 and assumed to consist entirely of 50 year assets in good repair
- For the lagoon enhancement alternative, the civil work capital costs have been considered 50 year assets; equipment listed in the NEI quote has been classified as either 20 year assets (60%) or 10 year assets (40%)
- For all mechanical treatment options, it has been estimated that 50% of the capital costs are 50 year assets, while 30% are 20 year assets and 20% are 10 year assets.
- All options[14] received one renewal of 10 year assets at the current estimated value.
- At the end of 20 years, 10 year assets (renewed at year 10) and 20 year assets are assumed to have a salvage value of zero.
- Salvage values for 50 year assets are assumed to be 60% of the current value (i.e. linear capital consumption).
- No costs have been incorporated for decommissioning.

The 20 Year LCCs are presented in Table 7-1.

Table 7-1 Present Value 20 Year Life Cycle Costs

Alternative	Present Value (PV) 20 years O&M	Capital Cost Estimate	Existing Asset Value	Renewal Costs - Year 10 (PV)	Salvage Value (PV)	Net Capital Consumption	Total 20 Year Life Cycle Cost
Lagoon Expansion: Conversion to Annual Discharge	$ 1,830,000	$ 18,000,000	$ 10,000,000	$ -	$ 16,800,000	$ 11,200,000	$ 13,000,000
Lagoon Enhancement	$ 4,240,000	$ 6,500,000	$ 10,000,000	$ 230,000	$ 8,700,000	$ 7,800,000	$ 12,000,000
SBR	$ 13,340,000	$ 18,500,000	$ -	$ 2,750,000	$ 5,550,000	$ 12,950,000	$ 26,300,000
MBBR	$ 13,110,000	$ 17,000,000	$ -	$ 2,530,000	$ 5,100,000	$ 11,900,000	$ 25,000,000
DSA	$ 11,910,000	$ 25,500,000	$ -	$ 3,790,000	$ 7,650,000	$ 17,850,000	$ 29,800,000

[14] *Lagoon expansion did not include any 10 year or 20 year assets and as such did not require or receive a renewal in year 10.*

8. Conclusions and Recommendations

The Assessment Report, based on findings from the Effluent Impact Report and the DIAND Report, concluded that the wastewater effluent from the lagoon was having minimal to negligible impact on the East Channel. Population and commercial trends have remained relatively stable since that time, so it is probable that the environmental impact of Inuvik's treated wastewater remains negligible.

The existing lagoon system is doing a reasonably good job of treating Inuvik's municipal wastewater, with excellent summer and fall performance and at least primary treatment for winter and spring.

The regulatory environment for wastewater treatment facilities in Canada is changing, such that the existing lagoon system may not meet new national standards for cBOD (December through May). During low flow periods in the East Channel (late winter), coliform counts may not be meeting existing NWT water quality objectives, but this is mitigated almost entirely by the thick ice cover and the recommended practice of treating all surface waters for downstream potable water applications.

For the purpose of fulfilling Condition B-10 of the Town of Inuvik's water licence G06L3-01, several alternatives for sewage treatment were explored, with the assumption that the DFO's Wastewater Systems Effluent Regulations, recently enacted in the rest of Canada, will also eventually be applied to Canada's Far North.

The options investigated, and the key results are presented below in Table 8-1.

Table 8-1 Alternative Highlights

Alternative	Meet DFO Regulated Standards?	Level of Skill Required for Operator	Estimated Annual O&M Cost (ADD)	Estimated Capital Cost	Estimated 20 Year Life Cycle Cost
Lagoon Expansion: Conversion to Annual Discharge	Yes	Basic	$115,000	$ 18,000,000	$ 13,000,000
Lagoon Enhancement	Yes	Basic	$260,000	$ 6,500,000	$ 12,000,000
SBR	Yes	Trained	$695,000	$ 18,500,000	$ 26,300,000
MBBR	Yes	Trained	$695,000	$ 17,000,000	$ 25,000,000
DSA	Yes	Trained	$530,000	$ 25,500,000	$ 29,800,000

Based on the findings in this report, the recommended course of action for the Town of Inuvik (should it be required to improve the effluent quality due to new regulatory constraints) would be to implement the SAGR tertiary treatment lagoon enhancement recommended by NEI. This option would be the most appropriate option in consideration of capital and 20 year life cycle costs, as well as operational training requirements.

9. References

The following reports pertaining to the Inuvik lagoon have been reviewed and the applicable data have been incorporated into this report.

- "**Assessment of Wastewater Management Facilities – Report to the Gwich'in Land and Water Board**" AECOM, June 2004 (referred to as the Assessment Report)

- **"Inuvik Sewage Plume Study"** Department of Indian Affairs and Northern Development (DIAND) – Government of Canada, 1998 (referred to as DIAND Report)

- "**Report for Town of Inuvik, NT – Wastewater Treatment System Upgrade**" Nelson Environmental Inc., August 2011 (referred to as NEI 2011)

- **"Town of Inuvik, Lagoon Effluent Impact Assessment"** AECOM 1994 (legacy company Reid Crowther & Partners Ltd. – referred to as the Effluent Impact Report)

- "**Unit Cost of Water, 2006**" AECOM, February 2008 (referred to as the Unit Cost Report)

Appendix A

Nelson Environmental Inc.

Report for: Town of Inuvik, NT

Wastewater Treatment System Upgrade

Wastewater Treatment

NELSON ENVIRONMENTAL INC.

Report for:

Town of Inuvik, NT
Wastewater Treatment System Upgrade

August 30, 2011

Project Reference: 511.1922.01

OOOOO OOOOOO Nelson Environmental Inc.

94 Durand Road Winnipeg, Manitoba Canada R2J 3T2 **Toll Free:** (888) 426-8180 **Tel:** (204) 949-7500 **Fax:** (204) 237-0660 **www.nelsonenvironmental.com**

Contents

Appendices:

1.0 Introduction

This report has been prepared by Nelson Environmental Inc (NEI) on behalf of the Town of Inuvik. NEI is an engineering and construction company that specializes in lagoon based cold climate wastewater treatment processes. Based on our experience in other small to medium community cold climate work, a preferred option that will meet the long term wastewater treatment needs of the Town of Inuvik will be presented.

Nelson Environmental Company Profile

Nelson Environmental's (NEI) mission is to provide reliable, cost-effective solutions for water and wastewater treatment worldwide. We are complete solution providers, offering a diversified mix of expertise, methodologies and technologies. Our intention is to partner with our clients to reliably achieve water quality goals in the long-term. To that end, we continue to develop the most technically advanced wastewater treatment methods and equipment, while still maintaining simplicity of operation.

The company is currently involved in municipal and industrial water and wastewater projects from coast to coast in Canada, in the United States, and overseas. A significant percentage of the projects performed by the company are the result of strong referrals from previous clients. Nelson Environmental Inc. and parent company Nelson River Construction Inc. have roots tracing back to 1923.

NEI experience in surface water based treatment systems is extensive. We have designed and implemented more than 150 biological water and wastewater treatment systems in both hot and cold climates. We have successfully completed projects from raw water reservoir aeration systems to full "turn-key" design and construction of large industrial wastewater treatment facilities.

Nelson Environmental Inc. has focused on the development of integrated wastewater treatment technologies and designs that maintain the low capital and operation and maintenance costs of traditional stabilization and aerated lagoons, but can achieve effluent quality more in line with “high-tech” advanced treatment facilities. Through our in-house Research and Development program, we are continually improving both our treatment processes and equipment.

With any project, NEI’s goal is to create systems that have a minimum design life of 20 years and that can meet effluent requirements during this design period. Through modular design of treatment technologies, future regulations (i.e. nutrient removal) can be met without significant changes to the fixed infrastructure.

2.0 Background

The community of Inuvik currently treats wastewater in a 5-cell facultative lagoon system. The facility has been in service since 1957, with a significant upgrade in 1982. The Inuvik sewage treatment facility discharges to the East Channel of the Mackenzie River. Information on the current state of treatment facilities, including dimensions and loading, is based on site inspection and discussion with the operator, as well as information contained in the following reports:

"Operation & Maintenance Manual", prepared by Earth Tech Canada
"Unit Cost of Water, 2006", prepared by Earth Tech Canada.
"*Assessment of Wastewater Management Facilities – Report to the Gwich'in Land and Water Board",* prepared by Earth Tech Canada

The facility services a population of 3,354 (2006). Approximately 97 percent of the wastewater entering the facility originates at the water treatment plant, and is distributed and recollected by Inuvik's above ground piped utilidor system. An additional 3 percent is distributed and recollected by trucks. Wastewater originating from separate water supplies is negligible. Because inflow and infiltration is not common with the Utilidor system, inflow into the lagoon is approximately equal to the community's metered production of water.

In 2003, the total estimated retention time in the lagoons was approximately 200 days in summer. Ice formation reduces the total retention time to approximately 56 days in winter. It is estimated, based on flow projections by Earth Tech Canada, that total retention time in 2026 will be 150 days in summer, and 42 days in winter. While biological treatment in summer is excellent in the lagoon system, the short winter retention time, ice cover, and cold water temperatures limit treatment in winter to primary solids settling. Actual lagoon volumes have not been calculated due to the irregular shape and bottom profile of the cells.

Past studies by Earth Tech Canada indicate that the facility struggles to meet the effluent quality requirements of their permit during the cold winter months. Efforts to reduce water consumption in the community have reduced hydraulic loading to the lagoon system, but have had the effect of increasing the wastewater influent and effluent BOD and TSS concentrations. These same reports have projected a community growth that will further tax the existing wastewater treatment facility. The upgraded system design flow is based on projected 2026 water demand at 700,000 m^3 per year.

3.0 Effluent Quality Regulations

The Canadian Council of Ministers of the Environment (CCME) has developed a strategy to harmonize wastewater treatment facility management Canada-wide. The federal government has developed the *Wastewater Systems Effluent Regulations* under the *Fisheries Act* to implement the CCME strategy. These regulations came into effect in March 2010. Due to severe climatic conditions in Canada's far north, these regulations do not apply in the Northwest Territories, Nunavut and north of the 54th parallel in Quebec and Newfoundland and Labrador. As a result, Inuvik is currently exempt for meeting these regulations. (*Wastewater Systems Effluent Regulations*, Extract Canada Gazette, 2010)

It is anticipated that following a review of available technology and water quality objectives, the CCME will revise effluent standards for treatment facilities north of the 54th parallel, in Nunavut and the Northwest Territories within the next five years. These standards may be less stringent than those currently applicable to the rest of the country due to the extreme climate conditions faced by northern treatment facilities.

It is proposed that the design and construction of Inuvik's proposed upgraded facility ensure that current CCME effluent requirements of 25/25 BOD_5/TSS are met year round. It is also recommended that effluent total ammonia levels of 5 mg/l in summer and 10 mg/l in winter be targeted to ensure effluent will not be toxic to fish in the receiving stream. As a result, this facility will be poised to meet and exceed the anticipated effluent quality standards once they are published.

4.0 Nelson Environmental Site Visit

NEI performed a site visit on July 21, 2011, and toured the lagoon with the operator, Rick Campbell. The lagoons appeared to be in good condition and well maintained, and all berms appeared to be in good condition. The operator indicated that he has kept up with berm maintenance, grading, and sludge removal from the primary cells.

Effluent from the lagoon flows into a short creek, then into the East branch of the Mackenzie River. The lagoon system discharges continuously, with the water level in the secondary lagoon maintained by stop logs. There have been periodic issues with ice damming and freezing in the discharge waterway, but on the whole the system functions without serious operational issues.

The existing effluent control structure dates from the system upgrade that was done in 1982. The structure is still reasonably sound, but is in need of an upgrade. The existing CSP drain pipes under the discharge structure have started to fail, and remediation work will be needed in the near future.

There is little documentation regarding the actual bottom profile and sludge accumulations in the lagoon system. It was noted by the operator that sludge or other high points were visible when the water was partially drained down for maintenance. It is recommended that an accurate survey of the bottom be done if there is consideration to install aeration equipment in the lagoon.

The existing transfer structures and piping appear to be functioning, with the exception of the transfer pipe between the two primary cells. Assessing the physical condition of the piping and control structures was not part of the scope of this site visit.

Brief discussions were held with the operator regarding the availability of land near the lagoons for potential development of new wastewater treatment facilities. Land to the northeast of the lagoon is swampy and seemingly unsuitable. Significant commercial development is present immediately east of the lagoons. Land to the west, which formerly held the municipal airstrip, is currently broken up by a natural gas right of way. Town-owned land to the north of the existing lagoons may be suitable for the installation of additional treatment facilities. This land lies between the secondary lagoon and the Town tank farm. Note, however, that an existing natural gas pipeline right of way runs East-West immediately to the north of the lagoon. Piping would need to cross this ROW if any further facilities were developed on land north of the lagoon.

Figure 1: Site photos, 21 July 2011

5.0 Project Overview

Based on the NEI site visit and review and analyses of existing data and reports, three options to upgrade the town of Inuvik's lagoon wastewater treatment facility to meet existing and anticipated effluent requirements will be presented. Emphasis on technology functionality in extreme cold climates in remote locations such as Inuvik is critical in evaluating upgrade options.

The proposed upgrades would increase the treatment efficiency of the facility to consistently meet BOD_5 and TSS effluent requirements on a year round basis. A secondary goal for the upgraded system is to provide ammonia removal during both summer and winter operation to protect the East Channel and its aquatic biota from toxic effects associated with un-ionized ammonia (NH_3). The system designed is based on the Canadian Council of Ministers of the Environment's (CCME's) strategy to harmonize wastewater treatment facility management Canada-wide.

System Design Objectives

The system design flow is based on projected 2026 water demand at 700,000 m^3 per year, based on the *Unit Cost of Water, 2006* report by Earth Tech Canada. Preliminary design loads, flows and effluent requirements are summarized in the following table:

		Influent 2026**	Effluent Requirement	Effluent Objective
Design Flow	m^3year	700,000		
Design Flow	m^3/day	1,917		
cBOD	mg/L	203	100	25
TSS	mg/L	200	70	25
TAN	mg/L	40	-	5*/10
Fecal Coliform	CFU/100ml	-	1,000,000	200

summer*/winter

Influent loading assumed based on design population and flow

Effluent requirements are based on the current discharge permit, set to expire in 2016. Because a new permit is not in place, actual effluent requirements are not yet known. The effluent BOD and TSS objectives presented here are based on meeting current CCME guidelines in place in other parts of Canada. Effluent objective TAN levels will prevent toxicity to fish in the receiving stream. Effluent Fecal Coliform objective is typical of many facilities, and maintains recreational value of the receiving stream.

Proposed Options

The following three options will be presented and considered:

Option 1: Convert two existing facultative lagoons to aerated lagoons

> The proposed lagoon upgrade would consist of converting two (2) of the existing facultative lagoons to partial mix aerated cells followed by a facultative cell for secondary treatment, settling, and polishing.

Option 2: Existing Facultative lagoon with SAGR (Submerged Attached Growth Reactor)

> The proposed lagoon upgrade would consist of two existing (2) facultative primary treatment cells and the existing facultative secondary treatment cell, followed by a SAGR for BOD_5 polishing and TSS removal, as well as nitrification (ammonia reduction).

Option 3: Convert two existing facultative cells to aerated lagoons, and implement a SAGR (Submerged Attached Growth Reactor).

> The proposed lagoon upgrade would consist of converting two (2) of the existing facultative lagoons to partial mix aerated cells followed by a facultative cell for secondary treatment, settling, and polishing. The facultative lagoon system would be followed by a SAGR for BOD_5 polishing and TSS removal, as well as nitrification (ammonia reduction).

6.0 Option 1: Upgrade Existing Facultative Cells to Aerated Lagoon Cells

Process Overview:

The existing facultative lagoon would be upgraded by the addition of an aeration system to the two existing primary cells. The upgraded lagoon process includes the following technologies and/or process changes:

- Implement partial mix coarse bubble aeration in the existing two primary treatment facultative cells, operated in parallel.
- Retain the existing facultative secondary lagoon for effluent TSS settling and additional BOD removal.

Process Description: Aerated Lagoon Partial Mix (PM) Cell

In an aerated lagoon, BOD_5 is reduced to carbon dioxide, water, and inert ash by natural bacteria, which receive their oxygen supply from air provided through the aeration diffusers. Because the aeration bubbles not only provide oxygen but also mix the water, the oxygen is evenly distributed throughout the water body.

With aerated partial mix cells, the diffuser density is based upon oxygen demand. The aerated lagoon system does not rely on algae or natural surface aeration to provide oxygen to the wastewater.

The diffusers are suspended from floating HDPE laterals, at a uniform depth near the bottom of the cells. Diffuser assemblies can be retrieved from a light boat with no special equipment.

Through the rise of the bubbles and subsequent mixing, convection cells are created between the diffusers. Not only does the water rise with the bubbles, the solids settle out through the downward motion of the water between the diffusers where the circulation loop is completed. This, combined with the slow rate of bubble rise, contributes to the overall efficiency of the system.

When the solids reach the bottom of the lagoon, additional oxygen for biodegradation is provided through the diffusers near the cell bottom. This process results in minimal organic bottom sludge accumulation. Aerobic digestion takes place within the aerated cells at the sludge water interface. Because of low sludge production in the system, retention time is retained for long term BOD_5 removal.

Equipment Description: HDPE Header System (Aerated Treatment Cells)

Galvanized metal manifold/discharge piping is used to dissipate the heat produced by the blowers, to a level compatible with the HDPE distribution piping. An insulated, above ground, HDPE header piping connects to the galvanized metal header, and supplies air to the floating laterals. Each lateral is individually valved for ease of maintenance.

Laterals connect to the out of water header, and float on the water surface (freeze into the ice in winter). With floating laterals, no equipment is required to be in contact with the bottom of the lagoon. Laterals are secured against wind action with a stainless steel cable system. The cables are fastened to anchors in the lagoon berm using a self-adjusting lateral tensioning assembly. All header and lateral piping, joints, and fittings are thermally fused HDPE.

With floating laterals the cells do not have to be dewatered or taken out of service for system installation or maintenance. All maintenance can be performed from a boat with a 2-person crew.

All header, lateral, and feeder piping is designed to accommodate increased airflow for high pressure and volume cleaning without increasing header friction losses by more than 1 psi. This allows for management of additional organic load, improved diffuser maintenance and additional odor control.

A. Design Parameters

Aeration design parameters are summarized in the following table:

Aeration Design Parameters - Coarse Bubble System				
	Cell 1 (Aerated)	**Cell 2 (Aerated)**	**Cell 3 (Facultative)**	**Total**
Alpha	0.70	0.70	-	
Beta	0.95	0.95	-	
Theta	1.024	1.024	-	
Site elevation (m)	9	9	9	
Approximate Water depth (m)	4.4	4.4	3.5	
Approximate winter ice depth (m)	1.2	1.2	2.5	
Approximate water volume (m^3)	31,069	31,069	311,068	373,206
Min. Dissolved Oxygen (mg/l)	2.0	2.0	-	
Ke - summer (day-1)	0.126	0.126	-	
Ke - winter (day-1)	0.048	0.048	-	
Estimated Min Winter Water Temp (^oC)	0.5	0.5	-	
# HC-16 diffusers (design)	80	80	-	160
SCFM per diffuser	15.0	15.0	-	
Total SCFM (design)	1200.0	1200.0	-	2400.0

B. System Performance

Expected system effluent quality is shown in the following table:

		Influent 2026**	Effluent Requirement	Effluent Objective	Expected Effluent
Design Flow	m^3year	700			
Design Flow	m^3/day	1,917			
cBOD	mg/L	203	100	25	90
TSS	mg/L	200	70	25	40**
TAN	mg/L	40	-	5*/10	40
Fecal Coliform	CFU/100ml	-	1,000,000	200	-

*Summer/Winter
**May be exceeded in Summer due to Algae

The aerated lagoon system will typically meet the current system effluent requirements, but is not expected to meet any of the effluent quality objectives based on the anticipated upcoming CCME guidelines.

C. Operation and Maintenance Costs

Air supply for the lagoon aeration system would be provided by three (3) 60.0 hp positive displacement blowers. The blowers would each operate at 43.6 bhp. Two blowers would be in operation with one on standby.

				*Electrical Rate:	**0.4345**	$/kW-h		
		Operating	**Total**			**Monthly**	**Unit**	**Annual**
	Quantity	**# Months**	**SCFM**	**bhp**	**kW**	**cost**	**cost**	**Cost**
Aeration Lagoon Blowers	**3**							
Operating Conditions	2	12	**2400**	87.2	65.1	$20,633	-	$247,599
Filter Change (6 months)	-	-	-	-	-	-	$80	$320
Oil Change (12 months)	-	-	-	-	-	-	$200	$400
Belt Replacement (24 months)	-	-	-	-	-	-	$250	$250
Total Operation & Materials								$248,569
* Electrical rate from report, *Town of Inuvik Unit Cost of Watrer, 2006*								

The aeration system will require an operator for routine inspection & maintenance.
Maintenance requirements may include:

- Daily site inspection and recording of aeration system operating parameters (temperature, pressure, etc)
- Blower maintenance – belt tensioning, oil changes, intake filters
- Floating lateral adjustment
- Header condensate purging/operate blow-off valves

7.0 Option 2 – SAGR (Submerged Attached Growth Reactor)

Process Overview:

The existing facultative lagoon would be retained, and a SAGR (Submerged Attached Growth Reactor) would be constructed adjacent to the existing discharge location. The upgraded treatment process would include the following technologies and/or process changes:

- Retain existing lagoon infrastructure, using existing facultative cells for primary treatment and solids settling.
- Construct a SAGR process after the secondary facultative cell for BOD_5 and TSS removal, as well as nitrification (ammonia removal) and fecal and total coliform reduction.

The Submerged Attached Growth Reactor (SAGR) is designed to provide nitrification (ammonia removal) in cold to moderate climates as well as CBOD, TSS, and harmful bacteria removal. The SAGR is a clean gravel bed with evenly distributed wastewater flow across the width of the cell, and a horizontal collection chamber at the back end of the system. The top of SAGR is covered in a layer of mulch or wood chips to provide insulation for the gravel bed. Insulating material is chosen based on local availability/quality of material.

Figure 2: Rendering of the Glencoe, ON SAGR installation (2010)
SAGR following aerated lagoon, 1800 m^3/day

The SAGR is typically constructed as a pair of treatment beds, each receiving half the influent flow. The perimeter of the bed is defined by an impermeable geomembrane liner (e.g. 60 mil HDPE) supported by a sacrificial wood framed wall. Once the SAGR is filled with aggregate and the excavation backfilled, the surface of the SAGR is level with the surrounding grade. Because of permafrost conditions present at Inuvik, the SAGR beds would likely be built above ground on an insulating structure, with the sides of the bed supported and insulated by earthen berms. Local sources of aggregate appear to be adequate for SAGR construction.

Flow into the SAGR beds is divided by a splitting structure (between the beds at the upper right of Figure 2), and then distributed along the width of the bed into stacked distribution chambers. This ensures that flow is spread across the entire volume of the bed to avoid short-circuiting. Two sets of influent distribution (primary and secondary) are used at various times of year to ensure consistent year-round treatment. For further details of SAGR bed construction, please refer to the proposal drawings in Appendix A.

Process Performance: SAGR

The SAGR process was developed by Nelson Environmental in response to tightening effluent discharge ammonia limits being enacted in various jurisdictions across North America. Many small to medium size communities face new discharge regulations that formerly could only be met by capital- and technology-intensive mechanical treatment plants. Using three years of data from two demonstration sites, one at Steinbach, MB, near Winnipeg, and the other at Lloydminster, SK, the performance of the SAGR process has clearly been demonstrated.

While primarily developed for nitrification (ammonia removal) of lagoon effluent, the SAGR process is also highly effective at removing BOD_5 and TSS. The following three graphs present weekly BOD_5 and TSS data from the Steinbach and Lloydminster demonstration sites.

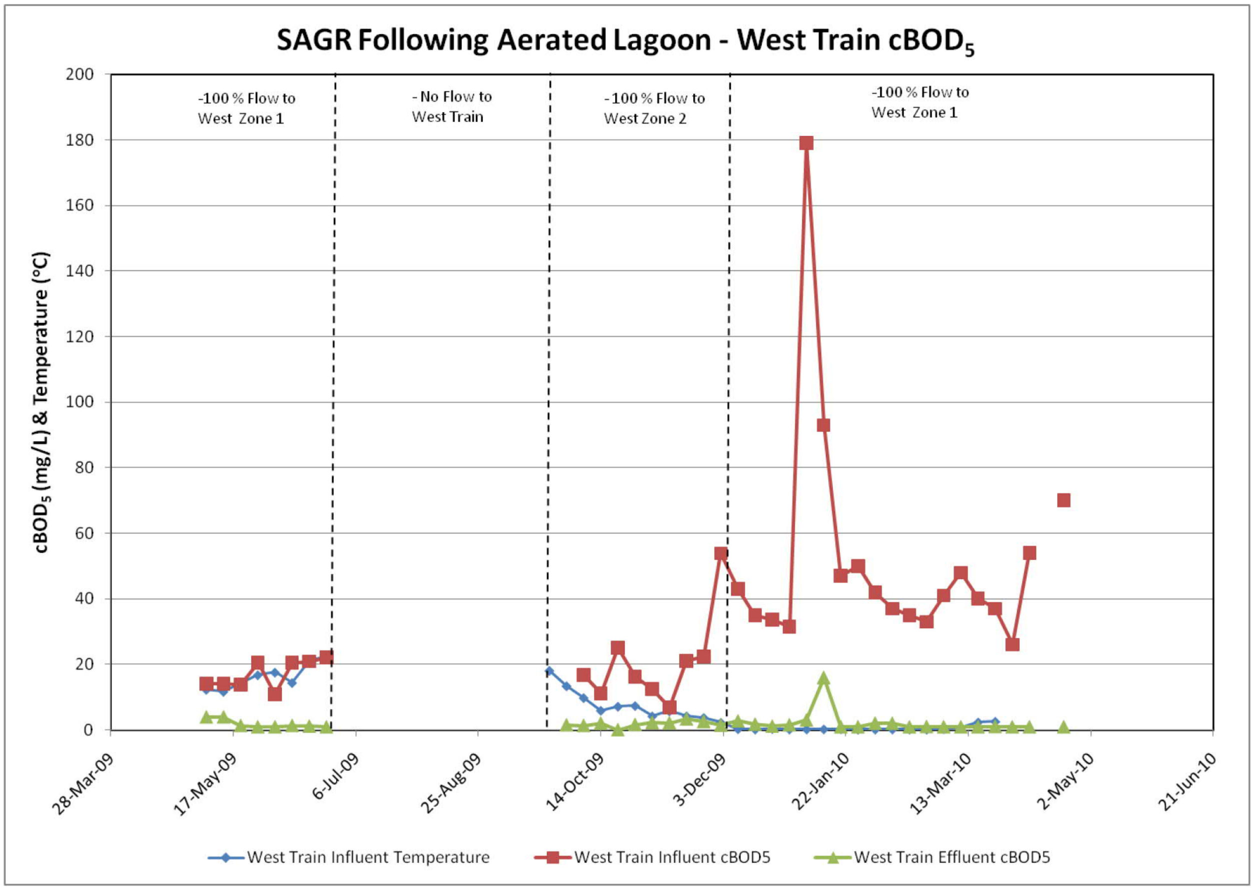


Figure 3: BOD_5 Removal at the Steinbach, MB SAGR Demonstration Site

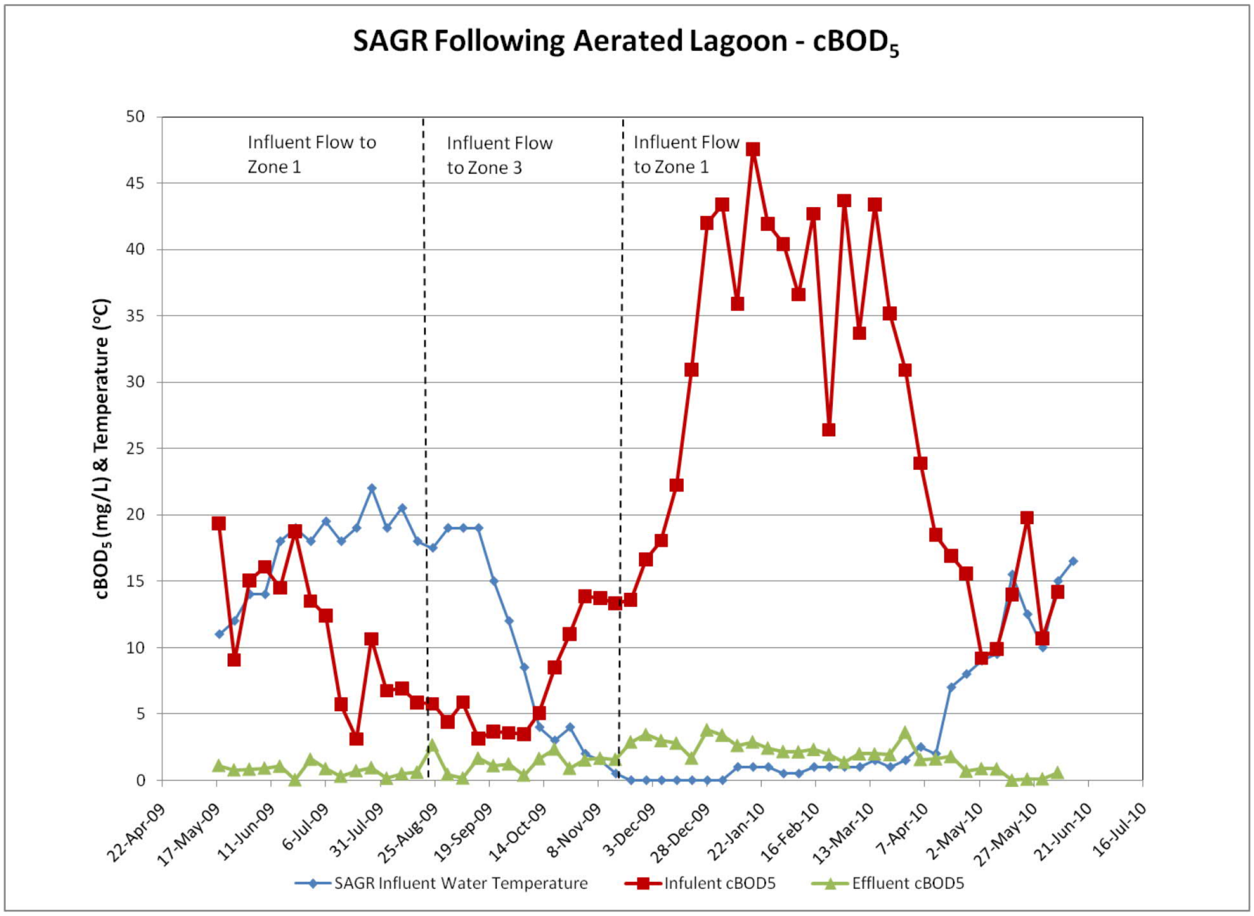


Figure 4: BOD_5 Removal at the Lloydminster, SK SAGR Demonstration Site

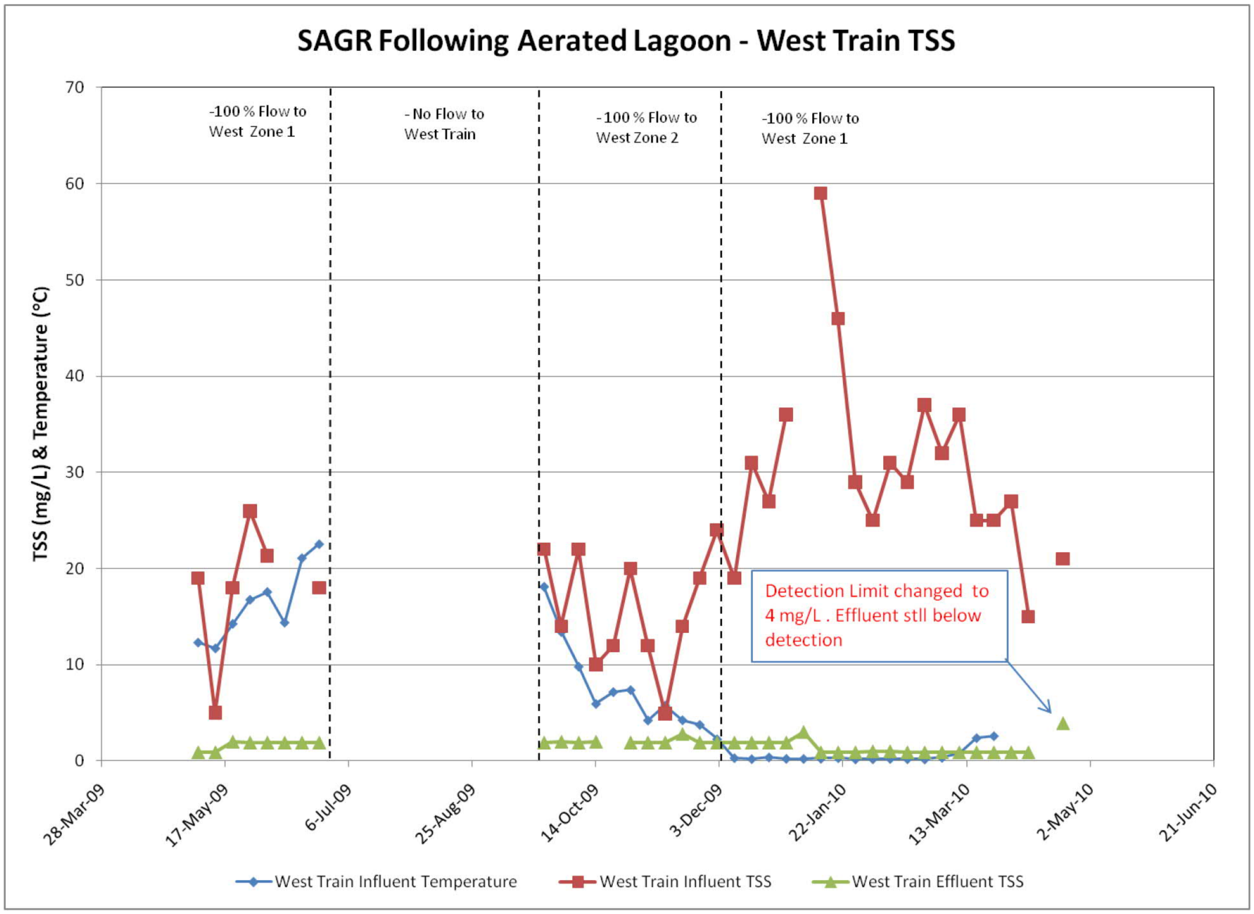


Figure 5: TSS removal at the Steinbach, MB SAGR Demonstration Site

For more complete data and discussion, please see additional information located in Appendix B.

The SAGR process is specifically designed for consistent treatment at low (<0.5°C) influent water temperatures. Both the Steinbach and Lloydminster sites experience influent water temperatures below 1.0°C for up to five months over the winter. As shown in the following comparison graph, Inuvik is significantly colder yet than either demonstration site. Given that the Town tempers the water supply throughout the winter to prevent freezing problems in the utilidor system, the climatic differences may not result in significantly longer periods of low influent water temperatures. It is anticipated that SAGR effluent water quality in Inuvik will closely match Winnipeg winter effluent quality year round. Some heat gain is expected due to biological activity in the bed.

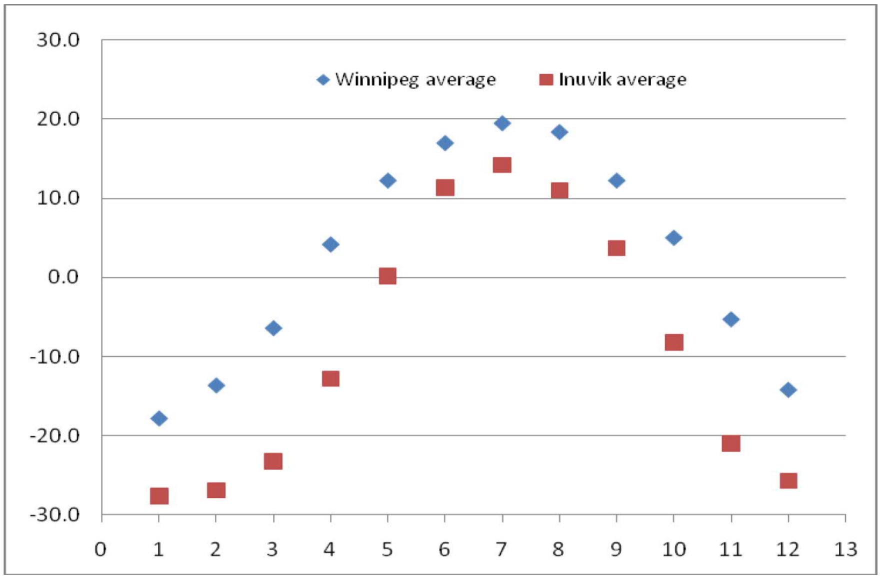


Figure 6: Comparison of Average Temperatures

The SAGR is not designed as a disinfection system; however, weekly data samples from the two demonstration sites have demonstrated consistent reductions in E.Coli as well as fecal and total coliform bacteria counts. As shown in the graph below, a SAGR could greatly reduce E.Coli discharge into the East Branch of the Mackenzie River.

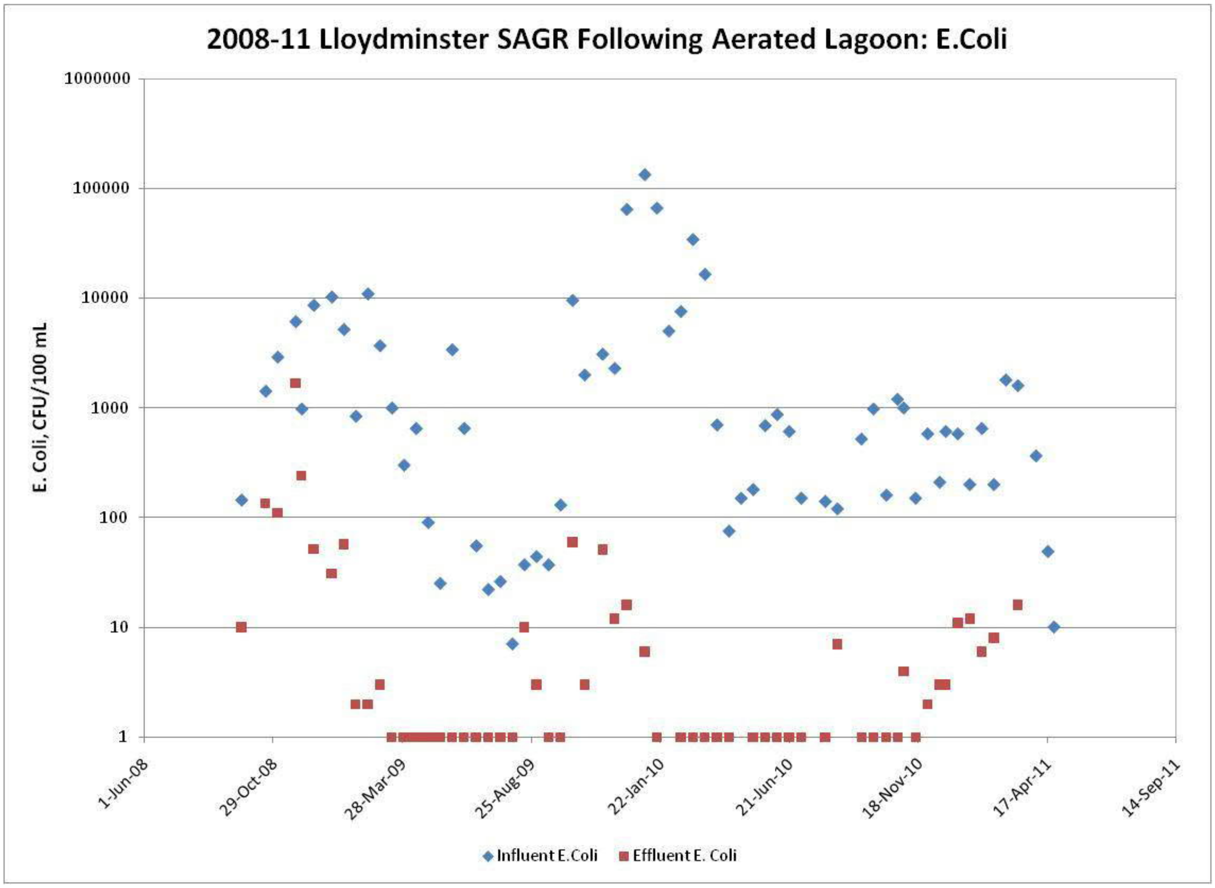


Figure 7: Influent and Effluent E. Coli at Lloydminster, SK Demonstration Site.

Equipment Description: SAGR

LINEAR aeration throughout the floor of the SAGR provides aerobic conditions that are required for the treatment process, as well as enhancing sludge digestion in the gravel layer. The diffusers are spaced according to the projected oxygen demand in the SAGR. The diffusers are specifically designed to be direct buried. Care has to be taken however during the rock installation to ensure that the diffusers remain aligned and are not moved excessively.

High Density Polyethylene (HDPE) air feed laterals are located in the top layer of insulating mulch along each side of the SAGR. A shallow buried HDPE header connects blowers to the SAGR laterals. All header and feeder piping is designed to accommodate increased airflow for high pressure and volume cleaning without increasing header friction losses by more than 1 psi.

Air supply for the SAGR aeration system will be provided by positive displacement blowers equipped with sound attenuating enclosures. The air supply is designed with multiple blowers in order to have standby (backup) in the case of a blower failure.

A. Design Parameters

SAGR system design parameters are summarized in the following table:

SAGR LINEAR Aeration System	
	SAGR
Alpha	0.70
Beta	0.95
Theta	1.024
Site elevation (m)	9
SAGR Depth (m)	3.5
Min. Dissolved Oxygen (mg/l)	3.0
Total SCFM	738

B. System Performance

		Influent 2026**	**Effluent Requirement**	**Effluent Objective**	**Expected Effluent**
Design Flow	m^3year	700			
Design Flow	m^3/day	1,917			
cBOD	mg/L	203	100	25	<25
TSS	mg/L	200	70	25	<25
TAN	mg/L	40	-	5*/10	<5*/10
Fecal Coliform	CFU/100ml	-	1,000,000	200	<200

*Summer/Winter

Option 2 which consists of a SAGR following the existing facultative lagoons, is expected to meet all current effluent requirements, as well as future anticipated requirements based on CCME guidelines in place in other regions in Canada.

C. Operation and Maintenance Costs

Air supply for the SAGR aeration system would be provided by two (2) 50.0 hp positive displacement blowers. One blower would operate at 35.0 bhp with one on standby.

			*Electrical Rate:		0.4345	$/kW-h		
		Operating	Total			Monthly	Unit	Annual
	Quantity	# Months	SCFM	bhp	kW	cost	cost	Cost
SAGR Blowers	**2**							
Operating Conditions	1	12	**740**	35	26.1	$8,282	-	$99,380
Filters (6 months)	-	-	-	-	-	-	$80	$160
Oil (12 months)	-	-	-	-	-	-	$100	$100
Belts (24 months)	-	-	-	-	-	-	$250	$125
Total Operation & Materials								$99,765

* Electrical rate from report, *Town of Inuvik Unit Cost of Watrer, 2006*

The aeration system will require an operator or routine inspection & maintenance. Maintenance requirements may include:

- Daily site inspection and recording of aeration system operating parameters (temperature, pressure, etc)
- Blower maintenance – belt tensioning, oil changes, intake filters
- Condensate purging/operate blow-off valves
- SAGR step feed operation (manipulating influent valves twice a year to ensure year-round treatment)

8.0 Option 3: Aerated lagoon followed by a SAGR

The performance of Option 1 can be improved by constructing a SAGR following the facultative secondary cell. This SAGR would be smaller than the SAGR required in Option 2. See Options 1 and 2 for detailed descriptions of the aerated lagoon and SAGR processes.

The upgraded lagoon with SAGR process includes the following technologies and/or process changes:

- Implement coarse bubble partial mix aeration in the existing two primary treatment facultative cells.
- Retain the existing facultative secondary cell for additional solids settling.
- Design and construct a SAGR Basin (civil works by others)
- Construct a SAGR after the secondary facultative cell for BOD_5 and TSS removal, as well as nitrification (ammonia removal) and fecal and total coliform reduction.

A. Design Parameters

Aeration design parameters are summarized in the following table:

Aeration Design Parameters - Coarse Bubble System				
	Cell 1 (Aerated)	Cell 2 (Aerated)	Cell 3 (Facultative)	Total
Alpha	0.70	0.70	-	
Beta	0.95	0.95	-	
Theta	1.024	1.024	-	
Site elevation (m)	9	9	9	
Approximate Water depth (m)	4.4	4.4	3.5	
Approximate winter ice depth (m)	1.2	1.2	2.5	
Approximate water volume (m^3)	31,069	31,069	311,068	373,206
Min. Dissolved Oxygen (mg/l)	2.0	2.0	-	
Ke - summer (day-1)	0.126	0.126	-	
Ke - winter (day-1)	0.048	0.048	-	
Estimated Min Winter Water Temp (^oC)	0.5	0.5	-	
# HC-16 diffusers (design)	80	80	-	160
SCFM per diffuser	15.0	15.0	-	
Total SCFM (design)	1200.0	1200.0	-	2400.0

SAGR aeration design parameters are summarized in the following table:

SAGR LINEAR Aeration System	
	SAGR
Alpha	0.70
Beta	0.95
Theta	1.024
Site elevation (m)	9
SAGR Depth (m)	3.5
Min. Dissolved Oxygen (mg/l)	3.0
Total SCFM	522

B. System Performance

		Influent 2026**	**Effluent Requirement**	**Effluent Objective**	**Expected Effluent**
Design Flow	m^3year	700			
Design Flow	m^3/day	1,917			
cBOD	mg/L	203	100	25	<25
TSS	mg/L	200	70	25	<25
TAN	mg/L	40	-	5*/10	<5*/10
Fecal Coliform	CFU/100ml	-	1,000,000	200	<200

*Summer/Winter

Design option 3 consisting of an aerated lagoon with SAGR is expected to meet all current effluent requirements, as well as future anticipated requirements based on CCME guidelines in place in other regions in Canada.

C. Operation and Maintenance Costs

Air supply for the lagoon aeration system would be provided by three (3) 60.0 hp positive displacement blowers. The blowers would each operate at 43.6 bhp. Two blowers would be in operation with one on standby.

Air supply for the SAGR aeration system would be provided by two (2) 50.0 hp positive displacement blowers. One blower would operate at 24.2 bhp with one on standby.

			*Electrical Rate:	0.4345	$/kW-h			
		Operating	**Total**			**Monthly**	**Unit**	**Annual**
	Quantity	**# Months**	**SCFM**	**bhp**	**kW**	**cost**	**cost**	**Cost**
Aeration Lagoon Blowers	**3**							
Operating Conditions	2	12	**2400**	87.2	65.1	$20,633	-	$247,599
Filter Change (6 months)	**-**	**-**	**-**	-	-	-	$80	$320
Oil Change (12 months)	**-**	**-**	**-**	-	-	-	$200	$400
Belt Replacement (24 months)	**-**	**-**	**-**	-	-	-	$250	$250
SAGR Blowers	**2**							
Operating Conditions	1	12	**528**	24.2	18.1	$5,726	-	$68,714
Filters (6 months)	**-**	**-**	**-**	-	-	-	$60	$120
Oil (12 months)	**-**	**-**	**-**	-	-	-	$75	$75
Belts (24 months)	**-**	**-**	**-**	-	-	-	$250	$125
Total Operation & Materials								$317,604

* Electrical rate from report, *Town of Inuvik Unit Cost of Watrer, 2006*

The aeration system will require an operator or routine inspection & maintenance. Maintenance requirements may include:

- Daily site inspection and recording of aeration system operating parameters (temperature, pressure, etc)
- Blower maintenance – belt tensioning, oil changes, intake filters
- Floating lateral adjustment
- Condensate purging/operate blow-off valves
- SAGR step feed operation (manipulating influent valves twice a year to ensure year-round treatment)

9.0 Budgetary Process Equipment Capital Cost

The intent of this report is not to provide a full turnkey cost for each of the treatment options, but rather to outline the costs associated with the scope of supply that Nelson Environmental would propose for each option. Approximate civil construction quantities for the SAGR beds are also provided in *Section 10.0 Civil Works Required for SAGR Implementation* below, though costs for civil construction are outside the scope of this report.

i. Option 1: Lagoon Aeration System

<u>$1,475,000 plus taxes, FOB Jobsite</u>

Included in the **Option 1** *budgetary capital cost are:*

- System Process Design
- CAD Drawings, as-built drawings, and operation and maintenance manuals
- Aeration header piping, feeder piping, diffusers, valves, and fittings as required
- Positive displacement blowers with sound attenuating enclosures and control panel
- Prefabricated insulated blower and control building (Building foundation by others)
- ***Aeration System installation/start-up/commissioning/operator training/ 3 year annual follow-up***

Items Specifically not Included in the budgetary capital cost are:

- Civil works including berm design and construction, cell liner, transport piping, inter-cell piping, discharge piping, effluent return pumping, manholes, valves, access roads to site, site roads and landscaping, etc.
- Permits and Approvals required
- Survey of existing lagoon bottom profile
- Permafrost foundation design and construction
- Electrical supply to blower building

ii. Option 2: SAGR (Submerged Attach Growth Reactor)

$1,975,000 plus taxes, FOB Jobsite

Included in the **SAGR®** *budgetary capital cost are:*

- System Process Design
- CAD Drawings, as-built drawings, and operation and maintenance manuals
- Influent distribution and effluent collection chambers
- Aeration header piping, feeder piping, diffusers, valves, and fittings as required
- Positive displacement blower with sound attenuating enclosures and control panel.
- Prefabricated insulated blower and control building (Building foundation by others)
- ***Aeration installation/start-up/commissioning/operator training/ 3 year annual follow-up***

Items Specifically Not Included:

- Civil works including berm design and construction, cell liner, transport piping, inter-cell piping, discharge piping, effluent return pumping, manholes, valves, access roads to site, site roads and landscaping, etc.
- Permits and Approvals required
- Electrical hookup to blower building.
- Permafrost foundation design and construction
- Materials and construction required for the SAGR :
    - Granular material
    - SAGR basin construction
    - Permafrost protection
    - Insulating peat or mulch

iii. Option 3: Lagoon Aeration with SAGR

$3,450,000 plus taxes, FOB Jobsite

Included in the **Lagoon Aeration and SAGR System** *budgetary capital cost are:*

- System Process Design
- CAD Drawings, as-built drawings, and operation and maintenance manuals
- Aeration header piping, feeder piping, diffusers, valves, and fittings as required
- Influent distribution and effluent collection chambers
- Positive displacement blowers with sound attenuating enclosures and control panel
- Prefabricated insulated blower and control building (Building foundation by others)
- ***Aeration System installation/start-up/commissioning/operator training/ 3 year annual follow-up***

Items Specifically Not Included:

- Civil works including berm design and construction, cell liner, transport piping, inter-cell piping, discharge piping, effluent return pumping, manholes, valves, access roads to site, site roads and landscaping, etc.
- Permits and Approvals required
- Permafrost foundation design and construction
- Electrical hookup to blower building.
- Materials and construction required for the SAGR :
    - Granular material
    - SAGR basin construction
    - Permafrost protection
    - Insulating peat or mulch

All budgets are subject to final design.

All budgetary prices include shipping to jobsite but do not include taxes.
Budget prices valid for 30 days.

10.0 Civil Works Required for SAGR Implementation

The preceding budgetary costs cover design, equipment supply, and equipment installation for the three options presented. For the two options which include a SAGR, additional civil construction will be required. The costs of this construction are best estimated using local rates for heavy civil construction, which are outside the scope of this report. In addition, the costs of permafrost design and construction for the SAGR beds and blower buildings for each option must be considered in the overall project budget.

The following is a summary of the major civil works components required to implement the SAGR process.

- Construct new HDPE Lined SAGR cells with permafrost protection.
- Construct a flow distribution structure and inter-cell piping and pump stations
- Construct discharge control structure after SAGR
- Materials and construction required for the SAGR:
    - Impermeable geomembrane liner
    - Sacrificial exterior wood framed wall
    - Granular material (Drain field rock)
    - Insulating peat or mulch

Estimated material quantities for construction of the SAGR are shown in the following table.

SUMMARY				
Item Description	UOM	Option 1	Option 2	Option 3
Uniform Graded Clean Rock	m3	-	10,930	9,000
Insulating Mulch	m3	-	1,570	1,290
Non-Woven Geotextile (8oz)	m2	-	8,440	6,730
HDPE Liner (60mil)	m2	-	5,450	4,270
SAGR Permafrost protection	m2	-	3,128	2,576
blower building Permafrost protection	m2	50	50	50
		-		
Wall Framing & Sheathing	lm	-	490	360
		-		
Influent Flow Splitter Structure	ea	-	2	1
Piping, fittings, valves from splitter to SAGR	LS	-	1	1
Effluent Level Control MH	ea	-	4	2
		-		
Install process equipment within SAGR	LS	-	1	1
		-		
Additional Civil Works (As Required)		-		
Common Excavation - Backfill	m3	-	TBD	TBD
New Berm Construction	m3	-	TBD	TBD
Piping from Lagoon to SAGR Splitterstructure	LS	-	TBD	TBD
Piping from SAGR to discharge	LS	-	TBD	TBD

We anticipate that the preliminary quantities above could be used to develop a civil construction bid package for tender by local general contractors and aggregate suppliers.

11.0 Design Recommendations

Based on the technical descriptions and budgetary costs provided above, it is recommended by Nelson Environmental that **Option 2 be pursued** to upgrade the Inuvik wastewater treatment facility. The recommendation is based on the following:

Option 1:

1. Option 1 provides only a small water quality improvement over the current system, while incurring significant capital costs, and increasing O&M costs. Given the high cost of power in the Town of Inuvik, the additional operating expenses of switching from a facultative to an aerated lagoon should only be incurred if significant improvements in treatment are anticipated. The configuration analyzed in Option 1 does ensure that the current effluent requirements are met throughout the year, however, the improvement in effluent quality does not come close to treatment standards typically found in the rest of Canada. Given that tighter effluent regulations are likely to be enforced within the design life of this project, incurring significant capital costs at this time without anticipating future changes in discharge requirements is a short-term outlook.
2. There is significant uncertainty regarding the bottom profile of both the primary and secondary lagoon cells. Unevenness in the cell bottoms (causing some diffusers to sit higher than others) could result in uneven aeration pattern and poor treatment. Additional costs for de-sludging the lagoons could be incurred before aeration equipment could be installed successfully.
3. Floating HDPE headers are well suited to ice covered lagoons, and Nelson Environmental has many such systems in operation. The potential ice conditions in Inuvik are extreme, however, and may cause long-term equipment damage and maintenance problems for the Town.

Option 2:

1. Option 2 meets future anticipated CCME effluent quality requirements.
2. Option 2 does not require aeration in the existing ponds, eliminating concerns regarding ice thickness, uneven/unknown bottom elevations, and sludge accumulations.
3. Option 2 provides ammonia removal (nitrification) capacity in addition to BOD_5 and TSS removal.
4. Lowest long term energy and O&M costs

Option 3:

1. Option 3 meets future anticipated CCME effluent quality requirements
2. Option 3 requires the installation of aeration equipment in the two primary ponds, with the same drawbacks, as listed in Option 1 above.
3. Option 3 has the highest capital and O&M costs to the Town, without significant effluent quality improvement over Option 2.

12.0 Conclusion

Design and implementation of wastewater treatment processes in remote extreme cold climate applications such as Inuvik presents a series of unique challenges. Since most wastewater treatment systems are biological processes, the performance of the systems is temperature dependant and in many cases the systems do not function well in cold temperatures. Aside from the process challenges, the extended cold temperature periods and associated ice build-up presents accelerated wear and tear on equipment.

Based on our extensive experience designing and implementing wastewater treatment projects in cold regions in Canada, lagoon based systems are still a reliable, low operation and maintenance treatment option. Lagoon design and performance has evolved as more stringent discharge regulations have come into effect.

The evolution of processes such as the SAGR are allowing lagoon based processes to produce effluent quality near that of high intensity mechanical treatment plants while maintaining simple, cost effective operation and maintenance requirements.

As discussed in the report, we would suggest that while implementing aeration in the existing lagoons (Options 1 and 3) will improve the effluent quality, the operation and maintenance of any aeration process in these lagoons would be a significant strain on the community.

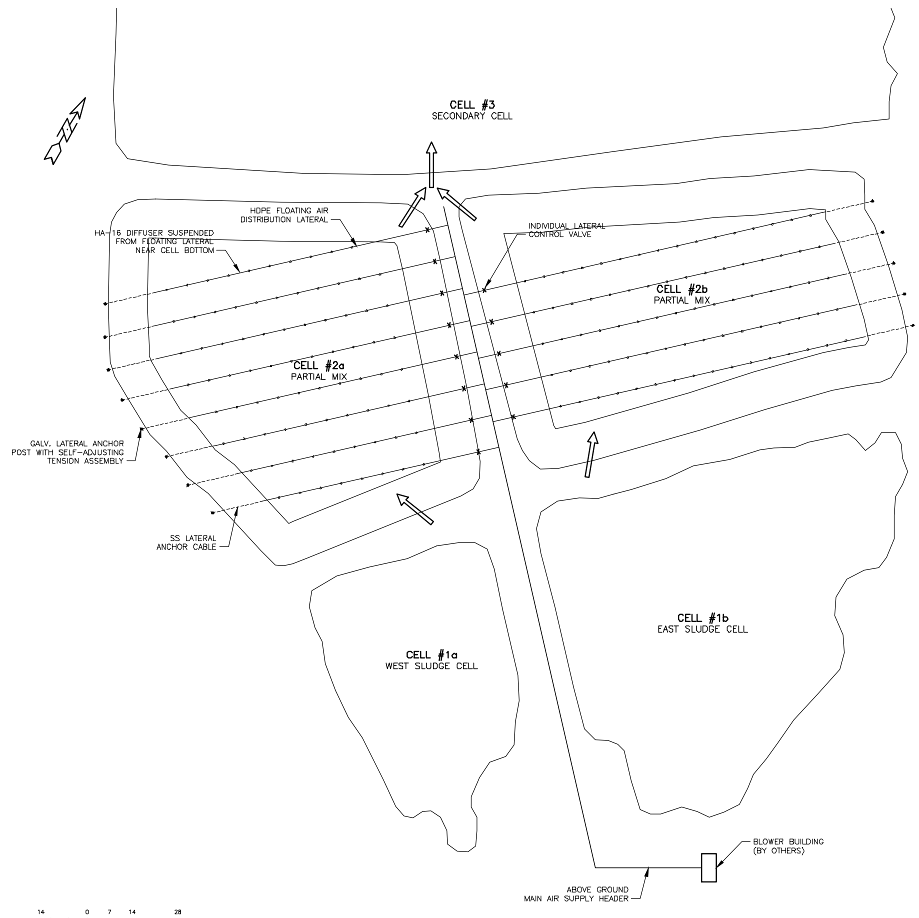
Option 2 (SAGR following facultative lagoons) allows for the existing lagoons to remain as they are. This is our recommended option when considering capital cost, operation and maintenance cost and complexity, as well as treatment performance and environmental compliance.

Any questions or comments can be directed to:

Nelson Environmental Inc.
94 Durand Road
Winnipeg, Manitoba, Canada
R2J 3T2
Tel: 204-949-7500
Fax: 204-237-0660

Appendix A:

Proposed Lagoon Upgrade Layouts



PROPOSED AERATION LAYOUT – OPTION #1 & #3

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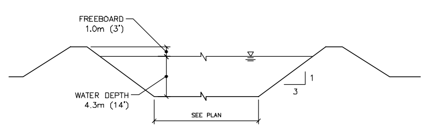
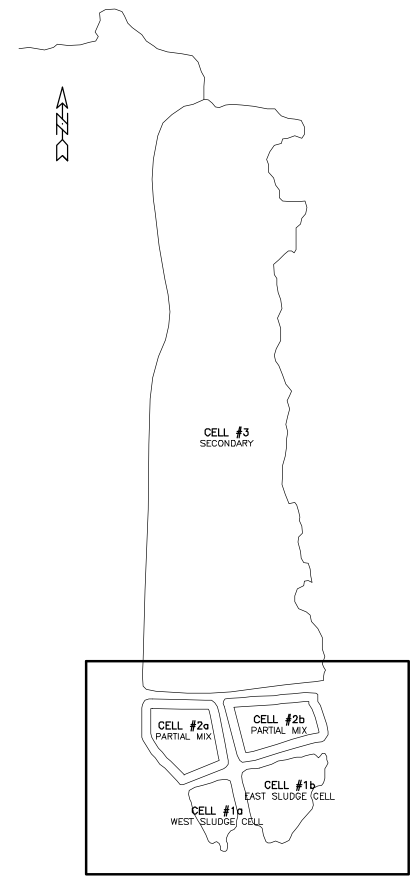


LAGOON SECTION



KEY PLAN

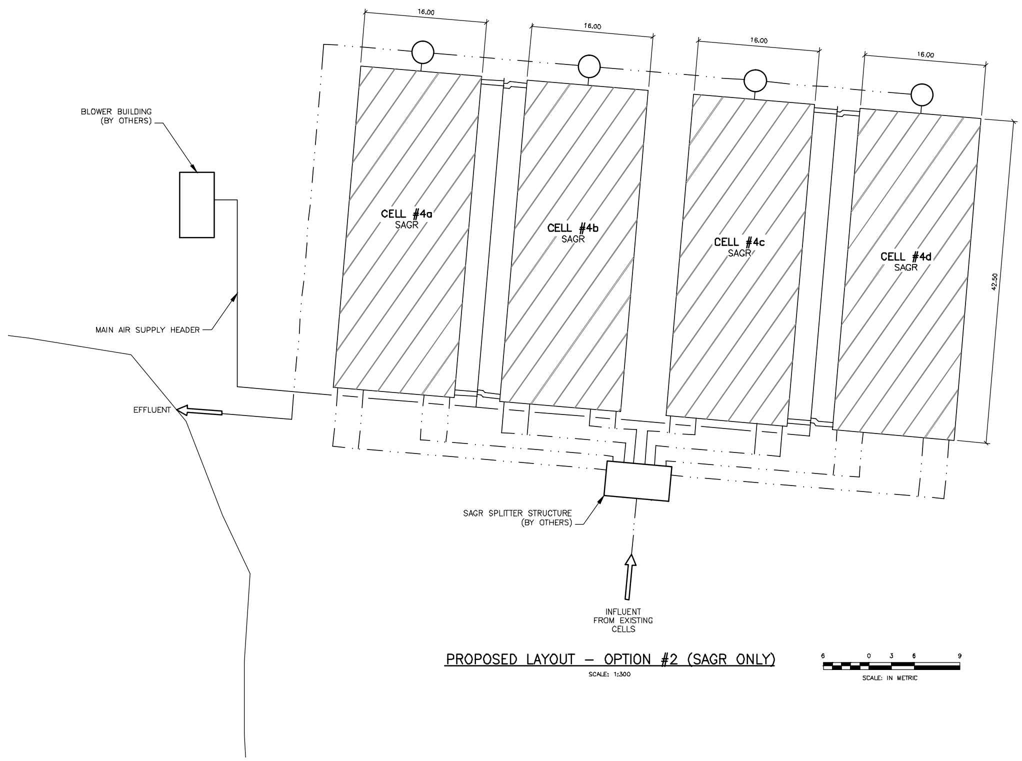
SCALE: 1:500

NELSON ENVIRONMENTAL INC.
94 DURAND ROAD
WINNIPEG, MANITOBA
CANADA R2J 3T2
Ph: (204) 949-7500
Fax: (204) 237-0660
www.nelsonenvironmental.com

PROJECT: INUVIK, NT PROPOSED WASTEWATER SYSTEM UPGRADE					
TITLE: OPTAER WASTEWATER TREATMENT SYSTEM PROPOSED AERATION LAYOUT – OPTION #1					
DRAWN BY: MAH	APPROVED BY: LE	SCALE: AS NOTED	DRAWING NO. NE01	SHT. 1 of 5	REV. 0
DATE: 2011/08/25	FILE #: 511.1922				

REDUCED SIZE PLOT - DO NOT SCALE

PLOT SIZE: 610mm x 914mm (24" x 36")

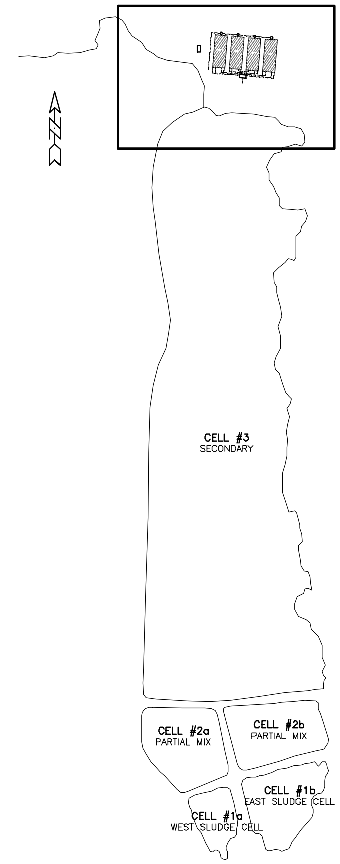


PROPOSED LAYOUT – OPTION #2 (SAGR ONLY)

SCALE: 1:300

6 0 3 6 9

SCALE: IN METRIC



KEY PLAN

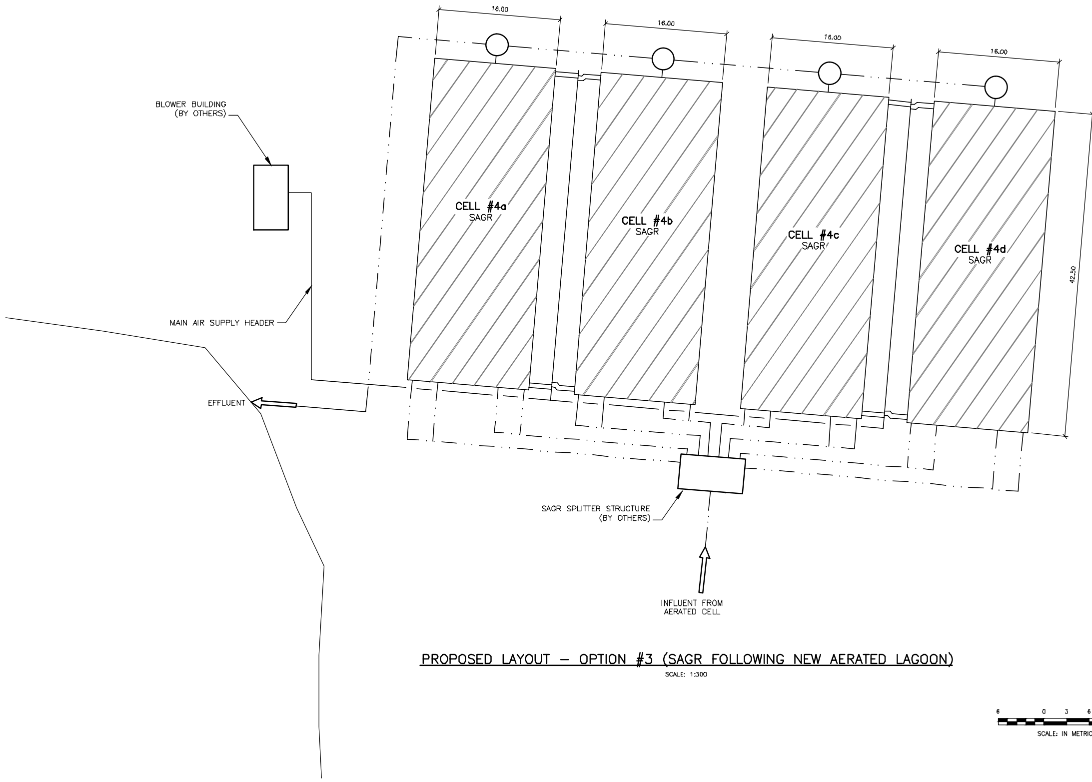
SCALE: 1:300

NELSON ENVIRONMENTAL INC.

94 DURAND ROAD
WINNIPEG, MANITOBA
CANADA R2J 3T2

Ph: (204) 949-7500
Fax: (204) 237-0660
www.nelsonenvironmental.com

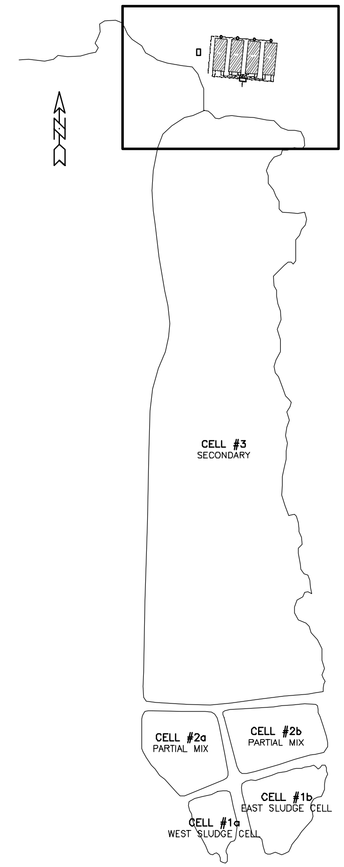
PROJECT:	INUVIK, NT PROPOSED WASTEWATER SYSTEM UPGRADE				
TITLE:	OPTAER WASTEWATER TREATMENT SYSTEM PROPOSED AERATION LAYOUT – OPTION #2				
DRAWN BY: MAH	APPROVED BY: LE	SCALE: AS NOTED	DRAWING NO. NE02	SHT. 2 of 5	REV. 0
DATE: 2011/08/25	FILE # 511.1922				



PROPOSED LAYOUT – OPTION #3 (SAGR FOLLOWING NEW AERATED LAGOON)

SCALE: 1:300

SCALE: IN METRIC



KEY PLAN

SCALE: 1:300

REDUCED SIZE PLOT - DO NOT SCALE

PLOT SIZE: 610mm x 914mm (24" x 36")

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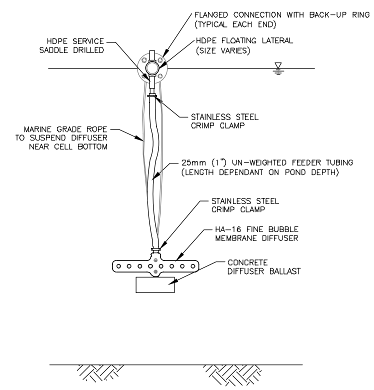
94 DURAND ROAD
WINNIPEG, MANITOBA
CANADA R2J 3T2

Ph: (204) 949-7500
Fax: (204) 237-0660
www.nelsonenvironmental.com

PROJECT: INUVIK, NT PROPOSED WASTEWATER SYSTEM UPGRADE						
TITLE: OPTAER WASTEWATER TREATMENT SYSTEM PROPOSED AERATION LAYOUT – OPTION #3						
DRAWN BY: MAH	APPROVED BY: LE	SCALE: AS NOTED		DRAWING NO. NE03	SHT. 3 of 5	REV. 0
DATE: 2011/08/25	FILE #: 511.1922					



LATERAL DETAIL – SECTION

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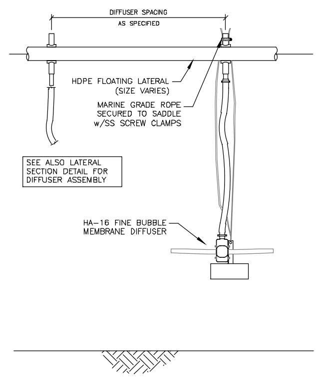

LATERAL DETAIL – ELEVATION

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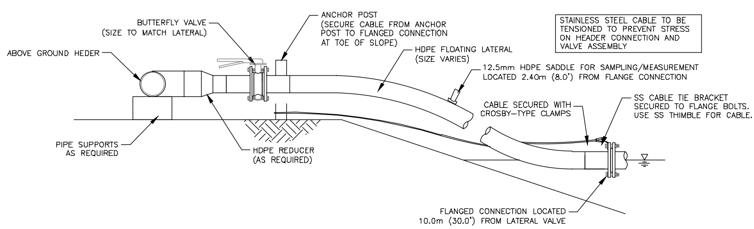
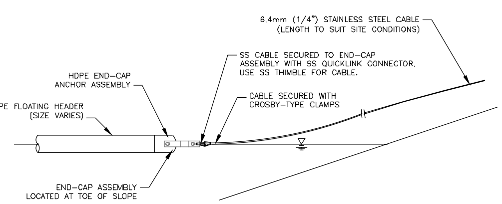


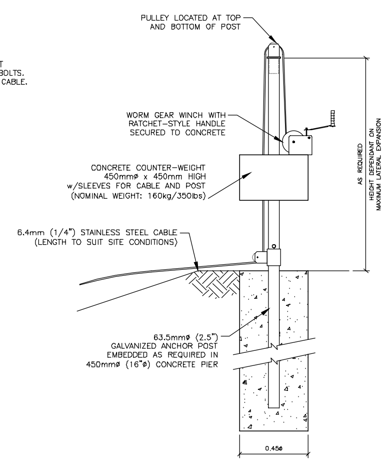
LATERAL DETAIL AT HEADER

SCALE: 1:15



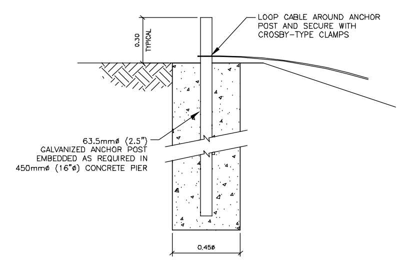
LATERAL DETAIL AT PLUGGED END

SCALE: 1:15



SELF-ADJUSTING TENSION ASSEMBLY

SCALE: 1:15



FIXED ANCHOR POST AT HEADER DETAIL

SCALE: 1:15

NELSON ENVIRONMENTAL INC.

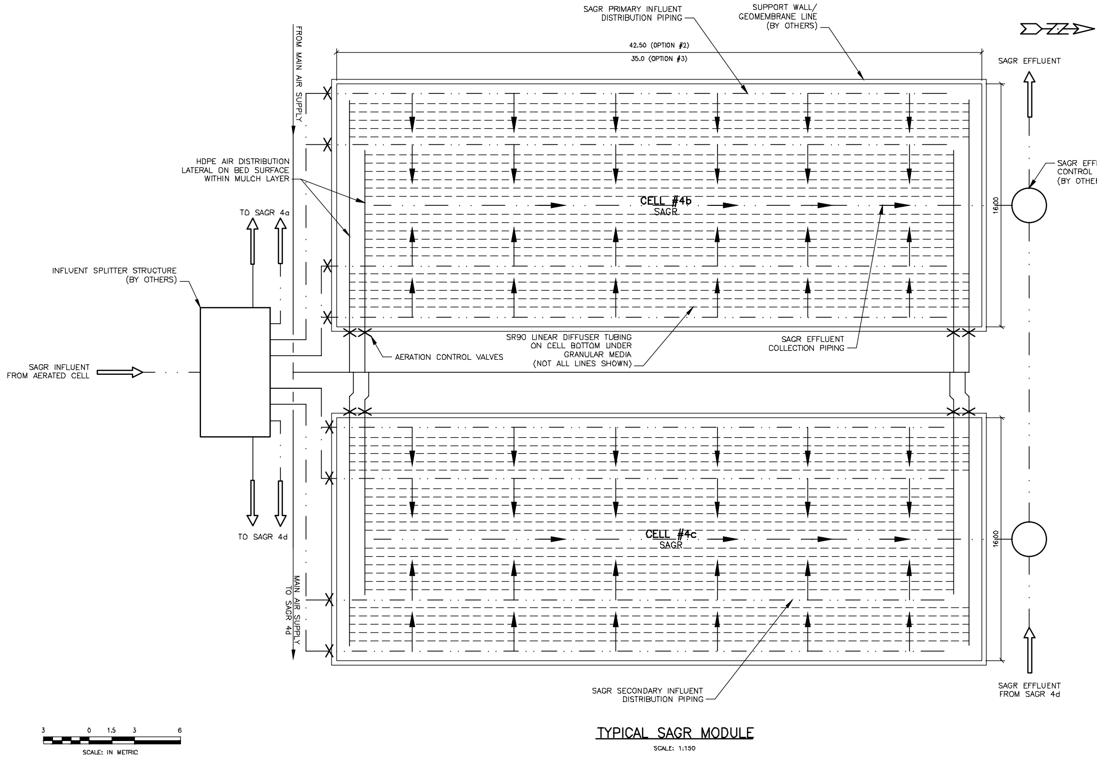
94 DURAND ROAD
WINNIPEG, MANITOBA
CANADA R2J 3T2

Ph: (204) 949-7500
Fax: (204) 237-0660
www.nelsonenvironmental.com

PROJECT:	INUVIK, NT PROPOSED WASTEWATER SYSTEM UPGRADE
TITLE:	OPTAER WASTEWATER TREATMENT SYSTEM AERATION DETAILS
DRAWN BY:	MAH
APPROVED BY:	LE
SCALE:	AS NOTED
DRAWING NO.	NE04
SHT.	4 of 5
REV.	0
DATE:	2011/08/25
FILE #	511.1922

REDUCED SIZE PLOT - DO NOT SCALE

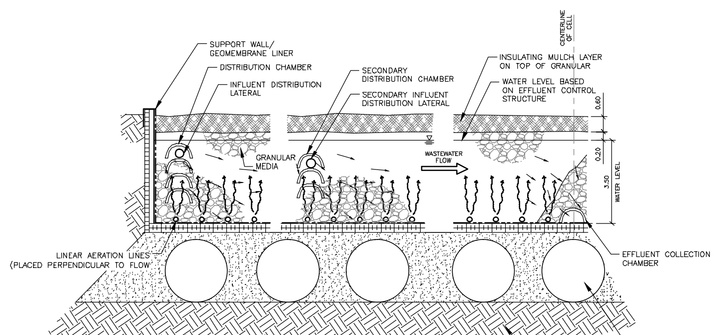
PLOT SIZE: 610mm x 914mm (24" x 36")



INFLUENT/EFFLUENT PIPING TO SAGR SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. EXACT PIPING ROUTING TO BE DETERMINED BASED ON FINAL LOCATION OF SAGR.

TYPICAL SAGR MODULE

SCALE: 1:150

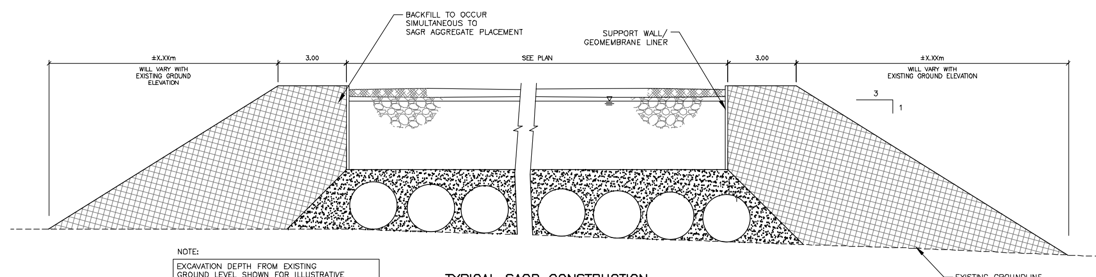


NOTE FOR GRAVITY FEED SYSTEMS:

SAGR WATER LEVEL TO BE MINIMUM 300mm (12") LOWER THAN WATER LEVEL OF FINAL CELL.

HORIZONTAL FLOW SAGR – SECTION

SCALE: N.T.S.



NOTE:

EXCAVATION DEPTH FROM EXISTING GROUND LEVEL SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. FINAL EXCAVATION DEPTHS TO BE DETERMINED AFTER SITE SURVEY

TYPICAL SAGR CONSTRUCTION

SCALE: 1:100

NELSON ENVIRONMENTAL INC.

94 DURAND ROAD
WINNIPEG, MANITOBA
CANADA R2J 3T2

Ph: (204) 949-7500
Fax: (204) 237-0660
www.nelsonenvironmental.com

PROJECT:	INUVIK, NT PROPOSED WASTEWATER SYSTEM UPGRADE
TITLE:	OPTAER WASTEWATER TREATMENT SYSTEM SAGR LAYOUT AND SECTIONS
DRAWN BY:	MAH
APPROVED BY:	LE
SCALE:	AS NOTED
DRAWING NO.	NE05
SHT.	5 of 5
REV.	0
DATE:	2011/08/25
FILE #	511.1922

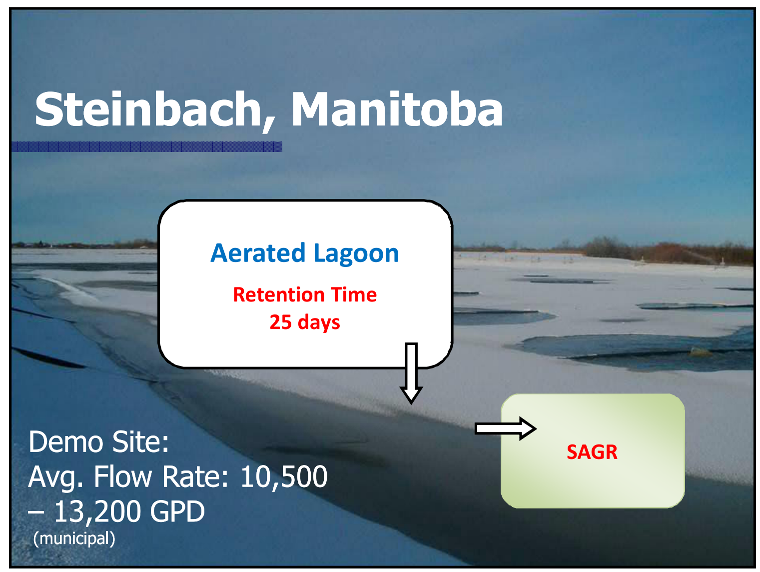
Appendix B:

SAGR Performance Data and Project Information

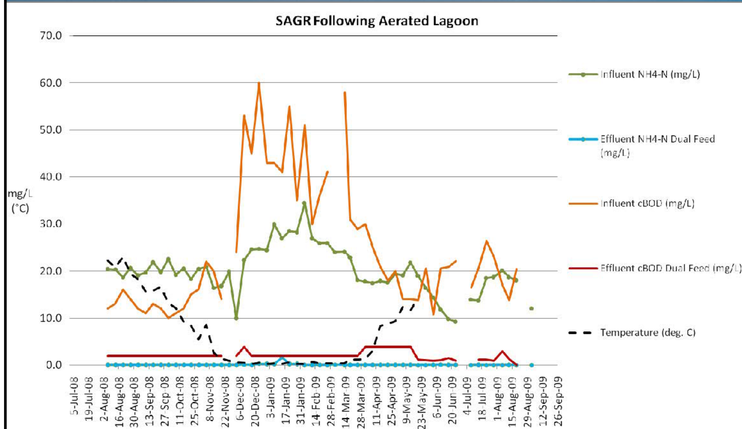

Nelson Environmental Inc.
Post Lagoon - Cold Temperature Nitrification, cBOD and TSS removal
Martin Hildebrand, P.Eng.
Winnipeg, Canada
www.nelsonenvironmental.com


SAGR
(Submerged Attached Growth Reactor)
Post Lagoon Cold Temperature Nitrification, cBOD and TSS removal
Fully aerated coarse gravel bed reactor
Stable dense rock media that is not susceptible to temperature shock
Insulating mulch layer prevents bed freezing
Minimize complexity and operational costs
Able to adapt to existing lagoon systems


Submerged Attached Growth Reactor (SAGR)


Steinbach, Manitoba
Aerated Lagoon
Retention Time
25 days
SAGR
Demo Site:
Avg. Flow Rate: 10,500 – 13,200 GPD
(municipal)

Steinbach SAGR Data



Winter 2010 Steinbach SAGR Demonstration Tracking Report

Intended to fulfil the 3rd party verification requirements for certification of the SAGR as a Standard Technology in the Province of Quebec

Jan A. Oleszkiewicz, PhD, PEng, CEng, BCEE;
Jong Hyuk Hwang , PhD, Post-doctoral Fellow
University of Manitoba

Statistical representation of the influent characteristics

Parameter	Average	Minimum	Maximum	s.d
TSS (mg/L)	30	13	59	11.6
Total BOD (mg/L)	48	35	83	13.3
cBOD (mg/L)	47	26	93	16.5
TN (mg/L)	32.9	24.9	41.1	5.1
TKN (mg/L)	32.6	24.6	41.0	5.2
NH_4-N (mg/L)	24.88	20.80	29.20	2.80
NO_2-N & NO_3-N (mg/L)	0.30	0.02	0.54	0.16
TP (mg/L)	5.25	4.06	5.84	0.60
Fecal coliform (MPN/100mL)	253533	13000	790000	257448

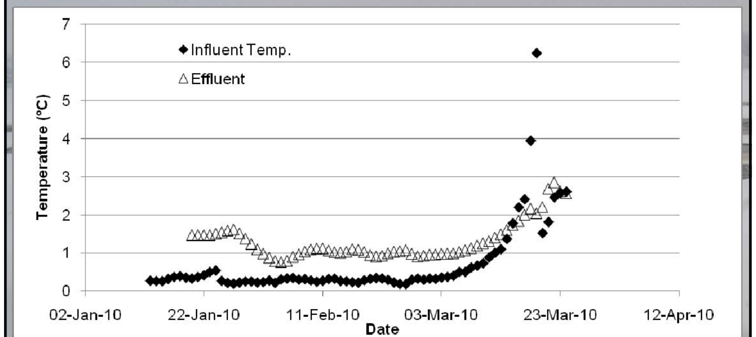
(1) Based on 15 consecutive weeks of sampling results

Summary of parameters in the effluent from the SAGR

Parameter	Average concentration (8)	Standard deviation (8)	AADL (2)	ASDL (3)	APDL (4)
TSS (mg/L) (5)	1.4	1.1	1.0	1.0	1.0
Total BOD (mg/L) (5)	2.1	2.3	2.9	3.8	5.5
cBOD (mg/L) (5)	2.1	3.9	2.5	3.3	5.0
TN (mg/L) (6)	29.5	4.1	33.77	36.08	39.13
TKN (mg/L) (6)	1.8	0.9	2.70	3.51	4.52
NH_4-N (mg/L) (6)	0.12	0.32	0.26	0.84	1.44
NO_2-N & NO_3-N (mg/L) (6)	27.75	4.25	32.09	34.52	37.72
TP (mg/L) (6)	5.25	0.31	5.57	5.71	5.92
Fecal coliform (col./100mL) (7)	13.5	35.4	15	27	63

(1) Based on 15 consecutive weeks of sampling results
(2) Average annual discharge limit (AADL) -a percentile not exceeding 99% of an average of twelve results with a confidence level of 95%
(3) Average seasonal discharge limit (ASDL) -a percentile not exceeding of 99% of an average of six results with a confidence level of 95%
(4) Average periodic discharge limit (APDL) -a percentile not exceeding of 99% of an average of three results with a confidence level of 95%

Temperature of SAGR process influent and effluent



Year 3 operation

Pushing the limits – Testing modes of failure

- What are the limits of the SAGR technology?
- What factors could lead to SAGR failure?
- What happens to effluent quality in this case?

Year 3 operation

West Train – Operation Objective

- What happens if no ammonia is available to feed the bed in summer due to full nitrification in the lagoon
  - 100% design flow till July 1
  - No flow between July 1 and September 16 (11 weeks)
  - 100% design flow after September 16
- What is the optimum window for operating the step feed system?

Low Ammonia feed Testing

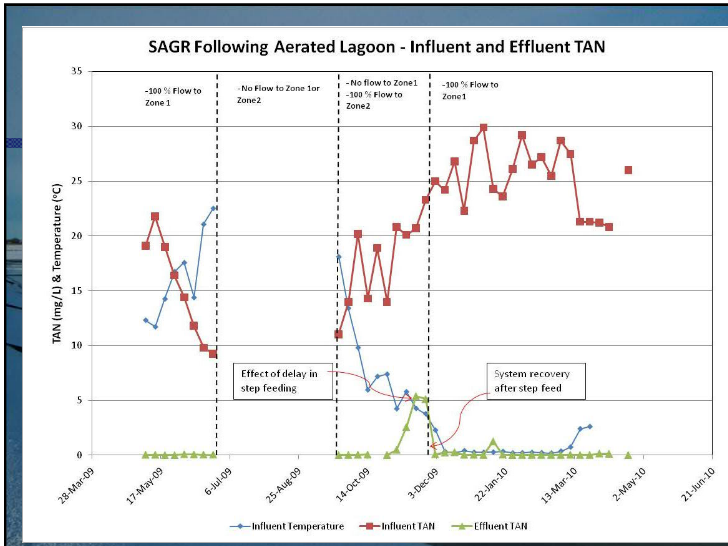
- If lagoon system preceding SAGR fully nitrifies during summer, would nitrifying biomass developed within SAGR system die off?
  - i.e. no ammonia in SAGR influent to sustain nitrifying biomass
- Could this situation lead to SAGR system failure and ultimately increase effluent ammonia levels to a point of non-compliance?

Low Ammonia feed Testing

- Two options to ensure sufficient influent ammonia during summer operation were presented:
  1. Reduce lagoon retention time
     - bypass part of lagoon by drawing feed at point closer to the front end (where nitrification has not yet fully occurred)
  2. Add urea as artificial source of ammonia to SAGR in summer to generate nitrifying bacteria.
     - NEI conducted testing to show this as a viable option

Low Ammonia feed Testing

- Stress testing (ST) at Steinbach SAGR demonstration facility shows that neither option will be likely required for long term system performance
- ST protocol involved "starving" nitrifiers for extended period of time (no flow to SAGR treatment zones)
- Testing proved nitrifying biomass was resilient:
  - Remain dormant in the absence of ammonia but immediately resume nitrifying once ammonia is available

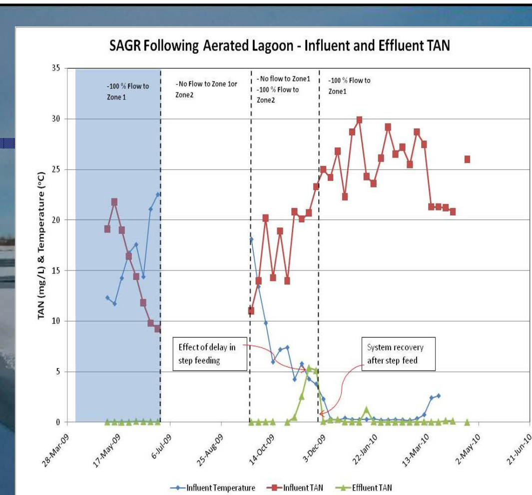


April 1 to June 30 /09 – 13 weeks

100% flow to Zone 1
Weekly avg. effluent TAN from Zone 1 – ***0.067 mg/L***

TAN feeding Zone 2 near or below detection – 0.067 mg/l

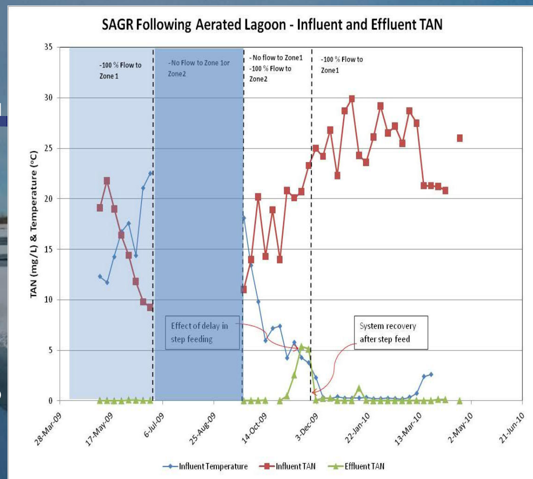
Zone 2 Starved



July 1 to Sept 16/09 – 11 weeks

Flow and TAN load to Zones 1 & 2 terminated

By Sept 16 no flow to Zone 1 for 11 wks & no TAN loading to Zone 2 for 24 wks



Sept 17 to Dec 2/09 – 11 weeks

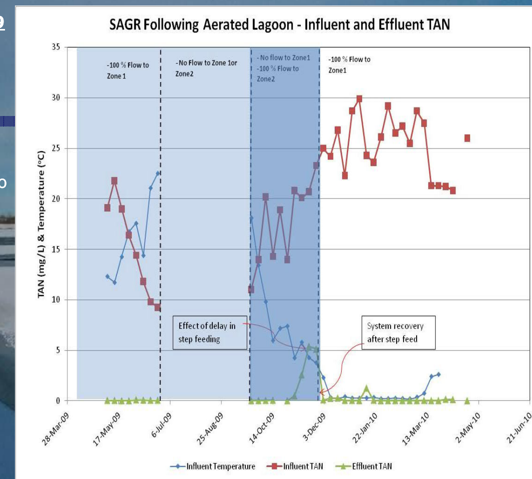
100% flow to Zone 2 (step feed)

Zone 1 bypassed

Though no TAN load to Zone 2 for 24 wks, effluent TAN <0.05 mg/L (influent 11 mg/L)

Water temp. drops to <5ºC, effluent TAN increase to 5.4 mg/L

Zone 1 still being bypassed (only zone 2 in operation)



Dec 3/09 to April 21/10

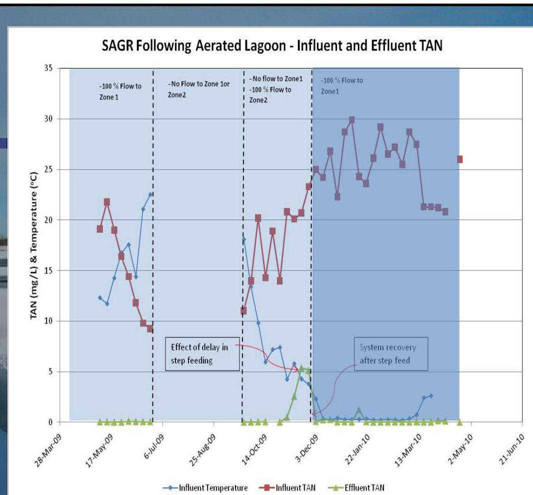
100% flow to Zone 1

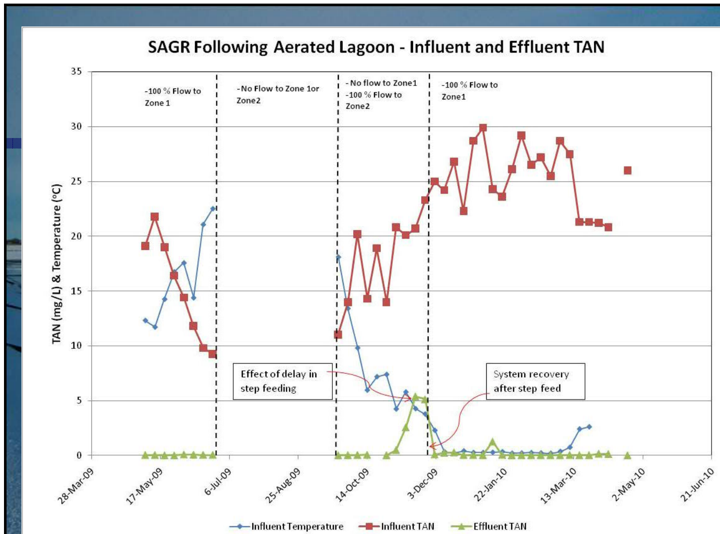
Zone 1 without TAN loading for for 22 wks

Immediate nitrification in Zone 1

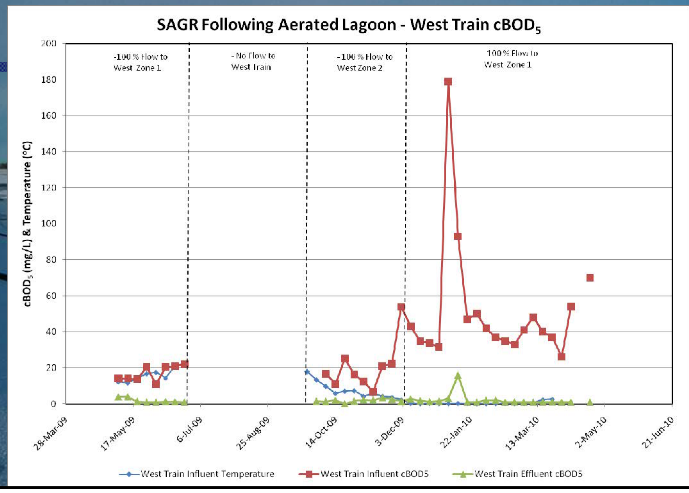
Avg. effluent TAN 0.12 mg/L

Single point 1.26 mg/L – Jan 13/10 – caused by large spike in influent BOD.

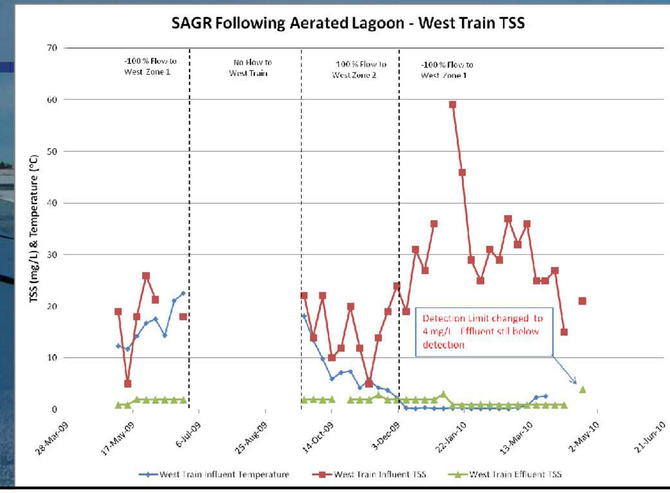




Steinbach - Year 3 Operation



Steinbach - Year 3 Operation



Low Ammonia feed Testing

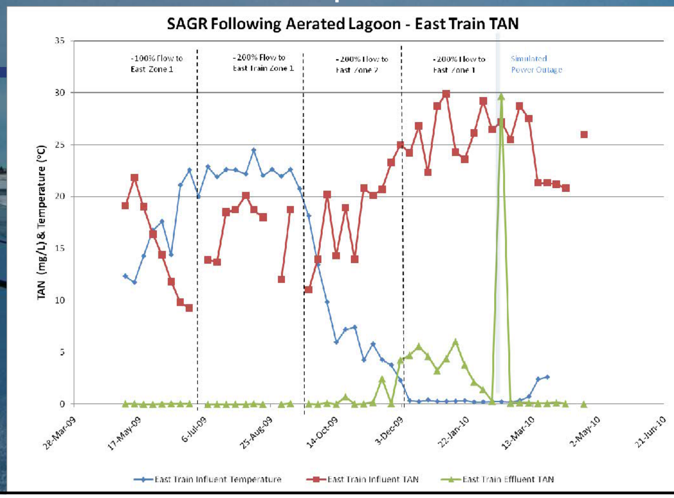
- Aeration system kept on during entire zero load stress testing period
- SAGR Zone 2 starved for 24 weeks resumed full nitrification to < 0.05 mg/L at warm water temp
- SAGR Zone 1 starved for 22 weeks resumed nitrification of cold water (temp. < 0.5°C)

Year 3 operation

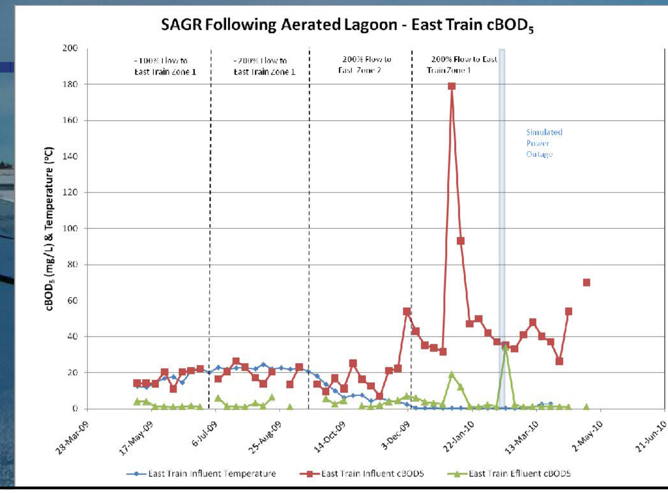
East Train– Operation Objective

- 200% design flow for extended duration
- Determine ammonia, CBOD and TSS removal performance when the SAGR is overloaded by 100% during both summer and winter conditions

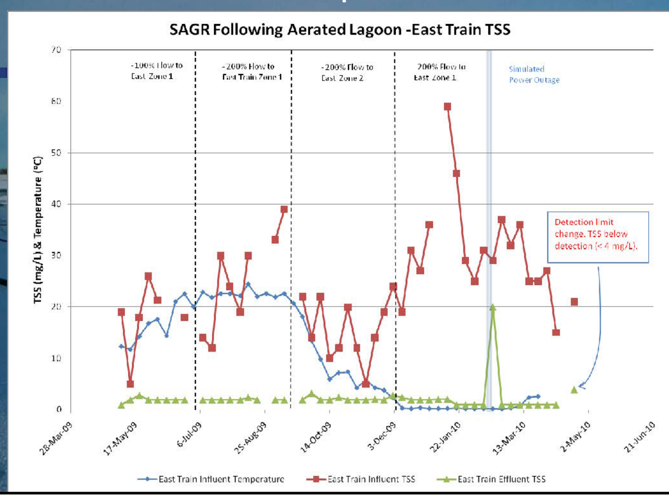
Steinbach - Year 3 Operation



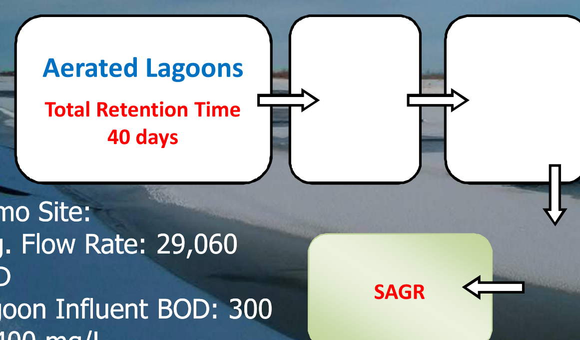
Steinbach - Year 3 Operation



Steinbach - Year 3 Operation



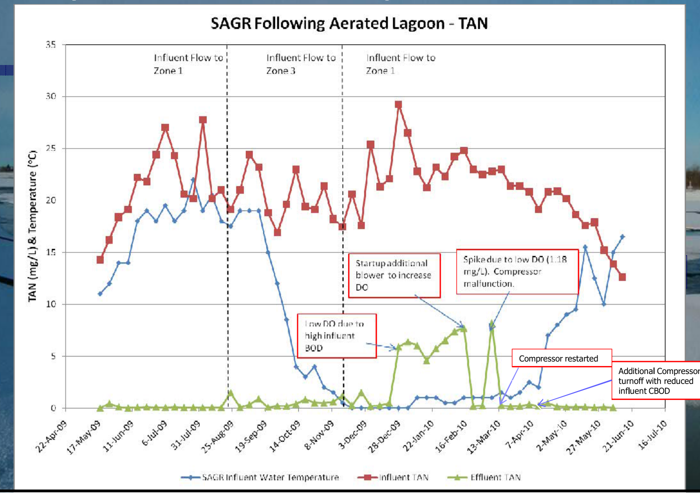
Lloydminster, Saskatchewan



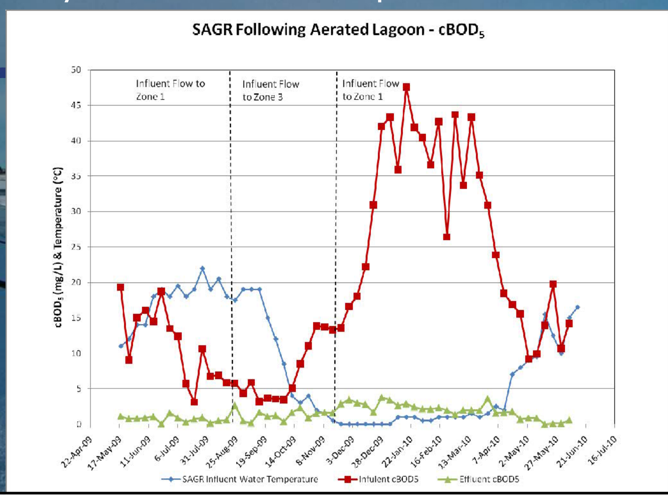
Demo Site:
Avg. Flow Rate: 29,060 GPD
Lagoon Influent BOD: 300 to 400 mg/L
(combined municipal & industrial)

Lloydminster, Saskatchewan

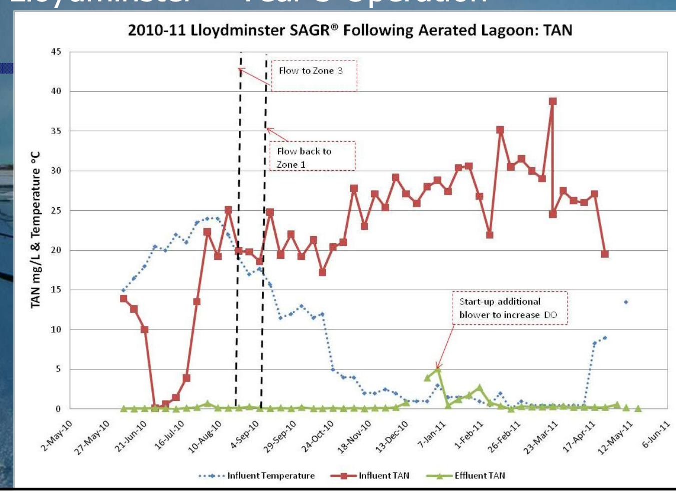
Lloydminster - Year 2 Operation



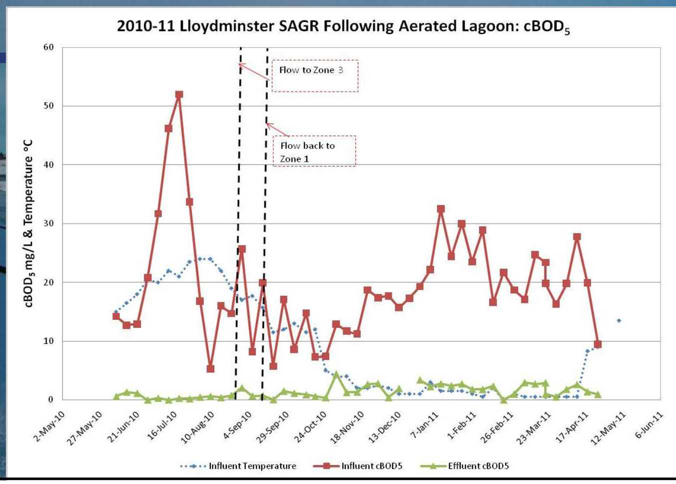
Lloydminster - Year 2 Operation



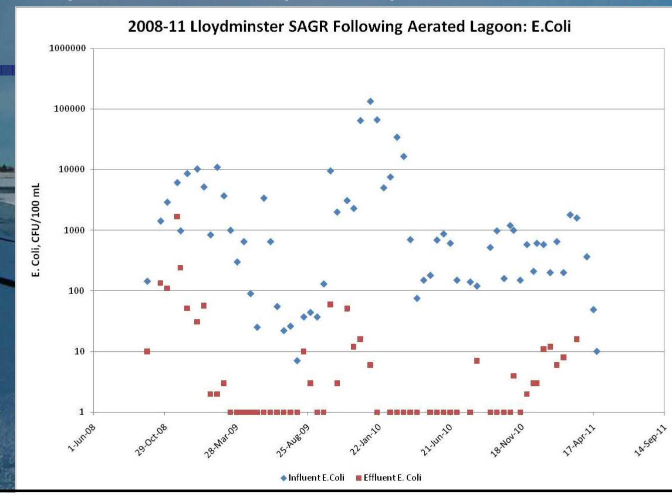
Lloydminster - Year 3 Operation



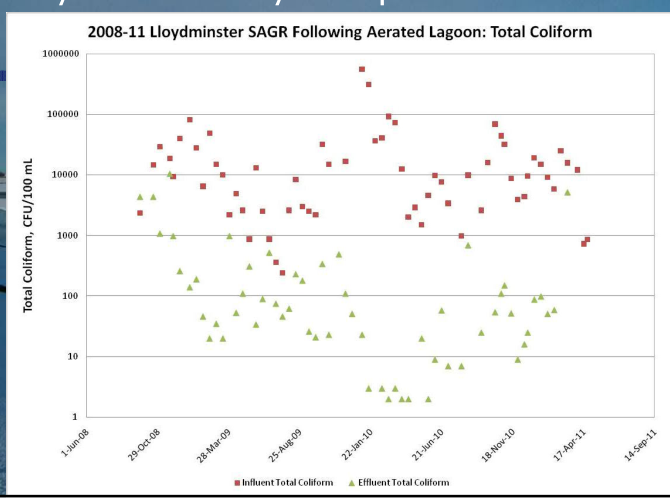
Lloydminster - Year 3 Operation



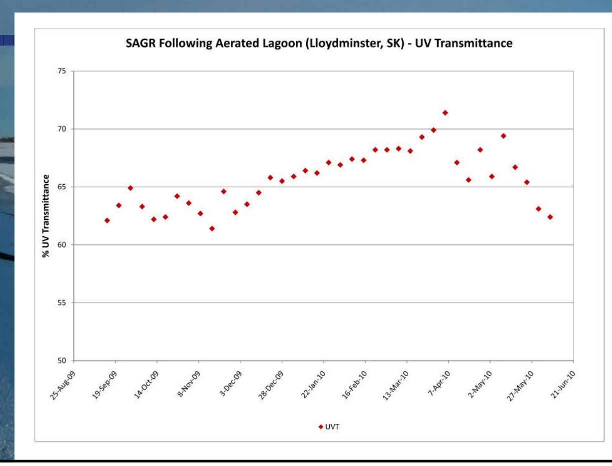
Lloydminster - 3 years operational data

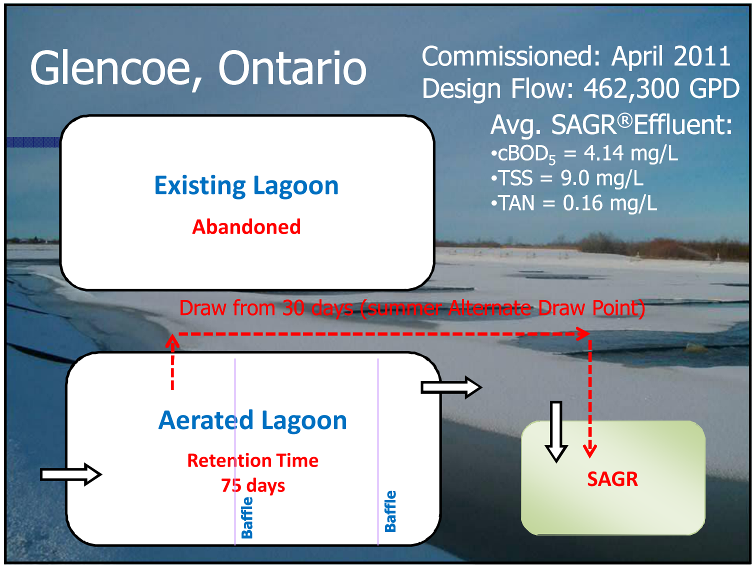


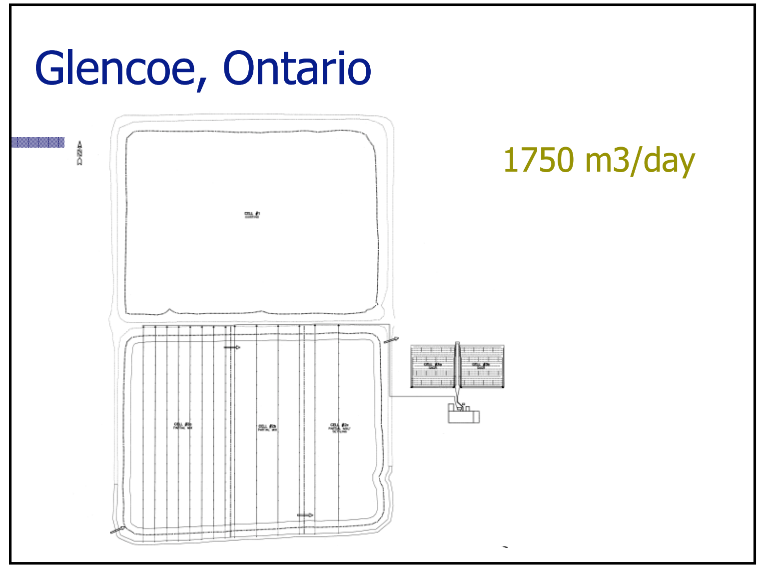
Lloydminster - 3 years operation data

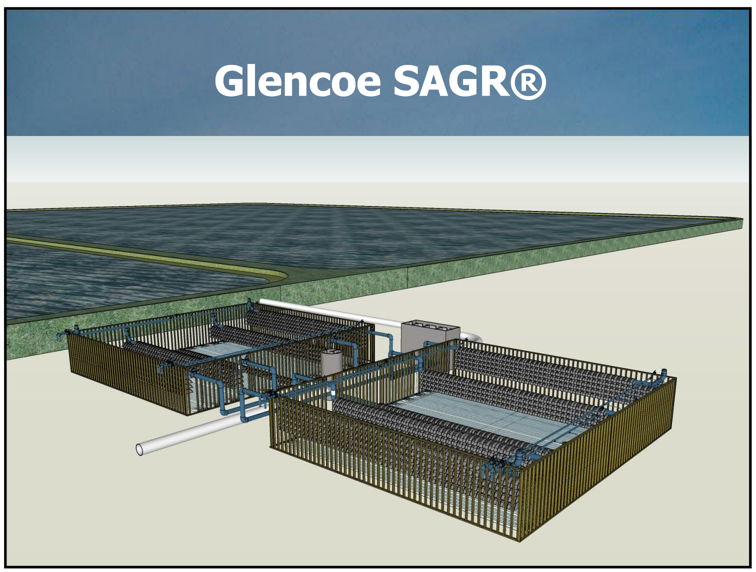


Lloydminster




Glencoe, Ontario
Commissioned: April 2011
Design Flow: 462,300 GPD
Avg. SAGR®Effluent:
•cBOD5 = 4.14 mg/L
•TSS = 9.0 mg/L
•TAN = 0.16 mg/L
Existing Lagoon
Abandoned
Draw from 30 days (summer Alternate Draw Point)
Aerated Lagoon
Retention Time
75 days
Baffle
Baffle
SAGR


Glencoe, Ontario
1750 m3/day

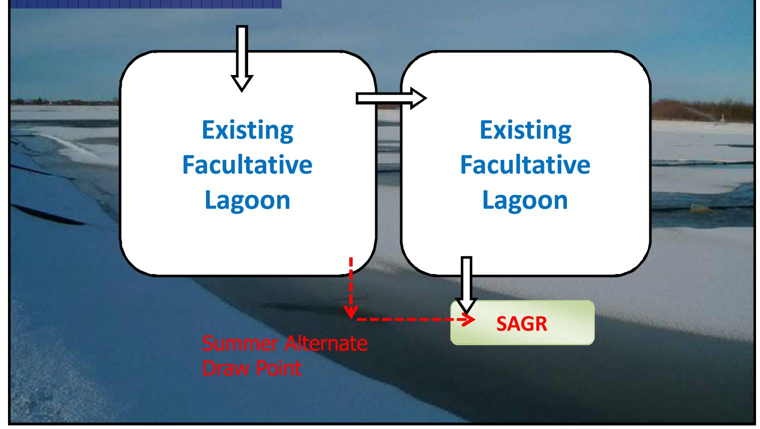

Glencoe SAGR®


Glencoe, Ontario

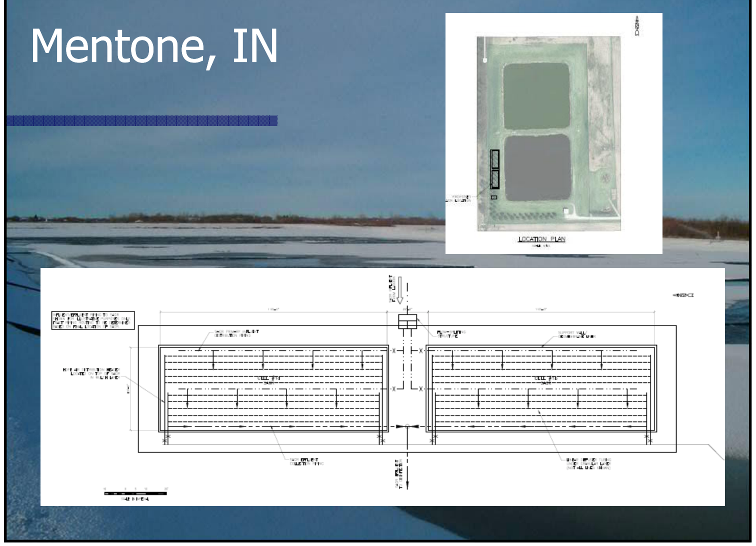
Glencoe, Ontario

Mentone, IN

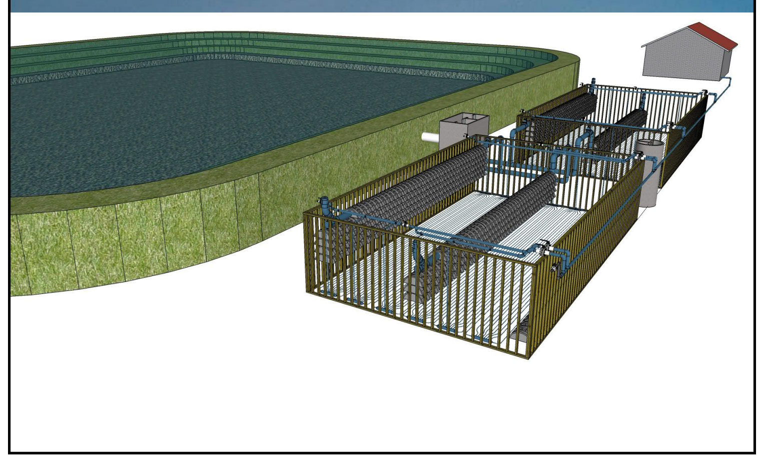
Commissioned:



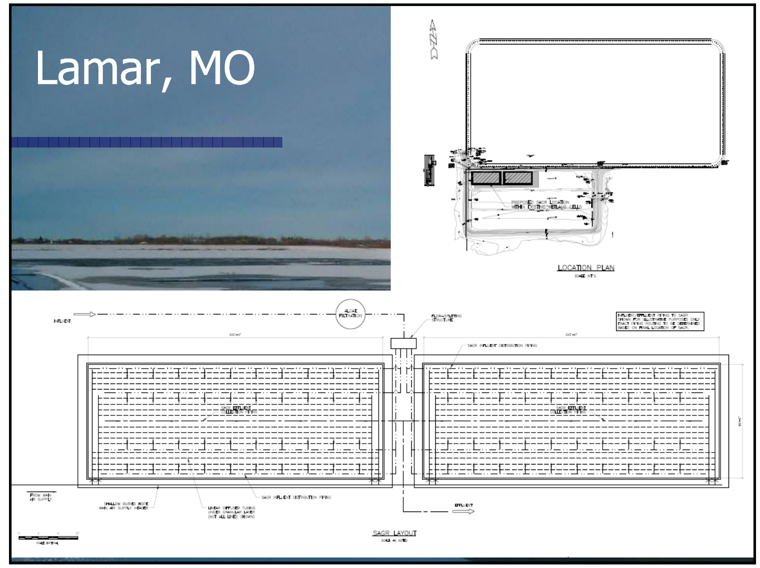
Mentone, IN

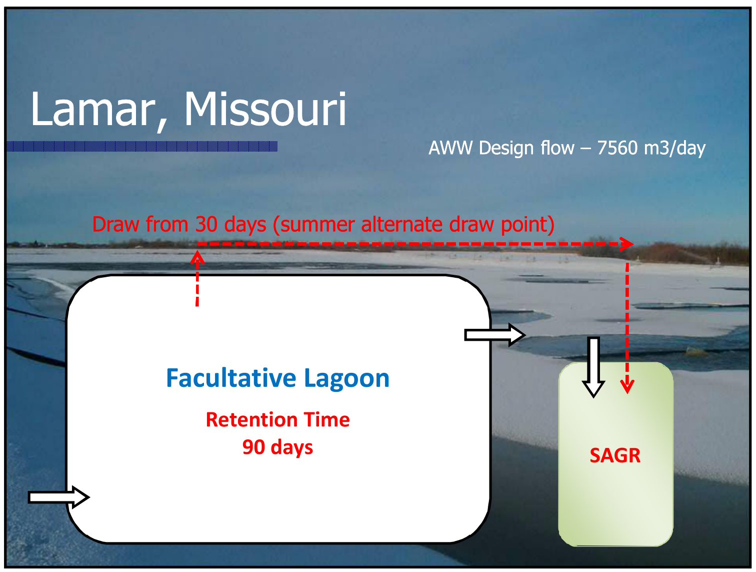


Mentone SAGR®




Mentone, IN


Lamar, MO
LOCATION PLAN
SAGR LAYOUT


Lamar, Missouri
AWW Design flow – 7560 m3/day
Draw from 30 days (summer alternate draw point)
Facultative Lagoon
Retention Time
90 days
SAGR


Doaktown, New Brunswick

Shellbrook, Saskatchewan

Dawson Creek, British Columbia

Dawson Creek, British Columbia

Buffalo, New York
Airport Deicing Fluid Treatment

Post Lagoon SAGR projects

- Steinbach, MB – demonstration site 2007 – 2010 - operated between 10,000 and 13,200 gpd (design is 10,000) - demo site
- Lloydminster, SK – operating demonstration site 2008 to present (29,000 gpd) - Final design for the full 4.2 mgd build-out. Construction will begin in 2011.
- Glencoe, ON – operating – 0.46 mgd
- Mentone, IN – operating - 0.12 mgd
- Doaktown, NB – operating - 0.16 mgd

Post Lagoon SAGR projects

- Shellbrook, Saskatchewan - under construction - startup in 2011 – 0.265 mgd
- Lamar, MO - under construction - startup in 2011 – 0.7 mgd dry weather with 2.0 mgd peak flows
- Dawson Creek, BC - under construction - startup in 2011 – 1.1 mgd
- Long Plain First Nation, MB - under construction - startup in 2011 – 0.265 mgd
- Mountain View, WY - under construction - startup in 2011 – 0.50 mgd

Other SAGR projects

- Buffalo International Airport De-icing runoff treatment - operating - rated capacity at 10,000 lb CBOD/day
- Perigrine Financial, IA – operating – 5000 gpd
- Edmonton International Airport De-icing runoff treatment - under construction - startup in 2011 - rated capacity at 1,562 lb/day CBOD

Other Aerated Gravel Bed projects

Aerated Gravel Bed Wastewater Treatment Systems

Project	Start Date	County	State
Fields of St. Croix	1998	Washington	Minnesota
Hamlet on Sunfish Lake	1998	Washington	Minnesota
Lutsen SV O&M 00-	1998	Cook	Minnesota
Jackson Meadow North	1999	Washington	Minnesota
Lutsen EF O&M 99-	1999	Cook	Minnesota
SuperAmerica Ham Lake	1999	Anoka	Minnesota
Carriage Station	2000	Washington	Minnesota
Dellwood Op	2000	Washington	Minnesota
Fields of St. Croix Phase II	2000	Washington	Minnesota
Super America Wyoming	2000	Chisago	Minnesota
TamarackFarms WW Op	2000	Washington	Minnesota
Clearwater Ops	2001	Stearns	Minnesota
Meadowwoods Op	2001	Sherburne	Minnesota
Tamarack	2001	Aitkin	Minnesota
Jackson Meadow South	2002	Washington	Minnesota
Sunrise Trails	2002	Chisago	Minnesota
Turtle Run South Phase I	2002	Anoka	Minnesota
Wildflower Shores	2002	Washington	Minnesota
Lutsen Employee Housing	2004	Cook	Minnesota
Lutsen Resort	2004	Cook	Minnesota
Morton Farms	2004	Sherburne	Minnesota
Thumper Ponds	2004	Otter Tail	Minnesota
Turtle Run South Phase II	2004	Anoka	Minnesota
Whistling Valley Phase I	2004	Washington	Minnesota
Woods at Eagle Lake	2004	Sherburne	Minnesota
Wyldewood Acres	2004	Washington	Minnesota
Heritage at Lutsen	2005	Cook	Minnesota
Mulberry Meadows	2005	Stearns	Minnesota
Prinsburg	2005	Kandiyohi	Minnesota
Cambridge Isanti	2006	Pine	Minnesota
Diamond Lake Woods	2006	Anoka	Minnesota
Preserve at Birch Lake	2006	Chisago	Minnesota
Sanctuary	2006	Washington	Minnesota
Whistling Valley Phase II	2006	Washington	Minnesota
Rock Point Church	2007	Washington	Minnesota

Conclusion

Cold climate lagoon based treatment performance:

- Consistent summer and winter nitrification at 100% design flow.
- Consistent BOD/TSS < 5/10 mg/l (lower with tertiary filtration)
- Good Fecal Coliform and Ecoli removal without supplementary disinfection (>99.9% removal)
- SAGR can handle significant variation in incoming water quality without upset

Conclusion

Modified lagoons are a cost effective and viable wastewater treatment method even when nutrient removal is required.

Nelson Environmental Inc.

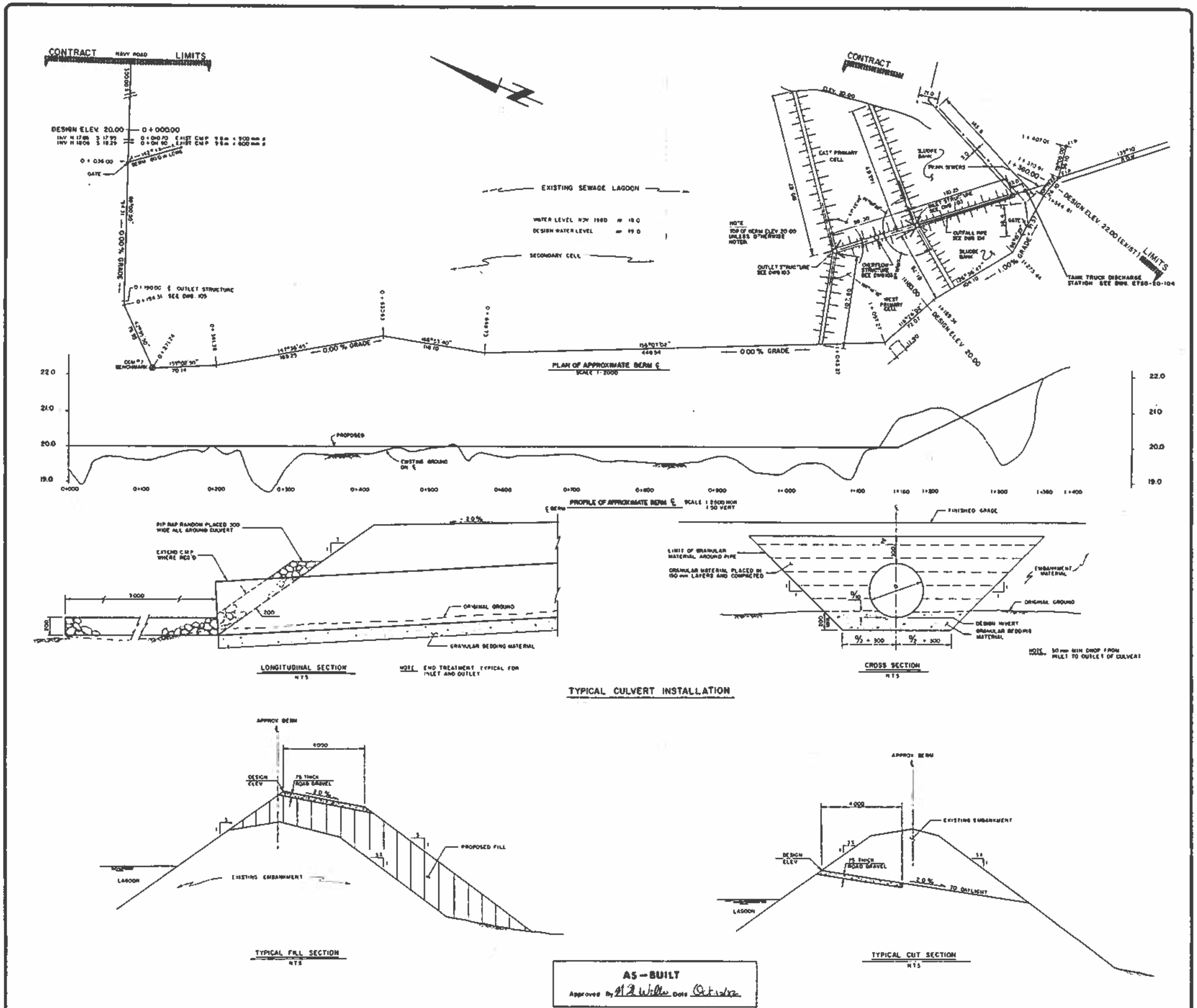
Martin Hildebrand, P.Eng.

94 Durand Road
Winnipeg, Canada
R2J 3T2
www.nelsonenvironmental.com

OPTAER

Appendix B

Lagoon As-built Drawings (Associated Engineering. 1982)



ASSOCIATED ENGINEERING SERVICES LTD.

DRAWING REFERENCE

NOTES:

DIMENSIONS ON PLAN OF APPROXIMATE BERM ℄ ARE IN METRES UNLESS OTHERWISE SPECIFIED

DIMENSIONS ON SECTIONS ARE IN MILLIMETRES

ALL ELEVATIONS ARE RELATIVE TO GEODETIC DATUM IN METRES : BENCHMARK ON CCM#7 ELEV. 019.62

—— FENCING

NO	DATE	BY	ENG	SUBJECT
2	82-10-02	R.V.B.	N.S.W.	AS BUILT
1	82-06-17	M.S.	G.S.	ISSUED FOR CONSTRUCTION
0	82-03-22	M.S.	G.S.	ISSUED FOR TENDER
A	81-09-11	A.J.	E.C.	PRELIMINARY

REVISIONS

JOB NUMBER	E750
SCALE	AS SHOWN
DRAWN	
DESIGNED	
CHECKED	NLW
APPROVED	NLW
APPROVED	
DATE	AUG 1981

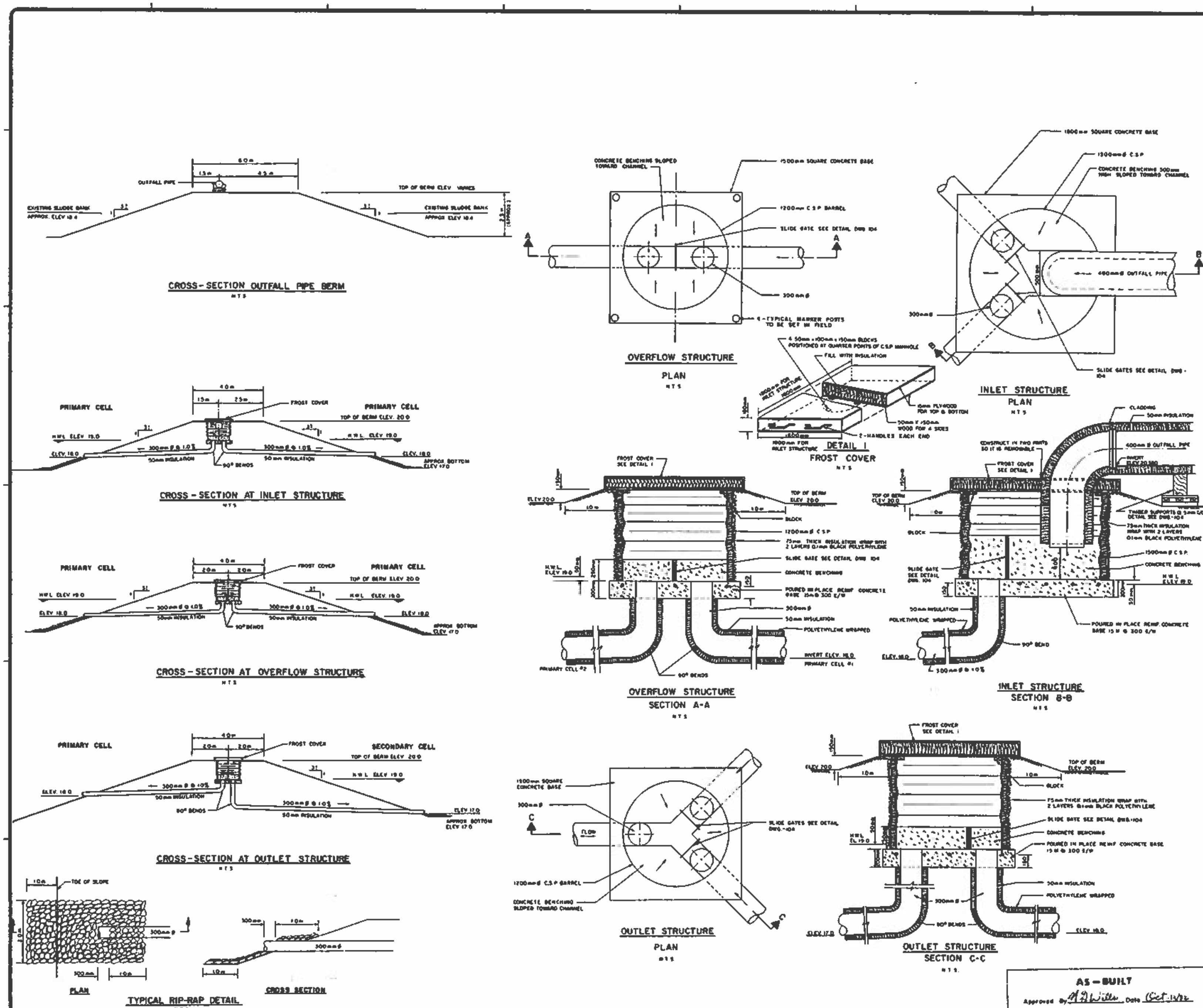
GOVERNMENT OF THE NORTHWEST TERRITORIES

INUVIK , N.W.T.

SEWAGE TREATMENT FACILITY

LAGOON PLAN AND DETAILS

DRAWING NUMBER	REV	SHEET
E75D-20-102	2	2/6



ASSOCIATED ENGINEERING SERVICES LTD.

AESL

DRAWING REFERENCE

NO	DATE	BY	ENG	SUBJECT
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0	82 03 22	M.S	G.S	ISSUED FOR TENDER
A	82 03 04	PC	GS	PRELIMINARY ISSUE

REVISIONS

JOB NUMBER	E75D
SCALE	AS SHOWN
DRAWN	P. CHEUNG
DESIGNED	G. STALKER
CHECKED	
APPROVED	
APPROVED	
DATE	1982-03-04

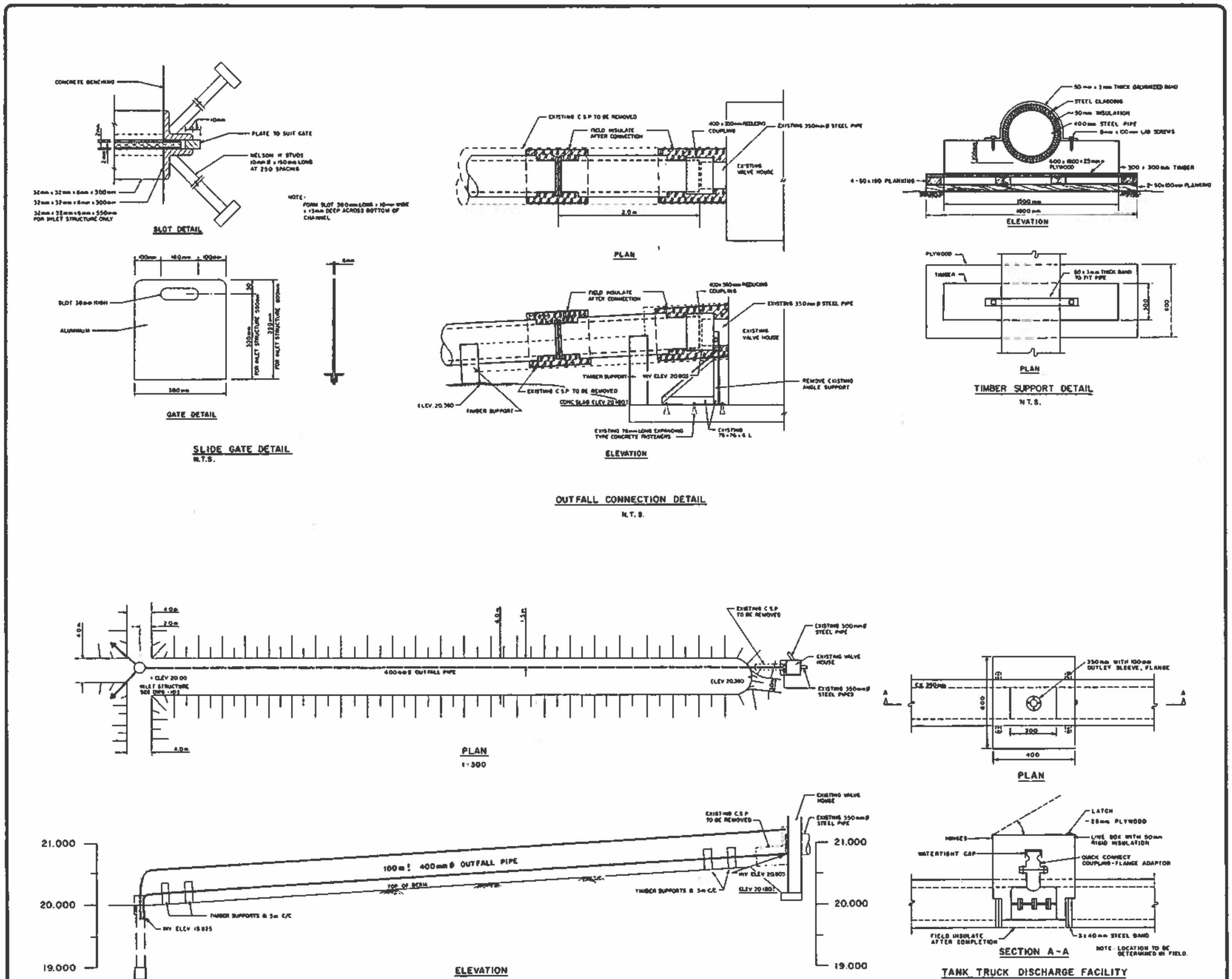
GOVERNMENT OF THE NORTHWEST TERRITORIES

INUVIK, N.W.T.

SEWAGE TREATMENT FACILITY

LAGOON DETAILS

DRAWING NUMBER	REV	SHEET
E75D-20-103	2	3/6



AS – BUILT

Approved By [illegible] Date Oct.15/82

ASSOCIATED ENGINEERING SERVICES LTD

AESL

DRAWING REFERENCE

NO	DATE	BY	ENG	SUBJECT
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0	82-03-22	[illegible]	G.S.	ISSUED FOR TENDER
A	82-03-04	PC	G.S.	PRELIMINARY ISSUE

REVISIONS

JOB NUMBER	E75D
SCALE	AS SHOWN
DRAWN	P. CHEUNG
DESIGNED	G. STALKER
CHECKED	NGW
APPROVED	NGW
APPROVED	
DATE	1982-03-04

GOVERNMENT OF THE NORTHWEST TERRITORIES

INUVIK, N.W.T.

SEWAGE TREATMENT FACILITY

OUTFALL PIPE AND DETAILS

DRAWING NUMBER	REV	SHEET
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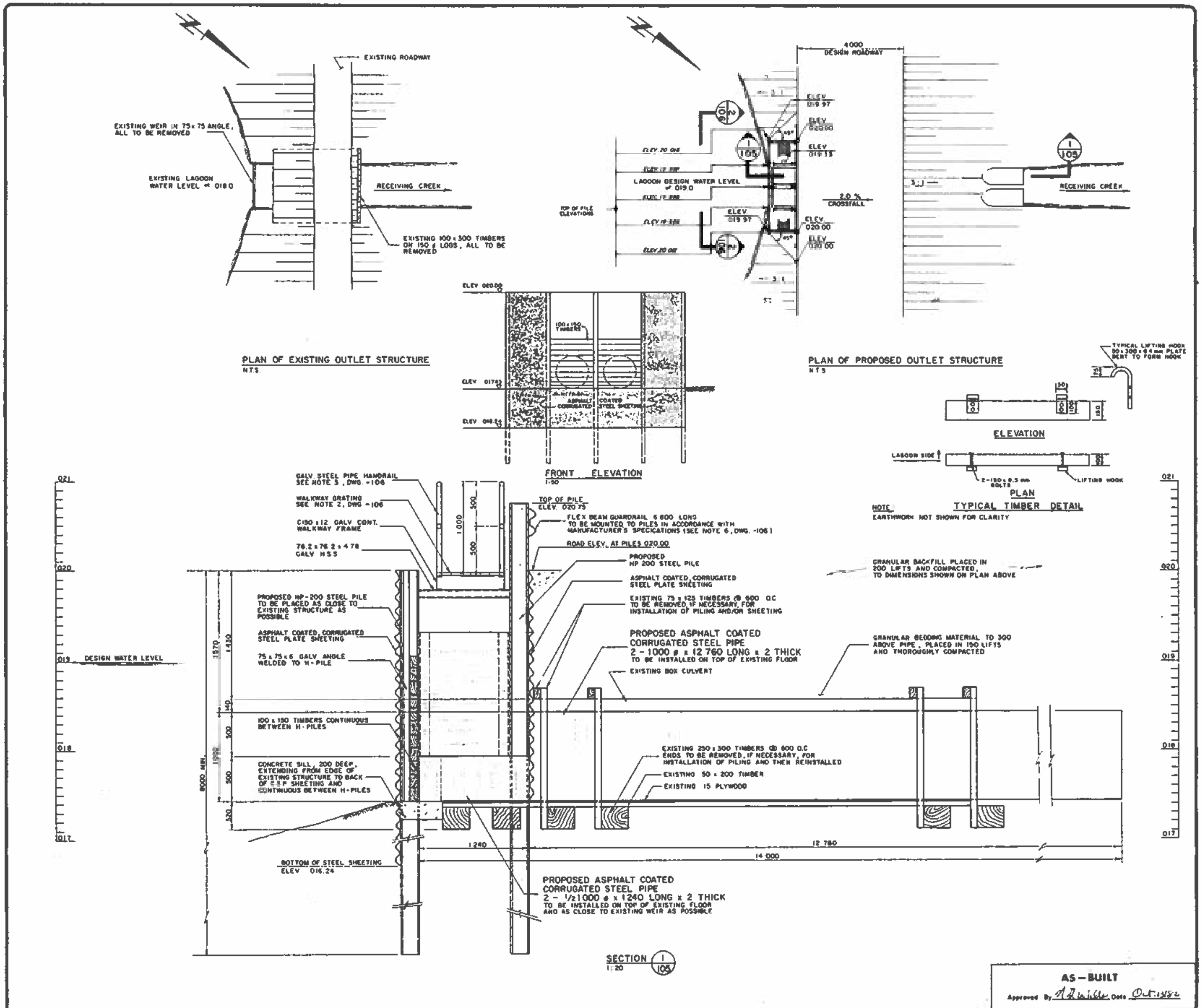


ASSOCIATED ENGINEERING SERVICES LTD.

DRAWING REFERENCE

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. ALL ELEVATIONS ARE RELATIVE TO GEODETIC DATUM IN METRES; BENCHMARK ON CCM67 ELEV. 019.62
3. ALL PILES TO EXTEND 4000 BELOW PERMAFROST LEVEL WHERE POSSIBLE.
4. ALL LOCATIONS AND DIMENSIONS OF THE EXISTING STRUCTURE ARE APPROXIMATE.

ABBREVIATIONS

CCM	CONCRETE SURVEY MONUMENT
℄	CENTRELINE
C.S.P.	CORRUGATED STEEL PIPE
ELEV.	ELEVATION
I.S.P.	IRON SURVEY MONUMENT
INV.	INVERT
MIN.	MINIMUM
N.T.S.	NOT TO SCALE
R.O.W.	RIGHT OF WAY

NO	DATE	BY	ENG.	SUBJECT
2	82-10-16	R.V.G.	N.G.W.	AS BUILT
1	82-05-17	M.S.	G.S.	ISSUED FOR CONSTRUCTION
0	82-05-28	M.S.	G.S.	ISSUED FOR TENDER
A	81-09-01	A.J.	E.C.	PRELIMINARY

REVISIONS

JOB NUMBER	E75D
SCALE	AS SHOWN
DRAWN	
DESIGNED	
CHECKED	
APPROVED	
APPROVED	
DATE	

PROFESSIONAL ENGINEER N.G. WELLS TERRITORY

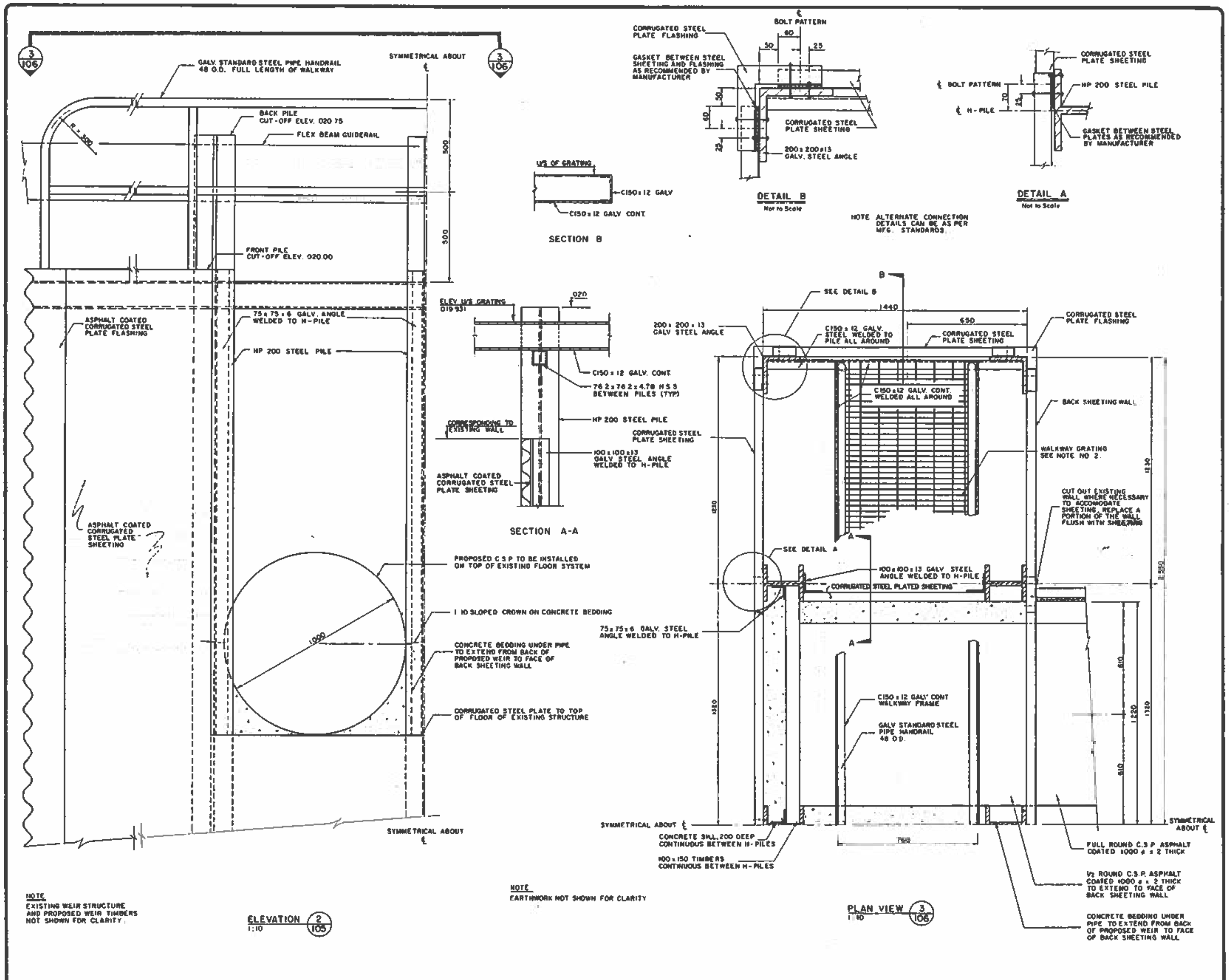
GOVERNMENT OF THE NORTHWEST TERRITORIES

INUVIK, N.W.T.

SEWAGE TREATMENT FACILITY

SEWAGE LAGOON OUTLET STRUCTURE

DRAWING NUMBER	REV	SHEET
E75D-20-105	2	5/6



AS-BUILT
Approved By [signature] Date Oct. 13/82

ASSOCIATED ENGINEERING SERVICES LTD
AESL

DRAWING REFERENCE

NOTES

1. CORRUGATED STEEL PLATE TO BE ASPHALT COATED
   7 THICK WITH 150 x 50 CORRUGATIONS
   NOMINAL SHEET SIZE 1220 x 3 660
   OVERALL SHEET SIZE 1340 x 3 760
   2 BOLTS PER CORRUGATION
2. WALKWAY FLOORING TO BE.
   ARMCO TYPE 'AA' GALV. STEEL PRESSURE GRATING (OR APPROVED ALTERNATE)
   BEARING BARS 25 x 5 @ 30 O.C.
   CROSS BARS 16 x 3 @ 102 O.C.
   WIDTH 760
   LENGTHS TO SUIT FRAME
3. PIPE FOR HANDRAILS TO BE GALV. STANDARD STEEL PIPE WITH O.D. OF 48
4. ALL DIMENSIONS ARE IN MILLIMETRES
5. ALL ELEVATIONS ARE RELATIVE TO GEODETIC DATUM IN METRES. BENCHMARK ON CCM#7 ELEV. 019.62
6. GUIDE RAIL TO BE 2.8 THICK GALV. STEEL FLEX BEAM, 1 ½ STANDARD LENGTHS PLUS 2 STANDARD TERMINAL SECTIONS, CENTRED ABOUT STRUCTURE.

NO	DATE	BY	ENG	SUBJECT
2	82 10 12	R.W.B.	N.G.W.	AS BUILT
1	82 05 17	M.S.	G.B.	ISSUED FOR CONSTRUCTION
0	82 01 22	M.B.	G.B.	ISSUED FOR TENDER
A	81 08 30	A.J.	E.C.	PRELIMINARY

REVISIONS

JOB NUMBER	E75D
SCALE	AS SHOWN
DRAWN	[signature]
DESIGNED	E. Collin
CHECKED	NGW
APPROVED	NGW
APPROVED	
DATE	24 AUG. 1981

PROFESSIONAL ENGINEER YUKON TERRITORY N.G. WILLS

GOVERNMENT OF THE NORTHWEST TERRITORIES

INUVIK, N.W.T.

SEWAGE TREATMENT FACILITY

SEWAGE LAGOON OUTLET STRUCTURE DETAILS

DRAWING NUMBER	REV	SHEET
E75D-20-106	2	6/6

Contact

Jordan Hoffart, P. Eng., PMP
Project Manager
T +1 (780) 732-9465
E Jordan.hoffart@aecom.com

aecom.com

Figure 1: Overall Location Plan

Figure 2: Lagoon Cross Sections and Hydraulic Profile

Figure 3: System Layout Plan

Contact

Jordan Hoffart, P. Eng., PMP
Project Manager
T +1 (780) 732-9465
E Jordan.hoffart@aecom.com

aecom.com