TECHNICAL MEMORANDUM

Golder Associates Ltd.
500 – 4260 Still Creek Drive
Burnaby, British Columbia, Canada V5C 6C6

Telephone: 604-296-4200
Fax Access: 604-298-5253

TO:	Louise Grondin Agnico-Eagle Mines Limited	**DATE:**	August 23, 2007
		JOB NO:	07-1413-0047-2000
CC:	Dan Walker Golder Associates Ltd.	**DOC NO:**	498
FROM:	Erin O'Brien, John Hull	**VERSION:**	0
EMAIL:	EObrien@golder.com; JHull@golder.com		
RE:	Landfarm Option Analysis, Meadowbank Gold Project, Nunavut		

The following presents the option analysis for a landfarm biocell(s) to treat petroleum contaminated soils at the Meadowbank Gold Project, Nunavut. It is understood that Meadowbank Mining Corporation (MMC), formerly Cumberland Resources Ltd. (Cumberland), wishes to investigate possible alternatives to shipping contaminated soils off-site for treatment at a licensed disposal facility. A description of how petroleum contaminated soils on site will be managed during operation is required as part of the Type-A Water Licence Application for the project.

This technical memorandum specifically addresses soil treatment by landfarming. Other remedial options that may be possible to treat contaminated soils, but were not reviewed as part of the current scope of work include: thermal treatment (incineration), thermal desorbtion, chemical fixation and soil washing.

1.0 BACKGROUND

1.1 Definition

Landfarming is 'a remediation technology for soils that reduces the concentration of petroleum hydrocarbon constituents through biodegradation'. This technology typically involves spreading excavated contaminated soils in a thin layer, or in windrows, on the ground surface and stimulating aerobic microbial activity within the soils through aeration and/or the addition of minerals, nutrients, and moisture. Biocells or biopiles, refer to an above ground, lined cell where *ex-situ* landfarming practices can occur. Landfarming has been proven effective at reducing concentrations of most petroleum hydrocarbons but is not recommended means of treating heavily contaminated soils (*i.e.,* hazardous waste) (SAIC, 2005), or soils with other contaminants, such as metals.

SAIC (2005) reports that climatic conditions and precipitation may impact operating times for landfarms: longer operating times can be expected in colder climates since biodegradation rates of petroleum hydrocarbons lower as temperatures decrease.

1.2 Literature Review

The use of *ex-situ* bioremediation for the treatment of petroleum hydrocarbon impacted soil has been studied extensively. The research shows that bioremediation is very successful in temperate climates but the results in colder climates are less well known. A review of current literature was undertaken to establish if bioremediation may be effective in arctic climatic conditions, such as those encountered in the Meadowbank Gold Project area.

1.2.1 Cold Climate Bioremediation

In a summary paper presented to Assessment and Remediation of Contaminated Sites in Arctic and Cold Climates (ARCSACC) in 2005, Reimer (*et. al.*) cited the following:

- Numerous studies have identified the presence of cold-adapted micro-organisms cable of degrading petroleum hydrocarbons.

- Bio-stimulation through the addition of nutrients is effective at reducing petroleum hydrocarbon constituents, but the concentrations applied should be lower than those recommended at more temperate Canadian locations.

- The use of biosurfactants, such as the brand Biosolve®, has also been proven effective, but at a rate equal to 25% of that recommended by the manufacturer. A biosurfactant is used to increase the solubility and dispersion of hydrophobic compounds (petroleum hydrocarbon contaminants) that bind to soil particles and have limited solubility in water, and thereby resulting in limited availability to soil microorganisms.

- Studies have shown that little to no biodegradation occurs at temperatures at 0 or -5° C, but that losses by volatization do continue at these temperatures. Heating bio-piles has been found effective at extending the period of microbial biodegradation.

1.2.2 Alert, Nunavut

In a paper presented to ARCSACC in 2007, a biopile was found effective at reducing petroleum hydrocarbons in soil in Alert, the most northerly inhabited place in the world (Greer *et. al.,* 2007). In the study, petroleum hydrocarbon contaminated soil was placed into a biocell, mixed with fertilizer and tilled into 1-2 m high windrows. After a period of two months during the spring, a 60% reduction of residual hydrocarbons was measured; and a reduction of 70% was achieved after one year of treatment and the soils had reached industrial quality within 15 months of treatment.

1.2.3 Resolution Island, Nunavut

In a paper presented to ARCSACC in 2005, diesel contaminated soil on Resolution Island was placed in four sets of landfarming conditions (Paudyn *et. al*., 2005). The trials found that enhanced bioremediation occurred with the addition of fertilizer and when the soils were aerated. Over the period of two summers, the fertilized soils achieved a reduction of 90% of total petroleum hydrocarbons. The nutrients applied used a carbon: nitrogen: phosphorous (C: N: P) ratio of 100: 7.5: 0.5.

1.2.4 Other Bioremediation Technologies

An on-site biopile was found effective at treating petroleum hydrocarbon-impacted soil at a former power plant in Tulita, NWT (Pouliot *et. al*, 2005). The on-site biopile consisted of installing wells into the contaminated zone to allow for aeration, and to treat the soil with nutrients. This technique minimized the handling of the contaminated materials, but would not be particularly suitable at an active location, such as Meadowbank.

2.0 OTHER NORTHERN MINE SITES

Information was gathered from Snap Lake, Ekati, Jericho and Diavik mines/projects and reviewed to determine if landfarming and bioremediation has been effective in other arctic locations.

2.1 Snap Lake Project

The Snap Lake Project currently does not utilize a landfarm system; however, it is projected that a landfarm will be constructed in 2007 (Lasha Young, Pers. Comm.) to treat petroleum hydrocarbon-contaminated soil. A design report was prepared by AMEC Americas Limited (AMEC) entitled: "Snap Lake Project, Landfarm for Hydrocarbon Contaminated Soils," Project No. 142222, revision 01, dated August 3, 2006. The

AMEC report describes the on-site environmental *ex-situ* remediation system ("landfarm") designed to treat petroleum hydrocarbon-impacted soil and snow/ice. This design employs two side-by-side engineered "biocells." In one biocell, snow and ice are stored until they can be melted and treated using an oil/water separator prior to the ultimate disposal through either the domestic sewage treatment plant or the water treatment plant. The aeration, fertilizers and water would be added to the soil biocell to enable degradation of petroleum hydrocarbons by microbes. Once remediated, the soil would be disposed of on-site as 'reclaimed' fill material.

The proposed design of the landfarm for hydrocarbon contaminated soils by AMEC consists of a bottom or lower containment system for the biocells that would be constructed using various fills overlain by a low permeable liner consisting of high density polyethylene (HDPE), and geotextile. In additional, the proposed design includes a provision for fill to be placed on top of the liner. A snow fence would mark the limits for excavation for the heavy equipment operator. The base cells are designed with a slope to allow for water drainage and collection from a sump. Water will be pumped or vacuumed from the sump and transferred to tank and then run through an oil-water separator. The cells are designed to hold up to 2,600 m^3 of soil and 2,000 m^2 of snow/ice. The base and top of the soil biocell will be tarped to minimize leachate generation.

2.2 Ekati Diamond Mine

Mr. Brent Murphy, Environmental Manager, with Ekati Diamond Mine, was contacted by Golder on May 26, 2007. Mr. Murphy provided the following information about the landfarm operation to treat hydrocarbon-contaminated soils at the Ekati Diamond Mine site.

The operation consists of one main biocell used to treat petroleum hydrocarbon, in particular diesel, contaminated soil. The cell measures approximately 20 m by 40 m and up to 5 m high, and is underlain by a HDPE liner. The soil is piled in windrows to maximize the surface area and thereby expose the soil to the air, as there is no upper liner. The cell is situated on a slight gradient to facilitate drainage of surface water and leachate. A sump in one corner collects water in which free phase hydrocarbons are skimmed and collected, and the water is disposed of in the tailings facility. The cell gets aerated and turned twice annually, in mid summer and just before freeze up. Soil samples are collected annually to evaluate soil quality. Bioremediation occurs with endemic bacteria supplemented by the addition of commercial grade fertilizers. Although no soil has yet been remediated down to disposal grade quality, Mr. Murphy anticipated reaching these quality levels following two to three years of treatment. The other two options Ekati considered for contaminated soil disposal were trucking off-site and thermal desorption, but landfarming was considered the most economical option.

2.3 Jericho Diamond Mine

Mr. Bruce Ott, with Jericho Diamond Mine, was contacted by Golder on May 26, 2007. Mr. Ott reported that Jericho does not currently have a landfarming operation, but is considering the option of engineering a bioremediation cell to remediate petroleum-hydrocarbon contaminated soil following a petroleum hydrocarbon spill that occurred in December 2006. Currently, smaller volumes of contaminated soils are trucked off-site for disposal at a licensed facility.

2.4 Diavik Diamond Mines

The Interim Closure and Reclamation Plan prepared by Golder Associates Ltd., Document Control #: RPT-197 Version 0, dated September 2006 was reviewed. The following information regarding proposed landfarming practices at Diavik was presented. Petroleum hydrocarbon-impacted soils will be land-treated in a designated cell within the Waste Transfer Area. The cell will be bermed and lined with a geomembrane. The hydrocarbon contaminated soil will be placed within the cell and spread during the summer months to allow for remediation to acceptable levels by using natural micro-biological processes (bio-remediation). Fertilizers such as ammonium nitrate will be applied to enhance the bio-remediation process and improve the efficiency of the landfarm.

Diavik currently has a small scale landfarm in the Waste Transfer Area (Amy Langhorne, pers. comm.). Information about the landfarm was made available in the unpublished thesis prepared by Brenda Lee Bailey of the Institute of Environmental Science of Carleton University entitled "*Removal of Hydrocarbons from Contaminated Crushed Granitic Rock at the Diavik Diamond Mine Site.*" In an experimental trial, it was found that contaminated granitic crush rock augmented with sewage sludge, and aerated was effective at reducing TPH from 15,000 mg/kg to less than 2,000 mg/kg over a period of 88 days.

3.0 REGULATORY FRAMEWORK

Based on similar projects completed by Golder in Nunavut, the Nunavut Impact Review Board ("NIRB") will define acceptable target levels of soil remediation (Tanya Shultz, Pers. Comm.). NIRB's decision will be principally based on the Canadian Council of Ministers of the Environment (CCME) *Canada-Wide Standards for Petroleum*

Hydrocarbons (PHC) in Soil and the *Technical Supplement* (dated January 2001). The four types of land use included in the regulations are: Agricultural, Residential/Parkland, Commercial and Industrial. Based on the objective of the Closure and Reclamation Plan to return the mine site footprint back to productive use, the soil should be screened against the most stringent criteria (i.e., Residential/Parkland levels). The Canada Wide Standards (CWS) for petroleum hydrocarbons (PHC) in the range of diesel (F3) for coarse grained soils, such as fill, is 2,500 mg/kg. This is the anticipated level the NIRB will require for on-site disposal of hydrocarbon-impacted soils.

The Federal Guidelines for Landfarming Petroleum Hydrocarbon Contaminated Soils. SAIC (Science Applications International Corporation) Canada, dated December 2005, provide information about the construction and use of landfarms. The Generic Plans and Operating Procedures of a Remediation Facility for Hydrocarbon Contaminated Materials in the NWT (Government of NWT, 1995) presents plans and operating procedures for facilities used to treat hydrocarbon contaminated soil and snow. This report also provides a review of various remediation technologies.

The Federal Transportation and Dangerous Goods (TDG) regulations apply to contaminated soils once the material leaves the mine site.

4.0 CLIMATE

The following information was taken from the Final Environmental Impact Statement for the Project (FEIS; Cumberland, 2005). The Meadowbank Gold Project is situated within an Arctic ecoclimate described as one of the coldest and driest regions of Canada. Arctic winter conditions occur from October through May, with temperatures ranging from +5°C to -40°C. Summer temperatures range from -5°C to +25°C with isolated rainfall increasing through September.

The long-term mean annual air temperature for Meadowbank is estimated to be approximately -12°C. The adjusted mean annual precipitation totals for Meadowbank are 292.8 mm.

Based on the climatic data presented in the FEIS (Cumberland, 2005), average temperatures for June to September are above freezing, therefore it is anticipated that bioremediation may be feasible during those months.

5.0 LOCATION FACTORS

Several factors should be considered when selecting a location for the proposed landfarm including:

1. Proximity to other mine services, in particular to an access road.

2. Reducing transport distances of contaminated soil and/or snow and ice. It is anticipated that incidental releases and/or spills of fuel could potentially occur principally in the storage and refuelling areas for heavy equipment and air craft; and to a lesser degree in shop areas where hydraulic oils, motor oils and waste oils will be handled.

3. Distance from fish-bearing water bodies and potable water should also be considered. Previous experience on similar projects indicates that the minimum distance the remediation system should be from a fish-bearing water body is 10 m, but the ideal distance would be 300 m (Tanya Shultz, Pers. Comm.). Environment Canada recommends that landfarm should be sited greater than 500 m from a permanent surface water body (for both potable and non-potable surface waters) and from a potable groundwater well (SAIC, 2005).

4. The landfarm should be sited where the groundwater table is greater than 3 m from the surface and not within a 50 year floodplain (SAIC, 2005).

5. The natural slope of the landfarm area should be less than 5% to reduce site preparation and engineering costs.

6. The landfarm should be situated in a location to protect of the health of human and wildlife. It should be a minimum distance of 500 m from residential dwellings. Depending on the landfarm/biocell design and requirements, the top of the biocell may be uncovered and open to the environment. As such, the facility should be located in an area with limited access for humans and wildlife inhaling volatile petroleum hydrocarbons.

7. The soil characteristics should also be considered including the texture, pH, nutrient availability, microbial population, etc. (Government of NWT, 1995).

The three sites considered for the evaluation on the site are north of the Airstrip (Option 1), north of the Batch Plant (Option 2) and west of the Portage Pit (Option 3). The locations of the options are noted on Figure 1.

6.0 OPTION ANALYSIS

The options analysis was carried out to determine which of the three proposed locations would be most suitable for a landfarm operation. Two categories of factors were considered important for this analysis: environmental and operational. The relative weighting factors, based on the relative distribution of influence are Environmental 76% and Operational 24% (refer to Table 1).

6.1.1 Scale Factor

In order to separate the best alternatives from the others, a scaling, or scoring factor was applied (S_{IND}). Each sub-indicator was assigned a score between 1 and 9 points. The scores provide a relative ranking between the options, with the 'best' option receiving a score of 9, and the 'worst' a score of 1. All subsequent options were then compared to the 'best' option and assigned a lower relative score.

6.1.2 Relative Weighting Factor

Each sub-indicator of the primary categories was assigned a relative weighting factor (W_{IND}), ranging from one to ten, to introduce a value bias between the individual sub-indicators, based on the relative subjective importance of one indicator versus another. A higher weighting factor indicates a perceived greater relative value or importance between sub-indicators. Table 1 presents the weighting factors for the sub-indicators in each of the primary categories as well as the maximum possible value and maximum possible score that could potentially be achieved. Table 1 also summarizes the three areas that have been selected as possible locations for the landfarming operation (refer to Figure 1). Each location has been screened against the location criteria.

TABLE 1 Options for Landfarm Locations and Location Criteria

Factor	Sub-indicator (thresholds in brackets)	Relative Weighting W_{IND}	Max Score	Option 1		W_{IND} X S_{IND}	Option 2		W_{IND} X S_{IND}	Option 3		W_{IND} X S_{IND}
				Result	**S_{IND}**		**Result**	**S_{IND}**		**Result**	**S_{IND}**	
Environmental	Distance from Fish-Bearing Water Bodies, m (500 m).	10	9	325	6.5	65	450	9	90	350	7	70
	Distance from Residential Zoning[1], km	10	9	1	9	90	0.5	9	90	1.8	9	90
	Distance from Potable Groundwater wells, m (500 m)[2]	10	9	475	7	70	475	7	70	2,200	9	90
	Sensitive Areas Restriction	10	9	unrestricted	9	90	unrestricted	9	90	unrestricted	9	90
	Depth to Groundwater Table, m	3	9	2 to 3	7	21	2 to 3	7	21	2 to 3	7	21
	Hydrology Restriction (outside 50 year flood)	9	9	Yes	9	81	Yes	9	81	Yes	9	81
	Limited Access for Humans and Wildlfe	3	9	Yes[3]	9	27	Yes[3]	9	27	Yes[3]	9	27
Operational	Natural Slope (<5%)	5	9	Yes	9	45	Yes	9	45	Yes	9	45
	Distance from Access Road, m	9	9	300	0.3	2.7	10	9	81	60	1.5	13.5
	Distance from Fueling Area/ Storage Tanks, m	8	9	2,100	0.64	5.12	150	9	72	2,400	0.5	4
	Total Score					**496.8**			**667.0**			**531.5**
Notes												
1	Minesite will not have residential zoning but used worker's residence in lieu.											
2	Potable water will be collected from the fresh water pumps located in bay south of the campsite, in Portage Lake. Distance indicated is to Third Portage Lake.											
3	Will require fencing											

Based on the screening criteria, Option 2 is the best location for a landfarm on the mine site, as at this site it is closest to the access road and fuelling areas, but at the greatest distance from fish-bearing water bodies. While, Option 3 scores very well on the environmental factors it scores poorly on the operational factors as it is located a relatively long distance from the access road and is remote from the tank farm.

7.0 OTHER OPTIONS

Three other options that MMC may like to consider to handle petroleum hydrocarbon contaminated soil that may be generated at Meadowbank are: on-site disposal in the permitted landfill, off-site disposal in Baker Lake, and off-site disposal at a licensed facility in southern Canada. In order to dispose of the soil in the on-site landfill, the current permit would need to be modified pending approvals from the governmental authorities. It is our understanding that in order to ship the contaminated material to Baker Lake, the current facility there would need to be licensed to accept the material.

8.0 CLOSING REMARKS

We trust the information contained in the above report meets your requirements at this time. Please feel free to contact us if you need more detailed information on any of the information presented in the report.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED BY

Erin O'Brien, P.Geo.
Geoscientist

ORIGINAL SIGNED BY

J.A. Hull, P.Eng.
Principal

EOB/GH/JAH/drw/lw
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REFERENCES

AMEC Americas Limited (2006): *Snap Lake Project, Landfarm for Hydrocarbon Contaminated Soils," Project No. 142222, Revision 01*, submitted to Mackenzie Valley Land and Water Board on behalf of DeBeers Canada Inc, dated August 3, 2006.

Cumberland Resources Ltd. (2005): Meadowbank Gold Project, Final Environmental Impact Statement.

Environment Canada, Environmental Protection Operations Directorate (2007): *MV2007x0007 – Application Review process – Type "A" Land Use Application – Decommissioning and Reclamation of Pointed Grey Mountain Gas Plant*, dated May 10, 2007.

Golder Associates Ltd. (2006): Interim Closure and Reclamation Plan, submitted to Diavik Diamond Mines, Document Control #: RPT-197 Version 0, dated September 2006.

Government of NWT, Environmental Protection Division, Department of Renewable Resources (1995) The Generic Plans and Operating Procedures of a Remediation Facility for Hydrocarbon Contaminated Materials in the NWT, dated August 1995.

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Paudyn. K., Poland, J.S., Rutter, A. and Rowe, R.K. (2005): *Remediation of Hydrocarbon Contaminated Soils in the Canadian Arctic with Landfarms.* Proceedings in ARCSACC '05.

Pouliot, Y., Moreau, N. and Thomassin-Lacroix, E. (2005): *Soil Remediation of a Former Power Plant Site in Tulita, Northwest Territories*. Proceedings in ARCSACC '05.

Reimer, K, Zeeb, B., Koch, I., Sanscartier, D, Trummer, M. and Mohn, W. (2005): *A Critical Review of Cold Climate Remediation*. Proceedings in ARCSACC '05.

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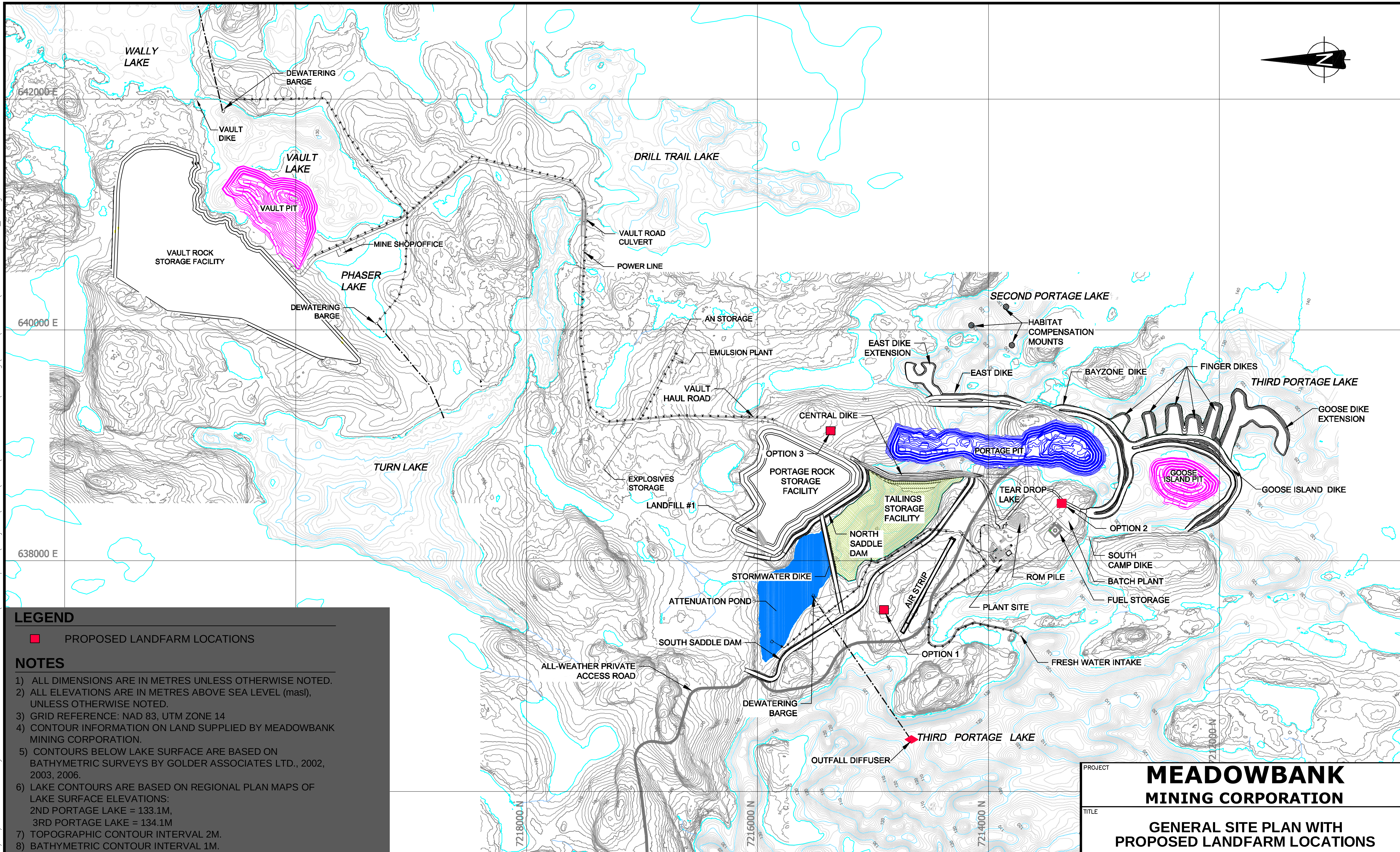

LEGEND

■ PROPOSED LANDFARM LOCATIONS

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 WITH PROPOSED LANDFARM LOCATIONS

Golder Associates

PROJECT No. 07-1413-0047			FILE No. 0714130047-FIG_1	
DESIGN	DW	15AUG07	SCALE AS SHOWN	REV. –
CADD	AS	15AUG07	FIGURE 1	
CHECK				
REVIEW				

CADD FILE: N:\Bur-Graphics\Projects\2006\1413\06-1413-089\Drafting\FINAL\Doc.498\0714130047-FIG_1.dwg
REVISION DATE: 07/08/22 10:55AM By: ASalvador