TECHNICAL MEMORANDUM

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TO:	Louise Grondin Meadowbank Mining Corporation	**DATE:**	August 13, 2007
		JOB NO:	06-1122-386/4000
FROM:	Laura Laurenzi and Valérie Bertrand	**DOC NO:**	355
EMAIL:	llaurenzi@golder.com / vbertrand@golder.com	**VERSION:**	1
REVIEWED BY:	Nural Kuyucak		
RE:	**SEWAGE TREATMENT SYSTEM TO BE USED AT MEADOWBANK GOLD PROJECT, NUNAVUT**		

1.0 INTRODUCTION

The following technical memorandum provides details on the camp sewage treatment types that will potentially be used at the Meadowbank Gold Project (Meadowbank), operated by Meadowbank Mining Corp. (MMC) formerly Cumberland Resources Ltd. (Cumberland). This information was identified by the Nunavut Impact Review Board (NIRB; item 10) as a requirement for Meadowbank's water license application (NIRB, 2006).

> *Cumberland shall provide details of the camp sewage treatment, including the type of treatment to be used and the expected treatment capabilities, in the water license application to the NWB.*

In the Final Environmental Impact Statement (FEIS) for Meadowbank (Cumberland, 2005), two potential treatment systems for the on-site treatment of camp sewage were proposed, including a sequencing batch reactor (SBR), and a rotating biological contactor (RBC). Descriptions of these systems, including expected treatment capabilities, are provided in this document.

2.0 BACKGROUND

2.1 Principle of Sewage Treatment

Sewage, liquid waste from toilets, baths, showers and kitchen, is treated for removal of contaminants including organic and inorganic compounds as well as bacteria. Treatment of sewage produces 1) a clean waste stream (or treated effluent) suitable for reuse or discharge back into the environment and 2) a solid waste (or sludge) also suitable for proper disposal or reuse. Contaminants that require treatment may include organic constituents (measured using biochemical oxygen demand (BOD)), ammonium (NH_4^+), phosphorus, oil and grease, grits and suspended solids (TSS). Sewage treatment incorporates physical, chemical and/or biological methods requiring various levels of treatment processes, which define the operations and processes that occur to complete the treatment. The stages of treatment processes are typically referred to as (Metcalf and Eddy, 2003).

- Preliminary (or mechanical) treatment: physical removal of large objects such as floatables, sticks, grit and grease.

- Primary treatment: physical removal of suspended and faecal solids and sand and grit by pre-precipitation.

- Secondary treatment: removal of organic matter via biological/chemical processes.

- Tertiary treatment: physical removal of residual suspended solids (after secondary treatment).

Package plants, such as SBR and RBC, often combine all or at least two stages of the three main treatment stages (*i.e.*, primary to tertiary treatment processes) into one combined stage. They are often employed to serve small populations, deal with intermittent flows and/or reduce the need for large footprints to achieve higher environmental standards. A tank (*e.g.*, septic tank, equalization pond) is usually installed upstream of the package treatment system to collect sewage and provide inflow to the treatment system. This tank can also act as a primary treatment tank where solids can settle and homogeneous liquid is produced for further treatment. The secondary treatment stage offers the main treatment processes where the biological content of the sewage containing human waste, food waste, soaps and detergents will degrade with the help of bacterial activities. The majority of sewage treatment systems are based on aerobic biological processes where organic compounds (such as carbonaceous BOD) are degraded and soluble organic contaminants (*e.g.*, sugars, fats, short organic chain carbon molecules) are consumed by the bacteria and less soluble fractions are bound into floc particles. Ammonia is also converted to nitrate with the help of microorganisms under the aerated conditions (*i.e.*, nitrification). Combination of decaying bacteria resulting from the biological processes (or "biomass") and floc particles form sludge that require separation and disposal. In order for the microorganisms to perform effectively, the environment within the treatment system must be well-aerated (to provide oxygen), and must include suitable nutrients (*i.e.*, substrate) for the microorganisms. After these reactions are complete, the treated wastewater (effluent) is removed from the system for disposal or reuse.

During the construction phase of the project before construction of the tailing impoundment, treated sewage water will be discharged into Tear Drop Lake (Figure 2.1), a small, shallow (less than 2m deep) and fishless, water body. This water body is located between the proposed plant site and Portage Pit. It is contained within the mine footprint. Treated water from Tear Drop Lake will be pumped to the Tailings Storage Facility (TSF) via the tailings line following commissioning of the TSF and tailings line. During mine operation and until closure of the tailing containment area during mine closure period, the treated water will be disposed of into the tailings pond and sludge will be co-disposed with treated water or incinerated. The tailings pond water will not be discharged until the end of mine life, at which tailing water will be treated prior to discharge (MMC, 2007). The dewatered tailings pond will be covered with unreactive waste rock for decommissioning and is expected to freeze in time.

2.2 Site-Specific Parameters

There are a number of site-specific parameters that need to be accounted for in the design of a sewage treatment facility. These include the following:

- Anticipated influent characteristics (*i.e.*, quality and quantity of wastewater), estimated from the site conditions (*e.g.*, number of workers, operational season, etc.);
- Effluent requirements;
- Maximum and minimum ambient temperature; and
- Proximity of system to wastewater inputs.

As shown in the potable water balance provided in the Mine and Waste Water Management Report (MMC, 2007), approximately 29,000 m^3 of sewage will require treatment per year at Meadowbank, based on a flow rate of 80 m^3/day (AMEC, 2005b). For the comparative purposes of this document the sewage treatment plants for the proposed camp facilities are designed to meet the following general discharge criteria (Golder, 2006):

- Carbonaceous biochemical oxygen demand (cBOD) <20 mg/L;
- Total suspended solids (TSS) <20 mg/L;
- Total fecal coliform (TFC) <200 cfu/100mL; and
- Ammonia (NH-4) <10 mg/L after 30 days.

The annual maximum and minimum air temperature at Meadowbank is 16.8˚C and -35.5˚C respectively (AMEC, 2005a).

The sewage treatment facility for the camp will be housed in a prefabricated structure adjacent to the accommodations camp (Cumberland, 2005), such that the proximity of the system to wastewater inputs is optimized.

2.3 QA/QC Monitoring

After the sewage treatment facility is installed discharge from the sewage treatment facility will be tested quarterly for the above listed parameters (Section 2.2). These quarterly tests will be done for four quarters.

3.0 SEQUENCING BATCH REACTORS (SBR)

3.1 Equipment

An SBR system consists of the following equipment:

- Tank(s);
- Aeration and mixing equipment;
- A decanter; and
- A control system.

Although an SBR system generally consists of a single tank, multiple tanks can be used to optimize of the performance of the system. Tanks are either constructed from steel or concrete, depending on the site-specific parameters and applications of the system. SBR systems are automated by the control system, which includes the control unit, operator interface, automatic switches and valves, remote access modem, timer based control software and motor starters that sequence and time the different operations (Siemens, 2006a).

3.2 Operation

The operation of an SBR system is based on a “fill and draw” principle occurring in cycles. In general, wastewater is added to a tank, treated to remove contaminants, and then discharged. All SBR systems have five steps in common, which are carried out in the following sequence:

- Fill;
- React (aeration);
- Settle (sedimentation/clarification)
- Draw; and
- Idle.

Prior to entering the SBR tank, wastewater may require passing through screens and/or grit removal. Primary clarifiers may also be recommended if either TSS or BOD is greater than 400 to 500 mg/L (EPA, 1999). Influent wastewater is then added into the tank during the fill step. Three basic variations of the fill step can be employed (*i.e.*, static fill, mixed fill, or aerated fill), based on the operation strategy of the system.

All biological reactions are completed by microorganisms during the react step. Throughout this step, aeration and mixing equipment provide oxygen to support the microorganisms. There are various types of aeration and mixing equipment available, including equipment that is capable of both aeration and mixing (*e.g.*, jet aeration equipment).

The settle step is a period of quiescent conditions in the tank. During this step, gravity causes solids in the wastewater to collect at the bottom of the tank. Wastewater is not allowed to enter or exit the system during this step, such that the settling process can occur uninterrupted.

During the draw step, a decanter removes the treated wastewater (or effluent). There are various possible configurations for the decanter, which can either be fixed or floating. The decanter configuration is designed by the manufacturer for the specific needs of the system.

The idle step is an interim step that occurs between the draw and the fill steps, during which effluent is removed and influent (untreated) wastewater is added into the vessel. In a multi-tank system, the idle step provides time for one reactor to complete its fill step before switching to another tank. During the idle step, equalization, sludge wasting and mixing to condition the wastewater can be performed. The idle step is not a necessary step and is sometimes omitted from the design of an SBR.

Sludge wasting is a phase of treatment that can occur at any time in the SBR. Sludge wasting is the removal of excess solids (including fine material and large floc particles) from the tank. Sludge can be removed manually; using plug valves, or by pumps (Siemens, 2006a). Wasting holds the mass ratio of influent substrate to biomass nearly constant from cycle to cycle (EPA, 1999).

3.3 Size

The footprint of an SBR system is dependant on the number of tanks used and the size of the tanks, which are designed based on the flow characteristics of the influent wastewater. For Meadowbank, a two tank SBR system, with each tank having a maximum surface area of 4 m x 5 m (4 m height), would likely need to be constructed to produce effluent that meets the aforementioned general discharge criteria (Siemens, 2006a).

3.4 Performance

In general, SBRs have a BOD removal efficiency of 85 to 95% (EPA, 1999). SBR manufacturers will typically provide a process guarantee to produce effluent of less than 10 mg/L BOD, 10 mg/L TSS, 5 – 8 mg/L total nitrogen (TN) and 1 – 2 mg/L total phosphorous (TP) (EPA, 1999).

3.5 Advantages

Listed below are some of the advantages of using an SBR system for wastewater treatment.

- **Design Simplicity**; SBR systems use a single tank in which equalization, primary clarification (in most cases), biological treatment, and secondary clarification can be achieved.

- **Operating Flexibility and Control**; SBR systems are able to handle a wide range of flow variations and influent variations.

- **Minimal Footprint**; as compared to RBC systems, SBR systems require a smaller footprint because wastewater treatment can occur in a single tank.

3.6 Disadvantages

Listed below are some of the disadvantages of using an SBR system for wastewater treatment.

- **Sophistication**; The timing and unit controls of an SBR system are highly sophisticated. As a result, SBR systems typically require a trained employee for operation and maintenance (Siemens, 2006a).

- **Sludge Discharge**; during the draw or decant phase of the cycle there is a potential for discharge of floating or settling sludge (with some SBR configurations) (EPA, 1999).

- **Maintenance**; depending on the aeration system used there is the potential for plugging of aeration devices (EPA, 1999).

- **Energy Cost**; as compared to RBC systems, SBR systems have a higher energy cost due to the automation of the control system (Siemens, 2006a).

- **Purchase Cost**; SBR systems are more expensive than RBC systems (Siemens, 2006a).

4.0 ROTATING BIOLOGICAL CONTACTORS (RBC)

4.1 Equipment

An RBC system consists of a number of units. Each unit consists of the following equipment:

- A shaft;
- Disks;
- A drive system; and
- An enclosure.

The disks of an RBC unit are attached to the shaft, which is rotated within an enclosure by the drive system. Each unit operates as an independent cell, or stage. An RBC system contains a series of stages, which are either situated within a series of individual tanks (*i.e.*, one stage per tank), or separated by baffles within a single tank. The number of stages used in an RBC system depends on treatment goals, with specifically designed stages for nitrification (*i.e.*, conversion of ammonia to nitrate) and BOD removal. RBC systems are typically enclosed in segmented fibreglass reinforced plastic covers that are usually provided as part of the system (Metcalf and Eddy, 2003). In cold weather climates, it is typical for the RBC system to be housed in a building to promote efficiency.

4.2 Operation

The operation of an RBC system is based on a continuous flow of wastewater through a series of stages. As wastewater flows through the RBC system, each successive RBC stage receives influent with lower contaminant concentrations than the previous (EPA, 2002). In general, treatment of wastewater by an RBC system includes the following processes:

- Aeration and mixing via rotating disks;
- Biological reactions on disk surfaces; and
- Sloughing of solids from rotating disks.

Prior to entering the RBC, wastewater requires some form of pretreatment of either primary clarification or passing through fine screens for liquid/solid separation (Metcalf and Eddy, 2003). Wastewater can then flow into an RBC unit, where it comes in contact with the disks attached to the rotating shaft. The disks can be configured and corrugated in various patterns to provide increased surface area and enhanced structural stability as they rotate through the wastewater (Metcalf and Eddy, 2003). Aeration and mixing occurs as the shaft and associated disks rotate through the wastewater (Metcalf and Eddy, 2003). The disks provide surfaces on which microorganisms can react with ambient air and wastewater (EPA, 2002).

As wastewater flows through the disks, sloughing of solids accumulated on the disks occurs by displacement and gravity (Metcalf and Eddy, 2003). After the treatment process within the RBC is complete, the resulting wastewater is directed to settling tanks. These tanks are necessary for secondary clarification, such that solids within the treated wastewater can be separated from the liquid to form sludge (Metcalf and Eddy, 2003).

4.3 Size

The footprint of an RBC system is dependant on the number of stages needed to produce effluent that meets the required discharge criteria. The size of each stage is affected by site-specific parameters such as temperature and proximity to influent input. At Meadowbank, an RBC of 4 stages, with each stage having maximum dimensions of 4 m x 8 m (4 m height), would likely need to be constructed to produce effluent that meets the aforementioned general discharge criteria (Siemens, 2006b).

4.4 Performance

In general, RBCs show up to 90% BOD removal efficiency (EPA, 2002). EPA (2002) states that currently available RBC systems should be capable of producing effluent BOD and TSS of 4 – 40 mg/L, 0 – 35 % nitrogen removal, phosphorous removal of 10 to 15 %, and reductions in fecal coliform count (EPA, 2002).

4.5 Advantages

Listed below are some of the advantages of using an RBC system for wastewater treatment.

- **Energy Cost;** RBC units are driven by mechanical units that have lower energy demands than an SBR system.

- **Operating Flexibility and Control;** RBC systems are capable of handling a wide range of flows. RBC systems also have low sludge production and good process control.

- **Sludge Discharge;** Sloughed biomass exhibits good settling characteristics and can easily be separated from waste stream.

- **Sophistication;** RBC systems are mechanically driven units that are easier to operate. A lower level of skill is required for the maintenance and operation of an RBC treatment system as compared to an SBR system.

- **Purchase Cost;** RBC systems, excluding the extra infrastructure that may be required for efficiency in colder climates, are typically less expensive than SBR systems for the treatment of wastewaters having similar characteristics in term of quality and quantity (Siemens, 2006b).

4.6 Disadvantages

Listed below are some of the disadvantages of using an RBC system for wastewater treatment.

- **Efficiency;** RBC systems experience reduced efficiency in colder climates due to heat loss. Covering of units, insulation of infrastructure and proximity to influent input is necessary for efficiency (Siemens, 2006b).

- **Maintenance;** Shaft bearings and mechanical drive units require frequent maintenance (EPA, 2002).

- **Aesthetics;** Odour and flies can develop during times of cessation (EPA, 2002).

- **Greater Footprint;** RBC systems have greater footprints than SBR systems and require additional construction of primary and secondary clarifying units.

5.0 SUMMARY

In the Final Environmental Impact Statement (FEIS) for Meadowbank, two potential treatment systems for the on-site treatment of camp sewage were proposed, including a sequencing batch reactor (SBR), and a rotating biological contactor (RBC). Both systems are designed based on a number of site-specific parameters, including flow characteristics, anticipated influent characteristics, effluent requirements, ambient temperature, and proximity to wastewater inputs. At Meadowbank, both treatment facilities can be designed to treat the waste waster produced in camp to the required effluent standards. Summarized in Table 5-1 are the typical effluent capabilities of each sewage treatment system compared to the general discharge criteria used in this document for comparative purposes.

TABLE 5-1: General Discharge Criteria for Treated Sewage and Expected Capabilities per Proposed Sewage Treatment System

Parameters	General Effluent Criteria	SBR (EPA, 1999)	RBC (EPA, 2002)
Biochemical Oxygen Demand	<20 mg/L (cBOD)	10 mg/L (BOD)	4 – 40 mg/L (BOD)
Total Suspended Solids	<20mg/L	10 mg/L	4 – 40 mg/L
Total Fecal Coliform (TFC)	<200 cfu/100mL	-	reductions in TFC counts
Ammonia (NH-4)	<10 mg/L after 30 days	-	-

The treated sewage effluent discharge will not be discharged directly to the receiving environment. During construction, treated sewage discharge will be disposed of in a shallow water body contained within the mine footprint, and during operation, will be discharged to the tailing impoundment and will be recycled to the mill. Tailing reclaim water will not be discharged until end of mine life, at which time it will be treated prior to release to the receiving environment.

5.1 Characteristics of the Systems

SBR systems treat influent wastewater in single batches, as opposed to RBC systems which treat wastewater in a series of stages. To meet the criteria required for discharge to the reclaim pond at Meadowbank, an SBR system would require two tanks, while an RBC system would require four stages (tanks). Coupled with the fact that the dimensions of an RBC stage are larger than that of an SBR tank, the footprint of an RBC facility would be larger than the footprint of an SBR facility at Meadowbank.

Both SBR and RBC systems require equipment maintenance. The most common maintenance requirement for SBR systems is unplugging of the aeration equipment, while RBC systems typically require mechanical maintenance of the drive unit and shaft bearings. However, since the equipment used in SBR systems is more sophisticated, a trained employee is required for maintenance and operation. RBC systems, which are simpler, do not have this requirement.

In colder climates, RBC systems experience reduced efficiency and require covering (or housing) because the tanks are open to the atmosphere. RBC systems are also required to be in close proximity to the influent wastewater input. SBR systems use enclosed tanks, and therefore do not typically require covering in colder climates. However, it is understood that at Meadowbank the sewage treatment facility will be placed in a prefabricated structure in close proximity to the accommodations camp such that the effect of ambient temperature on efficiency is minimized.

The energy demand of an SBR system is greater than the energy demand of an RBC due to the automation of the system and the constant power required for the control unit. RBC systems, however, are powered by a mechanical unit, and wastewater flows through the system by the rotation of the shaft and gravity. As a result, RBC systems are also typically less expensive, than SBR systems.

Selection of the sewage treatment system for use at the project site will be made by MMC, prior to construction.

GOLDER ASSOCIATES LTD.

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Attachments
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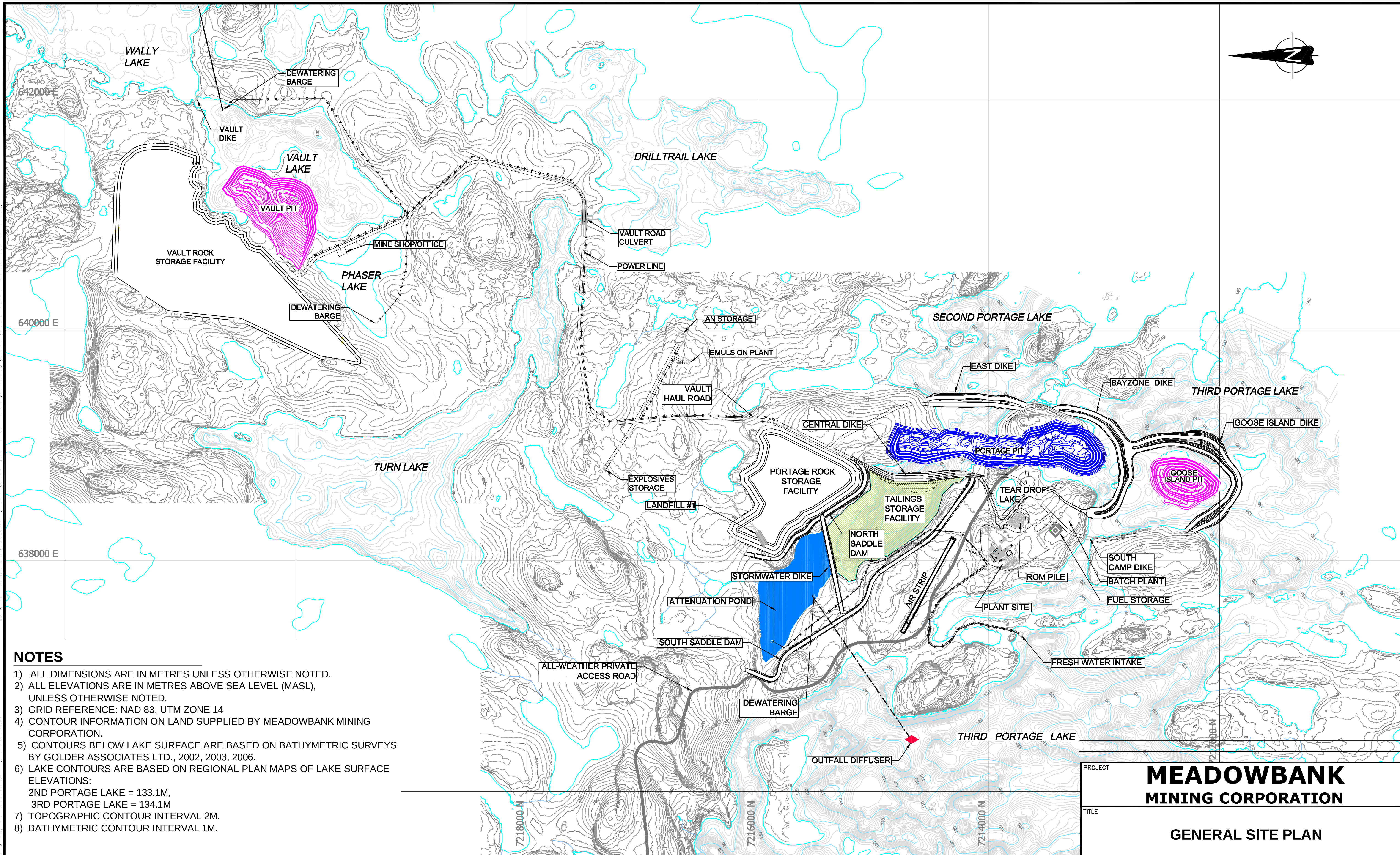

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REVISION DATE: 07/08/01 04:12PM By: ASalvador

NOTES

1) ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2) ALL ELEVATIONS ARE IN METRES ABOVE SEA LEVEL (MASL), UNLESS OTHERWISE NOTED.
3) GRID REFERENCE: NAD 83, UTM ZONE 14
4) CONTOUR INFORMATION ON LAND SUPPLIED BY MEADOWBANK MINING CORPORATION.
5) CONTOURS BELOW LAKE SURFACE ARE BASED ON BATHYMETRIC SURVEYS BY GOLDER ASSOCIATES LTD., 2002, 2003, 2006.
6) LAKE CONTOURS ARE BASED ON REGIONAL PLAN MAPS OF LAKE SURFACE ELEVATIONS:
   2ND PORTAGE LAKE = 133.1M,
   3RD PORTAGE LAKE = 134.1M
7) TOPOGRAPHIC CONTOUR INTERVAL 2M.
8) BATHYMETRIC CONTOUR INTERVAL 1M.

REFERENCES

1) AMEC AMERICAS LTD., DRAWING NUMBER A1-131395-100-C-0001 (100-C-0001.DWG), MEADOWBANK FEASIBILITY STUDY, APRIL 2005.

PROJECT

MEADOWBANK MINING CORPORATION

TITLE

GENERAL SITE PLAN

Golder Associates

PROJECT No.	06-1122-386		FILE No.	FIG-2.1
DESIGN	LL	01AUG07	SCALE AS SHOWN	REV. -
CADD	AS	01AUG07		
CHECK				
REVIEW				

FIGURE 2.1