These facilities may result in a smaller footprint area due to their increased density; however, a secondary facility for re-circulation of water may still be required.

The nature of the tailings produced, both the grain size and mineralogy, can play an important role in determining the effectiveness of filter processing. Tailings with a high percentage of clay-sized particles and also clay mineralogy may negate the effectiveness of a filtering system.

These facilities still may require surface water runoff and seepage management systems. Ditches to redirect non-contact water away from the facility and ditches to collect runoff from the stack are utilized. Additionally, methods to collect seepage and prevent groundwater contamination may be required. A series of under drains, groundwater cut-off walls, or liners may be used. A closure cover is required to prevent erosion, prevent dust generation, and to provide an appropriate media for re-vegetation. Potentially acid generating tailings may require an infiltration barrier to reduce ARD generation.

Examples of dry stack tailings facilities are: Greens Creek Mine, Alaska; Raglan, Quebec; and La Coipa, Chile (Davies and Rice, 2001; Brown, 2002). Additional facilities are being considered or planned at: Pogo Gold Mine, Alaska; Las Cruces, Spain; and Mineral Hill, Montana.

3.3.4 Sub-Aerial Paste

Paste tailings have to be thickened using chemical additives, or a combination of mechanical devices and chemical additives, such as hydrating agents (i.e., Portland cement, fly ash), creating a slurry that will not separate. Pastes typically consist of approximately 60% solids for fine grained tailings and up to 80% solids for coarse tailings.

Paste tailings are frequently used for backfilling underground mines; however, surface disposal of paste tailings is also possible. Above ground use of paste technology, still requires the use of containment facilities, although due to the increased density of the tailings and lower moisture content, the size and/or height of the facilities may be reduced compared to other slurry type methods of disposal. Paste tailings can be transported using high pressure pipelines to the storage area. Two methods for deposition of paste tailings are shown in Figure 9.

These facilities require surface water runoff and seepage management systems. Ditches to redirect non-contact water way from the facility and ditches to collect runoff from the stack are utilized.

A secondary facility for re-circulation of water may still be required.

The following are examples of mines that use the paste method technology for tailings deposition: Bulyanhulu, Tanzania; Myra Falls, on Vancouver Island; and Kidd Creek Mine, Timmons, Ontario. The Colstrip power plant in Montana also utilizes this technology for fly ash disposal.

3.4 Description of the Meadowbank Site Potential Tailings Storage Areas

Based on the initial screening criteria, two potential tailings storage areas were identified:

- Storage within Second Portage Arm (Option B and Option C); and
- On land storage north of Second Portage Arm (Option F and Option G).

The locations of these two areas are shown on Figure 3. The following sections briefly describe these two areas and the ancillary components and structures for each of the Options that were evaluated.

3.4.1 Storage Within Second Portage Arm (Option B and Option C)

Option B

Option B is to dispose of the tailings as a Sub-aerial Paste or Dry Stack in the natural rock basin of the northwest arm of Second Portage Lake. This will require dewatering of this portion of the lake. As part of mine construction, a dike and haul road will be constructed across the east end of this portion of the lake to facilitate dewatering and mining of the Portage Deposit. The dike will isolate the northwest arm of Second Portage Lake from the remaining portion. The water level within the arm of Second Portage Lake would be lowered by 38 m (elevation 95 m asl). Once de-watered, the rock basin would freeze. Once the base was frozen, then thickened tailings (“dry stack”) or paste tailings would be transported, by truck (if dry stack method was selected) or by pipeline (if paste technology was utilized), and placed in lifts, such that each lift would freeze. The tailings stack at closure would be frozen and permafrost would eventually penetrate further into the base of the storage facility.

A separate water reclaim pond would be required, and would likely be constructed just to the west of the proposed plant site in a small basin of Third Portage Lake (sometimes referred to as Third Portage Arm). This small basin of Third Portage Lake would be isolated from the remaining portion of the lake by constructing small dikes. At the end of the mine life, the water quality within this basin would be monitored, and if it met water quality guidelines, the basin would be re-connected to the remainder of Third Portage Lake by removal of the dike system.

The tailings facility within the northwest arm of Second Portage Lake would be progressively reclaimed during operations by covering with a layer of relatively inert capping material. The cover would be designed to contain the depth of annual thaw within the relatively benign capping material so that the entire tailings mass would remain encapsulated by permafrost. Advantages to the Option B method of tailings storage include the following:

- The option is inherently more stable than the other alternatives that place tailings on land, or at a higher ‘potential energy’. Option B utilizes a natural depression with the tailings placed in a “dry” form.
- Regardless of where tailings are stored, the northwest arm of Second Portage Lake will be impacted by mine activities due to the construction of a series of de-watering dikes to allow mining of the ore. Consequently, this option takes advantage of a necessary requirement for the mining process to proceed, avoiding the need to construct a specific on-land disposal area which would result in a greater area of impact by the mine.
- The option is located immediately downstream from the proposed Portage Waste Rock Storage Facility. Runoff from the waste rock can be collected and managed within the facility if necessary.
- Freezing of the tailings and the talik beneath Second Portage Lake will limit the potential for ARD and ML generation and migration of contaminants into the surrounding environment (groundwater and surface water).
- Second Portage Lake is currently a regional discharge point for deep groundwater flow. The hydraulic gradient will continue to be towards the lake once the lake level has been drawn down to allow mining. This will reduce the potential for contaminant migration into the surrounding environment. The potential for contaminant release is further reduced by the low hydraulic conductivity of the surrounding bedrock.
- The surface of the facility is low relative to the surrounding topography, and relative to an equivalent facility that might be constructed on land. Consequently, the potential for the generation of dust from the tailings during operations and closure is less than for an equivalent on-land facility. Furthermore, capping of the tailings will reduce the potential for post-closure dust generation and also help ensure that tailings remain in a frozen state, year round.
- The facility will be located close to the plant site and other mine facilities which will make it easier to operate and will reduce the risk of operational problems.

Disadvantages to Option B method of tailings storage include the following:

- There is a greater potential for ARD generation during operation as tailings will be exposed to oxygen and therefore have the potential for sulfide oxidation.
- The northwest arm of Second Portage Lake will permanently contain tailings.

Option C

Option C is to dispose of tailings by sub-aerial deposition in the natural rock basin of the northwest arm of Second Portage Lake, and would involve partial dewatering. The East Dike and haul road that will be constructed across the east end of this portion of the lake to permit dewatering and mining of the Portage Deposit and to provide road access to the plant site, as previously discussed, will isolate the northwest arm from the remaining portion of the lake. For Option C, the water level upstream will be lowered by 28 m (elevation 105 m asl) to permit tailings dike construction. Once the tailings dike has been constructed, slurried tailings would be transported by a pipeline and deposited within the tailings facility. The tailings and talik beneath the northwest arm of the lake will eventually freeze. The facility would be progressively reclaimed during operations by covering with a layer of relatively inert capping material. The cover would be designed to contain the depth of annual thaw within the relatively benign capping material so that the entire tailings mass would remain encapsulated by permafrost. Advantages to the Option C method of tailings storage include:

- The option is inherently more stable than other alternatives that place tailings on land, or at a higher 'potential energy' as it utilizes the natural depression of Second Portage Lake.
- Regardless of where tailings are stored, the northwest arm of Second Portage Lake will be impacted by mine activities due to the construction of a series of de-watering dikes to allow mining of the ore. Consequently, this option takes advantage of a necessary requirement for the mining process to proceed, avoiding the need to construct a specific on-land disposal area which would result in a greater area of impact by the mine.
- The option is located immediately downstream from the proposed Portage Waste Rock Storage Facility. Runoff from the waste rock can be collected and managed within the facility.
- Freezing of the tailings and the talik beneath Second Portage Lake will reduce the potential for ARD and ML generation and migration of contaminants into the surrounding environment (groundwater and surface water).
- Second Portage Lake is currently a regional discharge point for deep groundwater flow. The hydraulic gradient will continue to be towards the lake once the lake level has been drawn down to allow mining. This will reduce the potential for contaminant migration into the surrounding environment.
- The surface of the facility is low relative to the surrounding topography, and relative to an equivalent facility that might be constructed on land. Consequently, the potential for the generation of dust from the tailings during operations and closure is less than for an equivalent on-land facility. Furthermore, capping of the tailings will reduce the potential for post-closure dust generation and also help ensure that tailings remain in a frozen state, year round.

- The facility will be located close to the plant site and other mine facilities which will make it easier to operate and will reduce the risk of operational problems.
- This method of tailings management has been used at numerous locations both in temperate and cold climates.

Disadvantages to the Option C method of tailings storage include:

- Higher potential for ML during operation as tailings will be submerged and therefore have the potential for leaching and release of metals. However, leaching and release of metals will be contained within the storage facility.
- The northwest arm of Second Portage Lake will permanently contain tailings.

3.4.2 Storage North of Second Portage Arm (Option F and Option G)

Option F

Option F is to dispose of tailings slurry sub-aerially on land, north of Second Portage Lake. There are several small ponds and drainage channels in this area. However, the aquatic habitat studies (CRL 2005a, and CRL 2005b) have indicated that these ponds do not contain fish and are not considered suitable fish habitat due to their shallow depth and the typical thickness of ice that forms on the lakes during the winter months.

Option F would require the construction of conventional tailings containment berms on frozen ground in a permafrost region that contains soft compressible soils including peat and an active layer that is variable, all of which provide challenges to designing and constructing a geotechnically stable containment system. A geomembrane liner system would likely need to be installed on the tailings (upstream) side of the containment berms, and keyed into the permafrost. There are insufficient natural materials suitable for use as a liner. The berms would require additional quarrying of rock material which would create greater land disturbance. It is likely that the additional rock material for construction of the embankment berms would require the development of a separate quarry from the mining activities. Material from mining operations has been identified as potentially acid generating, and the current mine plan takes this into consideration when defining where the material will be stored in specific waste storage facilities, and how the waste will be managed in the long term to minimize impacts on environment. Furthermore, the current plan optimizes the use of waste from pre-mining activities in the construction of the de-watering dikes, and specifically places potentially acid generating material under water where possible. There would be insufficient quantities of material produced during pre-mining activities to be used for the construction of the extensive embankment system that would be required for on-land storage. In addition to this, based on the current understanding of the geochemistry of the materials produced from pre-mining activities, these would not be suitable for construction of the berms as they would be continually exposed to an oxidizing environment in the thaw layer, and would be flushed annually during spring freshet, and during rain storm events. The run-off from the embankment system would need to be collected, managed, and treated unless an alternative quarry site of geochemically benign material could be identified and exploited for the construction of the berms.

Once the embankments were constructed slurried tailings would be transported in a pipeline and deposited within the berms. Eventually, the tailings would freeze and the tailings would be encapsulated by permafrost. A capping system consisting of geochemically benign materials would need to be designed to limit infiltration of water into the tailings, and to restrict the annual thaw depth within this layer.

The dike and haul road that will be constructed across the east end of the northwest arm of Second Portage Lake to permit dewatering and mining of the Portage Deposit, will isolate the northwest arm from the remaining portion of the lake. For Option F, the northwest arm of Second Portage Lake would be used for water management and tailings reclaim water and this basin would likely be permanently be lost for fish habitat. A dike would need to be constructed in the area of the currently proposed tailings dike for water management purposes. Tailings reclaim water would also be stored and re-circulated from the tailings facility. Once mine operations were finished, the water contained within the northwest arm of Second Portage Lake would need to be treated. Once the treated water meets guideline requirements, the dike would be removed, reconnecting the northwest arm of Second Portage Lake with the rest of the lake.

Advantages to Option F method of tailings storage include:

- The northwest arm of Second Portage Lake may only be isolated from the remaining portion of the lake during the operational phase of the mine. Depending on the water quality at the completion of mine operation, it may be possible for the northwest arm to be re-connected with the remainder of the lake.
- Freezing of the tailings and the underlying soil layer will reduce the potential for ARD and ML generation and migration of contaminants into the surrounding environment.
- Capping of the tailings will reduce the potential for post-closure dust generation and will shed water, thus limiting infiltration into the facility.
- This method of tailings management has been used in both temperate and cold climates.

Disadvantages to Option F method of tailings storage include:

- A substantial system of containment berms will need to be constructed on poor soil foundation conditions. Consequently, there is an elevated risk of failure of the foundations, and hence the containment berms. The containment facility would be constructed immediately up-slope of the northwest arm of Second Portage Lake. A failure of the containment berms could potentially result in the introduction of tailings into Second Portage Lake. The introduction of tailings into the lake could result in the development of a silt plume which could conceivably impact on the entire lake, although this would be a relatively short term impact.

- There is a higher potential for dust generation during operation and closure, due to the higher relief. Wind erosion of the tailings surface during operations and during closure could result in the transportation and deposition of tailings over considerable distances down-wind of the facility.
- It is likely that a separate quarry source of non-PAG rock will need to be developed to produce the materials required to construct the embankment berms. There are insufficient quantities of rock available from pre-mining activities to construct the perimeter de-watering dikes as well as embankment berms. The rock from the pre-mining activities is unsuitable for use as construction material for the scale of facility that would be required to enclose the tailings due to its potential for acid generation. If there were sufficient material available from pre-mining activities for this use then a substantial water collection and treatment system would need to be constructed to collect run-off from the embankment berms.
- There is a higher potential for generating acidic drainage and leaching metals during operation as the tailings will be in a partially saturated state, and exposed to oxygen.
- The tailings facility will have greater visibility.
- The system would require a geomembrane liner or similar seepage cutoff system on the upstream face of the embankment berms, keyed into the permafrost.
- The mine footprint (area of disturbance) would be increased substantially.
- Native sediments in the northwest basin of Second Portage Lake may become metals contaminated due to prolonged contact with mine tailings reclaim water, which could pose a source of metals to the receiving environment for a prolonged period after re-flooding.

Option G

Option G is to dispose of thickened (“dry”) or paste tailings sub-aerially on land, north of Second Portage Lake. There are several small lakes or ponds and streams in this area. However, the aquatic habitat studies (CRL 2005a, and CRL 2005b) have indicated that these ponds do not contain fish and are not considered suitable fish habitat due to their shallow depth and the typical thickness of ice that forms on the lakes during the winter months.

The development of the site would involve constructing minor embankment berms and diversion ditches on frozen ground. Once the berms were constructed, tailings would be transported by truck (if dry stack method was selected) or by pipeline (if paste technology was utilized), and placed or deposited in lifts within the berms. Tailings would eventually freeze. A capping system consisting of geochemically benign materials would need to be designed to limit infiltration of water into the tailings, and to restrict the annual thaw depth within this layer.

As with Option F, the northwest arm of Second Portage Lake would be de-watered, and a water containment dike would be constructed along the western edge of the proposed Portage Pit. The purpose of the dike would be to allow the management of site water and tailings reclaim water within the arm of Second Portage Lake. As an alternative to the use of the arm of Second Portage Lake for water management, the arm of Third Portage Lake, immediately to the west of the mill and mine site process plant, could be isolated by the construction of dikes, and then used to manage site and tailings reclaim water.

Advantages to Option G method of tailings storage include:

- The northwest arm of Second Portage Lake may only be isolated from the remaining portion of the lake during the operational phase of the mine. Depending on the water quality at the completion of mine operation, it may be possible for the northwest arm to be re-connected with the remainder of the lake.
- The height of containment dikes will be less than for Option F.
- Freezing of the tailings and the underlying soil layer will reduce the potential for ARD and ML generation and migration of contaminants into the surrounding environment.
- Capping of the tailings will reduce the potential for post-closure dust generation and will shed water, thus limiting infiltration into the facility.

Disadvantages to Option G method of tailings storage include:

- There is a higher potential for dust generation during operation and closure, due to the higher relief. Wind erosion of the tailings surface during operations and during closure could result in the transportation and deposition of tailings over considerable distances down-wind of the facility.
- There is a high potential for the generation of acidic run-off during operation as tailings will be only partially saturated state, thus exposed to oxygen enabling sulfide oxidation to occur.
- The tailings facility will be more readily visible.
- Long containment berms will need to be constructed on poor soil foundation conditions. These berms will be less than those required for Option F, however an inherent risk of failure remains and therefore the risk of releasing tailings to the environment.
- Native sediments in the northwest basin of Second Portage Lake may become metals contaminated due to prolonged contact with mine tailings reclaim water, which could pose a source of metals to the receiving environment for a prolonged period after re-flooding.

4.0 RESULTS

4.1 Base Line Analysis

Tailings facility Options B, C, F, and G for the proposed Meadowbank Project were analyzed using the decision matrix method of analysis described above. The following table summarizes the results.

Table 4.1: Summary of Baseline Analysis Decision Matrix Results

Factor	Options			
	B	C	F	G
	Second Portage Arm	Second Portage Arm	West of Waste Rock Storage	West of Waste Rock Storage
	Sub-aerial Paste	Sub-aqueous/ Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste
Environmental	438	475	372	432
Operational	263	216	160	256
Economic	60	135	75	60
TOTAL	**761**	**826**	**607**	**748**

Table 4.2 presents the full results of the decision matrix for the tailings storage options. The individual scores for each sub-indicator are shown along with the summed scores for environmental factors, operational factors, and economic factors.

Based on the decision matrix method Option C, tailings slurry disposal in the northwest arm of Second Portage Arm, is the best tailings management strategy for the Meadowbank Project site based on an evaluation that included environmental, operational, and economic considerations.

4.2 Sensitivity Analyses

The relative sensitivity of the decision matrix system and resulting selection to changes in the weighting factors was evaluated. Firstly, each of the individual weighting factors was set to 1. This assigns an equal weighting to each individual sub-indicator. The results of this analysis are presented and described in the following section. Secondly, only environmental factors and long term (post-closure) impacts were considered. This analysis excluded the influence of operating and economic impacts from the decision matrix. Finally, environmental factors specifically relating to lake and fish habitat impacts were weighted as highly as possible within the decision matrix so that the contribution of these sub-indicators towards on-land disposal options ranged between 31% and 35% of the total score, while the contribution to disposal options in Second Portage Lake were reduced to between 13% and 17% of the overall total.

TABLE 4.2: TAILINGS STORAGE OPTIONS DECISION MATRIX RESULTS

Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Option B	Option C	Option F	Option G	Scale Factor B	Scale Factor C	Scale Factor F	Scale Factor G	Sub-Indicator Weighted Scores B	Sub-Indicator Weighted Scores C	Sub-Indicator Weighted Scores F	Sub-Indicator Weighted Scores G
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm								
				Sub-aerial Paste or Dry Stack	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste or Dry Stack								
				Construction - Dewater Second Portage Arm by 38 m (El. 95m ASL) and allow base to freeze. Build water management pond near mill or in 3rd Portage Arm. Construct and maintain pipeline.	**Construction** - Dewater Second Portage Arm by 28 m (El. 105m ASL) to allow construction of dike. Construct and maintain pipeline.	**Construction** – build conventional tailings containment berms on frozen ground; install and maintain pipeline.	**Construction** – build minor containment berms on frozen ground; install and maintain pipeline.								
				Operation - Place thickened/paste tailings to 4 to 7 m above current lake level such that tailings freeze each year. Transport tailings by pipeline for paste, or by truck for thickened.	**Operation** - Place slurry to 7 m above current lake level. Maintain water management and reclaim pond at west end of lake. Transport tailings by pipeline.	**Operation** - Place tailings slurry on surface. Use Second Portage Arm for water management and reclaim water, plus reclaim from tailings area. Allow tailings to freeze each year. Transport tailings by pipeline.	**Operation** - Place thickened/paste tailings on surface. Use Second Portage Arm or Third Portage Arm for water management and reclaim water. Allow tailings to freeze each year. Transport paste tailings by pipeline, or truck thickened tailings.								
				Closure – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.								
Key Details	Dike construction volumes required (m^3)			1,140,000	1,140,000	1,250,000	250,000								
	Capping volume, assuming 2 m thickness (m3)			3,000,000	3,000,000	2,280,000	2,280,000								
	Length of tailings pipeline (m)			2,600	2,800	4,100	4,100								
	Length of reclaim pipeline (m)			800	2,800	1,200	1,000								
	Location of water pond			Near mill or 3rd Portage Arm	2nd Portage Arm	2nd Portage Arm and tailings	2nd or 3rd Portage Arm								
Environmental Factors (55% of Weighted Total)	Sub-catchment area (ha)	1	9	200	200	180	180	8	8	9	9	8	8	9	9
	Footprint area (ha)	1	9	150	150	114	114	7	7	9	9	7	7	9	9
	Potential for dust generation during operation	6	9	Moderate	Moderate	High	High	7	9	1	4	42	54	6	24
	Potential for dust generation after closure	4	9	Low	Low	Moderate	Moderate	9	9	6	6	36	36	24	24
	Potential for ARD generation during operation	5	9	Moderate	Low	High - Moderate	Moderate	7	9	3	5	35	45	15	25
	Potential for ARD generation after closure	7	9	Low	Low	Moderate	Moderate	7	7	5	5	49	49	35	35
	Potential for ML during operation	2	9	Low	Moderate	Moderate	Low	8	7	7	9	16	14	14	18
	Potential for ML after closure	5	9	Moderate	Moderate	Low	Low	7	7	9	9	35	35	45	45
	Potential for seepage to groundwater during operation	5	9	Low	Low	Low	Low	9	9	9	9	45	45	45	45
	Potential for geotechnical hazards[1]	6	9	Low	Low	High	Moderate	9	9	1	5	54	54	6	30
	Potential for seepage to groundwater after closure	5	9	Low - Moderate	Low - Moderate	Low	Low	7	7	9	9	35	35	45	45
	Area of lakes impacted (ha)	5	9	100 - 140	100	40 - 100	40 - 100	5	6	9	9	25	30	45	45
	Number of lakes impacted	4	9	1 - 2	1	1	1	6	9	9	9	24	36	36	36
	Visual Impact	2	9	Low	Low	High	Moderate	9	9	1	3	18	18	2	6
	Impact on Fish and Fish Habitat	9	9	High	High	Moderate	Moderate	1	1	4	4	9	9	36	36
	Sum of Environmental Weightings	**67**	**603**									**438**	**475**	**372**	**432**
Operational Factors (33% of Weighted Total)	Ease of operation	9	9	High	Moderate	Low	Moderate	9	4	2	6	81	36	18	54
	Distance from mill	8	9	1200 m	1200 m	2800 m	2800 m	9	9	4	4	72	72	32	32
	Potential for delays due to freezing	10	9	Low	Moderate	High	Moderate	9	6	1	7	90	60	10	70
	Construction Risk	4	9	Moderate	Moderate	Low	Low	3	2	7	9	12	8	28	36
	Disposal system has precedent in arctic environment	8	9	No	Yes	Yes	Yes	1	5	9	8	8	40	72	64
	Sum of Operational Weightings	**39**	**351**									**263**	**216**	**160**	**256**
Economic Factors[2] (assumes i = 8%) (12% of Weighted Total)	Initial Capital Cost ($CDN) (Approximate)[3]			$11,800,000	$2,860,000	$5,955,000	$14,675,000					0	0	0	0
	Net Present Value of Delayed Costs[3]			$2,986,613	$3,428,432	$5,955,892	$528,041					0	0	0	0
	Total Present Value of costs	15	9	$14,786,613	$6,288,432	$11,910,892	$15,203,041	4	9	5	4	60	135	75	60
	Sum of Economic Weightings	**15**	**135**									**60**	**135**	**75**	**60**
TOTAL SCORE			**1089**	**761**	**826**	**607**	**748**					**761**	**826**	**607**	**748**

Notes
1. Includes consideration of foundation conditions, impact of seismicity, and height of structure
2. Relative capital cost for comparison only. Interest rate assumed as 8%.
3. Value not used in scoring. Value is presented to allow calculation of total cost for comparison purposes.

4.2.1 Sensitivity Analysis – Part 1

To consider the impact of the weighting factors used in the decision matrix, a sensitivity analysis was conducted with all sub-indicator weightings set equal to one. This results in each of the sub-indicators having equal importance in the decision process and removes any value bias between the sub-indicators that might be imposed by personal preferences. The greatest numbers of sub-indicators were associated with the environmental category, while the lowest numbers of sub-indicators were associated with the economic category. Consequently, the relative importance of each category is determined by the number of sub-indicators representing that category. Based on the revisions to the weightings, the relative distribution of influence on the weighted total is:

- Environment 71%
- Operational 24 %
- Economic 5%

The results of this analysis are summarized in Table 4.3.

Table 4.3: Summary of Decision Matrix Results – Sensitivity Analysis (Part 1)

Factor	Options			
	B	**C**	**F**	**G**
	Second Portage Arm	Second Portage Arm	West of Waste Rock Storage	West of Waste Rock Storage
	Sub-aerial Paste	Sub-aqueous/ Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste
Environmental	106	113	91	104
Operational	31	26	23	34
Economic	4	9	5	4
TOTAL	**141**	**148**	**119**	**142**

The detailed analysis is shown in Table 4.4.

As with the baseline case, Option C received the highest overall score although only marginally greater than Options B and G.

TABLE 4.4: SENSITIVITY ANALYSIS RESULTS (PART 1)

Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Option B	Option C	Option F	Option G	Scale Factor B	Scale Factor C	Scale Factor F	Scale Factor G	Sub-Indicator Weighted Scores B	Sub-Indicator Weighted Scores C	Sub-Indicator Weighted Scores F	Sub-Indicator Weighted Scores G
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm								
				Sub-aerial Paste or Dry Stack	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste or Dry Stack								
				Construction - Dewater Second Portage Arm by 38 m (El. 95m ASL) and allow base to freeze. Build water management pond near mill or in 3rd Portage Arm. Construct and maintain pipeline.	**Construction** - Dewater Second Portage Arm by 28 m (El. 105m ASL) to allow construction of dike. Construct and maintain pipeline.	**Construction** – build conventional tailings containment berms on frozen ground; install and maintain pipeline.	**Construction** – build minor containment berms on frozen ground; install and maintain pipeline.								
				Operation - Place thickened/paste tailings to 4 to 7 m above current lake level such that tailings freeze each year. Transport tailings by pipeline for paste, or by truck for thickened.	**Operation** - Place slurry to 7 m above current lake level. Maintain water management and reclaim pond at west end of lake. Transport tailings by pipeline.	**Operation** - Place tailings slurry on surface. Use Second Portage Arm for water management and reclaim water, plus reclaim from tailings area. Allow tailings to freeze each year. Transport tailings by pipeline.	**Operation** - Place thickened/paste tailings on surface. Use Second Portage Arm or Third Portage Arm for water management and reclaim water. Allow tailings to freeze each year. Transport paste tailings by pipeline, or truck thickened tailings.								
				Closure – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.								
Key Details	Dike construction volumes required (m^3)			1,140,000	1,140,000	1,250,000	250,000								
	Capping volume, assuming 2 m thickness (m3)			3,000,000	3,000,000	2,280,000	2,280,000								
	Length of tailings pipeline (m)			2,600	2,800	4,100	4,100								
	Length of reclaim pipeline (m)			800	2,800	1,200	1,000								
	Location of water pond			Near mill or 3rd Portage Arm	2nd Portage Arm	2nd Portage Arm and tailings	2nd or 3rd Portage Arm								
Environmental Factors (71% of Weighted Total)	Sub-catchment area (ha)	1	9	200	200	180	180	8	8	9	9	8	8	9	9
	Footprint area (ha)	1	9	150	150	114	114	7	7	9	9	7	7	9	9
	Potential for dust generation during operation	1	9	Moderate	Moderate	High	High	7	9	1	4	7	9	1	4
	Potential for dust generation after closure	1	9	Low	Low	Moderate	Moderate	9	9	6	6	9	9	6	6
	Potential for ARD generation during operation	1	9	Moderate	Low	High - Moderate	Moderate	7	9	3	5	7	9	3	5
	Potential for ARD generation after closure	1	9	Low	Low	Moderate	Moderate	7	7	5	5	7	7	5	5
	Potential for ML during operation	1	9	Low	Moderate	Moderate	Low	8	7	7	9	8	7	7	9
	Potential for ML after closure	1	9	Moderate	Moderate	Low	Low	7	7	9	9	7	7	9	9
	Potential for seepage to groundwater during operation	1	9	Low	Low	Low	Low	9	9	9	9	9	9	9	9
	Potential for geotechnical hazards[1]	1	9	Low	Low	High	Moderate	9	9	1	5	9	9	1	5
	Potential for seepage to groundwater after closure	1	9	Low - Moderate	Low - Moderate	Low	Low	7	7	9	9	7	7	9	9
	Area of lakes impacted (ha)	1	9	100 - 140	100	40 - 100	40 - 100	5	6	9	9	5	6	9	9
	Number of lakes impacted	1	9	1 - 2	1	1	1	6	9	9	9	6	9	9	9
	Visual Impact	1	9	Low	Low	High	Moderate	9	9	1	3	9	9	1	3
	Impact on Fish and Fish Habitat	1	9	High	High	Moderate	Moderate	1	1	4	4	1	1	4	4
	Sum of Environmental Weightings	**15**	**135**									**106**	**113**	**91**	**104**
Operational Factors (24% of Weighted Total)	Ease of operation	1	9	High	Moderate	Low	Moderate	9	4	2	6	9	4	2	6
	Distance from mill	1	9	1200 m	1200 m	2800 m	2800 m	9	9	4	4	9	9	4	4
	Potential for delays due to freezing	1	9	Low	Moderate	High	Moderate	9	6	1	7	9	6	1	7
	Construction Risk	1	9	Moderate	Moderate	Low	Low	3	2	7	9	3	2	7	9
	Disposal system has precedent in arctic environment	1	9	No	Yes	Yes	Yes	1	5	9	8	1	5	9	8
	Sum of Operational Weightings	**5**	**45**									**31**	**26**	**23**	**34**
Economic Factors[2] (assumes i = 8%) (5% of Weighted Total)	Initial Capital Cost ($CDN) (Approximate)[3]			$11,800,000	$2,860,000	$5,955,000	$14,675,000								
	Net Present Value of Delayed Costs[3]			$2,986,613	$3,428,432	$5,955,892	$528,041								
	Total Present Value of costs	1	9	$14,786,613	$6,288,432	$11,910,892	$15,203,041	4	9	5	4	4	9	5	4
	Sum of Economic Weightings	**1**	**9**									**4**	**9**	**5**	**4**
TOTAL SCORE			**189**	**141**	**148**	**119**	**142**					**141**	**148**	**119**	**142**

Notes
1. Includes consideration of foundation conditions, impact of seismicity, and height of structure
2. Relative capital cost for comparison only. Interest rate assumed as 8%.
3. Value not used in scoring. Value is presented to allow calculation of total cost for comparison purposes.
4. Note the relative distribution of scores between the three primary factors has changed, due to the weightings allocated. The new distribution is Environmental = 71%, Operational = 24%, and Economic = 5%.

4.2.2 Sensitivity Analysis – Part 2

An additional sensitivity analysis was carried out by excluding economic factors, and by reducing the effect of operational factors. The resulting decision matrix was weighted strongly towards the influence of environmental factors. Based on the revisions to the weightings, the relative distribution of influence on the weighted total is:

- Environment 89%
- Operational 11%
- Economic 0%

Table 4.5 summarizes the results of the analysis.

Table 4.5: Summary of Decision Matrix Results – Sensitivity Analysis (Part 2)

Factor	Options			
	B	**C**	**F**	**G**
	Second Portage Arm	Second Portage Arm	West of Waste Rock Storage	West of Waste Rock Storage
	Sub-aerial Paste	Sub-aqueous/ Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste
Environmental	438	475	372	432
Operational	8	40	72	64
Economic	0	0	0	0
TOTAL	**446**	**515**	**444**	**496**

The detailed analysis is presented in Table 4.6.

The analysis indicates that when the decision matrix is heavily weighted towards the consideration of environmental factors Option C (tailings slurry disposal in Second Portage Lake) is the preferred option.

TABLE 4.6: SENSITIVITY ANALYSIS RESULTS (PART 2)

Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Option B	Option C	Option F	Option G	Scale Factor B	Scale Factor C	Scale Factor F	Scale Factor G	Sub-Indicator Weighted Scores B	Sub-Indicator Weighted Scores C	Sub-Indicator Weighted Scores F	Sub-Indicator Weighted Scores G
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm								
				Sub-aerial Paste or Dry Stack	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste or Dry Stack								
				Construction - Dewater Second Portage Arm by 38 m (El. 95m ASL) and allow base to freeze. Build water management pond near mill or in 3rd Portage Arm. Construct and maintain pipeline.	**Construction** - Dewater Second Portage Arm by 28 m (El. 105m ASL) to allow construction of dike. Construct and maintain pipeline.	**Construction** – build conventional tailings containment berms on frozen ground; install and maintain pipeline.	**Construction** – build minor containment berms on frozen ground; install and maintain pipeline.								
				Operation - Place thickened/paste tailings to 4 to 7 m above current lake level such that tailings freeze each year. Transport tailings by pipeline for paste, or by truck for thickened.	**Operation** - Place slurry to 7 m above current lake level. Maintain water management and reclaim pond at west end of lake. Transport tailings by pipeline.	**Operation** - Place tailings slurry on surface. Use Second Portage Arm for water management and reclaim water, plus reclaim from tailings area. Allow tailings to freeze each year. Transport tailings by pipeline.	**Operation** - Place thickened/paste tailings on surface. Use Second Portage Arm or Third Portage Arm for water management and reclaim water. Allow tailings to freeze each year. Transport paste tailings by pipeline, or truck thickened tailings.								
				Closure – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.								
Key Details	Dike construction volumes required (m^3)			1,140,000	1,140,000	1,250,000	250,000								
	Capping volume, assuming 2 m thickness (m3)			3,000,000	3,000,000	2,280,000	2,280,000								
	Length of tailings pipeline (m)			2,600	2,800	4,100	4,100								
	Length of reclaim pipeline (m)			800	2,800	1,200	1,000								
	Location of water pond			Near mill or 3rd Portage Arm	2nd Portage Arm	2nd Portage Arm and tailings	2nd or 3rd Portage Arm								
Environmental Factors (89% of Weighted Total)	Sub-catchment area (ha)	1	9	200	200	180	180	8	8	9	9	8	8	9	9
	Footprint area (ha)	1	9	150	150	114	114	7	7	9	9	7	7	9	9
	Potential for dust generation during operation	6	9	Moderate	Moderate	High	High	7	9	1	4	42	54	6	24
	Potential for dust generation after closure	4	9	Low	Low	Moderate	Moderate	9	9	6	6	36	36	24	24
	Potential for ARD generation during operation	5	9	Moderate	Low	High - Moderate	Moderate	7	9	3	5	35	45	15	25
	Potential for ARD generation after closure	7	9	Low	Low	Moderate	Moderate	7	7	5	5	49	49	35	35
	Potential for ML during operation	2	9	Low	Moderate	Moderate	Low	8	7	7	9	16	14	14	18
	Potential for ML after closure	5	9	Moderate	Moderate	Low	Low	7	7	9	9	35	35	45	45
	Potential for seepage to groundwater during operation	5	9	Low	Low	Low	Low	9	9	9	9	45	45	45	45
	Potential for geotechnical hazards[1]	6	9	Low	Low	High	Moderate	9	9	1	5	54	54	6	30
	Potential for seepage to groundwater after closure	5	9	Low - Moderate	Low - Moderate	Low	Low	7	7	9	9	35	35	45	45
	Area of lakes impacted (ha)	5	9	100 - 140	100	40 - 100	40 - 100	5	6	9	9	25	30	45	45
	Number of lakes impacted	4	9	1 - 2	1	1	1	6	9	9	9	24	36	36	36
	Visual Impact	2	9	Low	Low	High	Moderate	9	9	1	3	18	18	2	6
	Impact on Fish and Fish Habitat	9	9	High	High	Moderate	Moderate	1	1	4	4	9	9	36	36
	Sum of Environmental Weightings	**67**	**603**									**438**	**475**	**372**	**432**
Operational Factors (11% of Weighted Total)															
	Disposal system has precedent in arctic environment	8	9	No	Yes	Yes	Yes	1	5	9	8	8	40	72	64
	Sum of Operational Weightings	**8**	**72**									**8**	**40**	**72**	**64**
Economic Factors (0% of Weighted Total)															
	Sum of Economic Weightings	**0**	**0**									**0**	**0**	**0**	**0**
TOTAL SCORE			**675**	**446**	**515**	**444**	**496**					**446**	**515**	**444**	**496**

Notes
1. Includes consideration of foundation conditions, impact of seismicity, and height of structure
2. Note the relative distribution of scores between the three primary factors has changed, due to the revised number of sub-indicators. The new distribution is Environmental = 89%, Operational = 11%, and Economic = 0%.

4.2.3 Sensitivity Analysis – Part 3

A final sensitivity analysis was carried out on the baseline case to address specific concerns relating to the effect the proposed methods of disposal may have on fish and fish habitat. For this case, issues relating specifically to impact on fish and fish habitat were adjusted to weight these indicators high in the overall analysis. Based on the revisions to the weightings, the relative distribution of influence on the weighted total is:

- Environment 57%
- Operational 31%
- Economic 12%

The relative weighting factor for "number of lakes impacted" and "impact on fish and fish habitat" were adjusted so that these two indicators carried the highest relative weights of all the environmental sub-indicators. The scale factors for the sub-indicator "number of lakes impacted" remained the same as the previous analyses, as the number of lakes impacted by either on-land or in lake disposal is the same regardless of the disposal method selected. The scale factors for the sub-indicator "impacts on fish and fish habitat" however were increased to the maximum possible value of 9 for on-land disposal, representing the 'best' possible case, and were maintained at the least possible value of 1 for disposal in Second Portage Arm, representing the 'worst' possible case. The result of this re-scaling is that "impacts on fish and fish habitat" and "number of lakes impacted" contribute between 31% and 35% to the overall environmental weighting for on-land storage, compared with 13% to 17% contribution for disposal within Second Portage Arm.

Table 4.7 summarizes the results of the analysis.

Table 4.7: Summary of Decision Matrix Results – Sensitivity Analysis (Part 3)

Factor	Options			
	B	**C**	**F**	**G**
	Second Portage Arm	Second Portage Arm	West of Waste Rock Storage	West of Waste Rock Storage
	Sub-aerial Paste	Sub-aqueous/ Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste
Environmental	468	520	462	522
Operational	263	216	160	256
Economic	60	135	75	60
TOTAL	**791**	**871**	**697**	**838**

The detailed analysis is presented in Table 4.8.

The analysis indicates that when environmental factors are weighted heavily towards impact on lakes and on fish habitat, disposal on-land or in Second Portage Lake carry equivalent total environmental weighting, resulting in a ‘null’ decision based on that category alone. When economic and operational issues are considered in the decision analysis, then Option C, disposal of slurry tailings in the basin of Second Portage Arm, is the preferred option.

TABLE 4.8: SENSITIVITY ANALYSIS RESULTS (PART 3)

Key Indicators	Sub-Indicators	Relative Weighting Factor	Maximum Possible Score	Option B	Option C	Option F	Option G	Scale Factor B	Scale Factor C	Scale Factor F	Scale Factor G	Sub-Indicator Weighted Scores B	Sub-Indicator Weighted Scores C	Sub-Indicator Weighted Scores F	Sub-Indicator Weighted Scores G
				Second Portage Arm	Second Portage Arm	North of Second Portage Arm	North of Second Portage Arm								
				Sub-aerial Paste or Dry Stack	Sub-aerial Slurry	Sub-aerial Slurry	Sub-aerial Paste or Dry Stack								
				Construction - Dewater Second Portage Arm by 38 m (El. 95m ASL) and allow base to freeze. Build water management pond near mill or in 3rd Portage Arm. Construct and maintain pipeline.	**Construction** - Dewater Second Portage Arm by 28 m (El. 105m ASL) to allow construction of dike. Construct and maintain pipeline.	**Construction** – build conventional tailings containment berms on frozen ground; install and maintain pipeline.	**Construction** – build minor containment berms on frozen ground; install and maintain pipeline.								
				Operation - Place thickened/paste tailings to 4 to 7 m above current lake level such that tailings freeze each year. Transport tailings by pipeline for paste, or by truck for thickened.	**Operation** - Place slurry to 7 m above current lake level. Maintain water management and reclaim pond at west end of lake. Transport tailings by pipeline.	**Operation** - Place tailings slurry on surface. Use Second Portage Arm for water management and reclaim water, plus reclaim from tailings area. Allow tailings to freeze each year. Transport tailings by pipeline.	**Operation** - Place thickened/paste tailings on surface. Use Second Portage Arm or Third Portage Arm for water management and reclaim water. Allow tailings to freeze each year. Transport paste tailings by pipeline, or truck thickened tailings.								
				Closure – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.	**Closure** – Permafrost encapsulation: Place ultramafic capping layer to maintain tailings frozen below active layer and to shed water.								
Key Details	Dike construction volumes required (m^3)			1,140,000	1,140,000	1,250,000	250,000								
	Capping volume, assuming 2 m thickness (m3)			3,000,000	3,000,000	2,280,000	2,280,000								
	Length of tailings pipeline (m)			2,600	2,800	4,100	4,100								
	Length of reclaim pipeline (m)			800	2,800	1,200	1,000								
	Location of water pond			Near mill or 3rd Portage Arm	2nd Portage Arm	2nd Portage Arm and tailings	2nd or 3rd Portage Arm								
Environmental Factors (57% of Weighted Total)	Sub-catchment area (ha)	1	9	200	200	180	180	8	8	9	9	8	8	9	9
	Footprint area (ha)	1	9	150	150	114	114	7	7	9	9	7	7	9	9
	Potential for dust generation during operation	6	9	Moderate	Moderate	High	High	7	9	1	4	42	54	6	24
	Potential for dust generation after closure	4	9	Low	Low	Moderate	Moderate	9	9	6	6	36	36	24	24
	Potential for ARD generation during operation	5	9	Moderate	Low	High - Moderate	Moderate	7	9	3	5	35	45	15	25
	Potential for ARD generation after closure	7	9	Low	Low	Moderate	Moderate	7	7	5	5	49	49	35	35
	Potential for ML during operation	2	9	Low	Moderate	Moderate	Low	8	7	7	9	16	14	14	18
	Potential for ML after closure	5	9	Moderate	Moderate	Low	Low	7	7	9	9	35	35	45	45
	Potential for seepage to groundwater during operation	5	9	Low	Low	Low	Low	9	9	9	9	45	45	45	45
	Potential for geotechnical hazards[1]	6	9	Low	Low	High	Moderate	9	9	1	5	54	54	6	30
	Potential for seepage to groundwater after closure	5	9	Low - Moderate	Low - Moderate	Low	Low	7	7	9	9	35	35	45	45
	Area of lakes impacted (ha)	5	9	100 - 140	100	40 - 100	40 - 100	5	6	9	9	25	30	45	45
	Number of lakes impacted	9	9	1 - 2	1	1	1	6	9	9	9	54	81	81	81
	Visual Impact	2	9	Low	Low	High	Moderate	9	9	1	3	18	18	2	6
	Impact on Fish and Fish Habitat	9	9	High	High	Moderate	Moderate	1	1	9	9	9	9	81	81
	Sum of Environmental Weightings	**72**	**648**									**468**	**520**	**462**	**522**
Operational Factors (31% of Weighted Total)	Ease of operation	9	9	High	Moderate	Low	Moderate	9	4	2	6	81	36	18	54
	Distance from mill	8	9	1200 m	1200 m	2800 m	2800 m	9	9	4	4	72	72	32	32
	Potential for delays due to freezing	10	9	Low	Moderate	High	Moderate	9	6	1	7	90	60	10	70
	Construction Risk	4	9	Moderate	Moderate	Low	Low	3	2	7	9	12	8	28	36
	Disposal system has precedent in arctic environment	8	9	No	Yes	Yes	Yes	1	5	9	8	8	40	72	64
	Sum of Operational Weightings	**39**	**351**									**263**	**216**	**160**	**256**
Economic Factors[2] (assumes i = 8%) (12% of Weighted Total)	Initial Capital Cost ($CDN) (Approximate)[3]			$11,800,000	$2,860,000	$5,955,000	$14,675,000					0	0	0	0
	Net Present Value of Delayed Costs[3]			$2,986,613	$3,428,432	$5,955,892	$528,041					0	0	0	0
	Total Present Value of costs	15	9	$14,786,613	$6,288,432	$11,910,892	$15,203,041	4	9	5	4	60	135	75	60
	Sum of Economic Weightings	**15**	**135**									**60**	**135**	**75**	**60**
TOTAL SCORE			**1134**	**791**	**871**	**697**	**838**					**791**	**871**	**697**	**838**

Notes
1. Includes consideration of foundation conditions, impact of seismicity, and height of structure
2. Relative capital cost for comparison only. Interest rate assumed as 8%.
3. Value not used in scoring. Value is presented to allow calculation of total cost for comparison purposes.

4.3 Discussion

The result of the initial base case decision matrix analysis, and the subsequent sensitivity analyses are similar. The best disposal option for tailings management at the Meadowbank Project is disposal of tailings into the natural rock basin of the northwest arm of Second Portage Lake. Permafrost encapsulation of the tailings will form the control strategy for acid mine drainage and metal leaching. The primary advantages provided by Option C are as follows:

- Lowest potential for the generation of acidic drainage and the release of metal constituents to the environment;
- Lowest potential for the generation of dust from the facility during operations and closure, and consequently the lowest potential for the migration of contaminants beyond the limits of the storage facility and the mine site. Facilities exposed to wind erosion will have a greater risk of release of wind-blown contaminants to the environment by deposition on-land or into lakes;
- Simplest construction methodology requiring construction materials from the mining activities;
- Simplest closure methodology, requiring least amount of borrow materials;
- Low risk of instability of tailings facility, and hence lower risk of potential release of tailings to the environment;
- Ease of operation in harsh Arctic climates;
- Lowest relative capital cost; and
- Precedence in Arctic climate.

5.0 CASE STUDY – NORTH RANKIN INLET NICKEL MINE

The North Rankin Inlet Nickel Mine presents a case study that is directly comparable to the conditions at the Meadowbank Project and to the recommended tailings management plan. Rankin Inlet is a community located approximately 250 km south, and 430 km east of the Meadowbank Project site (see Figure 1). The community is located on Hudson Bay. The similarities between the Meadowbank Project site and Rankin Inlet are: the sites are in the zone of continuous permafrost; the mean annual air temperature at both sites is approximately -11ºC; remedial measures to manage the reactive and acid generating tailings at Rankin Inlet have included the disposal of the tailings by permafrost encapsulation in a drained bedrock basin to maintain the tailings and their saline pore water in a chemically inert state. Thermal instrumentation at the Rankin Inlet site has shown the tailings to be frozen or freezing, and that freeze-back is occurring more rapidly than predicted. There is no evidence of thermal heating due to oxidation of tailings. The results of the field and laboratory investigations of the tailings at Rankin Inlet are presented by Meldrum, et. al. (2001) and are summarized in the following sections.

5.1 Summary of Rankin Inlet Remediation Project

The North Rankin Inlet Nickel Mine was operated for five years from 1957 to 1962 and produced 297,000 tonnes of tailings. Prior to remediation the acid-generating sulphide rich tailings were exposed on the shores of Hudson Bay for 30 years, releasing acidic, metal-rich water. In addition to release of the contaminated pore water into Hudson Bay, oxidized tailings dust was wind blown through the town of Rankin Inlet, and deposited on the tundra as well as further out on to the sea ice covering the bay during the winter months, and on to the water surface during the summer months. In 1991 a remedial program was initiated which involved the burial of the tailings in a drained bedrock basin, relying on eventual permafrost encapsulation to limit the tendency of contaminated pore water to migrate further from the site. The remediation involved the *in-situ* treatment of 100,000 m^3 of contaminated water, the draining of a bedrock basin, and the subsequent filling of the basin with 48,000 m^3 of tailings to a maximum depth of 16 m with the intention of encapsulating the tailings in permafrost rendering them chemically inert (Erickson, 1995). The tailings were covered with 1 m of gravel fill from a nearby esker to host the active layer, thus keeping the tailings in a frozen state as permafrost was expected to grow downward over time through the tailings.

Pyrrhotite is estimated to comprise between 5% and 20% by volume of the tailings at Rankin Inlet. Pyrrhotite is the most rapidly oxidizing sulphide commonly found in mine waste. In addition to the rapidly oxidizing sulphides, the tailings exhibited freezing point depression due to the high salinity of the porewater resulting from inundation with seawater. By comparison, the tailings at the Meadowbank Project are estimated to contain between 4% and 5% sulphides, primarily pyrite.

Three years after burial a series of field investigations and instrumentation was undertaken at the site. The field investigations involved the drilling of boreholes, the collection of a frozen core sample of tailings using a Cold Regions Research and Engineering Laboratory (CRREL) core barrel, and the installation of a series of thermistor cables to monitor the thermal conditions within the tailings. Additional laboratory experimentation was carried out to determine the effect of freezing point depression on sulphide oxidation rates and whether or not this will affect the local thermal regime.

5.2 Thermal Regime in the Tailings at Rankin Inlet

A map showing the locations of the thermistor installations, as well as the results of the monitoring program between March 29, 1997 and February 4, 1998 are shown on Figure 10. The figures indicate that the tailings at the time the data were collected were freezing or were frozen. A thermistor installed outside of Deep Pond but adjacent to the reclamation site shows the permafrost thermal regime to a depth of 16 m, with a mean annual ground temperature of about -7ºC (see Thermistor Cable 8 on Figure 10). By comparison, the mean annual ground temperature at the Meadowbank Project is expected to be on the order of -8ºC to -10ºC, based on site specific data collected from thermistors.

Figure 11 shows the predicted mean annual ground temperature in the reclaimed tailings for a range of time intervals after burial, with the data for borehole six plotted for comparison. The results indicate that the freezing of the tailings occurs more rapidly than predicted, and that the entire tailings thickness will be at least partly ice-bonded 15 years after burial (Meldrum et. al., 2001). Meldrum suggests this may be a result of lower volumetric moisture content than assumed by the modeling. However, an alternative explanation could be that the two-dimensional model used to predict ground freezing does not take into account the three-dimensional effect of perimeter freezing.

5.3 Key Conclusions of the Rankin Inlet Studies and Implications for the Meadowbank Project Site

The following key conclusions were drawn from the laboratory testing and field instrumentation measurements at the Rankin Inlet site and are compared with the expected site conditions at the Meadowbank Project.

- A significantly reduced but measurable oxidation takes place at -2ºC, augmented by freezing point depression due to saline pore waters. There is no measurable oxidation at -10ºC.
- The reactivity and oxidation of the tailings at Rankin Inlet below a mean annual ground temperature of -2ºC is expected to be very low. It is expected that the reactivity and oxidation of the tailings at the Meadowbank Project will be similar, provided that similar disposal philosophies are adopted.

- Freeze-back of the reclaimed tailings at Rankin Inlet is underway. Eventually a pocket of unfrozen brine may remain, enclosed between the overlying ice-bonded tailings and the refrozen bedrock beneath the former Deep Pond. Although the salinity of the tailings pore water results in considerable freezing-point depression, the effect of this on oxidation rate is low.
- Heating by tailings oxidation has not been noticeable at Rankin Inlet.
- Based on the field studies and laboratory testing of tailings at the Rankin Inlet site, encapsulating tailings in permafrost should minimize oxidation where the tailings temperature is maintained below -2ºC. At Rankin Inlet, a mean annual air temperature of about -11ºC produces a mean annual ground temperature of about -7ºC. Consequently, Meldrum et. al. (2001) suggest that any prospective site for tailings disposal by permafrost encapsulation should have a mean annual air temperature of less than -6ºC, as the field studies at the Rankin Inlet site indicated that ice bonding of the tailings begins at about -4ºC. At the Meadowbank Project, the mean annual air temperature of the site is estimated to be about -11.3ºC, and the mean annual ground temperature is estimated to range from about -8ºC to about -10ºC, based on site specific measurements. Long-term temperature trends based on monitoring data collected over a period of 50 years at Baker Lake, when applied to the Meadowbank Project site, suggest a mean annual air temperature of -12.8ºC. Consequently, the encapsulation of tailings in permafrost is a preferred control strategy for the Meadowbank Project site.
- The tailings at the Rankin Inlet site are expected to be fully ice-bonded approximately 15 years after burial. This is consistent with predicted thermal modeling of the Meadowbank Tailings Facility in the northwest arm of Second Portage Lake.
- Freezing of the tailings at Rankin Inlet is occurring at a faster rate than predicted. Meldrum et. al. (2001) attributes this to a lower volumetric moisture content than assumed in the modeling. However, an alternative explanation is that the two-dimensional modeling does not account for the three-dimensional effect of perimeter freezing of the tailings, or the advancement of the freezing front from the permafrost surrounding the drained rock basin into which the tailings were deposited. A similar situation, more rapid freezing than predicted, may occur at the Meadowbank Project with the permafrost freezing front advancing into the tailings deposited into the drained rock basin of the northwest arm of Second Portage Lake.
- The precipitation of secondary minerals due to progressive freezing of the tailings may locally inhibit fluid migration by cementation.

6.0 SUMMARY AND CONCLUSIONS

This report has provided additional clarification of terminology, and of the decision making process used to select a tailing management system (location and technology) for the Meadowbank Gold Project. A decision matrix approach was utilized. An important aspect of the decision matrix methodology is that it requires all factors be weighed in the final outcome, rather than allowing a single factor to dictate the overall outcome.

Three primary categories were considered:

- Environmental;
- Operational; and
- Economic.

Sub-indicators within each category were identified, and weighting factors were assigned based on the relative importance of sub-indicators to each other. A scale, or scoring factor was applied to help separate 'best' options from 'worst' options. In the evaluation of all options, environmental factors contributed the most significantly to the outcome of the decision analysis.

Seven potential tailings management facilities were identified. These facilities were screened to determine if they met the basic site selection criteria:

- The site was required to have sufficient volume to store planned volume of tailings;
- The site required the potential to provide additional capacity for tailings storage;
- The location would permit mine expansion;
- The location is within catchments of the open pits; and
- The site allows control and collection of supernatant.

Only four of the options met these criteria, as listed below.

Location	Disposal Type
Second Portage Arm	Sub-aerial Paste or Dry Stack
Second Portage Arm	Sub-aerial Slurry
North of Second Portage Arm	Sub-aerial Slurry
North of Second Portage Arm	Sub-aerial Paste or Dry Stack

A decision matrix analysis was carried out for these four options. In addition to the initial, or baseline analysis, two sensitivity analyses were completed to consider the impact of the weighting factors. The first sensitivity analysis removed the influence of the weighting factors by setting each to one, thus placing an equal level of importance on each sub-indicator. The second analysis reduced the influence of operational factors and eliminated any economic influence on the decision process.

The results of the decision matrix analysis indicate that the preferred tailings management option for the Meadowbank Project, based on environmental, operational, (including engineering and technical) and economic considerations, is the disposal of tailings into the natural basin of the northwest arm of Second Portage Lake, followed by permafrost encapsulation. The sensitivity analyses showed that even when economic factors were removed from consideration, and operational factors were reduced in terms of relative importance leaving environmental factors as having the greatest importance, the preferred option is still indicated to be disposal in the northwest arm of Second Portage Lake followed by permafrost encapsulation as a control strategy for acid mine drainage.

A case study of the oxidation of mine tailings from Ranking Inlet, Nunavut, at sub-zero temperatures was presented. The tailings are acid generating and metal leaching, with saline pore waters. A remediation program begun in 1991 consisted of depositing the tailings into a drained rock basin, with the expectation that permafrost would aggrade into the facility. This is similar to the preferred option for tailings management at the Meadowbank project. A series of thermistors installed in the test area indicated that freeze-back of the tailings was occurring more rapidly than predicted. There was no indication of heating by tailings oxidation, despite the highly reactive nature of the pyrrhotite rich tailings. The results of the laboratory and field investigations indicated that prospective sites for permafrost encapsulation of tailings should have a mean annual air temperature colder than about -6ºC. The Meadowbank Project site has a mean annual air temperature of about -11.3ºC and mean annual ground temperature of -8ºC to -10ºC Based on long-term temperature trends at Baker Lake, applied to the Meadowbank Project site, a mean annual air temperature of -12.8ºC is indicated. Based on the results presented in the case study, permafrost encapsulation of tailings disposed in a drained rock basin, such as the northwest arm of Second Portage Lake, is the preferred method of disposal of tailings at the Meadowbank Project.

7.0 CLOSURE

We trust that this report meets your requirements at this time. If you have any additional questions, please do not hesitate to contact the undersigned.

Yours very truly,

GOLDER ASSOCIATES LTD.

Fiona Esford, M.A.Sc., P.Eng., LEG
Geotechnical Engineer

Cameron J. Clayton, M.Eng., P.Geo.
Associate

FCE/CJC/kt/vee/lba
N:\FINAL\2005\1413\05-1413-036A\3000\RPT-1006_05 CUMBERLAND RESOURCES-TAILINGS STORAGE FACILITY SELECTION.DOC

REFERENCES

AMEC Americas Ltd. 2005. Meadowbank Gold Project, Hydrologic Monitoring 2004 Data Report – Draft. February 2005.

Access Consulting Group. 2003. Examination of Revegetation Methodologies for Dry Stack Tailings in Northern Environments. Prepared for: Mining Environmental Research Group, Government of Yukon. March 2003.

Brown, Bruce S. 2002. Management of Tailings Disposal on Land. Knight Piesold Consulting.

Caldwell, Jack A., and Andrew Mac G. Robertson. 1983. Selection of tailings impoundment sites. Die Siviele Ingenieur in Suid-Afrika. Oktober 1983.

Canter. 1985. Ground Water Pollution Control. CRC – Taylor & Frances, New York.

CH_2MHILL. 2004. Clark Fork River Operable Unit, of the Milltown Reservoir/Clark Fork River Superfund Site, Record of Decision, Part 3: Responsiveness Summary, April 2004, U.S. Environmental Protection Agency, Region 8, Montana.

CRL. 2005a. Meadowbank Gold Project, Baseline Fish Habitat Report, Cumberland Resources Ltd., January 2005.

CRL. 2005b. Meadowbank Gold Project, Baseline Aquatic Ecosystem Report, Cumberland Resources Ltd., January 2005.

Davies, Michael, P. and Stephen Rice. 2001. An alternative to conventional tailing management – “dry stack” filtered tailings. Infomine.

Decision – Makers Field Guide. 2005. Environmental and Water Quality Issues (Chapter 2); Sustainable Development, Technology, and a look to the Future (Chapter 4). Mining in New Mexico, Decision – Makers Field Conference 2005 Taos Region.

European Commission. 2004. Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities. July 2004. Sustainability in Industry, Energy, and Transport European IPPC Bureau, Spain. (http://eippcb.jrc.es).

Golder. 2004. Mine Waste and Water Management Meadowbank Gold Project, Nunavut. Prepared for Cumberland Resources Ltd. Golder Associates Ltd., March 5, 2004. Report No. 03-1413-427-5000.

Golder. 2005. Alternative Waste and Water Management Plan, Meadowbank Gold Project, Nunavut. Prepared for Cumberland Resources Ltd. Golder Associates Ltd., March, 2005. Report No. 04-1413-034/2600.

International Atomic Energy Agency (IAEA). 2000. Recycle and reuse of materials and components from waste streams of nuclear fuel cycle facilities. January 2000, Waste Technology Section, Austria.

Martin, T.E., et.al. 2002. Stewardship of Tailings Facilities. Mining Minerals and Sustainable Development. No. 20, April 2002. AMEC Simons Ltd., Vancouver.

Meldrum, J. L., et. al. 2001. Oxidation of Mine Tailings From Rankin Inlet, Nunavut, at Sub-zero Temperatures. Canadian Geotechnical Journal 38: 957-966.

Mine Effluent Neutral Drainage (MEND) Project 1.61.2. 1996. Acid Mine Drainage in Permafrost Regions: Issues, Control, Strategies, and Research Requirements. July 1996.

Molycorp Watch Project. ----. Current Regulatory Permitting for the Molycorp Mine, Amigos Bravos Friends of the Wild Rivers (NGO, New Mexico). Website: http://amigosbravos.org/molycorpwatch/permits/index.html (July 19, 2005).

Norman, David K., and Robert L. Raforth. 1998. Innovations and Trends in Reclamation of Metal-Mine Tailings in Washington. Washington Geology, Vol. 26 No. 2/3, September 1998.

Northern Liner. 2005. "Mining Across Alaska – Summaries. The Journal of the Northern Alaska Environmental Center, Summer 2005, Volume XXVII, Number 2.

Robertson, A. MacG. 1982. Site selection and design options for uranium mine waste and plant tailings. Proceedings, 12th CMMI Congress. H.W. Glen (Ed.) Johannesburg, S. Africa. Institute of Mining and Metallurgy.

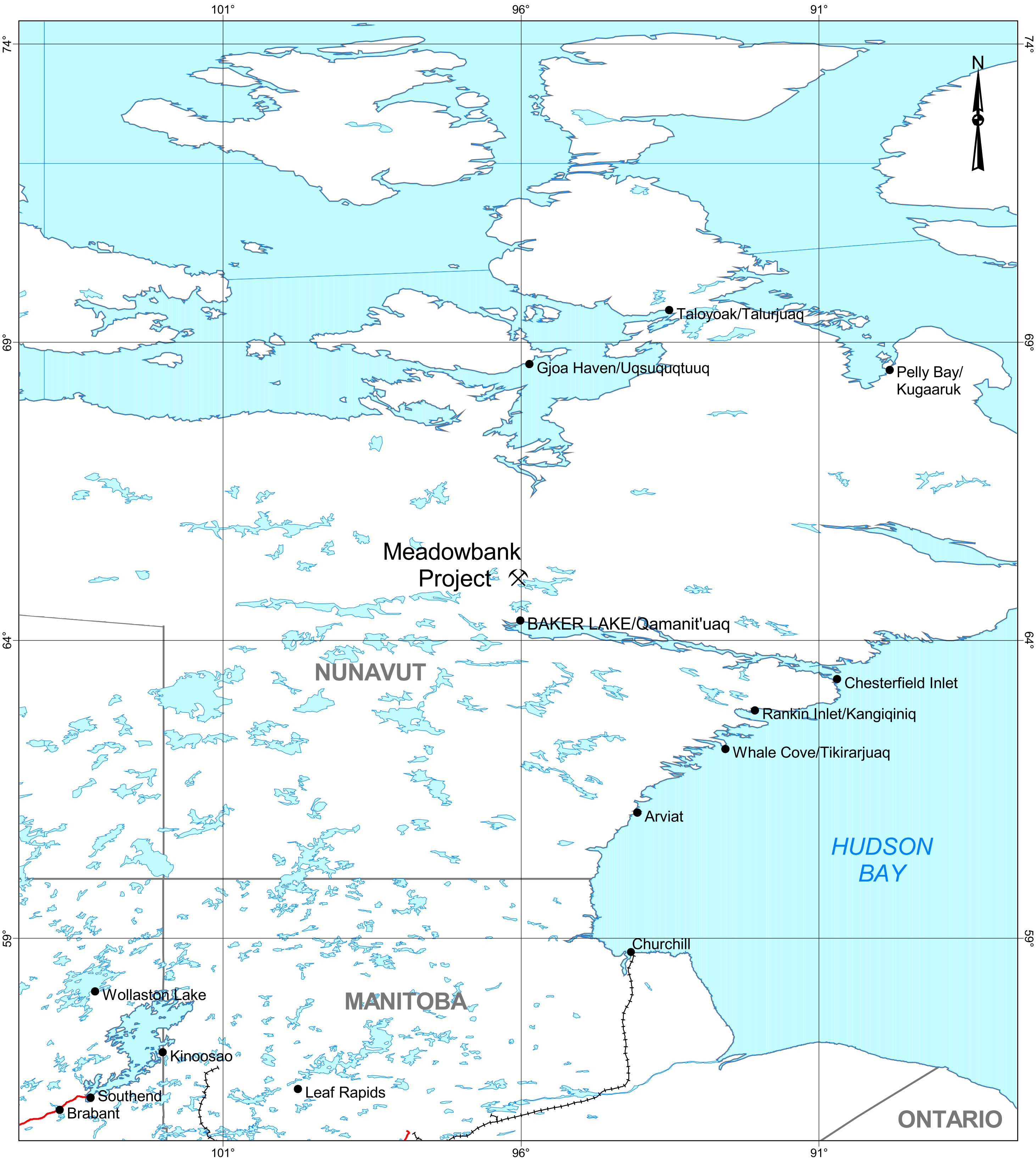
Robertson, A. MacG., and S.C. Shaw. 1998. Alternative analysis for mine development and reclamation. Proceedings of the 22nd Annual BC Mine Reclamation Symposium, Penticton, BC. Canada, (September 14-17, 1998) pp. 51-62.

Robertson, A. MacG., and S.C. Shaw. 1999. A multiple accounts analysis for tailings site selection. In Sudbury '99 - Mining and the Environment II Proceedings, D. Goldsack, N. Belzile, P. Yearwood and G. Hall (Eds) September 12-16, Sudbury, Ontario, Can. Pages 883-892.

Robson Valley Land and Resource Management Plan – April 1999. Government of British Columbia.

Shaw, S.C., et.al. 2001. Review of the Multiple Accounts Analysis Alternatives Evaluation Process Completed for the Reclamation of the Zortman and Landusky Mine Sites. Presented at the 2001 National Association of Abandoned Mine Lands Annual Conference, August 19-22, 2001, Athens, Ohio.

Vick, Steven G. 1990. Planning, Design, and Analysis of Tailings Dams, BiTech Publishers Ltd., Vancouver. ISBN 0-921095-12-0.



LEGEND

- Meadowbank Project
- Town/Village
- Provincial Border
- Water
- Primary Highway
- Railroad

200 0 200 Kilometers

Scale - 1:10,000,000

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

LOCATION PLAN
MEADOWBANK PROJECT

Golder Associates

PROJECT No. 05-1413-036A			SCALE AS SHOWN	REV. 0
DESIGN	CJC	26 Sep. 2005	**FIGURE 1**	
GIS	CDB	26 Sep. 2005		
CHECK	CJC	26 Sep. 2005		
REVIEW				

REFERENCE

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DATUM: WGS84 PROJECTION: Geographic

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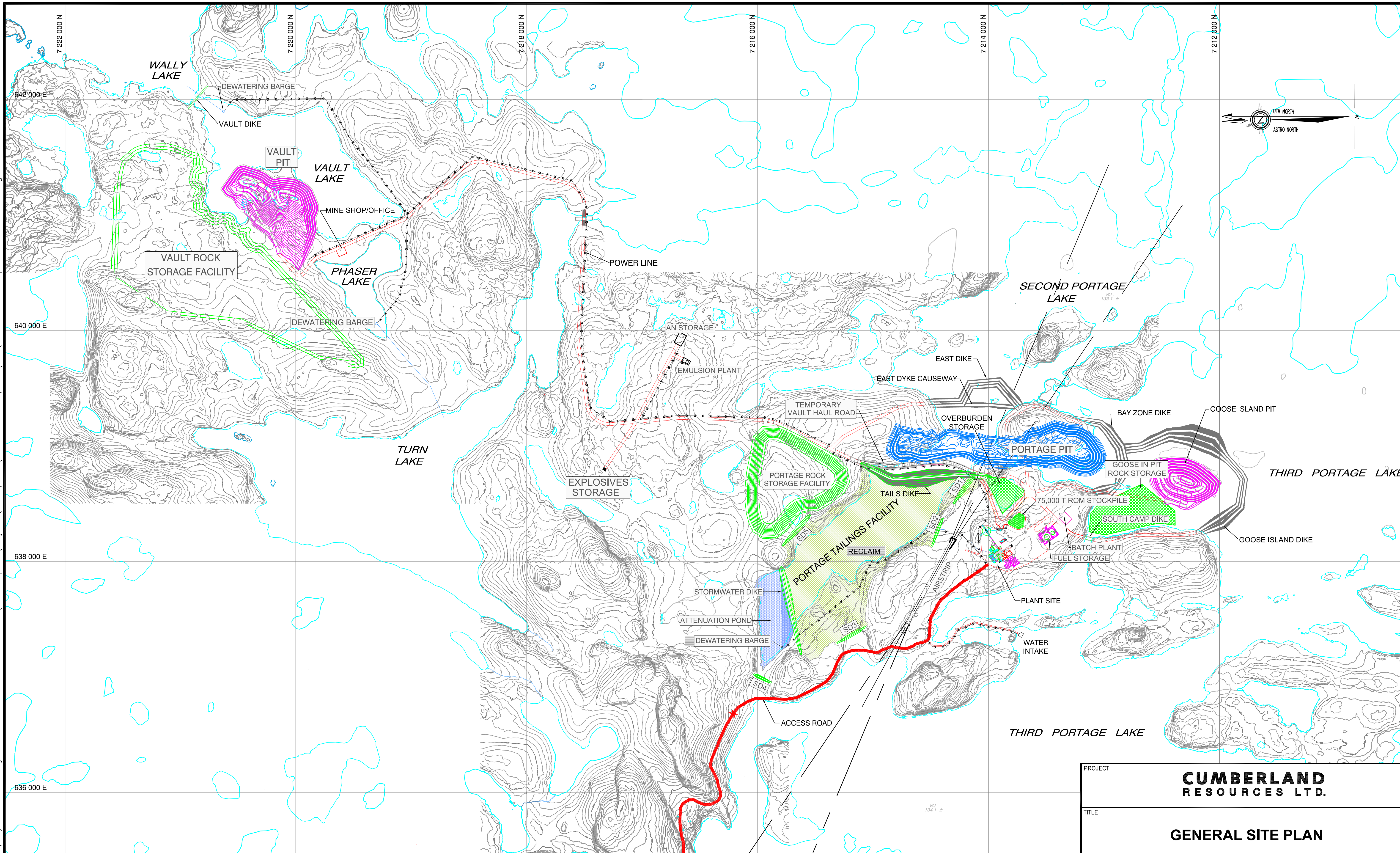

0 300 600 900 1200 1500

Scale in Meters

REFERENCES

1) Drawing taken from AMEC, Drawing # A1-131395-100-C-0001.

LEGEND

SD: SADDLE DAM

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

GENERAL SITE PLAN

Golder Associates

PROJECT No. 05–1413–036A			FILE No. 051413036A–SK10
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CADD	WLI	26SEP05	**FIGURE 2**
CHECK	CJC	27SEP05	
REVIEW	CJC	27SEP05	

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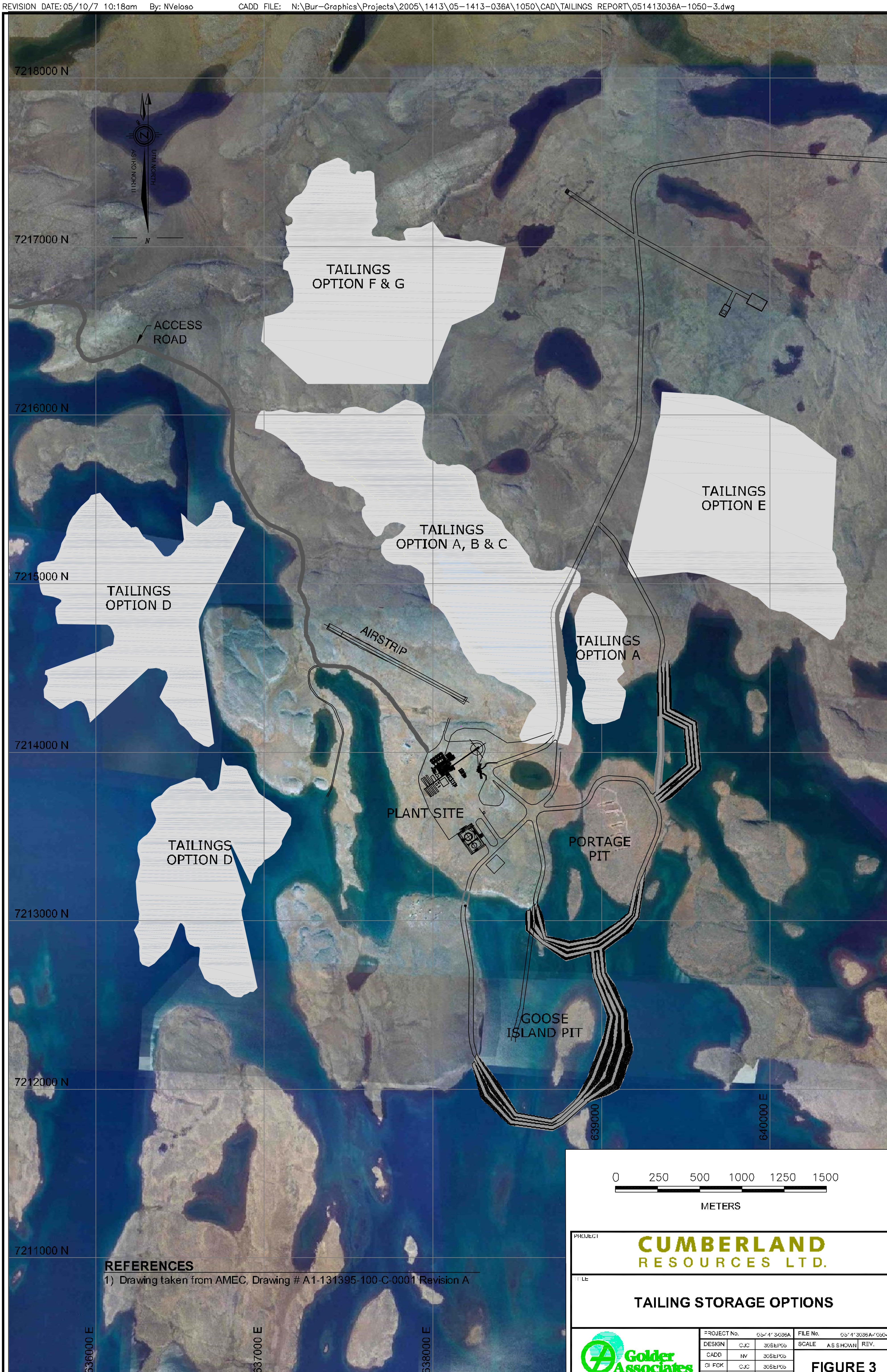

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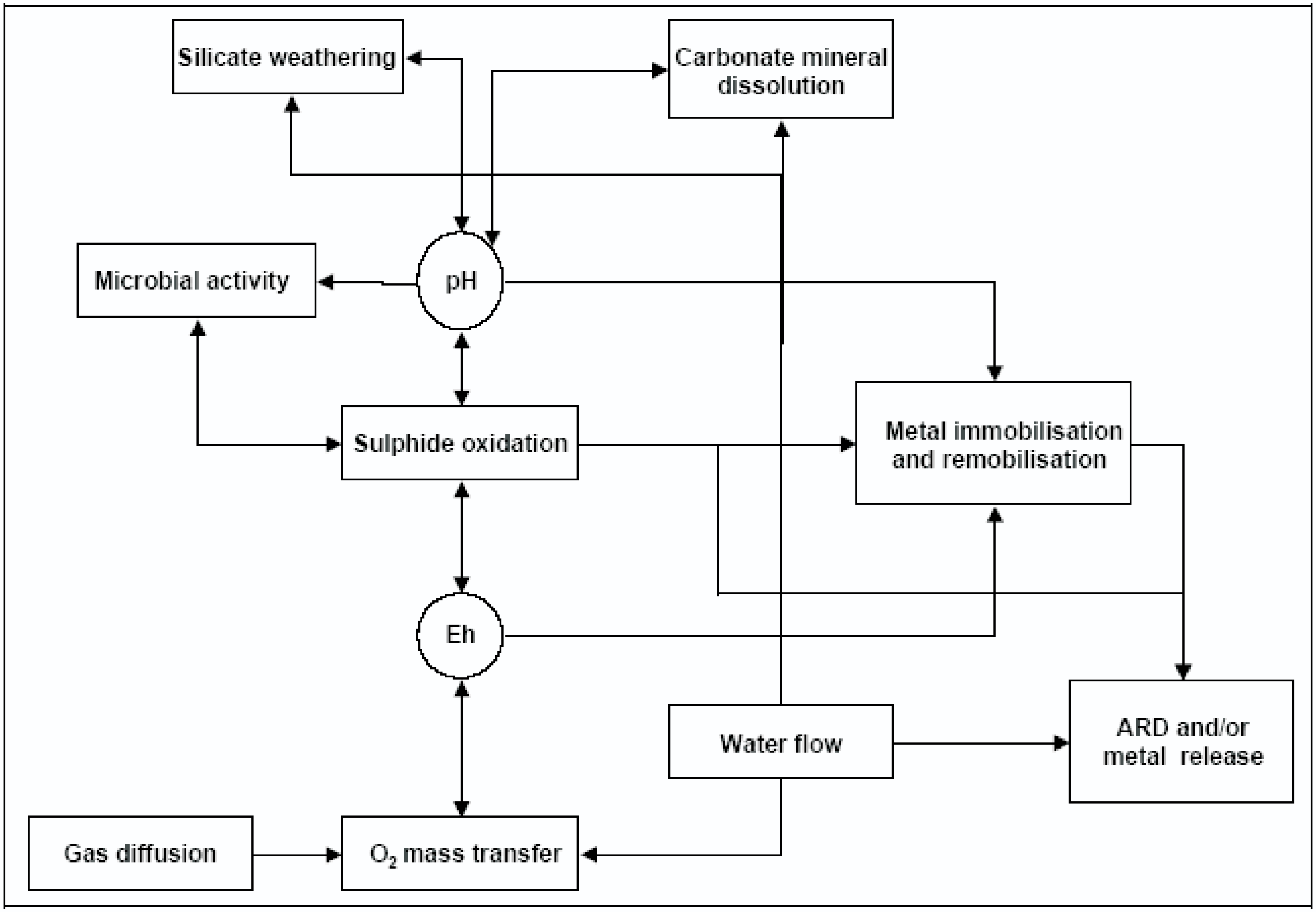

Source: European Commission, 2002.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

GEOCHEMICAL AND PHYSICAL PROCESSES POTENTIALLY RESULTING IN ARD AND ML

Golder Associates

PROJECT No.	05-1413-036A		FILE No.	FIGURES 3
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CHECK	CC	28SEP05		
REVIEW				

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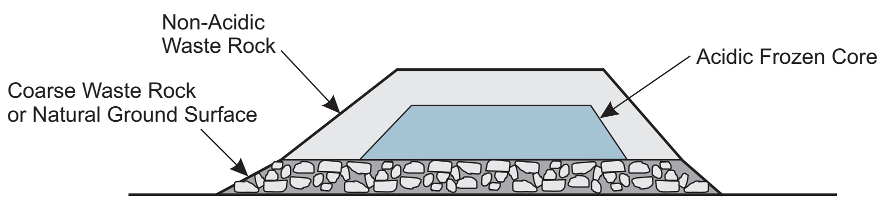

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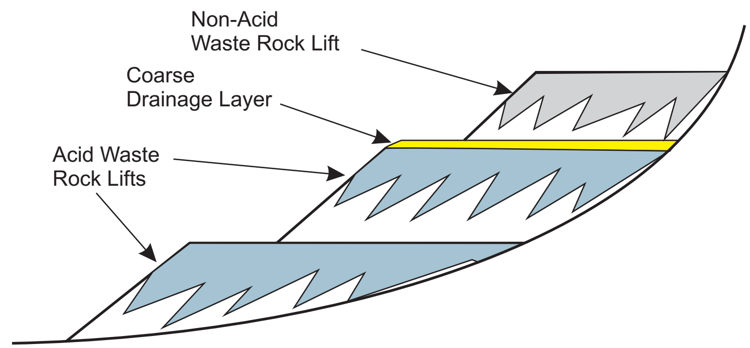

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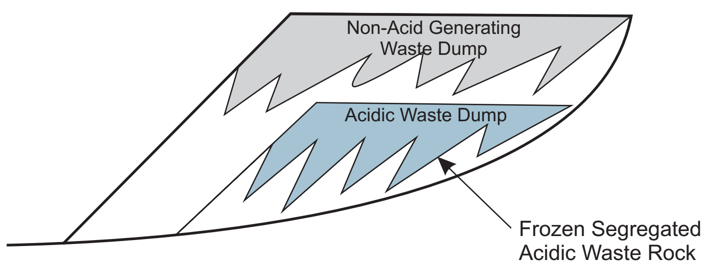

Freeze Controlled ARD Strategies

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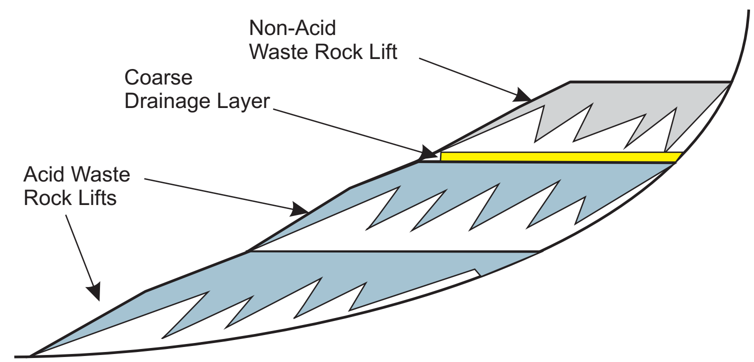

Climate Controlled ARD Strategies

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Reference: MEND 1.61.2, 1996

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CUMBERLAND RESOURCES LTD.

TITLE
WASTE ROCK STORAGE FACILITY CONSTRUCTION METHODS

PROJECT No.	05-1413-036A		FILE No.	FIGURE
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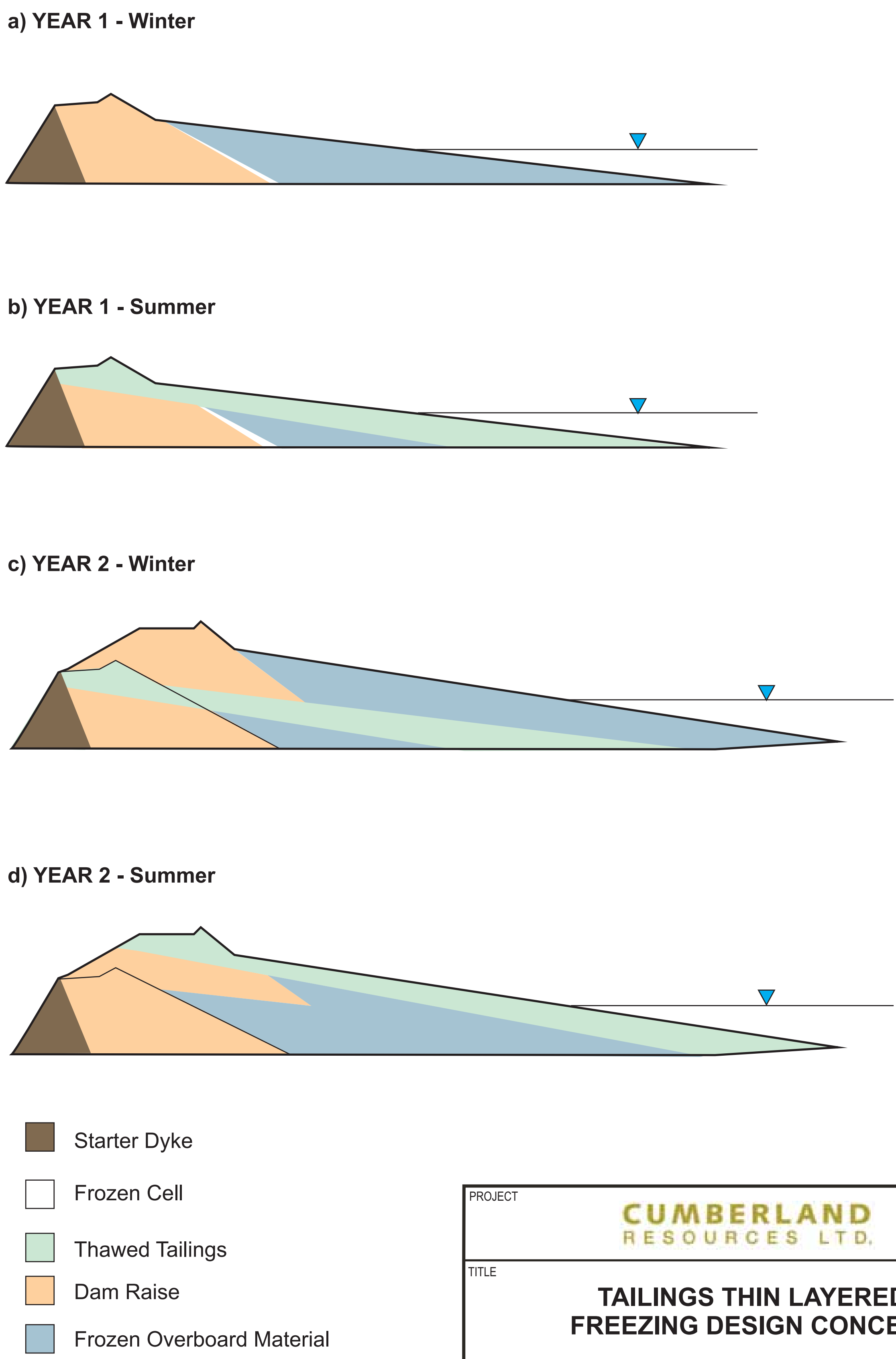
REVIEW				



Reference: MEND 1.61.2, 1996

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

TAILINGS THIN LAYERED FREEZING DESIGN CONCEPT

Golder Associates

PROJECT No.	05-1413-036A	
DESIGN	CC	06OCT05
CADD	SS	06OCT05
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REVIEW		

FILE No. FIGURE 2

SCALE NTS

REV.

FIGURE 6

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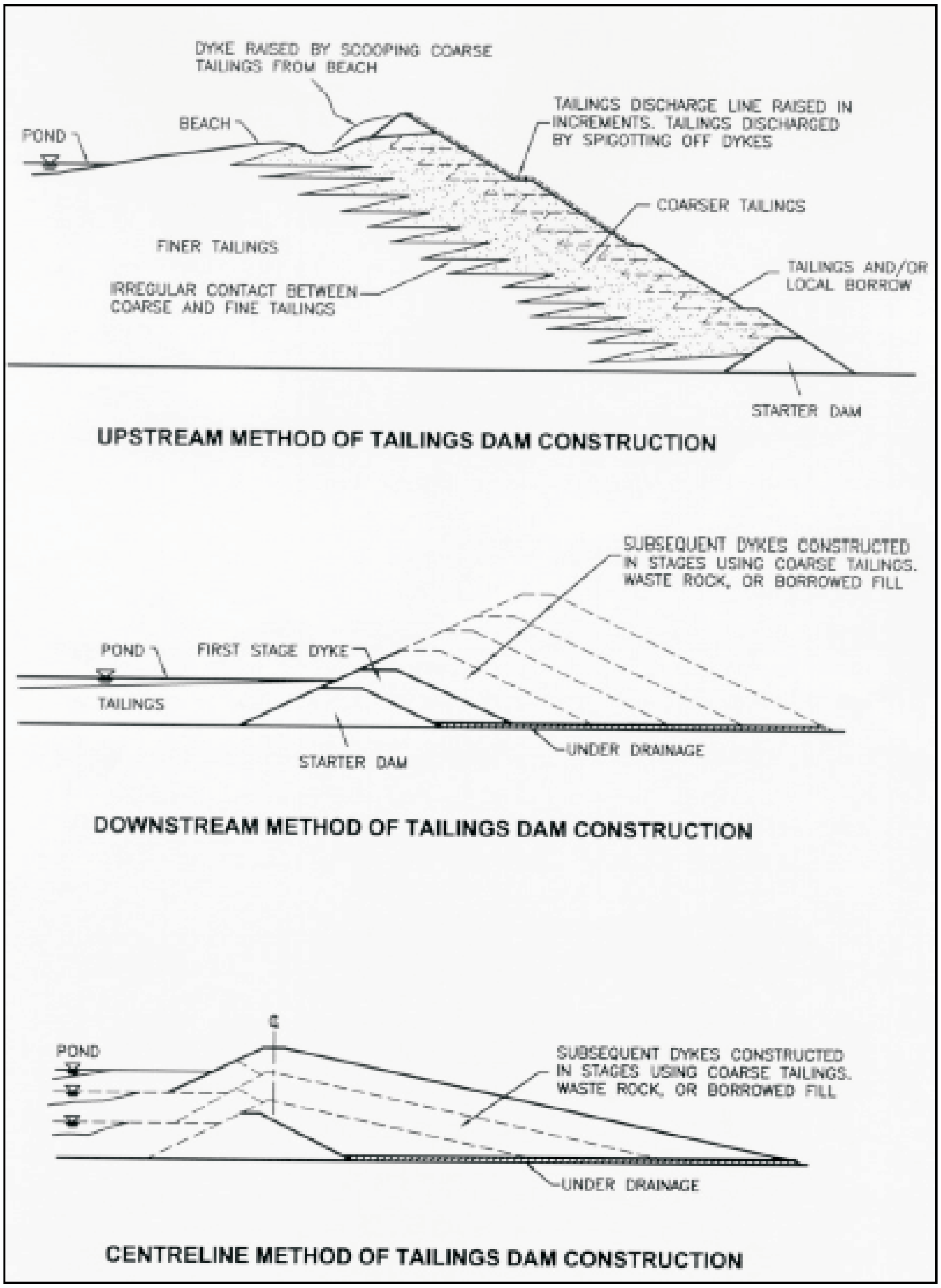

Source: Martin, 2002.

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TITLE	TAILING DAM CONSTRUCTION METHODS			
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	CADD	VEE	28SEP05	FIGURE 7
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	REVIEW			

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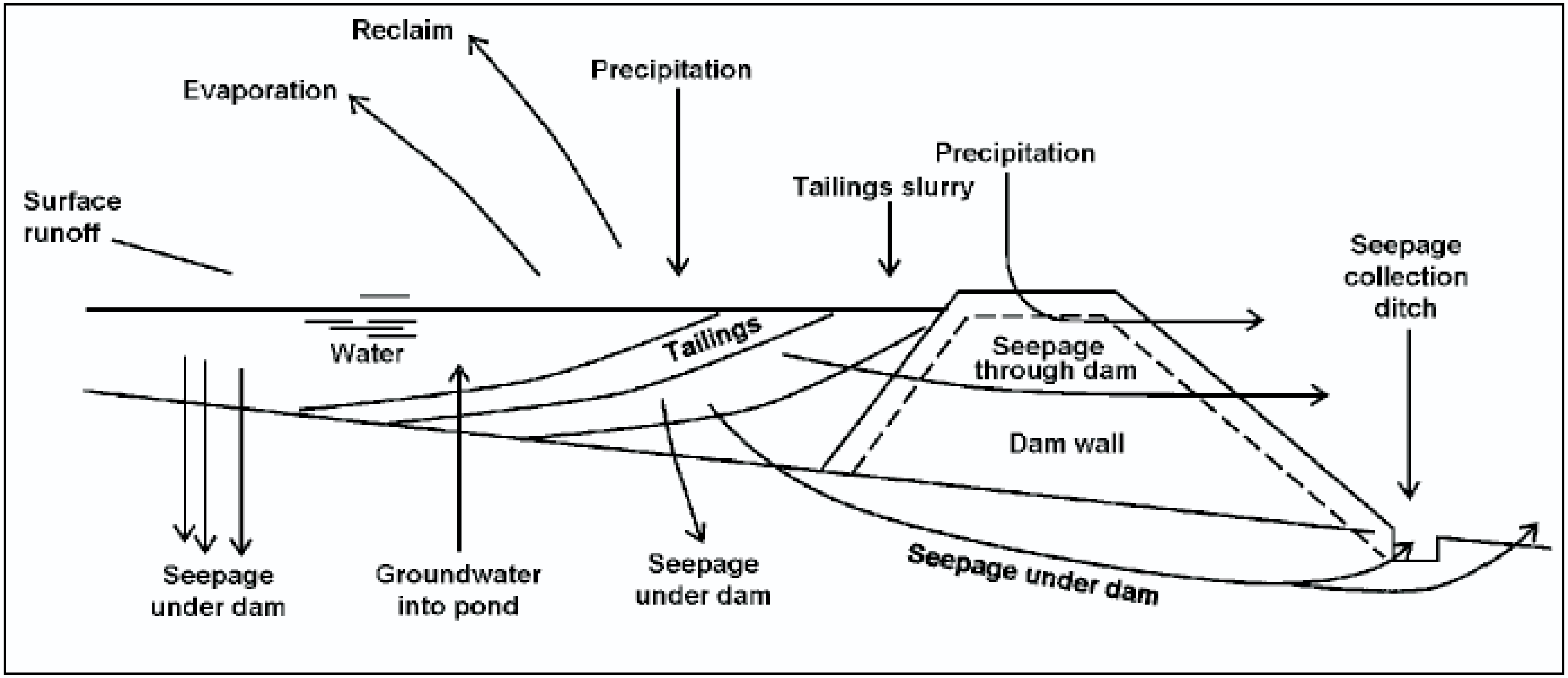

Source: European Commission, 2003.

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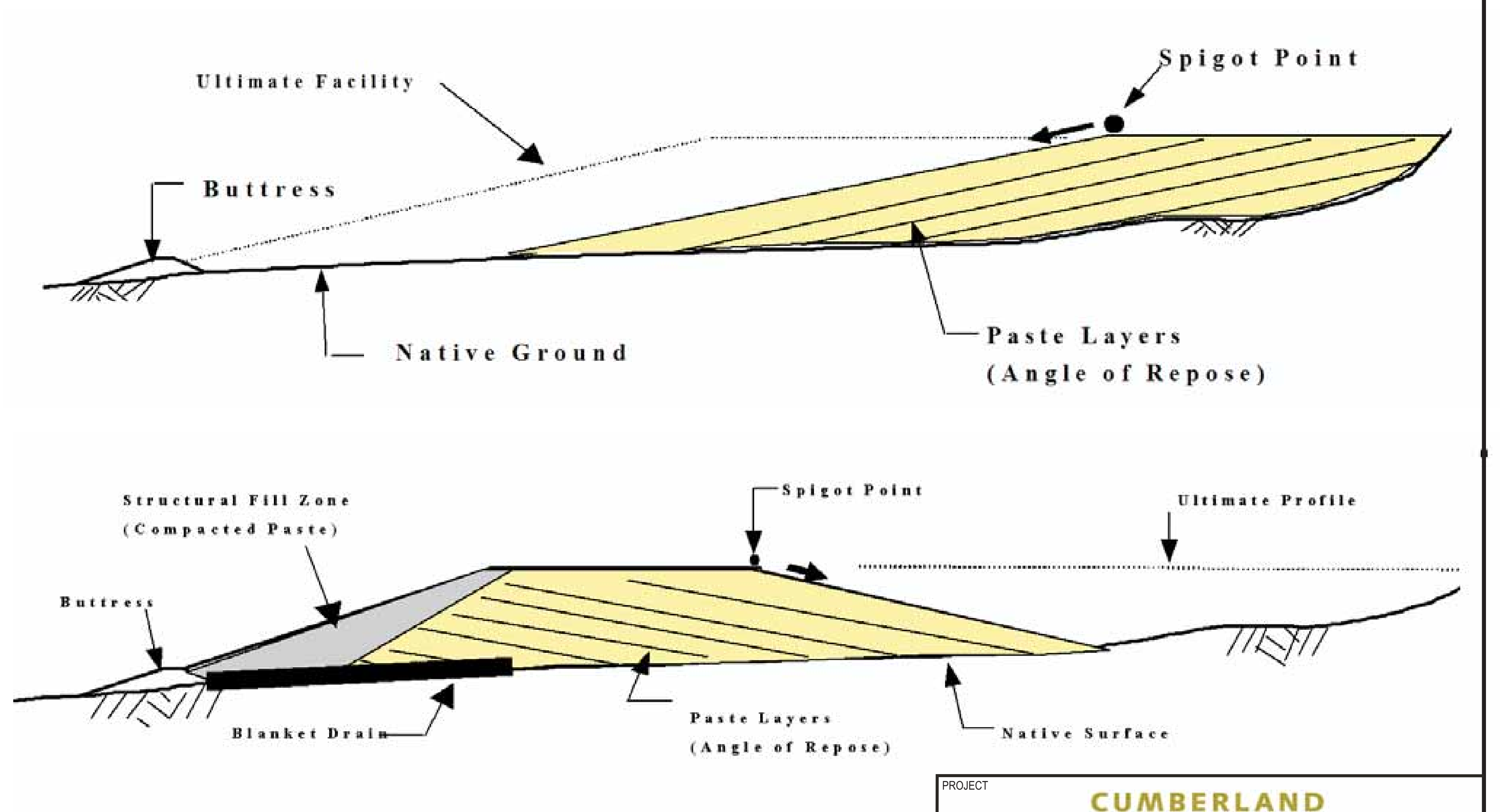

Source: European Commission, 2002.

PROJECT
CUMBERLAND RESOURCES LTD.

TITLE
ABOVE GROUND PASTE TAILINGS DEPOSITION METHODS

Golder Associates

PROJECT No.	05-1413-036A		FILE No. FIGURES 3	
DESIGN	CC	28SEP05	SCALE NTS	REV.
CADD	VEE	28SEP05	FIGURE 9	
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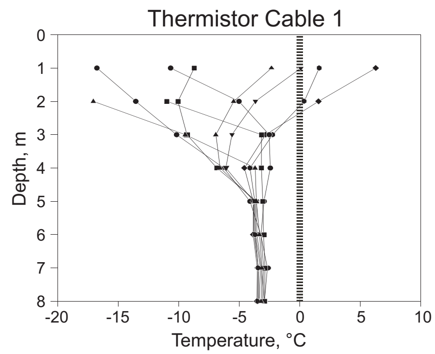

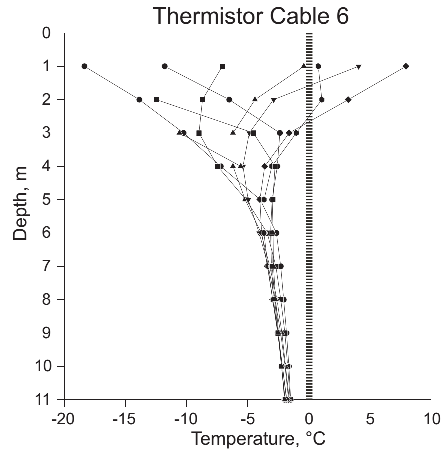

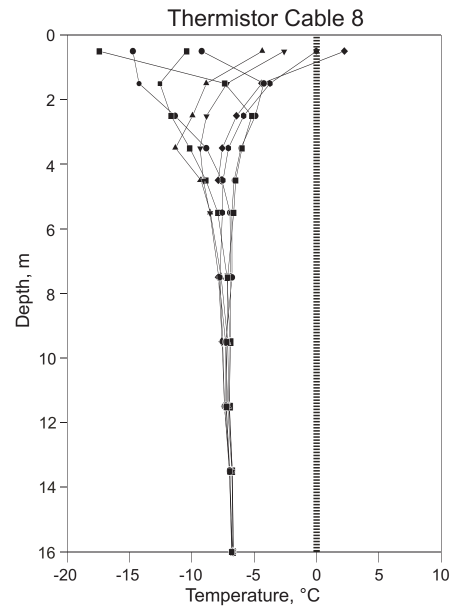

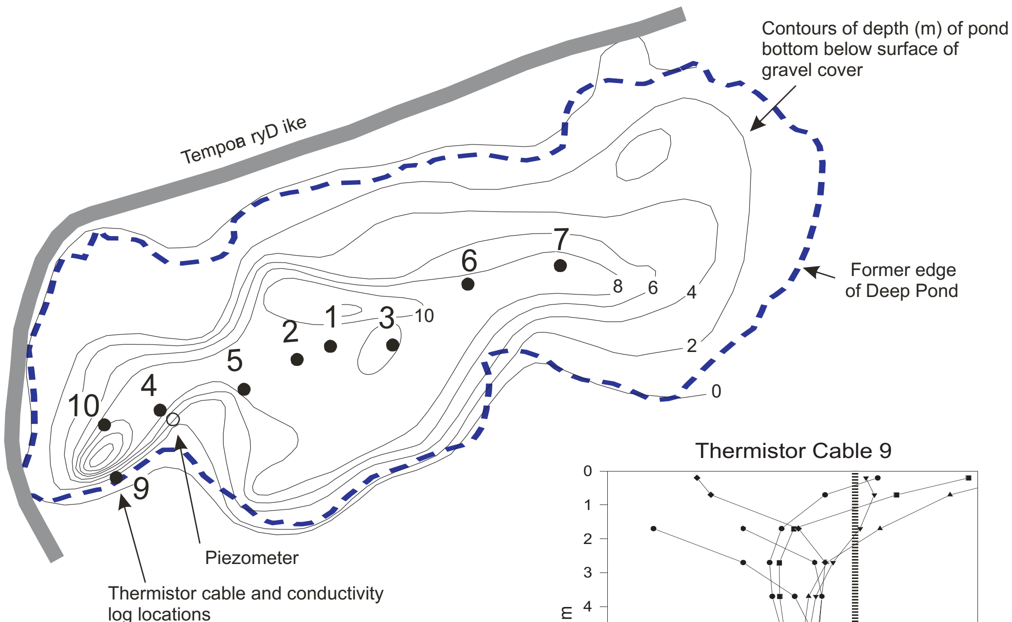

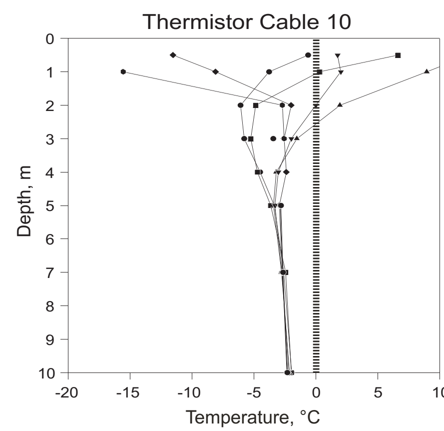

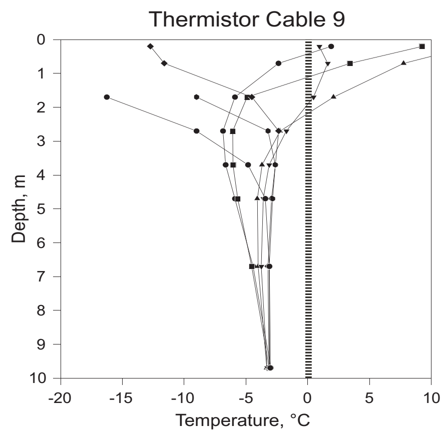

Map of Deep Pond showing borehole locations and depth of bottom below surface of gravel cover (2 m contour interval). Insets show ground temperature records between March 29, 1997 and Feb. 4, 1998

Reference: Oxidation of Mine Tailings from Rankin Inlet, Nunavut, at Subzero Temperatures. Meldrum, et.al., 2001.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

RANKIN INLET TAILINGS STUDY THERMAL MONITORING

Golder Associates

PROJECT No.	05-1413-036A	FILE No.	FIGURES 2
DESIGN	CC	26SEP05	SCALE NTS REV.
CADD	SS	26SEP05	**FIGURE 10**
CHECK	CC	26SEP05	
REVIEW			

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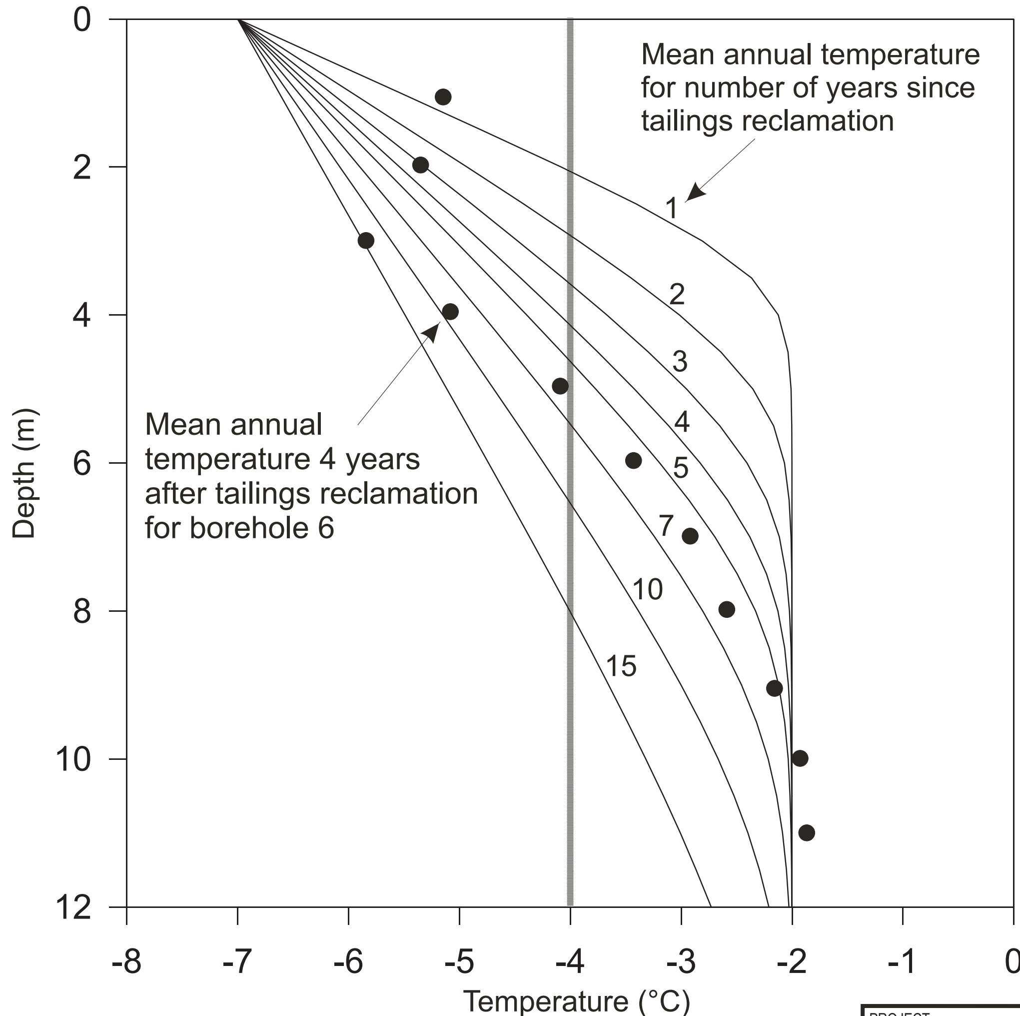

Prediction of mean annual ground temperature in reclaimed tailings for a range of time intervals after burial in late 1993. Dashed line at -4°C shows temperature at which tailings become noticeably ice-bonded. Dots show mean annual ground temperatures for borehole 6, 4 years after burial. Temperature reversal for uppermost 2 m is due to annual variation of thermal properties in the active layer.

Reference: Oxidation of Mine Tailings from Rankin Inlet, Nunavut, at Subzero Temperatures. Meldrum, et.al., 2001.

PROJECT				
CUMBERLAND RESOURCES LTD.				
TITLE: RANKIN INLET TAILINGS STUDY PREDICTED FREEZE-BACK TIME				
Golder Associates	PROJECT No. 05-1413-036A		FILE No. FIGURES 2	
	DESIGN	CC	26SEP05	SCALE NTS	REV.
	CADD	SS	26SEP05	FIGURE 11
	CHECK	CC	26SEP05	
	REVIEW			

APPENDIX B

Waste Rock Site Selection

Golder Associates Ltd.

500 – 4260 Still Creek Drive
Burnaby, British Columbia, Canada V5C 6C6
Telephone (604) 296-4200
Fax (604) 298-5253

REPORT ON

EVALUATION OF WASTE ROCK MANAGEMENT ALTERNATIVES MEADOWBANK GOLD PROJECT NUNAVUT

Submitted to:

Cumberland Resources Ltd.
Suite 950, One Bentall Centre
505 Burrard Street
Vancouver, BC
V7X 1M4

DISTRIBUTION:

3 Copies - Cumberland Resources Ltd.
2 Copies - Golder Associates Ltd.

October 14, 2005 05-1413-036A/1000

EXECUTIVE SUMMARY

A series of Technical Meetings were held in Baker Lake on June 2 and 3, 2005 to review the Draft Environmental Impact Statement (DEIS) for Cumberland Resources Limited (CRL), Meadowbank Gold Project. Following the technical meeting, a list of commitments by CRL was prepared, which would either be addressed as soon as possible or appear in the Final Environmental Impact Statement. This report responds to Items #5 and #26 from this list, which requested additional information relating to the decision matrix used to evaluate waste rock disposal options.

Items #5 and #26 from this list specifically requested that:

1) Revised wording for the elimination of options be provided;

2) Clarification be provided regarding the decision matrices for the Portage Rock Storage Facility (as it relates to the possible effects on all affected fish-bearing lakes) – to be provided to parties as soon as possible;

   a) The rationale for selecting the various factors, sub-indicators and relative weightings and the ranking of the various options needs to be supported with scientific evidence. The various options need to be clearly described with supporting rationale for each component.

Two reports have been issued previously describing the strategy for selecting the waste rock storage facility and details of the mine waste and water management plan:

- Golder Associates Ltd., Report on Alternative Waste and Water Management Plan, Meadowbank Gold Project, Nunavut, March 7, 2005; and
- Golder Associates Ltd., Report on Mine Waste and Water Management, Meadowbank Gold Project, Nunavut, March 5, 2004.

The Meadowbank Gold Project is located near Baker Lake, Nunavut. Cumberland Resources Ltd. is conducting a feasibility study to develop a gold mine that will consist of a series of open pits with a single processing plant, a tailings storage facility and two waste rock storage areas. The revised mine plan estimates 22 million tonnes of ore will be produced over a mine life of 8.3 years, and will generate a total volume of 173 million tonnes (bulked) of waste rock. The geochemical testing has shown that the waste rock will have the potential to produce acid rock drainage (ARD) and metal leaching (ML). Consequently, disposal methods to limit the potential for ARD and ML are desirable.

The Mine Waste and Water Management Report (Golder, 2004) previously presented the results of the waste rock facility selection process. Due to the distance between the Portage and Goose Island mining areas and the Vault mining area and volume of waste rock storage required, it was decided that two waste rock storage facilities would be required. One facility would be near the Vault open pit, to accommodate waste rock generated from mining at this location, and the second would be near the Portage pits (North Portage and Third Portage) and Goose pit.

The process used to select the waste rock storage facilities involved:

- Identifying potential locations; and
- Developing a site specific, decision matrix model to evaluate, rank, and select the best overall facility or facilities.

This approach, sometimes known as a Multiple Accounts Analysis (MAA), is commonly used as a decision making tool for the selection of waste management facilities. The decision matrix model considered factors in three primary categories: environmental, operational and economic. Each category was further subdivided to consider various components. Weighting factors were assigned to each sub-indicator and to the overall factors. Environmental factors were judged as being the most important and were therefore assigned the highest overall weighting.

The Vault open pit is located in a region of low relief, is surrounded by numerous lakes (i.e., Phaser Lake, Vault Lake and Wally Lake), and near a drainage subdivide. There are few suitable locations for a waste rock storage facility near the Vault pit owing to the presence of numerous lakes adjacent to Vault Lake and the lack of topographical relief in the immediate area, which limits the height to which a rock storage facility could be constructed without becoming visible at great distance from the site. In addition, placing waste rock in areas south of Vault Lake would affect a sub-watershed that does not drain toward the Vault open pit. The best alternative for the storage of the waste rock from the Vault pit is on a broad area of land immediately to the west of the open pit area. Because there was only one suitable area for waste rock storage in the Vault area, a Multiple Accounts Analysis was not performed.

Alternatives for the Portage rock storage facility were evaluated in the Report on *Alternative Waste and Water Management Plan* (Golder, 2005), due to a revised mine plan. This report was prepared to provide additional information on the decision making process used to select the final location for the Portage rock storage facility. This information is provided to fulfill commitments made by Cumberland Resources Ltd. during a prehearing conference and technical meetings, specifically Items 5 and 26.

Options A and B were evaluated with options C and D located to the East of Vault Haul Road using the MAA decision matrix model. Locations for each are described below:

Option	Location Description
Option A*	North of Second Portage Arm – small footprint
Option B	North of Second Portage Arm – large footprint
Option C	East of Vault Haul Road – small footprint
Option D	East of Vault Haul Road – large footprint

* Option A was originally evaluated in Golder, 2004 report. Alternatives (A & B) to the original Option A were evaluated in *Report on Alternative Waste and Water Management Plan* (Golder, 2005) and compared to Option A.

Through this process Option A (located north of the Portage tailings storage facility) was shown to have the least impact on fish bearing lakes and the smallest over-all foot print. Option A along with the Vault rock storage facility were chosen as the best options for waste rock storage.

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LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

A series of Technical Meetings were held in Baker Lake on June 2 and 3, 2005 to review the Draft Environmental Impact Statement (DEIS) for Cumberland Resources Limited (CRL), Meadowbank Gold Project. During these sessions stakeholders requested additional clarification regarding the decision matrix method used to select the waste rock storage facilities for the project. The following report has been prepared to explain in more detail the evaluation process used to select the rock storage facilities for the proposed Meadowbank Gold Project. The decision matrix used to identify the most appropriate rock storage site based on environmental, engineering and economic considerations is presented and explained in greater detail.

Golder Associates Ltd. (Golder) was retained by Cumberland Resources Ltd. (CRL) to identify and select appropriate waste rock storage facilities for the Meadowbank Gold Project in Nunavut. Two reports were prepared that described the strategy for selecting the rock storage facility:

- Golder Associates Ltd., Report on Alternative Waste and Water Management Plan, Meadowbank Gold Project, Nunavut, March 7, 2005; and
- Golder Associates Ltd., Report on *Mine Waste and Water Management, Meadowbank Gold Project, Nunavut*, March 5, 2004.

A Multiple Accounts Analysis (MAA), or decision matrix method of analysis, was used to rank and select the best rock storage facility for the project.

Based on the distance between the Portage and the Vault deposits and the volume of storage required, two waste rock storage facilities are required. The Vault Rock Storage Facility near the Vault Pit was selected on the basis of available on-land storage space near this pit, topographic relief, and the desire to have the facility located within the same watershed as the open pit. The rock storage facility near the Portage deposit (called Portage Waste Rock Storage Facility) was selected to contain waste rock generated from the Portage and Goose Island open pits.

Only one suitable site location was identified for the Vault Rock Storage Facility. Four options were evaluated for the Portage Rock Storage Facility using a decision matrix method of analysis. The best overall location selected for the waste rock was located north from Second Portage Lake, with a relatively small footprint.

The alternative analyses and subsequent revision to the initial waste rock storage facility location was conducted as the volume of waste rock was reduced and the option to store a portion of the waste rock within open pits became available, during the completion of the feasibility study.

Primary objectives established for the waste rock storage facility (or facilities) were:

- Minimize potential long-term environmental impacts (including ARD generation, metal leaching, seepage to the underlying groundwater regime);
- Maximize ease of water management during operation;
- Maximize ease of decommissioning/closure;
- Minimize catchment area impacted;
- Minimize dust generation;
- Minimize visual impact;
- Minimize areas of fish bearing lakes impacted;
- Minimize footprint area (to reduce the volume of affected runoff);
- Minimize the potential for geotechnical hazards (including slope instability, seismic risk); and
- Minimize haul costs.

1.1 Physical Setting

The proposed Meadowbank Gold Project is located approximately 70 km north of Baker Lake, Nunavut, as shown in Figure 1.1.

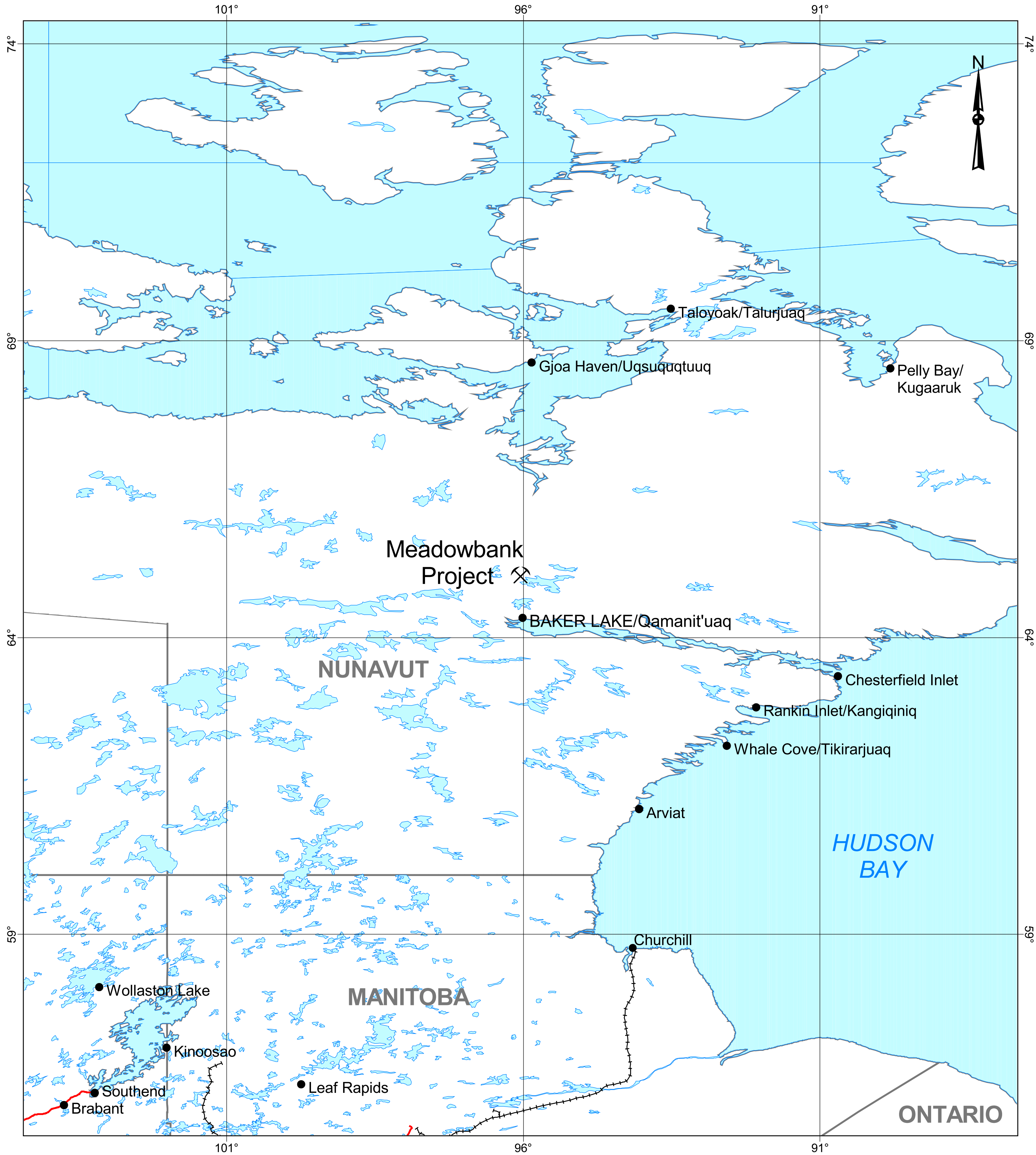
The site area consists of low, rolling hills with numerous small lakes. Laterally extensive deposits of glacial till cover the area, with thicknesses typically of 2 to 4 meters. Bedrock consists of a sequence of Archean greenstone (ultramafic and mafic flow sequences) and metasedimentary rocks. The area has low seismic activity.

The site has vegetation cover interspersed with bedrock outcrops and continuously aggrading surfaces. The vegetation includes lichens, mosses, shrubs, heaths, grasses and sedges (CRL, 2003).

No vital caribou areas or protected wildlife areas have been identified in close proximity to the site (CRL, 2003). The area is not regularly used for hunting due to its remoteness from Baker Lake and relatively low abundance of wildlife (CRL, 2003).

Water quality in the lakes is excellent, however, the lakes are nutrient poor and are classified as ultra-oligotrophic and hence have low fish productivity (CRL, 2003).

The annual average air temperature at the site is about -11.3°C, based on site data collected between 1997 and 2004, and has an annual precipitation of less than 200 mm. The depth of permafrost is estimated to range from about 450 meters to about 550 meters, but varies based on proximity to lakes. Taliks typically are located beneath bodies of water with depth exceeding 2 to 2.5 meters. The depth of the active layer ranges from about 1.3 meters in areas of shallow overburden and up to 4 meters adjacent to lakes.



LEGEND

- Meadowbank Project
- Town/Village
- Provincial Border
- Water
- Primary Highway
- Railroad

200 0 200 Kilometers

Scale - 1:10,000,000

REFERENCE

Base digital data obtained from ESRI Inc.,
DATUM: WGS84 PROJECTION: Geographic

PROJECT

CUMBERLAND
RESOURCES LTD.

TITLE

LOCATION PLAN
MEADOWBANK PROJECT

Golder Associates

PROJECT No. 05-1413-036A			SCALE AS SHOWN	REV. 0
DESIGN	CJC	26 Sep. 2005	**FIGURE 1.1**	
GIS	CDB	26 Sep. 2005		
CHECK	CJC	26 Sep. 2005		
REVIEW				

N:\Bur-Graphics\Projects\2005\1413\05-1413-036A\GIS\aprs\figure-01-01_location-plan-meadowbank-project.apr (Layout: 8.5x11 Portrait) September 26, 2005

1.2 Planned Mining Operations

A general site plan is shown in Figure 1.2. The mine plan estimates that 22 million tonnes of ore will be produced over the mine life of approximately 8.3 years. The project consists of several gold bearing deposits within reasonable proximity to one another. Mining of the deposits will primarily be performed as a truck and shovel, open pit operation. Ore is to be transported to a central plant site for processing.

Approximately 173 million tonnes of waste rock will be produced, with approximately 68 million tonnes (intermediate volcanic rocks) from the Vault Pit and 104 million tonnes (iron formation, intermediate volcanic and ultramafic rocks) from the Portage and Goose pits. Ultramafic rocks are not expected to be acid generating. Some of the intermediate volcanic rocks from the Vault Deposit are potentially acid generating. All other waste rock and the tailings are potentially acid generating.

Waste from the pits will be used as construction material for the dikes, tailings dam, roads and general site construction. Excess waste will be deposited in two waste dumps: 1) the Vault Rock Storage Facility located to the West of the Vault Pit and 2) the Portage Rock Storage Facility located to the north and east of Portage Pit. In addition, following Year 6, waste rock will be stored in empty sections of the Portage Pits.

1.3 Decision Matrix Models

Decision matrix types of analyses are also sometimes referred to as Multiple Accounts Analyses (MAA) or alternatives analyses. These types of analyses have been successfully used as site selection tools for mining facilities and related decision processes including at: Zortman and Landusky Mine Sites, Montana (Shaw et al., 2001), Red Dog Mine, Alaska (Northern Miner, 2005), and Questa Molybdenum Mine, New Mexico (Molycorp Watch Project, 2005). Numerous papers have been published on these types of analyses including: Robertson and Shaw (1998 and 1999), Caldwell and Robertson (1983), Vick (1990), Brown (2002), Decision – Makers Field Guide (2005).

Similar types of analyses are also used in the fields of risk assessment, risk management, selection of the best available technologies or options for environmental remediation projects, resource planning, and sustainable development (Canter, 1985; International Atomic Energy Agency, 2000; CH2MHill, 2004, Robson Valley Land and Resource Management Plan, 1999).

1.4 Meadowbank Waste Rock Facility Selection Process

The mining operations (open pits) for the Meadowbank project are located in two main areas, as shown on Figure 1.2:

- Vault Area which consists of the Vault Open Pit; and
- Portage Area which consists of the North Portage Pit, Third Portage Pit and Goose Island Pit.

The use of two separate waste rock storage facilities for each area was judged as being most efficient.

The Portage rock storage facility and the Vault facility were selected based on consideration of the following criteria:

- The potential for long-term environmental impacts, including ARD generation and metal leaching;
- Ease of water management during operation and closure;
- Ease of decommissioning and closure;
- Impact on lakes and catchment areas;
- Visual impact;
- Footprint size to reduce the volume of affected runoff;
- The potential for geotechnical hazards, such as slope instability and response to seismic activity; and
- Haulage costs.

1.4.1 Potential Rock Storage Facilities

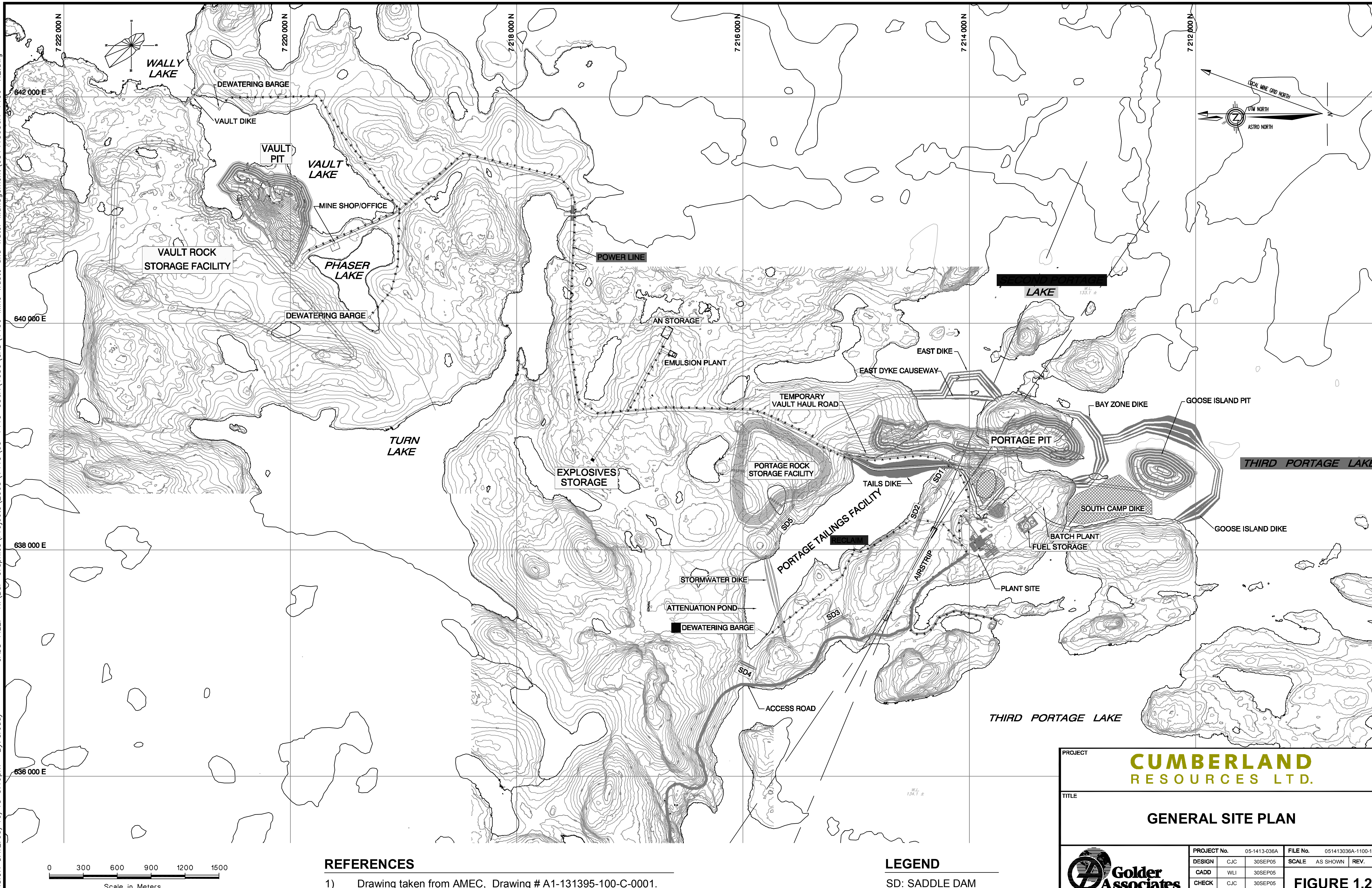
Potential storage locations and design footprints for the Rock Storage Facilities were identified in the area of the proposed mine site that would accommodate the predicted volume of waste rock. Alternatives for the Portage and Vault Rock Storage Facilities are shown on Figures 1.3 and 1.4.

The best alternative for the storage of the waste rock from the Vault pit is on a broad area of land immediately to the west of the open pit area. A cover layer of non-PAG rock is not presently required at the Vault waste rock storage facility because this rock is considered to be non-PAG. Further testing and monitoring during operations will be completed to confirm this.

To select an appropriate location for waste rock in the Portage Area four initial sites were identified (Golder, 2004). Portage Rock Storage Facilities included two additional alternatives (A and B) for Option A. These were evaluated in the Alternative Waste and Water Management Plan (March 7, 2005). The final selection process involved three main steps:

- Identifying potential locations;
- Developing a decision matrix model upon which the locations would be evaluated; and
- Evaluating each facility using the model and selecting the best overall facility.

The remaining portion of this report focuses on the process used to select the final locations for the waste rock storage facilities.



REFERENCES

1) Drawing taken from AMEC, Drawing # A1-131395-100-C-0001.

LEGEND

SD: SADDLE DAM

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

GENERAL SITE PLAN

Golder Associates

PROJECT No.	05-1413-036A	FILE No.	051413036A-1100-1.2
DESIGN	CJC	30SEP05	SCALE AS SHOWN REV. -
CADD	WLI	30SEP05	
CHECK	CJC	30SEP05	FIGURE 1.2
REVIEW			

1.4.2 Meadowbank Decision Matrix Model

The development of the decision matrix model for the Portage Rock Storage Facility involved developing a site specific list of criteria that would be utilized to evaluate and rank the facilities. The criteria covered three main areas:

- Environmental factors;
- Operational factors; and
- Economic factors.

Each of the factors was further subdivided into sub-indicators, in order to evaluate specific aspects. Weightings were assigned to each factor and sub-indicator.

Each facility option was then evaluated based on the sub-indicator and a relative score was assigned. These scores were then multiplied by the weighting factors and summed to give the overall score. The options were ranked according to the overall score, with the highest score indicating the preferred option.

Quantitative methods were utilized to assign the relative scores where possible, however some sub-indicators necessitated the use of qualitative assessment. Judgement and perception of the individual conducting the analyses is inevitably a part of any such decision making system, both in the assignment of qualitative scores and of weighting factors.

The weighting factors were specifically designed to place a higher significance on the environmental factors, and less on the operational and economic factors.

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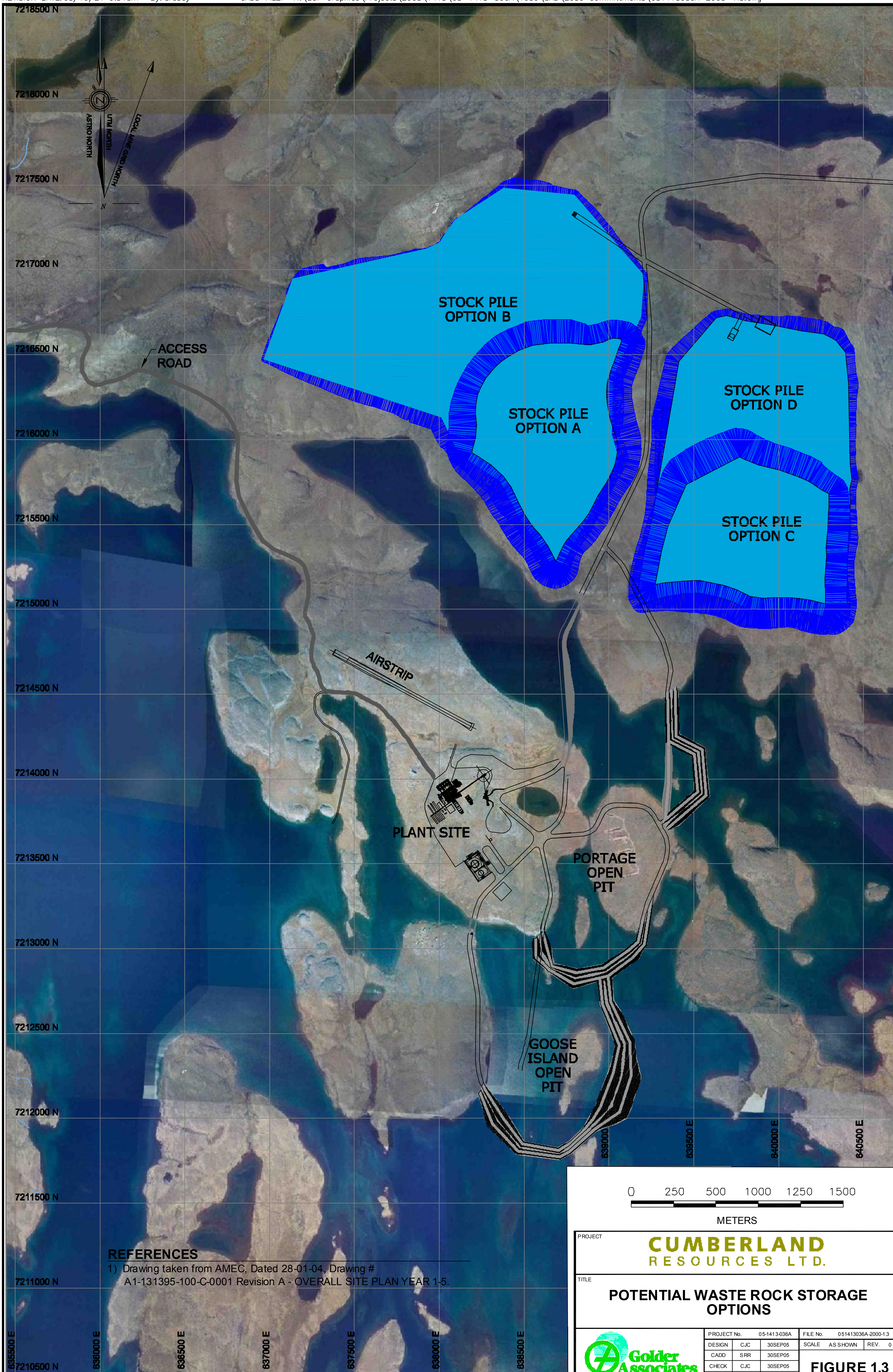

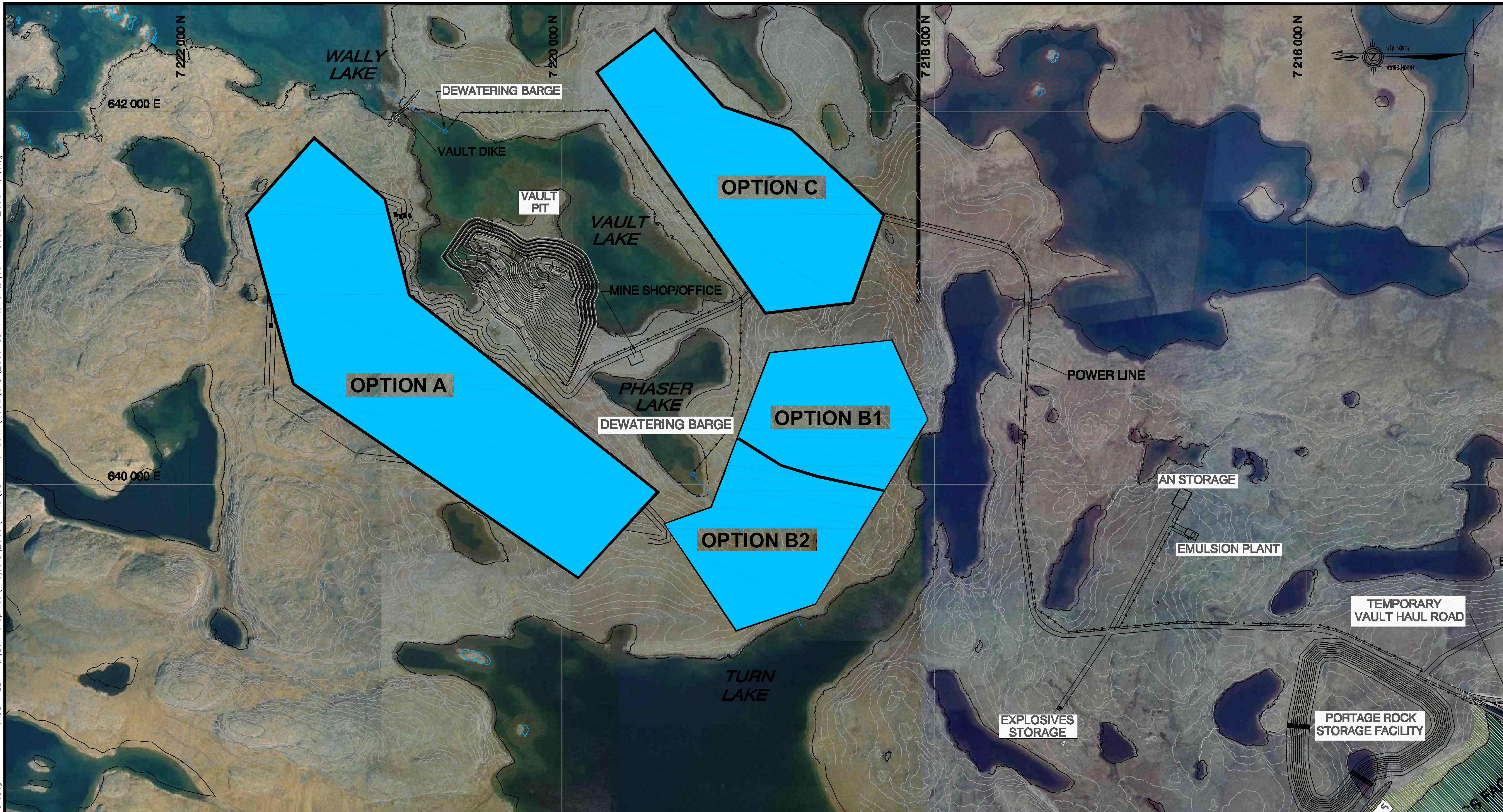

0 200 400 600 800 1000
Scale in Meters

REFERENCES

1) AMEC Americas Ltd., Drawing Number A1-131395-100-c-0001 (100-c-0001.dwg), Meadowbank Feasibility Study, April 2005.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

VAULT ROCK STORAGE OPTIONS

Golder Associates

PROJECT No.	05-1413-036A		FILE No.	051413036A-2000-1.4
DESIGN	CJC	17OCT05	SCALE AS SHOWN	REV. 0
CADD	GG	17OCT05		
CHECK	CJC	17OCT05	**FIGURE 1.4**	
REVIEW	CJC	17OCT05		

2.0 MEADOWBANK DECISION MATRIX METHOD OF ANALYSIS

This section will explain in greater detail the decision matrix component of the site selection analyses, and each of the sub-indicators used in the selection process, under the three primary factors of environmental, operational and economics. Sub-indicators were chosen to evaluate a wide spectrum of potential impacts, without double counting impacts.

2.1 Environmental Factors

The European Commission published a Report on Best Available Techniques (BAT) reference document for Management of Tailings and Waste-Rock in Mining Activities (2004). This document was developed in response to a Communication from the European Commission COM(2000) 664 [COM(2003) 319 final, 2.6.2003] on the 'Safe Operation of Mining Activities' that was a follow-up action to tailings dam bursts that occurred in Aznalcollar and Baia Mare. The follow-up measures included: an elaboration of the BAT Reference Document based on an exchange of information between European Union's Member States and the mining industry. The document was developed in response to the Commission's initiative and in anticipation of the proposed Directive on the management of waste from extractive industries (European Commission, 2004). The following key environmental issues or impacts associated with tailing and waste rock facilities were listed in this document:

- Site specific issues relating to facility location and relative land take;
- Potential emissions of dust and effluents during operation (to air, land and water) and their impact;
- Potential emissions of dust and effluents after closure (to air, land and water) and their impact;
- ARD and metal leaching generation, release and impact;
- Potential releases due to failures of facilities (i.e., burst or collapses of containment berms or dams); and
- Site rehabilitation and aftercare to minimize environmental impacts.

Table 2.1 presents a list of the sub-indicators that were used to evaluate the environmental impact of the various waste rock storage options. The following subsections briefly describe each of these sub-indicators and how they were evaluated.

Table 2.1: Environmental Sub-Indicators

	Sub-Indicators
Environmental Factors	Sub-catchment area
	Footprint area
	Area of lakes impacted
	Potential for geotechnical hazards [1]
	Visual impact
	Potential for dust generation
	Potential for seepage to groundwater
	Potential for ARD generation
	Potential for ML

Note:

[1] Includes consideration of foundation conditions, and impact of seismicity.

2.1.1 Sub-catchment Area

A catchment is an area of land bounded by natural high points (hills, ridges and mountains). Surface water (rainfall and runoff) flows down through the catchment area and into one low point (a creek, river or bay). Catchment areas may be further divided into sub-catchments, typically each sub-catchment area will have homogeneous physical characteristics.

A sub-catchment area for the purpose of this evaluation was defined as the primary portion of the watershed that would be impacted by the waste rock facility. The total sub-catchment area (hectares) was used to assign the relative scores and determine the impact of each option. Options having lower sub-catchment areas are preferable to those with greater areas, and hence were assigned a relatively higher score.

2.1.2 Footprint Area

The footprint area is defined as the area covered by the waste rock both on land and in water. The total footprint area, in hectares, was used to assign the relative scores and judge the impact of each facility location. The site having the smallest footprint area was given the highest relative score and the other options were assigned a lower score, relative to their footprint area.

2.1.3 Area of Lakes Impacted

The area of lakes impacted by the waste rock facility (footprint) was calculated and quantitatively used to assign relative scores. The site with no or little impact on lakes is most desirable, and would therefore receive the highest score.

2.1.4 Potential for Geotechnical Hazards

The relative potential for geotechnical hazards to occur at each facility, and in turn the potential release of contaminants into the environment was qualitatively judged and a value of low, moderate or high was assigned. The assessment included a consideration of foundation conditions, and seismic impacts. Depending on the type of waste rock facility and site conditions, failures of the containment facilities or structures may occur and cause the release of contaminants to the environment. The potential for geotechnical hazards of each option was qualitatively judged and a score assigned. The facility with the lowest potential for failure was assigned the highest score and the facility with the highest potential was assigned the lowest score.

2.1.5 Visual Impact

The relative visual impact for each facility was qualitatively judged and a value of low, moderate, or high was assigned. This factor considered such items as height, shape, and contrast with the surrounding terrain. A facility with a low profile and that would blend in with the surrounding area would receive a higher relative score than a facility with a high topographic relief that did not blend into the surrounding terrain.

2.1.6 Potential for Dust Generation

The relative potential for each facility to generate dust both during operation and after closure was qualitatively judged and a value of low, moderate, or high was assigned. This factor is dependent on grain size of material, methods of erosion protection, topographic profile, exposure of the site to wind, haulage distance and the planned method for closure. A facility with a closure plan that includes covering the waste rock, thus reducing or eliminating the potential for dust would receive a higher score. A facility that remained exposed after mine closure would have a lower value assigned.

2.1.7 Potential for Seepage to Impact Groundwater

The relative potential for seepage from each facility to impact groundwater resources during operation and closure was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the method of containment, including any steps that will be taken to control seepage into the groundwater. Methods of collecting and treating runoff from the site and generation of runoff are considered during the assessment of this sub-indicator. Facilities that generate low rates of seepage or runoff and with low levels of contamination would receive a high relative score in comparison to facilities that are expected to generate high quantities of seepage or runoff with a high concentration of contaminants (including metals and low pH).

One method of reducing the potential for groundwater impact may be achieved by controlling the flux of water through the facility, thus reducing the potential for groundwater impact. This may be controlled by the surrounding berms and diversion channels and liner and cap or low permeability boundary. Facility liners or caps may be man-made or natural, such as low permeability rock, till, clay, permafrost, or synthetic materials (i.e., high density polyethylene).

2.1.8 Potential for Acid Rock Drainage (ARD) Generation

Geochemical testing has shown that much of the waste rock that will be produced from mining operations may contain metal sulphides and will have the potential to generate ARD. The relative potential for each facility to generate ARD during mine operation and after closure was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the facility location, planned method of design, and the closure that may minimize the generation of ARD or contain and treat potential contaminated water.

Sulphides oxidize when exposed to oxygen and air, which in turn creates an acidic metal-laden leachate which can be generated over a prolonged period of time if acid buffering minerals are not present. The rate of generation of ARD is accelerated with fine particles as the surface area potentially exposed to oxygen is much greater, which is typically the case when dealing with tailings and processed mine waste. Other factors that may increase the rate of ARD generation are: high oxygen concentration, high temperature, low pH, and bacterial activity (European Commission, 2004).

Although quarry sites 8, 10, 21 and 22 from the proposed access road have a sulphide content that is expected to be too low to generate ARD, consideration should be given to avoiding these quarry sites as a precautionary measure. The quality of runoff contacting the open quarry sites and the excavated rock should be monitored during construction to document the effect of exposure of the quarry rock on receiving water quality.

2.1.9 Potential for ARD Generation After Closure

The relative potential for each facility to generate ARD after closure was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the planned method for closure which may reduce or control generation of

ARD. As discussed in the previous subsection, facilities that in the long term control factors that lead to acid generation would receive a relatively higher score in comparison to facilities that do not control these factors. For example a permafrost encapsulated facility would receive a higher score in comparison to above ground facilities exposed to air and precipitation.

2.1.10 Potential for Metal Leaching (ML) Generation During Operation

Geochemical testing has shown that waste rock generated at Meadowbank will have the potential to generate ML. The impact of metals released into the environment may be toxic, but depends on many factors including: concentration, pH, temperature, and water hardness (European Commission, 2004). Figure 2.1 schematically shows some of the primary geochemical and physical processes and their interaction that may lead to the generation of ARD and the potential release of metals (ML).

The relative potential for each facility to generate ML during mine operation was qualitatively judged and a value of low, moderate, or high was assigned. Facilities that reduce or eliminate the generation and/or transmission of soluble metals to the environment (i.e., hydraulic containment) would receive a high relative score, in comparison to facilities that do not control metal leaching.

Metals may leach from waste rock facilities and controlling the flux of water through and out of the waste rock storage facility may have the most significant impact on reducing contamination. Therefore, facilities that isolate waste rock from natural water sources (groundwater, surface water and precipitation) through the use of low permeability liners and covers, containment berms and diversion ditches, and prevent flow out of the facility will reduce the impact on the surrounding environment.

2.1.11 Potential for ML Generation After Closure

The relative potential for each facility to generate ML after closure was qualitatively judged and a value of low, moderate, or high was assigned. This factor is primarily dependent on the planned method for closure which may reduce or control generation and migration of ML. The evaluation of this sub-indicator is the same as discussed in the previous subsection.

2.1.12 Impact on Fish and Fish Habitat

The relative potential for each facility to have an impact on fish and/or fish habitat was qualitatively judged and a value of low, moderate, or high was assigned. Facility options that would have no impact on fish would receive a high relative score compared to options that would impact a larger fish population. This factor considered the fish habitat survey, bathymetric and aquatic ecosystem information.

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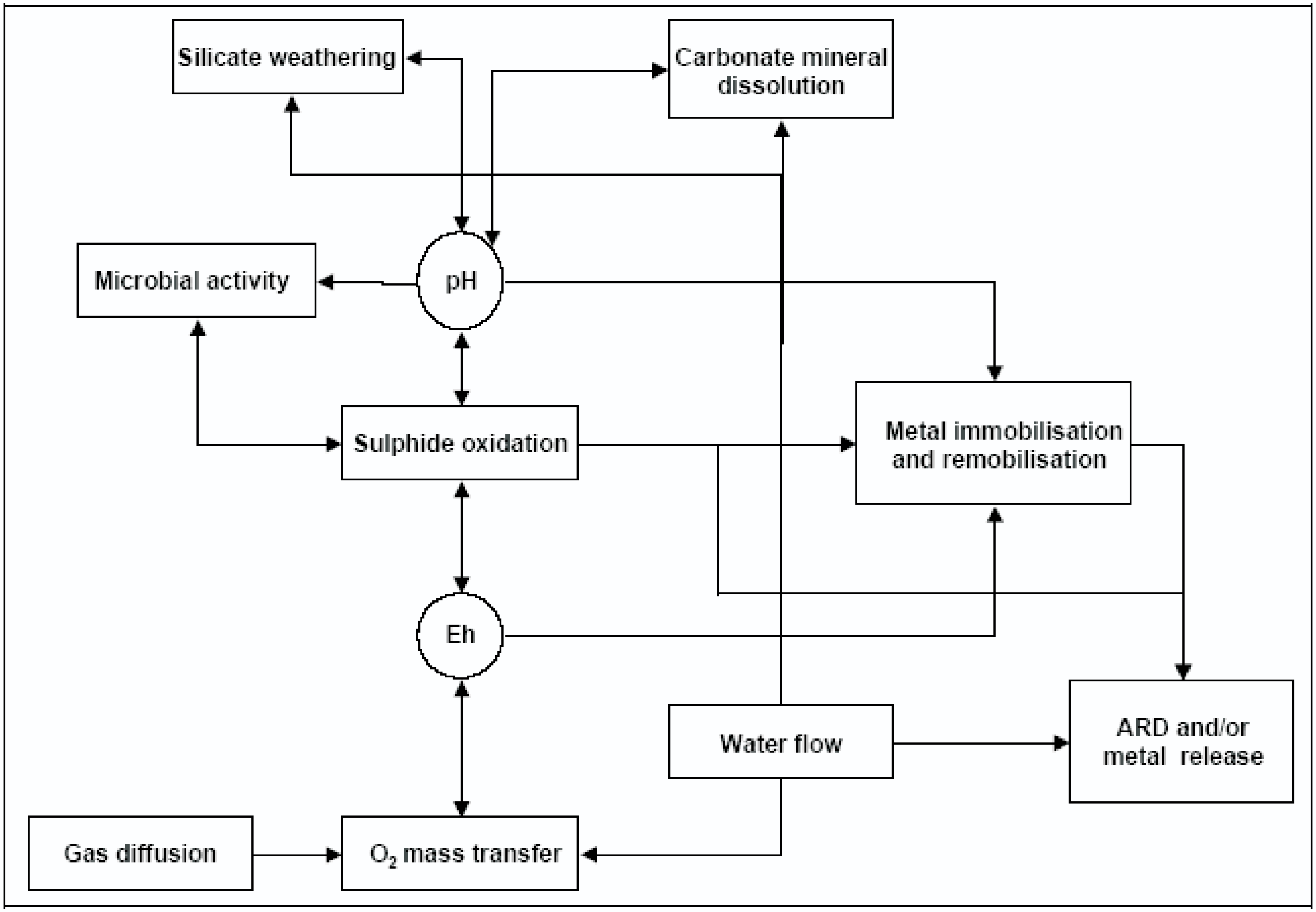


Source: European Commission, 2002.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

GEOCHEMICAL AND PHYSICAL PROCESSES POTENTIALLY RESULTING IN ARD AND ML

Golder Associates

PROJECT No. 05-1413-036A			FILE No. ARD & ML	
DESIGN	CC	28SEP05	SCALE NTS	REV.
CADD	VEE	28SEP05	**FIGURE 2.1**	
CHECK	CC	28SEP05		
REVIEW				

2.2 Operational Factors

Table 2.2 presents a list of the sub-indicators that were used to evaluate the operational factors for the waste rock facility options under consideration. The following subsections briefly describe each of these sub-indicators and how they were evaluated.

Table 2.2: Operational Sub-Indicators

	Sub-Indicators
Operational Factors	Ease of operation
	Distance from open pit
	Potential for delays due to freezing
	Construction risk
	Disposal system has precedent in arctic environment

2.2.1 Ease of Operation

The relative ease of operation of each facility was qualitatively judged and a value of low, moderate, or high was assigned. Various factors were considered including such items as: number of personnel, energy requirements and mechanical components.

2.2.2 Distance from Mill

The nominal distance from the mill to the proposed waste rock facility location was measured. This value was used to assign a relative score for each facility. The facility closest to the pit would receive the highest relative score, and the facility located furthest from the pit would receive the lowest relative score. Increased distance results in increased transportation costs, but also increased risk of accidents and hence environmental impacts, as well as additional dust generation.

2.2.3 Potential for Delays due to Freezing

The relative potential for delays to be caused due to freezing are considered negligible for the waste rock facility.

2.2.4 Construction Risk

The relative potential for delays or problems to occur during construction was qualitatively judged and a value of low, moderate, or high was assigned. Various factors including type of construction, likely construction schedule, and site conditions, were taken into account. Facilities that utilized local materials that can be placed on a year round basis received a higher score. In comparison, facilities that required a large number of components to be imported, and that could only be delivered by ship and during summer months when the port is open and free of ice, received a lower score.

2.2.5 Disposal System has Precedent in Arctic Environment

The relative precedent for use of the proposed waste rock facilities was qualitatively judged based on the evaluators' experience and published literature. Similar design and construction of waste rock dumps in cold climates include the Lupin, Ekati and Diavik mines.

A report titled Acid Mine Drainage in Permafrost Regions: Issues, Control Strategies and Research Requirements (Dawson and Morin, 1996) outlines perspectives on issues related to ARD from tailings and mine waste rock in permafrost conditions. Site information from 18 active and abandoned sites show that waste rock at only two sites in the Yukon and North West Territories have the potential to generate significant acid mine drainage (AMD). Consequently, disposal of potentially acid generating waste rock followed by permafrost encapsulation has been shown to be an effective method for managing acid rock drainage and metal leaching.

2.3 Economic Factors

Table 2.3 shows the sub-indicator factor that was used to evaluate the economic benefits of each of the waste rock facility options that were considered.

Table 2.3: Economic Sub-Indicators

	Sub-Indicator
Economic Factors	Total present value of costs (initial costs + delayed costs)

The previous report considered two economic factors, overall present value cost, and initial capital costs. To further reduce the influence of economic factors on the decision making process, the waste rock facility selection matrix was revised and now only considers the total present value cost.

The total present value costs for each facility were estimated and used to quantitatively rank the facilities. This value includes initial construction costs, facility operational costs over the 8.3 year mine life and closure costs. An 8% interest rate was used for these calculations. The resulting total costs were then ranked and scored, with the lowest cost allocated the highest score.

2.4 Weighting Factors and Scoring

Weighting factors amongst the three primary categories were assigned such that environmental factors had the most significance, followed by operational factors, and lastly economic factors (Table 2.4).

Table 2.4: Weighting Factors Used in the Decision Matrix

Factor	Contribution to Overall Weighting
Environmental	50 %
Operational	30 %
Economic	20 %

The weighting factors assigned to each of the sub-indicators is shown in Table 2.5.

Table 2.5: Weighting Factors for Sub-Indicators

Factor	Sub-Indicator	Relative Weighting	Max. Possible Score	Max. Possible Weighted Score[1]	Max. Possible Category Score
Environmental	Sub-catchment area	5	9	45	396
	Footprint area	4	9	36	
	Potential for generating dust	6	9	54	
	Potential for Acid Rock Drainage (ARD) generation during operation	7	9	63	
	Potential for metal leaching (ML) during operation	6	9	54	
	Potential for seepage to impact groundwater	6	9	54	
	Potential for geotechnical hazards [2]	3	9	27	
	Lake area impacted	4	9	36	
	Visual impact	3	9	27	
Operational	Difference between crest and adjacent land	5	9	45	234
	Ease of Water Management	7	9	63	
	Catchment Impacted	6	9	54	
	Ease of operation Decommissioning/closure	8	9	72	
Economic	Distance from north edge of North Portage Pit	18	9	162	162
TOTAL					792

Notes:

1 Values represent the maximum score, if 9 points was assigned for each sub-indicator.

2 Includes consideration of foundation conditions, impact of seismicity, and height of structure.

Each of the sub-indicators was assigned a score between 1 and 9 points (Robertson and Shaw, 1999). The scores provide a relative ranking between the options under consideration with the best option receiving a score of 9. All subsequent options are then compared to the 'best' option and assigned a lower score. An example of the scoring method is presented in Table 2.6.

Table 2.6: Example of Scoring System used in the Decision Matrix

Option	Foot Print Area	Points	Notes
A	30 ha	9 8 7 6	9 points awarded for least footprint area (BEST)
C	60 ha	5 4	9 points x 30 ha (least area)/60 ha = 5 points
B	90 ha	3 2 1	9 points x 30 ha (least area)/90 ha = 3 points

2.5 Calculations

For each sub-indicator, the point value was multiplied by the weighting to give a "weighted score" (see Table 2.5 for a sample calculation). Then all of these scores were summed to give an overall rating score for each of the three primary factors, environment, operation and economic.

Operational Factor Score = "Ease of operation weighted score" + "Distance from mill weighted score" + "Potential for delays due to freezing score" + "Construction risk score" + "System precedent score"

The scores were then summed to give one overall total score.

Overall Score = "Environmental Factor Score" + "Operational Factor Score" + "Economic Factor Score"

3.0 ANALYSIS OF MEADOWBANK WASTE ROCK STORAGE FACILITIES

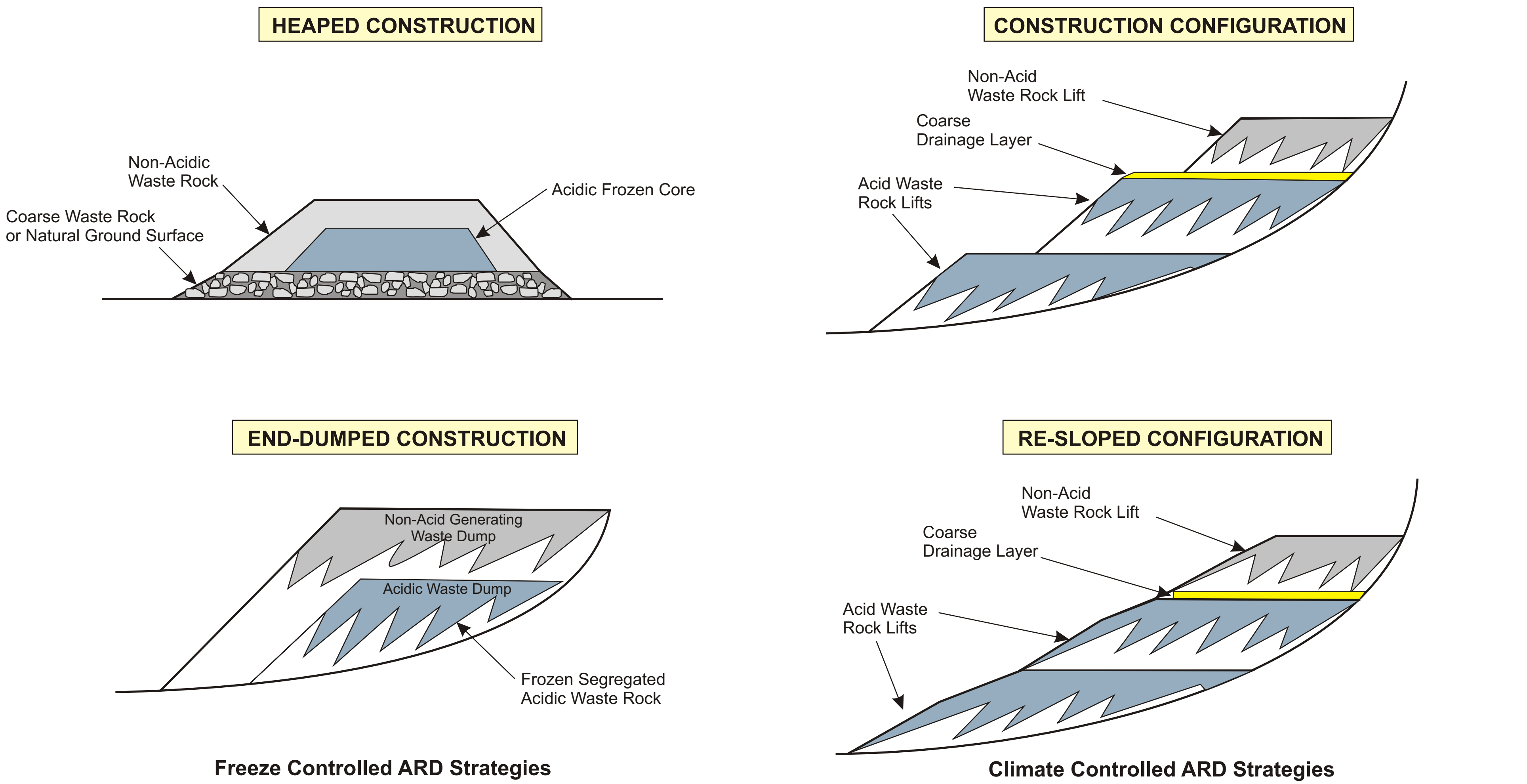
3.1 Description of Potential Waste Rock Storage Methods

The Meadowbank Project proposes the use of on-land rock storage methods followed by permafrost encapsulation for waste rock disposal. The revised mining plan has not yet been finalised in terms of mining sequence, waste rock disposal and mining areas, however assumptions have been made to allow completion of a conceptual level assessment of alternative waste rock management plans. Figure 3.1 shows waste rock storage facility construction methods.

At closure, a capping layer of ultramafic rock would be placed over the Portage Rock Storage Facility. The thickness of capping material would exceed the active layer thickness, such that the waste rock would be maintained in a frozen state, year round to constrain the active layer within relatively inert materials. The potential acid generating waste rock below the capping layer will freeze, reducing the low rates of acid mine drainage (AMD) over the long-term.

Water seepage and runoff from the waste rock of the Vault Rock Storage Facility is expected to be of suitable quality to allow discharge to the environment without treatment and capping of this facility is therefore not proposed.

DRAWING DATE: 05-Oct-05 COREL FILE: N:\Bur-Graphics\Projects\2005\1413\05-1413-036A\1050\Corel\Figure.cdr



Not to Scale

Reference: MEND 1.61.2, 1996

PROJECT
CUMBERLAND RESOURCES LTD.

TITLE
WASTE ROCK STORAGE FACILITY CONSTRUCTION METHODS

Golder Associates

PROJECT No. 05-1413-036A			FILE No. FIGURE	
DESIGN	CC	05OCT05	SCALE NTS	REV.
CADD	SS	05OCT05	**FIGURE 3.1**	
CHECK	CC	05OCT05		
REVIEW				

3.2 Description of Potential Waste Rock Storage Facility Areas

Due to the distance between the Vault open pit and other pits, it was determined that two rock storage facilities were required: one facility near the Portage Pit and Goose Pits; and one near the Vault open pit. Figure 1.2 shows the general site plan.

Alternatives that were considered are shown for the Portage and Vault rock storage facility in Figures 1.3 and 1.4 respectively, and are described in the following sections.

3.2.1 Portage Rock Storage Facility Alternatives

Figure 1.4 shows the alternatives for the Portage Rock Storage Facility. Four potential locations were considered and are listed in Table 3.1.

Table 3.1: Summary of Potential Portage Waste Rock Storage Facility Options

Option	Location	Footprint
A	North of Second Portage Arm	Small
B	North of Second Portage Arm	Large
C	East of Vault Haul Road	Small
D	East of Vault Haul Road	Large

Two options were located north of Second Portage Arm (Options A and B); and two east of Vault Haul Road (Option C and D). The following sections briefly describe each of areas and the ancillary components and structures for each of the options that were evaluated.

<u>North of Second Portage Arm (Option A and B)</u>

Recent revisions to the management of waste from the pits resulted in a reduction in surface storage requirements for the Portage rock storage facility (RSF) to about 34 mm^3. Ancillary components and structures are similar among the four sites and include a diversion ditch, sump pumps and attenuation pond. Primary differences are related to the size of the foot print. The maximum elevation of adjacent topography is 192 m.

Option A was the smallest footprint developed for the RSF and has a crest elevation of 210 m and estimated capacity of 34 mm^3, a height of 60 m, a footprint of 58 ha and a surface area of 66 ha. Option A was selected as the preferred alternative.

Option B was a larger footprint in the same area.

Based on the current study the proposed advantages to Option A includes the following benefits:

- The larger northernmost of the two small lakes will remain undisturbed;
- Option F has the smallest footprint and surface area. Consequently, runoff from the dump for Alternative B will be less than for the original designs (Options A & B) as well as Option E;
- The total area of non-contact water to be diverted is minimized, and hence the quantity of water will increase as a result of the decrease in size of the RSF; and
- Capping the RSF will reduce the potential for post-closure dust generation and also help ensure that potentially acid generating (PAG) waste rock remains in a frozen state, year round.

Disadvantages to Option A includes:

- A small tributary lake of Second Portage Arm will permanently contain waste rock and will not have any suitable fish habitat or contain fish.

East of Vault Haul Road (Option C and Option D)

Portage Rock Storage Facility Options located east of Vault Haul Road include Options C and D. Option C has an estimated crest elevation of 176 m, and estimated capacity of 35 Mm^3. Height is estimated at 30 m, with a footprint of 126 ha and a surface area of 195 ha.

Option D was located in the same area and had a larger footprint which is not required under the current design concept. Thus Option C was considered the preferred option for the Vault RSF.

- Capping of the RSF will reduce the potential for post-closure dust generation and also help ensure that PAG waste rock remains in a frozen state, year round.

Disadvantages to Option C and D include:

- Drainage is outside of drainage basin of main mine facility area; and
- Increased impacts to fish bearing lakes.

3.2.2 Vault Rock Storage Facility Alternatives

Figure 1.4 shows the alternatives for the Vault Rock Storage Facility. There are few suitable locations for a waste rock storage facility near the Vault pit owing to the presence of numerous lakes adjacent to Vault Lake and the lack of topographical relief in the immediate area, which limits the height to which a rock storage facility could be constructed without becoming visible at great distance from the site. In addition, placing waste rock in areas south of Vault Lake would affect a sub-watershed that does not drain toward the Vault open pit.

- Immediately west of the Vault pit (Option A): This alternative consists of a broad, relatively flat area within the catchment area of the Vault pit. This alternative offers the advantage of allowing the storage facility to be developed with a low profile, reducing the potential visual impact as well as reducing the potential impact to wildlife movement. The location of Option A results in the least travel distance for waste rock haulage and disposal.

- South of the Vault deposit (Options B1 and B2). This alternative was rejected as it places the waste rock material within a catchment area and sub-watershed that previously remained unaffected.

- On-land storage to the east of Vault Lake (Option C). This alternative was rejected due to the small area in which to store the waste rock, and due to the distance from the deposit area, which would result in an increase in the overall footprint area for the mine development, as well as an increase in haulage costs. The smaller area in which to store the material would result in a waste dump with a higher final elevation, resulting in visual impact as well as exposure to wind dispersion. The additional distance for haulage would require the construction of additional roads. Increased traffic would result in increased levels of particulate matter (including dust and exhaust) to the atmosphere to be transported and deposited elsewhere.

- Disposal into Wally Lake (Option D). This alternative was rejected because there is no convincing evidence to suggest that placing the Vault waste rock material in a submerged environment will have less impact than placing on land. Placing the waste rock into Wally Lake would un-necessarily impact on fish habitat within that lake.

The best alternative for the storage of the waste rock from the Vault pit is on a broad area of land immediately to the west of the open pit area. A cover layer of non-PAG rock is not presently required at the Vault waste rock storage facility because this rock is considered to be non-PAG. Further testing and monitoring during operations will be completed to confirm this.

4.0 RESULTS

4.1 Analysis

Options for the Portage Rock Storage Facility for the proposed Meadowbank Mine were then analyzed using the Multiple Accounts Analysis decision matrix method of analysis described in Section 2.0. Table 4.1 presents the results of this analysis. The individual scores for each sub-indicator are shown along with the summed scores for environmental factors, operational factors and economic factors. Table 4.2 summarizes the results.

Table 4.2: Summary of Decision Matrix Results

Factor	Rock Storage Options			
	A	B	C	D
	North of Second Portage Arm	North of Second Portage Arm	East of Vault Haul Road	East of Vault Haul Road
	Small foot print (58ha)	Large foot print (296 ha)	Small foot print (126 ha)	Large foot print (222 ha)
Environmental	268	199	241	188
Operational	148	170	33	51
Economic	144	90	162	116
TOTAL	**560**	**459**	**436**	**355**

Option A scored the highest among the four Portage Rock Storage Facility options.

TABLE 4.1: WASTE ROCK STORAGE AREAS DECISION MATRIX			ROCK STORAGE OPTIONS (Portage and Goose Pits)				SCORE, S_{IND} (1=worst 9=best)				WEIGHTED SCORE			
Key Indicators	Sub-Indicators	Weighting, W_{IND}	Stockpile Option A	Stockpile Option B	Stockpile Option C	Stockpile Option D	A	B	C	D	A	B	C	D
			North-west from Second Portage Lake	North-west from Second Portage Lake	East from Vault Haul Road - Small Footprint	East from Vault Haul Road - Large Footprint								
Key Details	Crest Elevation to Store 60 Mm3		210m	172m	210m	178m								
	Maximum elevation of nearby land		El. 192m	El 192m	El. 164m	El. 164m								
	Maximum height from foundation		60 m	28 m	71 m	94 m								
	Total Surface Area		660,000 m2	3,000,000 m2	1,280,000 m2	2,200,000 m2								
	Capping volume (assumes 2m thickness)		1,3200,000 m3	6,000,000 m3	2,560,000 m3	4,400,000 m3								
Environmental Factors	Sub-catchment area	5	147 ha	426 ha	215 ha	268 ha	9	3	4	5	45	15	20	25
	Footprint area	4	58 ha	296 ha	126 ha	222 ha	8	4	9	5	32	15	36	20
	Area of lakes impacted	4	3 ha	29.2 ha	26.8 ha	34.2 ha	9	3	5	1	36	12	20	4
	Potential for geotechnical hazards[1]	3	Moderate	Low	Moderate	Moderate	2	9	2	2	6	27	6	6
	Visual Impact	3	Moderate	Low-Moderate	Moderate	Low-Moderate	5	9	6	7	15	27	18	21
	Potential for dust generation	6	High	Moderate	Moderate	Moderate	4	9	3	6	24	54	18	36
	Potential for seepage to groundwater	6	Moderate	Moderate	Moderate	Moderate	8	6	9	7	48	36	54	42
	Potential for ARD generation	7	Moderate	Moderate to High	Moderate	Moderate to High	8	1	9	4	56	7	63	28
	Potential for Metal Leaching	6	Low	Low	Low	Low	1	1	1	1	6	6	6	6
	Sum of Environmental Weightings, SW_{ENV}	44	**Weighted Subtotals for Environmental Factors, $IND_{SCORE} = S(W_{IND} \times S_{IND})$**				**268**	**199**	**241**	**188**				
Operational Factors	Difference between crest and adjacent land	5	+13 m	-20 m	+46 m	+14 m	6	9	1	6	30	45	5	30
	Ease of water management	7	Good	Good	Good	Good	8	9	2	1	56	63	14	7
	Catchment impacted	6	Same as Mine	Same as Mine	Adjacent catchment	Adjacent catchment	9	9	1	1	54	54	6	6
	Ease of decommissioning/closure	8	Place dry cover	Place dry cover	Place dry cover	Place dry cover	1	1	1	1	8	8	8	8
	Sum of Operational Weightings, SW_{OPS}	26	**Weighted Subtotals for Operational Factors, $IND_{SCORE} = S(W_{IND} \times S_{IND})$**				**148**	**170**	**33**	**51**				
Cost Factors	Distance from north edge of North Portage Pit	18	1,200 m	1,700 m	1,000 m	1,4 00 m	8	5	9	6	144	90	162	116
	Sum of Economic Weightings, SW_{COST}	18	**Weighted Subtotals for Cost Factors, $IND_{SCORE} = S(W_{IND} \times S_{IND})$**				**144**	**90**	**162**	**116**				
TOTAL OPTION SCORE = $SIND_{SCORE}$			**560**	**459**	**436**	**355**	**560**	**459**	**436**	**355**				

Notes
1. Includes consideration of foundation conditions, impact of seismicity, and height of structure
2. Relative capital cost for comparison only.
3. Value not used in scoring. Value is presented to allow calculation of total cost for comparison purposes.
N:\Final\2005\1413\05-1413-036A\1000\[Table 4-1 Waste Rock Decision Matrix_Rev1.xls]Waste Rock Dumps

5.0 DISCUSSION

Only one potential site for the Vault Rock Storage Facility was identified due to environmental factors. Four potential sites (A, B, C, D) were identified for the Portage Rock Storage Facility. Results of the Multiple Accounts Analysis indicated that Option A was the best site overall site for the Portage Rock Storage site.

The primary advantages provided by these site locations are as follows:

- Minimizes potential long-term impacts;
- Minimizes catchment area impact;
- Minimizes height and visual impact;
- Minimizes loss of lake habitat;
- Reduces spatial footprint and surface area;
- Minimizes haul costs;
- Minimizes dust generation during hauling;
- Minimizes risk of haulage accidents and accidental release of waste rock to the environment;
- Improves ease of management;
- Lowest potential for ARD/ML generation;
- Simplifies closure, requiring least amount of borrow materials;
- Low risk of instability of rock storage facility;
- Ease of operation in harsh arctic climates;
- Lowest relative capital cost; and
- Precedence in arctic climate.

6.0 SUMMARY AND CONCLUSIONS

This report has provided an additional explanation on the decision making process used to select waste rock storage facilities (location and technology) for the Meadowbank Gold Project. A decision matrix approach was utilized. Three primary factors were utilized: environmental, operational and economic. Each factor was further subdivided to consider various components. Weighting factors were assigned to each sub-indicator and to the overall factors. Environmental factors were judged as being the most important, and were therefore assigned the highest overall weighting.

There are two waste rock storage facility locations (Vault and Portage). For the Portage Rock Storage Facility, four potential rock storage facilities were identified. These facilities were screened to determine if they met the basic site selection criteria:

- The site was required to have sufficient volume to store planned volume of waste rock;
- The site required the potential to provide additional capacity for waste rock storage;
- The location would permit mine expansion; and
- The location is within catchments of the open pits.

All four options met these criteria, as listed below.

Option	Location Description
Option A*	North of Second Portage Arm – small footprint
Option B	North of Second Portage Arm – large footprint
Option C	East of Vault Haul Road – small footprint
Option D	East of Vault Haul Road – large footprint

*Option A was originally evaluated in Golder, 2004 report. Alternatives (a & b) to the original Option A was evaluated *Report on Alternative Waste and Water Management Plan* (Golder, 2005) and compared to Option A.

The decision matrix analysis was then carried out on these four options. Option A had the highest score in all cases for the rock storage facility options. Thus, the Portage Rock Storage Facility Option A was selected as the best waste rock disposal site for the Portage and Goose Pits. Only one suitable site location was identified for the Vault Rock Storage Facility.

We trust that this report meets your requirements at this time. If you have any additional questions, please do not hesitate to contact the undersigned.

Yours very truly,

GOLDER ASSOCIATES LTD.

Cameron J. Clayton, M.Eng., P.Geo.
Associate, Mining Group

Marke Wong, M.Sc. (Cand.)
Project Manager, Mining, Environment and Community Affairs

CJC/MW/lba
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7.0 REFERENCES

Brown, Bruce S. 2002. Management of Tailings Disposal on Land. Knight Piesold Consulting.

Caldwell, Jack A., and Andrew Mac G. Robertson. 1983. Selection of tailings impoundment sites. Die Siviele Ingenieur in Suid-Afrika. Oktober 1983.

Canter. 1985. Ground Water Pollution Control. CRC – Taylor & Frances, New York.

CH2MHill. 2004. Clark Fork River Operable Unit, of the Milltown Reservoir / Clark Fork River Superfund Site, Record of Decision, Part 3: Responsiveness Summary, April 2004, U.S. Environmental Protection Agency, Region 8, Montana.

CRL. 2003. Meadowbank Gold Property, Project Description Report, Cumberland Resources Ltd., March 2003.

Dawson, R.F. and K.A. Morin, 1996. Acid Mine Drainage in Permafrost Regions: Issues Control Strategies and Research Requirements – MEND Project 1.61.2. Prepared by AGRA Earth and Environmental Limited Calgary, Alberta and Morwijak Enterprises Ltd., Vancouver, B.C. for the Department of Indian and Northern Affairs Canada, Ottawa, Canada CG250047.

Decision – Makers Field Guide. 2005. Environmental and Water Quality Issues (Chapter 2); Sustainable Development, Technology, and a look to the Future (Chapter 4). Mining in New Mexico, Decision – Makers Field Conference 2005 Taos Region.

European Commission. 2004. Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities. July 2004. Sustainability in Industry, Energy, and Transport European IPPC Bureau, Spain. (http://eippcb.jrc.es)

Golder Associates Ltd. 2005. Alternative Mine Waste and Water Management Plan, Meadowbank Gold Project, Nunavut. Prepared for Cumberland Resources Ltd. Golder Associates Ltd., March, 2005. Report No. 04-1413-034/2600.

Golder Associates Ltd. 2004. Mine Waste and Water Management, Meadowbank Gold Project, Nunavut. Prepared for Cumberland Resources Ltd. Golder Associates Ltd., March 5, 2004. Report No. 03-1413-427-5000.

International Atomic Energy Agency (IAEA). 2000. Recycle and reuse of materials and components from waste streams of nuclear fuel cycle facilities. January 2000, Waste Technology Section, Austria.

Molycorp Watch Project. 2005. Current Regulatory Permitting for the Molycorp Mine, Amigos Bravos Friends of the Wild Rivers (NGO, New Mexico). Website: http://amigosbravos.org/molycorpwatch/permits/index.html (July 19, 2005)

Northern Miner. 2005. "Mining Across Alaska – Summaries". The Journal of the Northern Alaska Environmental Center, Summer 2005, Volume XXVII, Number 2.

Robertson, A. MacG., and S.C. Shaw. 1999. A multiple accounts analysis for tailings site selection. In Sudbury '99 - Mining and the Environment II Proceedings, D. Goldsack, N. Belzile, P. Yearwood and G. Hall (Eds) September 12-16, Sudbury, Ontario, Can. Pages 883-892.

Robertson, A. MacG., and S.C. Shaw. 1998. Alternative analysis for mine development and reclamation. Proceedings of the 22nd Annual BC Mine Reclamation Symposium, Penticton, BC. Canada, (September 14-17, 1998) pp. 51-62.

Robson Valley Land and Resource Management Plan – April 1999. Government of British Columbia.

Shaw, S.C., et al. 2001. Review of the Multiple Accounts Analysis Alternatives Evaluation Process Completed for the Reclamation of the Zortman and Landusky mine Sites. Presented at the 2001 National Association of Abandoned Mine Lands Annual Conference, August 19-22, 2001, Athens, Ohio.

Vick, Steven G. 1990. Planning, Design, and Analysis of Tailings Dams, BiTech Publishers Ltd., Vancouver. ISBN 0-921095-12-0.

APPENDIX C

Blast Design

Golder Associates Ltd.

500 – 4260 Still Creek Drive
Burnaby, British Columbia, Canada V5C 6C6
Telephone (604) 296-4200
Fax (604) 298-5253

REPORT ON

BLAST DESIGN
MEADOWBANK GOLD PROJECT
NUNAVUT

Submitted to:

Cumberland Resources Ltd.
Suite 950, One Bentall Centre
505 Burrard Street
Vancouver, BC
V7X-1M4

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1.0 INTRODUCTION

Cumberland Resources Ltd. is currently evaluating the development of the Meadowbank Gold Project located some 70 km north of Baker Lake, Nunavut (Figure 1). This report will address the drilling and blasting operations related to open pit mining. This report should be read in conjunction with detailed geotechnical design reports.

1.1 Ore Deposits

The Meadowbank Gold Project consists of several gold bearing deposits within reasonably close proximity to one another (Figure 2). These are:

- Third Portage Deposit (including Bay Zone and Connector Zone).
- North Portage Deposit.
- Goose Island Deposit.
- Vault Deposit.

The Third Portage Deposit is located on a peninsula, and extends northward under Second Portage Lake, and southward under Third Portage Lake. The Goose Island Deposit lies some 1000 m to the south of the Third Portage Deposit, and beneath Third Portage Lake. The North Portage Deposit is located on the northern shore of Second Portage Lake, and is interpreted as an extension of the Third Portage Deposit. The Vault Deposit is located some 5 km to the northeast of the North Portage Deposit.

1.2 Mining

Mining of the deposits will be primarily by open pit production. Many of the deposits are situated adjacent to, or beneath, lakes. Consequently, a series of dikes will need to be constructed to allow mining of the deposits where these occur beneath the lakes.

1.3 Deposit Characteristics

The deposits of the Meadowbank Project generally consist of stratabound gold mineralization associated with fold limbs inclined at steep angles (>60 degrees) to shallow angles (<30 degrees). The gold mineralization at the Goose Island and Portage Deposit areas is generally associated with iron formation rock. The gold mineralization at the Vault Deposit is associated with intermediate volcanic rock.

Drill and blast designs have been developed for the project rather than for individual deposits. This is primarily due to the similarity in rock type, rock mass quality, and structure throughout the various deposits.

2.0 SUMMARY OF GEOMECHANICAL PROPERTIES

As part of the geotechnical investigations information was gathered on both the intact rock and discontinuity properties of the rock units at the project site. For the purposes of developing drill and blast designs summary information has been extracted from the larger geotechnical database. Complete geotechnical assessments for the various deposits have been issued in a series of Technical Memoranda over the period of August to December 2003, and January 2004. Typical cross sections through the deposits are shown on Figures 3 through 6.

2.1 Geotechnical Model

The following summarizes the geotechnical model for the Goose Island, Portage, and Vault Deposit areas.

- There are three main rock types: iron formation, intermediate volcanic, and ultramafic volcanic. A fourth rock type, quartzite, may form substantial portions of the upper west pit wall of the Goose Island and Portage Deposits. The ultramafic volcanic rock may be serpentinized, and where this occurs, may be considerably weaker than the non-serpentinized ultramafic rock.
- The sheared and faulted stratigraphic contacts, and overall foliation orientations for the Third Portage and Goose Island Deposits will dip at steep angles (>60 degrees) to the west at the eastern and western margins of these deposits. They will dip at shallower angles (<30 degrees) to the west through the central portion of the Third Portage Deposit, at the north end of the Third Portage Deposit, through the Connector Zone, and at the North Portage Deposit.
- The sheared stratigraphic contacts and overall foliation orientations at the Vault Deposit will dip to the south and southeast at inclinations between about 20 degrees and 30 degrees.
- The stratigraphic contacts are considered to be continuous structures, and will control bench scale and pit wall stability. The orientation of the contacts can be assumed to follow the general trend of the overall foliation orientations for the deposit area, although the foliation may exhibit a high degree of variability on a local scale.
- The iron formation, intermediate volcanic rock, and quartzite are expected to have good rock mass quality. The ultramafic rock is expected to have fair to good rock mass quality.
- Overall pit slope configurations will be controlled by the sheared and faulted main stratigraphic contacts.

2.2 Rock Properties

The Table 2-1 summarizes the results of laboratory strength testing of rock core samples. These are average values based on valid test results of samples collected from Goose Island, Third Portage, North Portage, and Vault. The values for Young's Modulus have been estimated from quality values for the individual rock types.

Table 2-1: Summary of Rock Strength Properties

Rock Type	Minimum Unconfined Compressive Strength (MPa)	Maximum Unconfined Compressive Strength (MPa)	Average Unconfined Compressive Strength (MPa)	E (GPa)	Density (g/cc)
Intermediate Volcanic	51.0	148.3	94	46	2.75 to 2.89
Iron Formation	137.1	248.3	175	50	3.44
Quartzite	69.5	140.1	107	46	2.70
Ultramafic	40.2	91.6	66	25	2.91

2.3 Discontinuity Properties

The orientation, spacing and condition of discontinuities in the rock mass can influence the determination of drill and blast designs. Table 2-2 is a summary level description of the discontinuity parameters relevant to this design procedure.

Table 2-2: Summary of Main Discontinuity Properties – Portage and Goose Island Deposits

Type	Dip	Dip Direction	Average Spacing (m)	Joint Roughness and Condition	Large Scale Joint Roughness
Foliation	12 – 73	255 – 300	0.5 – 1.5	Smooth to rough and planar, slightly altered.	Rough and Wavy
Orthogonal	76 – 10	067 – 121	1.4 – 12	Smooth and wavy, slightly altered.	Rough and Wavy
CJ1	43 – 79	201 – 237	2.5 – 11.4	Smooth and wavy, slightly altered.	Rough and Wavy
CJ2	36 – 81	025 – 068	2.5 – 8.3	Smooth and wavy, slightly altered.	Rough and Wavy
CJ3	65 – 86	125 – 148	1.2 – 9.5	Smooth and wavy, slightly altered.	Rough and Wavy
CJ4	58 – 73	299 – 340	1.0 – 7.0	Smooth and wavy, slightly altered.	Rough and Wavy
Cross	46 – 63	002 – 031	0.4 – 19.4	Smooth and wavy, slightly altered.	Rough and Wavy
Cross	62 – 88	341 – 350			
Cross	26 – 62	170 – 191			

Table 2-3: Summary of Main Discontinuity Properties – Vault Deposit

Type	Dip	Dip Direction	Average Spacing (m)	Joint Roughness and Condition	Large Scale Joint Roughness
Foliation	21 – 23	136 – 164	0.5 – 0.8	Smooth to rough and planar, slightly altered to staining.	Rough and Wavy
Orthogonal	60 – 70	333 – 336	2.8 – 8.1	Rough planar to smooth wavy, no alteration.	Rough and Wavy
CJ1	83 – 85	197 – 209	1.7 – 7.4	Smooth to rough planar, slightly altered to none.	Rough and Wavy
CJ2	80 – 82	040 – 053			
East Dipping	67 – 81	086 – 108	3.7 – 6.1	Smooth and wavy, slightly altered to none.	No Data
South Dipping	45 – 48	174 – 198	2.8 – 14.3	Smooth to rough planar, slightly altered.	No Data
Cross	73	253	4.4	Rough planar to smooth wavy, no alteration.	No Data
Flat	10 – 13	330 - 335	8.3	Rough planar to smooth wavy, no alteration.	No Data

2.4 Pit Slope Design Configurations

The general bench configurations for the north and south end walls of the Goose Island, Portage, and Vault Deposits, and the west pit walls for the Goose Island and Portage Deposits, are given in the Table 2-4.

Table 2-4: General Bench Configurations

Bench Face Angle	Operating Bench Height, m	Final Bench Height, m	Bench Width, m	General Wall Application		
				Goose Island	Portage Pits	Vault Pit
60º to 70º	12 (6m in ore)	24	8 to 10 m	North South West	North South West	West South East

For the east pit wall of the Goose Island and Portage Pit, and the west pit wall of the Vault Pit, a footwall design philosophy will be used whereby pit slopes will be excavated parallel to the dip of the stratigraphy to avoid undercutting the sheared stratigraphic contacts.

Table 2-5: Footwall Design Criteria

Dip of Faulted Contacts	Slope Configuration	
<30° to 35°	**Unbenched Slope**	Parallel to Bedding/Stratigraphy/Faulted Contacts
>35°	**Bench Face Angle:**	Parallel to Bedding/Stratigraphy/Faulted Contacts to a maximum 70°
	Bench Height:	24 metres
	Catch Bench Width:	10 metres
	Inter-Ramp Angle:	32° to 52° dependent on bench face

For the purposes of production blast design, the proposed pit area has been divided into sectors on the basis of the general orientation of the main structural features that may influence the effectiveness of the blast design. Consequently, there are potentially four wall orientations for the production blasts. These are:

- West facing walls.
- East facing walls.
- North facing walls.
- South facing walls.

The dominant structural influence on blast design will be the orientation of the main stratigraphic contacts, and axial planar foliation. The spacing of the foliation is expected to be on the order of 1 m to 2 m. The secondary structural influence on the blast design will be the orientation of the orthogonal jointing. As discussed previously, the orthogonal joints are expected to be discontinuous but systematically distributed throughout the various rock types in the deposit area. The spacing of these features is expected to be on the order of several metres.

2.5 Permafrost

The site is located in the zone of continuous permafrost. Based on thermistor installations at the site, the permafrost is well developed. The active layer is between 1.5 m and 2 m below the ground surface. Permafrost temperatures beneath the landmass are on the order of –8 degrees C. Permafrost temperatures are expected to be warmer adjacent to and beneath lakes. Where mining occurs in de-watered area of the lake, talik zones will be present. Water inflows to the open pits will therefore occur through the talik.

Successful blast design in Arctic environments carries with it the need to understand the nature of permafrost, and the effect permafrost may have on the blast design. Based on site instrumentation, the permafrost underlying the land mass is expected to be cold;

hence the drilled blast holes are likely to be dry. Where pit walls are excavated within the talik underlying the de-watered lakes, the drilled blast holes are expected to be wet.

The overall strength and modulus of the rock mass may be enhanced by the presence of permafrost, and this may have an effect on blasting results. The presence of permafrost may also influence stress induced fracturing and gas penetration if the fractures are ice filled.

2.6 Groundwater

The current operational plan to develop the Portage Pit will involve initial draw-down of the Second Portage Lake arm to a level approximately 28 m below the current lake surface elevation. Based on the lake bathymetry survey carried out in 2002, a north trending ridge is located to the west of the North Portage deposit. The water will be drawn down below this ridge, which will aid as a natural barrier to restrict flow into the open pit. In addition to drawing down of the lake, a tailings dike will be constructed west of the pit crest. At this time, a minimum setback of 80 m from the proposed crest of the open pits to the inside (pit side) toe of the de-watering dikes has been assumed. The central core of the dike will be located on the order of 100 m back from the pit crest.

The overburden is expected to consist of silt, sand and gravel till, with areas of sand and gravel deposits possibly of glacio-fluvial origin.

The hydraulic conductivity within the overburden is estimated to be 1 x 10^{-5} m/s. The hydraulic conductivity of the shallow bedrock (less than 25 m) is generally higher than that of the deeper bedrock (greater than 25 m). The geometric mean value of the shallow bedrock is approximately 1 x 10^{-6} m/s while that of the deeper bedrock is 1 x 10^{-8} m/s. Based on the hydraulic conductivity testing carried out to date at the site, the hydraulic conductivity of the Bay Zone Fault and Fault Splay is similar to that of the less fractured rock, while the hydraulic conductivity of the Second Portage Fault is higher at 5 x 10^{-6} m/s.

Potential sources of water inflows to the open pit will be from water stored in the overburden sediments, through potentially hydraulically conductive structures such as the Second Portage Lake Fault, and through the talik beneath Second Portage Lake. Initial estimates of water inflow to the Third Portage pit and North Portage pit through the bedrock talik are on the order of 250 m^3/day and 350 m^3/day, respectively (Ref. "Predictions of Groundwater Inflow to Open Pits – Meadowbank Project", Technical Memorandum, 6 Feb. 2004). Pit inflows along the Second Portage Lake Fault have initially been estimated to be on the order of 50 m^3/day to 100 m^3/day.

Based on this information, blasting will have to be undertaken in both wet and dry conditions. Explosive selection will be influenced by the presence of water.

3.0 BLAST DESIGN

3.1 Lilly's Blastability Index

An empirical method to assess the blastability of a rock mass was developed by Lilly (1986, 1992). The method takes into account both geotechnical factors, geological (structure) factors, and physical properties of a rock mass to arrive at an index rating known as the Blastability Index, or BI.

The following factors determine the Blastability Index:

1. Rock Mass Description (RMD): The Rock Mass Description is concerned with the overall character of the rock, and considers whether the rock is massive with little to no structural character, blocky with systematic jointing, or powdery and friable. The fragmentation of a massive rock will depend largely on the strain energy of the blast inducing fractures in the rock mass. The fragmentation of a heavily jointed rock mass will be controlled more so by the orientation of the joint systems.

2. Joint Plane Spacing (JPS): The Joint Plane Spacing refers to the spacing between all planes of weakness in the rock mass. Lower energy factors are required to break a rock mass having closely spaced joints. This value can be determined as the Block Size Index (Ib) as described by ISRM "Suggested Methods for the Quantitative Description of Discontinuities" (1978). The block size index represents the average dimensions of typical rock blocks, and is based on modal spacing of the joints.

3. Joint Plane Orientation (JPO): The Joint Plane Orientation accounts for the influence of major structural orientations on the distribution of the strain energy in a blast. The orientation of the major joint or bedding planes can significantly impact blasting results.

4. Rock Density Influence (RDI): The Rock Density Influence affects the blastability of the rock as greater energy is required to fragment a heavier rock mass than a lighter rock mass. The RDI is given by:

$$\text{RDI} = 25 \times \text{Rock Density } (t/m^3) - 50$$

5. Hardness Factor (HF): The Hardness Factor links the blastability of a rock mass to the Young's Modulus (γ) of weaker rocks where γ is less than 50 GPa (weak confinement). For stronger rock masses ($\gamma > 50$ GPa, strong confinement), the Hardness Factor is linked to the Unconfined Compressive Strength of the rock (in MPa). The hardness

The index has a maximum value of 100 corresponding to extremely hard, iron rich cap rock having a specific gravity of 4 t/m^3, while weaker rocks, such as shale, have indices of about 20.

The Blastability Index is defined as:

$$BI = [0.5 \text{ x } (RMD + JPS + JPO + RDI + HF)]$$

Where:

RMD = Rock Mass Description
JPS = Joint Plane Spacing
RDI = Rock Density Influence
HF = Hardness Factor

The Blastability Index is used to determine an appropriate powder factor and in the Kuz-Ram model for rock fragmentation to determine the parameter Rock Factor A.

Table 3-1: Blastability Index and Rock Factor for Meadowbank Rock Types

Rock Type	Iron Formation	Intermediate Volcanic	Ultramafic	Quartzite
Rock Mass Description	50	50	20	50
Joint Plane Spacing	50	50	50	50
Joint Plane Orientation	20	20	20	20
Rock Density Influence	30	18	18	18
Hardness Factor	14	15	9	15
BLASTABILITY INDEX, BI	**82**	**76**	**58**	**76**
Rock Factor, A (0.12*BI)	9.8	9.1	7.0	9.1

3.1.1 Blast Hole Diameter, D (mm)

The selection of an appropriate blasthole diameter is important in terms of fragmentation and cost. Ideally, it is desirable to obtain the maximum fragmentation at a minimum cost. The cost of drilling and of explosives decreases as the diameter of the blasthole increases. Other factors must be considered such as bench height, rock structure and rock hardness. Smaller diameter blastholes are more suited to strongly jointed rocks as the decreased spacing results in fewer joints between holes. This will tend to reduce the amount of oversize and result in better fragmentation.

Based on discussions with Cumberland the blasthole diameter will be 165 mm (6½ in.) with the capability of drilling larger diameter blast holes. Alternative designs are presented for larger blastholes of 229 mm (9 in.).

3.2 Explosive Selection

The project is located in the zone of continuous permafrost. Known permafrost temperatures in the area are as low as -8 to -10 degrees C. The depth of the active layer is between 1.5 m and 2 m. Much of the pit wall development will be within talik zones beneath de-watered lakes, and consequently will be unfrozen during development. These conditions will result in wet blast holes. Consequently, the water resistance of the chosen explosive must be considered. Where pit wall development will be within permafrost (i.e., beneath the existing land surface) dry blasthole conditions may exist. Under these circumstances, a product having a lower resistance to water may be considered.

3.2.1 ANFO

The location of the site is remote. Therefore, cost is a consideration. Ammonium nitrate-fuel oil, or ANFO, is the least expensive explosive used by the mining industry. However, the water resistance of ANFO is poor, and it can be desensitized relatively easily even with low water contents. The effect on ANFO of the presence of water in the blasthole has been overcome by a number of methods. Dewatering equipment can be used to dewater the blastholes before loading. The ANFO is then loaded using dryliners, or polythene tubing sealed at the bottom and installed in the blasthole. For surface mining, the ANFO is handled by bulk mix trucks.

3.2.2 ANFO/Emulsion Mixtures

An alternative to ANFO that overcomes some of the problems associated with water resistance, is an ANFO/emulsion mixture. The amount of emulsion added to the mixture varies depending on the energy and water resistance requirements. The use of emulsion improves the bulk strength of the explosive and allows for an increase in breakage capacity. Since the ANFO can be surrounded by emulsion, the water resistance of the product is enhanced considerably from that of straight ANFO.

Table 3-2: Typical Properties of ANFO/Emulsion Mixtures

ANFO (%)	Emulsion (%)	Density (g/cc)	Velocity of Detonation (m/s)	RWS/RBS	Minimum Diameter (mm)	Water Resistance	Loading
30	70	1.3	5700	84/132	115	Excellent	Pump
50	50	1.3	5500	89/141	150	Good	Auger
70	30	1.2	4700	93/131	125	Poor	Auger
75	25	1.1	4600	94/127	100	Poor	Auger

Reference: Dyno Nobel, Inc.

Given that the conditions in the talik areas will be wet and that there will be some water infiltration through and under the dike it is recommended that a "doped" emulsion be used. At this stage a 70:30 (emulsion:ANFO) mixture is recommended. Pumpable blends have better water resistance than augerable blends which tend to lose their water resistance as the percentage of emulsion decreases. Where blasthole conditions are found to be dry, alternative blast designs (30:70 Emulsion:ANFO) can be considered.

3.3 Blast Design Assumptions

The production blast design criteria were formulated on the basis of the engineering geological models for the deposits. Basic assumptions used for the process were:

- A doped emulsion will be used (70:30, emulsion:ANFO) to address potentially wet blasting conditions.

- The available equipment will be capable of drilling blasthole diameters ranging from 165 mm (6½ in) up to 229 mm (9 in). For the 12 m working benches, the larger blasthole size is appropriate to optimize fragmentation, reduce drilling inaccuracy, and reduce the number of blastholes required. For the 6 m high benches in ore, the smaller diameter blasthole is appropriate. **However, it is important to note that the critical diameter of the doped emulsion product is close to 165 mm (6½ in). This could potentially result in incomplete detonation of the product and poor fragmentation of the rock for smaller diameter holes.**

- A staggered pattern with millisecond delays and en echelon firing sequence shooting from a corner is assumed. An inter-hole 25 ms delay is suggested. The staggered pattern will result in better distribution of the explosives energy and consequently better movement of material and a lower muckpile for easier digging. If it is necessary to blast to one free face, a staggered V1 (flat) pattern should be used.

- Operating bench heights within the waste rock will be 12 m. Operating bench heights within the ore will likely be 6 m to facilitate grade control. A high degree of care and attention to blast design will be required.

- Final benches will generally be double-benched to 24 m. Single benching (12 m) in areas that may be susceptible to toppling failure may be required.

- The length of the blasted block will be a minimum of twice the width, which will be between three and five rows for production blasts.

- The bench face angles will generally be steep, between 60 and 70 degrees and hence vertical blastholes have been assumed. Inclined blastholes could improve the consistency of the burden and the efficiency of fragmentation, however, accuracy of drilling angled holes is difficult to achieve, particularly with smaller diameter blastholes.

3.4 Production Blast Design

The following tables summarize the blast designs considered for the Meadowbank Project.

Table 3-3: Blasthole Parameters

	Units	Constant Blasthole Diameter		Blasthole Diameter based on Bench Height	
		Waste	ORE	Waste	ORE
Working Bench Height	m	12	6	12	6
Blasthole Diameter	mm	165	165	229	165
Bench Face Angle	degrees	60 - 70	60 - 70	60 – 70	60 – 70
Hole Inclination	deg	90	90	90	90
Inclined Depth	m	12.0	6.0	12.0	6.0
Subdrill	m	1.3	1.3	1.8	1.3
TOTAL DRILLED DEPTH	**m**	**13.3**	**7.3**	**13.8**	**7.3**

Table 3-4: Blast Patterns

Blasthole Pattern	Staggered
Blast Sequence	En Echelon
Spacing/Burden Ratio	1:1.15
Number of Rows	5
Number of Holes per Row	10

Table 3-5: Charge Table – Wet Blastholes (Emulsion:ANFO 70:30)

Rock Type	Units	165 mm Blasthole, 6 m bench in ore, 12 m bench in waste			229 mm Blasthole, 12 m bench in waste	
		Ore	IV and Quartzite	Ultramafic	IV and Quartzite	Ultramafic
Stemming Length	m	3.8	5.4	5.4	5.7	5.9
Fallback	m	0.1	0.2	0.2	0.2	0.2
Charge Length	m	3.4	7.7	7.7	7.9	7.7
Linear Charge Density	kg/m	27.8	27.8	27.8	53.6	53.6
Burden	m	5.0	5.0	5.0	6.9	6.9
Spacing	m	5.7	5.7	5.7	7.9	7.9
Burden Volume	m^3	169	338	338	651	651
Explosives Mass per Hole, Q	kg	95	215	215	424	412
Powder Factor, PF	**kg/m^3**	**0.56**	**0.63**	**0.64**	**0.65**	**0.63**

The proposed general blast configuration is shown on Figure 7. Where blasting occurs within the shallow dipping ore and stratigraphy, a conceptual blast design is shown on Figure 8. For areas where toppling may be a concern, a conceptual blast design layout is shown on Figure 9.

In areas where dry blasthole conditions are encountered the following designs can be adopted.

Table 3-6: Charge Table – Dry Blastholes (Emulsion:ANFO 30:70)

Rock Type	Units	165 mm Blasthole, 6 m bench in ore, 12 m bench in waste			229 mm Blasthole, 12 m bench in waste	
		Ore	IV and Quartzite	Ultramafic	IV and Quartzite	Ultramafic
Stemming Length	m	3.5	4.8	4.7	5.1	5.3
Fallback	m	0.1	0.2	0.2	0.2	0.2
Charge Length	m	3.7	8.3	8.3	8.5	8.3
Linear Charge Density	kg/m	25.7	25.7	25.7	49.4	49.4
Burden	m	5.0	5.0	5.0	6.9	6.9
Spacing	m	5.7	5.7	5.7	7.9	7.9
Burden Volume	m^3	169	338	338	651	651
Explosives Mass per Hole, Q	kg	95	214	216	422	412
Powder Factor, PF	**kg/m^3**	**0.56**	**0.63**	**0.64**	**0.65**	**0.63**

3.4.1 Rock Fragmentation

The predicted fragmentation of the rock mass for the blast designs presented above is based on the Kuz-Ram Model (Cunningham. 1983; Kuznetsov, 1973; Rosin and Rammler 1933). The Rosin-Rammler equation defines the grain size curve for rock fragmentation. The Kuznetsov equation gives the mean fragmentation size when the Rosin-Rammler equation is equal to 0.5, or the point on the grain size curve with the mesh size that 50% of the blasted rock would pass. The following table summarizes the predicted rock fragmentation for the preceding design criteria, and for a five row blast pattern with ten holes per row. The predicted fragmentation curves are contained in Appendix I. The predicted fragmentation assumes a ratio of actual to theoretical VOD of 0.85, although this ratio could be as high as 0.95 if the bulk product is well mixed.

Table 3–7: Predicted Fragmentation (Emulsion:ANFO 70:30)

Rock Type	Bench Height, m	Hole Size, mm	t/blast, t[1]	Powder Factor, kg/m^3	50% passing, m	80% passing, m	Characteristic Size, m
Iron Formation	6 m	165 mm	29,412	0.56	0.51	1.1	0.70
Ultramafic	12 m	165 mm	46,170	0.63	0.38	0.72	0.50
Intermediate Volcanic	12 m	165 mm	47,880	0.64	0.49	0.94	0.65
Ultramafic	12 m	229 mm	88,306	0.63	0.42	0.79	0.55
Intermediate Volcanic	12 m	229 mm	91,577	0.65	0.54	1.01	0.71

1. Assumes 5 rows and 10 holes per row.

3.5 Controlled Blasting for Final Walls

Trim blasting should be used to shape the final wall. Trim blasting uses large-diameter blastholes for both production and final row holes and thus eliminates the additional costs associated with small diameter blasthole drilling. The trim row is designed as the last row of the blast.

The trim row burden volume should be approximately one-third of the volume of the production row and should be loaded with sufficient explosive to maintain the same powder factor as for the production row. The burden volume of the two buffer rows in front of the trim row should be approximately two-thirds of the rock volume of the production holes. The buffer rows should be loaded to maintain the same powder factor as for the production row. A typical layout for a trim and buffer blast for final wall shaping is shown on Figures 7 through 9 and will be applicable to areas of the final pit walls of the Goose Island, Portage, and Vault pits.

Table 3-8: Charge Table – Trim Blast

Rock Type	Units	165 mm Blasthole, 12 m bench		229 mm Blasthole, 12 m bench	
		IV and Quartzite	Ultramafic	IV and Quartzite	Ultramafic
Stemming Length	m	4.1	4.1	5.7	5.7
Fallback	m	0.2	0.2	0.2	0.2
Charge Length	m	9.0	9.0	7.9	7.9
Linear Charge Density	kg/m	6.3	6.4	13.7	13.4
Burden	m	2.5	2.5	3.4	3.4
Spacing	m	3.0	3.0	4.1	4.1
Burden Volume	m^3	90	90	167	169
Explosives Mass per Hole, Q	kg	57	58	109	107
Powder Factor, PF	**kg/m^3**	0.63	0.64	0.65	0.63

Table 3-9: Charge Table – Buffer Blast

Rock Type	Units	165 mm Blasthole, 6 m bench in ore, 12 m bench in waste		229 mm Blasthole, 12 m bench in waste	
		IV and Quartzite	Ultramafic	IV and Quartzite	Ultramafic
Stemming Length	m	4.1	4.1	5.7	5.7
Fallback	m	0.2	0.2	0.2	0.2
Charge Length	m	9.0	9.0	7.9	7.9
Linear Charge Density	kg/m	11.7	11.9	26.0	25.2
Burden	m	3.5	3.5	4.8	4.8
Spacing	m	4.0	4.0	5.5	5.5
Burden Volume	m^3	168	168	317	317
Explosives Mass per Hole, Q	kg	106	108	206	200
Powder Factor, PF	**kg/m^3**	0.63	0.64	0.65	0.63

Certain areas of the east pit wall of the Portage and the Goose Island pits will be excavated within shallow dipping structure, with bench face angles paralleling the stratigraphic contacts and foliation orientations. In these areas, the length of the trim holes will be shortened substantially. Pocket charges may be required to improve fragmentation. Alternatively a series of stab holes may be drilled between the trim and buffer rows.

In certain areas of the west wall of the Portage and Goose Island pits, the potential for toppling failure exists. This will be particularly true adjacent to the Bay Fault. In these areas, it may be necessary to alter the geometry of the buffer and trim rows.

3.6 Nitrate/Ammonia Considerations

The use of nitrate based explosives products in a wet environment increases the potential for nitrogen (as nitrate, nitrite or ammonia) to enter the water system. In order to minimize any potential impacts an effective explosives management system should be implemented as part of production startup. The management strategy should include the following:

- An education program for all production employees that outlines the potential problem and appropriate mitigation techniques.
- A spill handling procedure.
- A monitoring program that is integrated with baseline water quality information.
- A review of blasting operations early in production to determine efficiency levels.

3.7 Blast Induced Vibration

Blast induced vibrations have the potential to reduce the stability and performance of nearby earthen structures such as dikes. Where saturated conditions exist within the foundation materials and within the earthen structural fills of the de-watering dikes and the tailings dike, blast induced vibrations could result in the development of increased pore water pressures within the foundation and structural fill materials. This could lead to potential settlement of the structures and consequently impact to the water retaining capacity of the dikes.

As part of the mine development, a vibration monitoring program will be required in order to measure the response of the de-watering dikes and tailings dike to pit blasting. The data from this program would be assessed in conjunction with continuous measurements from piezometers that would be installed in the dikes, and within the dike foundation materials. From this analysis, the blasting could be adjusted to minimize the impact on the dikes. Mitigative measures to the blast design to minimize the development of blast induced vibration could include modifications to the blasthole patterns, reduction in blasthole size and hence charge weight in critical areas of the pit walls within a certain distance from the proposed de-watering and tailings dike, single blasthole initiation per delay, reduction in operating bench height in critical areas, or a combination of all these measures.

A more comprehensive program of blast vibration modelling and test blasting may be required during operations if blast vibration levels remain high and their frequency (cycles per second) is low.

The effects of blasting are typically assessed in terms of Peak Particle Velocity (PPV).

3.7.1 Estimates of Peak Particle Velocity

The preliminary estimates of Peak Particle Velocity (PPV) are based on the current understanding of the site layout, mine plan, and blast design. Changes to the current site layout, mine plan, and blast design will result in changes to the estimates of PPV. Certain site specific factors that are required to calculate PPV have been estimated based on published values. However, site specific parameters can only be determined by site vibration monitoring of actual blasts. Consequently, the actual PPV values may differ from those presented here.

The US Bureau of Mines has established that the peak particle velocity, PPV, is related to the scaled distance by the following relationship:

$$PPV = k * (R/W^{0.5})^{-b}$$

Where:

PPV	= Peak Particle Velocity, mm/s
R	= Distance from blast to point of concern, m
W	= Charge weight per delay, kg
k	= confinement factor – specific to site
b	= site factor

The constants k and b are specific to the site, and can be determined by blast vibration monitoring.

For this evaluation, a value of b = 1.6 was assumed. The PPV was evaluated for a range of values of confinement, ‘k’, of 400, 800, and 1500, for down hole blasting. This range in values is considered to be reasonable for the site and to provide an estimate of the sensitivity of PPV to different values of confinement. Based on the current understanding of site conditions and experience at two other northern sites, the confinement value of 800 is expected to be the most likely representative value for average conditions at the site. The actual value for confinement can only be determined through a detailed field monitoring program.

3.7.2 Minimum Setback Distance for Canadian Fisheries Guidelines

Design guidelines governing the use of explosives adjacent to Canadian fisheries waters (Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998) indicate that no explosive is to be detonated that produces a peak particle velocity greater than 13 mm/s in a spawning bed during the period of egg incubation.

For the Meadowbank Site, three scenarios have been assessed: the first assumes a charge weight per delay of 420 kg for 229 mm (9 in) blastholes and an operating bench height of 12 m, the second assumes a maximum charge weight of 250 kg for 165 mm (6½ in) blastholes and a bench height of 12 m, and the last assumes a charge weight of 86 kg for 165 mm blasthole and bench height of 6 m. The maximum charge weight determined in the above analyses has been used to assess the PPV. An Emulsion:ANFO ratio of 70:30 has been assumed.

The PPV's were evaluated for the Second Portage Lake East Dike, the Third Portage Peninsula east shoreline, the Bay Dike, and the Goose Island east shoreline. Based on the current mine layout, estimates of the minimum distance from the estimated final production blast near the pit crest, to the point of concern (either shoreline or dike face), and estimates of the distance from the pit centre to the point of concern (either shoreline or dike face) were made. The PPV were evaluated based on these estimated distances. The estimates of PPV will change as a result of further changes to the mine plan, pit optimization, dike alignment optimization, and blast design optimization.

The Table 3-10 summarizes the estimated PPV at points of concern either along the upstream face of the dike, or along the shoreline, whichever is closest.

Table 3-10: Preliminary Estimate of Peak Particle Velocities based on Production Blasting (420 kg charge weight per delay; 12 m bench height, 229 mm blasthole)

Location	Distance to Point of Concern (m)		PPV (mm/sec)		
			k=400	k=800	k=1500
Second Portage Lake East Dike	Pit Crest to U/S Dike Face	255	7	**14**	**27**
	Pit Centre to U/S Dike Face	375	4	8	**14**
Third Portage Peninsula	Pit Crest to Shoreline	101	**31**	**62**	**117**
	Pit Centre to Shoreline	295	6	11	**21**
Bay Dike	Pit Crest to U/S Dike Face	145	**17**	**35**	**66**
	Pit Centre to U/S Dike Face	355	4	8	**16**
Goose Island	Pit Crest to Shoreline	105	**29**	**59**	**110**
	Pit Centre to Shoreline	335	5	9	**17**

Distances are measured from approximate location of last production blast, not final trim blast.
Values of PPV in bold exceed 13 mm/sec.

To assess the sensitivity of the estimates of PPV to blast design, a charge weight of 250 kg, corresponding to a smaller 165 mm (6½ in) blasthole diameter, was used (decking of the charges could produce a similar result, while maintaining the larger blasthole diameter of 229 mm). The results are presented in the following table, and indicate that optimization and modification of the blast design near the crest areas can result in reduced PPV.

Table 3-11: Preliminary Estimate of Peak Particle Velocities based on Production Blasting (250 kg charge weight per delay; 12 m bench height, 165 mm blasthole)

Location	Distance to Point of Concern (m)		PPV (mm/sec)		
			k=400	k=800	k=1500
Second Portage Lake East Dike	Pit Crest to U/S Dike Face	255	5	9	**18**
	Pit Centre to U/S Dike Face	375	3	5	9
Third Portage Peninsula	Pit Crest to Shoreline	101	**21**	**41**	**77**
	Pit Centre to Shoreline	295	4	7	**14**
Bay Dike	Pit Crest to U/S Dike Face	145	12	**23**	**43**
	Pit Centre to U/S Dike Face	355	3	6	10
Goose Island	Pit Crest to Shoreline	105	**19**	**39**	**73**
	Pit Centre to Shoreline	335	3	6	11

Distances are measured from approximate location of last production blast, not final trim blast.
Values of PPV in bold exceed 13 mm/sec.

By reducing the working bench height further to 6 m within both the waste rock as well as within the ore, the charge weight can be reduced to approximately 86 kg per blasthole. This reduction in charge weight has the following effect on PPV.

Table 3-12: Preliminary Estimate of Peak Particle Velocities based on Production Blasting (86 kg charge weight per delay; 6 m bench height, 165 mm blasthole)

Location	Distance to Point of Concern (m)		PPV (mm/sec)		
			k=400	k=800	k=1500
Second Portage Lake East Dike	Pit Crest to U/S Dike Face	255	2	4	7
	Pit Centre to U/S Dike Face	375	1	2	4
Third Portage Peninsula	Pit Crest to Shoreline	101	9	**18**	**33**
	Pit Centre to Shoreline	295	2	3	6
Bay Dike	Pit Crest to U/S Dike Face	145	5	10	**18**
	Pit Centre to U/S Dike Face	355	1	2	4
Goose Island	Pit Crest to Shoreline	105	8	**16**	**31**
	Pit Centre to Shoreline	335	1	3	5

Distances are measured from approximate location of last production blast, not final trim blast.
Values of PPV in bold exceed 13 mm/sec.

The above analysis indicates that the Peak Particle Velocities along the upstream (lake side) face of the de-watering dikes can be managed and minimized, but not eliminated, through modifications to the blast design to adjust the charge weight in specific areas of the pit. These modifications would include reduction of blasthole size, reduction of bench height, or a combination of the two. Figure 10 shows the relationship between charge weight and distance from blast for a constant Peak Particle Velocity of 13 mm/s. The figure can be used as a guide to estimate the maximum charge weight per blasthole required so as not to exceed 13 mm/s criteria for fish habitat at a given distance from the blast, and to develop blast designs to minimize potential impacts to fish habitat where the 13 mm/s criteria can not be achieved. The minimum setback distances to achieve a PPV of 13 mm/s have been estimated for the various values of ‘k’, and for four potential charge weights per delay used in the above PPV estimates. The following table summarizes the estimates of minimum setback required to achieve a PPV value of 13 mm/s.

Table 3-13: Minimum Setback Distance for 13 mm/s Peak Particle Velocity Guideline

k	86 kg charge weight per delay (6 m bench, 165 mm hole)	250 kg charge weight per delay, (12 m bench, decked charge, 229 mm hole)	420 kg charge weight per delay, (12 m bench, 229 mm hole)
	Minimum Setback Distance to Achieve PPV = 13 mm/s		
400	79 m	135 m	175 m
800	122 m	208 m	269 m
1500	180 m	308 m	399 m

The above analysis suggests that for a charge weight per delay of 420 kg, the minimum setback for a PPV of 13 mm/s will be on the order 269 m, based on an average expected confinement value, k, of 800. The minimum setback distance can be reduced by modifying the bench blast designs and incorporating smaller bench heights, smaller blastholes, or a combination of the two. Figure 11 shows the 13 mm/s isopleth relative to the current dike configuration for the above charge weights and a confinement value, k, of 800.

In some cases it will be impractical to construct the proposed de-watering dikes at the minimum setback distances for fish habitat indicated in the above analyses. This is primarily due to engineering and constructability constraints relating to the proposed method of dike construction. However, during detailed engineering design, the final alignment of the proposed de-watering dikes can be assessed further to consider, among other items, the minimum setback required to minimize the impact of explosives detonation on the potential fish habitat along the upstream dike faces. As discussed previously, the effects on fish habitat of explosives detonation within the open pits can be mitigated to some degree by reducing the charge weight per delay through the use of smaller diameter blastholes or by decking of charges, by reducing the bench height, or through a combination of the two. Other mitigative methods may include the use of 'bubbler' systems along the upstream face of the dikes in areas that will be affected by PPV of 13 mm/s or greater. These systems would be operated during blasting operations to discourage fish from along the upstream embankment face.

3.7.3 Minimum Setback Distance for Threshold Damage Levels

Common threshold vibration levels for damage have been developed relating PPV to potential vibration damage. The following table summarizes additional threshold damage levels typically used in urban areas for assessing the potential for blast damage to occur.

Table 3-14: Peak Particle Velocity Threshold Damage Levels

Velocity (mm/s)	Damage
3 – 5	Vibrations Perceptible
10	Approximate limit for poorly constructed, and historic buildings
33 – 50	Vibrations objectionable
50	Limit below which risk of damage to structures is very slight (less than 5%)
125	Minor damage, cracking of plaster, serious complaints
230	Cracks in concrete blocks
300	Rock falls in unlined tunnel
380	Horizontal offset in cased drillholes
635	Onset of cracking in rock
1000	Shafts misaligned in pumps, compressors
1500	Prefabricated metal buildings on concrete pads, metal twisted and concrete cracked
2500	Breakage of rock

Charlie et al (1987) suggest the following criteria for blasting near dams, based on liquefaction potential.

Table 3-15: General Guidelines to Vibration Damage Thresholds for Blasting Near Dams

	Maximum PPV
Dams constructed of or having foundation materials consisting of loose sand or silts that are sensitive to vibration.	25 mm/s
Dams having medium dense sand or silts within the dam or foundation materials	50 mm/s
Dams having materials insensitive to vibrations in the dam or foundation materials	100 mm/s

Ref. Charlie et al, 1987.

The information presented in the above tables can be used as general guidelines for assessing the potential for blast vibration damage to structures. Due to the inherent variability in site conditions, caution must be exercised in assessing the potential damage from blast induced vibration. Actual vibrations will need to be monitored during construction and operations.

Minimum setback distances based on a maximum PPV of 50 mm/s, representing the situation of a dam having medium dense sands or silts in the dam or foundations, have been calculated for the various values of confinement, ‘k’, and for three potential charge weights per delay. The actual velocities will need to be determined during a vibration monitoring program that will be required in order to measure the response of the de-watering dikes and tailings dike to pit blasting. Depending on the actual velocities experienced by the dikes, charge weights may need to be modified during operations. The threshold value of 50 mm/s may be modified once more detailed information is obtained relating to the foundation materials beneath the dikes. Furthermore, in the case of the tailings dike, it is proposed to construct the till core of the dike in compacted lifts. Consequently, a threshold value on the order of 100 mm/s may be more appropriate, and would be on the order of requirements for similar dikes in the north which have used design threshold values of up to 125 mm/s to limit structural damage. However, for this stage of design, a threshold value of 50 mm/s is considered appropriate to limit structural damage.

Figure 12 shows the relationship between charge weight and distance from blast for a constant Peak Particle Velocity of 50 mm/s. The Table 3-15 summarizes the estimates of minimum setback required to achieve a PPV value of 50 mm/s.

Table 3-16: Minimum Setback Distance for 50 mm/s Peak Particle Velocity Guideline

k	86 kg charge weight per delay (6 m bench, 165 mm hole)	250 kg charge weight per delay, (12 m bench, decked charge, 229 mm hole)	420 kg charge weight per delay, (12 m bench, 229 mm hole)
	Minimum Setback Distance to Achieve PPV = 50 mm/s		
400	32 m	58 m	75 m
800	53 m	89 m	116 m
1500	78 m	133 m	172 m

The above analysis suggests that the peak particle velocities that the de-watering and tailings dikes may be exposed to can be managed effectively, if necessary, through the use of lighter charge weights by reducing bench heights, blasthole diameter, or combinations of the two. The table also suggests that the minimum toe setback distance of 80 m that is currently being carried through the feasibility study is a reasonable distance from the perspective of managing PPV. Additional sampling and testing of the till materials may allow refinements to be made to the above estimates of setback distance.

3.8 Instantaneous Pressure Change

Design guidelines governing the use of explosives adjacent to Canadian fisheries waters (Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998) indicate that no explosive is to be detonated in or near fish habitat that produces an instantaneous pressure change greater than 100 kPa in the swimbladder of a fish.

The required setback distance for confined explosives to achieve the 100 kPa guideline can be estimated from the following relationships (Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998).

The relationship between acoustic impedance and the density and velocity of the medium through which the compression wave travels is given by:

$$Zw/Zr = (Dw*Cw)/(Dr*Cr)$$

Where:

Dw = density of water = 1 g/cm^3
Dr = density of the substrate, g/cm^3
Cw = compression wave velocity in water
= 146,300 cm/s
Cr = compression wave velocity in substrate, cm/s

Typical values used for Dr and Cr for various substrates are:

Table 3–17: Typical Values for Substrate Density and Compression Wave Velocity

Substrate	Dr (g/cm^3)	Cr (cm/s)
Rock	2.64	457,200
Frozen Soil	1.92	304,800
Ice	0.98	304,800
Saturated Soil	2.08	146,300
Unsaturated Soil	1.92	45,700

Reference: Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998

The transfer of shock pressure from the substrate to the water can be estimated from:

$$Pw = (2*(Zw/Zr)*Pr)/(1+(Zw/Zr))$$

Where:

Pw	= pressure (kPa) in water
Pr	= pressure (kPa) in substrate
Zw	= acoustic impedance of water
Zr	= acoustic impedance of substrate

The equation can be re-written to solve for the pressure in the substrate, Pr, as:

$$Pr = (Pw*(1+(Zw/Zr)))/(2*(Zw/Zr))$$

The equation is solved by setting the value of Pw to the 100 kPa guideline to determine the pressure in the substrate, Pr, which is required to produce this detonation overpressure in the water. The resulting value for Pr is used to determine the Peak Particle Velocity in the rock for the given conditions based on the following:

$$PPV = (2*Pr)/(Dr*Cr)$$

The relationship between Peak Particle Velocity, charge weight, and distance was described in Section 3.7.1 and is given by:

$$PPV = k * (R/W^{0.5})^{-b}$$

Equating the two equations for Peak Particle Velocity, and solving for distance, R for a given charge weight, W, gives the minimum setback distance from fish habitat required so as not to exceed the 100 kPa overpressure guideline.

The following properties were used to assess the minimum setback distance.

Table 3–18: Properties Used to Assess Setback Distance for Instantaneous Overpressure

Medium	Density, g/cm^3	Compressional Wave Velocity, cm/s
Water	1	146,300[1]
Rock (Intermediate Volcanic)	2.8	457,200[1]

1. Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998

Based on the above properties, the range of potential charge weights, and the range in confinement value, k, the following minimum setback distances, below which the 100 kPa overpressure guideline will not be exceeded, are estimated.

Table 3-19: Minimum Setback Distance for Instantaneous Overpressure Guideline

Charge Weight per Delay	Minimum Setback Distance, m		
kg	k=400	k=800	k=1500
86	26 m	40 m	60 m
250	45 m	69 m	102 m
420	58 m	89 m	132 m

The relationship between charge weight per delay and minimum setback distance to achieve the 100 kPa guideline for instantaneous overpressure is shown on Figure 14. The figure can be used as a guide to the development of alternative blast designs in areas that may by affected by instantaneous overpressures greater than 100 kPa.

The analyses indicate that through the use of lighter charge weights, decreased blasthole diameters, and decreased operating bench heights, the guideline of 100 kPa instantaneous overpressure can be achievable for substantial portions of the proposed de-watering dike system, for the charge weights considered. Figure 15 shows the 100 kPa isopleth for the charge weights considered above, and for a confinement value, k, of 800. The figure illustrates that limited lengths of the proposed dikes will be subjected to instantaneous overpressure exceeding 100 kPa. In these areas, mitigative procedures to discourage fish habitat development could be adopted, and might include the use of ‘bubbler’ systems, or alternative means such as the development of an ‘ice barrier’ to prevent fish from spawning or inhabiting specific areas.

4.0 CLOSURE

Production bench blast designs have been presented for the proposed open pits at the Meadowbank Gold Project. The blast designs have been based on standard design methods applied to the specific rock types and structure that is known to exist in the deposit areas. Designs for two blasthole sizes have been presented, 229 mm and 165 mm. Due to the strength of the iron formation and intermediate volcanic rocks, and to the nature of the structure in the proposed open pit area, a smaller blasthole size would provide better fragmentation. However, the smaller blasthole size could result in greater inaccuracy during drilling, particularly for the 12 m working bench heights proposed. The economics of a reduced blasthole diameter would need to be compared with the need to drill more blastholes due to the reduction in spacing and burden. Under these conditions, the drilling costs usually over-ride the fragmentation.

Where the development of the pit walls is beneath the de-watered lakes, wet blasthole conditions can be expected. Where the walls are developed within permafrost beneath the existing land mass, drier blasthole conditions may be encountered, although actual conditions will remain unknown until the development phase. Two charge tables have been presented: one for wet blasthole conditions using a doped emulsion of 70:30 Emulsion/AN, and the other for dry blasthole conditions using a Emulsion/AN ratio of 30:70.

Analyses indicate that Peak Particle Velocities (PPV) along portions of the upstream (lake side) face of the de-watering dikes will exceed the fish spawning habitat guideline threshold of 13 mm/s, based on operating bench height of 12 m and full charge weight. Analyses indicate that the guideline threshold of 100 kPa for instantaneous overpressure is achievable for substantial portions of the dikes for the charge weights considered.

Along portions of the dikes where fisheries guidelines are exceeded, mitigative methods may include modifications to blasting designs to incorporate lower bench heights and lighter charge weights as described above, as well as the use of ‘bubbler’ systems along the upstream face of the dikes in specific areas. These ‘bubbler’ systems could be operated during blasting to discourage fish along the upstream embankment face. Alternatively, in areas where fisheries guidelines for blasting may be exceeded, the upstream (lake side) dike width could be increased by dumping of additional rock fill material, and thereby increasing the setback distance from the blasting.

Analyses indicate that peak particle velocity thresholds of 50 mm/s for limiting damage to the dike structures may be exceeded along certain portions of the proposed dike alignments. However, the threshold of 50 mm/s is likely conservative, based on experience with other mines in the north, but is considered to be appropriate for this level of study. Furthermore, the peak particle velocities experienced by the dikes can be effectively managed, if necessary, by modifications to the blast design.

During mine development, a vibration monitoring program will be required in order to measure the response of the de-watering dikes and tailings dike to pit blasting, and to measure peak particle velocities on the upstream (lake side) of the dikes to assess the blast designs.

GOLDER ASSOCIATES LTD.

Cameron J. Clayton, P.Geo.
Mining Group

Reviewed By:

W.W. (Bill) Forsyth, P.Eng.
Principal

CJC/WWF/vee
03-1413-427

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REFERENCES

Atlas Powder Company. **Explosives and Rock Blasting.** Field Technical Operations, Atlas Powder Company, Dallas, Texas, 1987.

Charlie, W. A., Doehring, D. O., and Lewis, W.A. (1987). "Explosive Induced Damage Potential to Earthfill Dams and Embankments", Proc. 13th Conference on Explosives and Blasting Technique, Society of Explosives Engineers, Annual Meeting, Feb. 1-6, Miami.

Cunningham, Claude. "The Kuz-Ram Model for Prediction of Fragmentation from Blasting", First International Symposium on Rock Fragmentation by Blasting, Lulea, Sweden, 1983.

Cunningham, Claude. "Fragmentation Estimations and the Kuz-Ram Model – Four Years On", 1987.

Golder Associates Ltd. **Pre-Feasibility Geotechnical Studies, Third Portage Deposit, Meadowbank Gold Project, Northwest Territories**. Report, February, 1999.

Golder Associates Ltd. **1997 Geotechnical Investigations, Meadowbank Gold Project, Northwest Territories**. Report, December, 1997.

Golder Associates Ltd. **Goose Island Pit Slope Design Criteria**. Technical Memorandum, July, 2003.

Golder Associates Ltd. **North Portage Pit Slope Design Criteria**. Technical Memorandum, October, 2003.

Golder Associates Ltd. **Third Portage Pit Slope Design Criteria**. Technical Memorandum, December, 2003.

Golder Associates Ltd. **Vault Pit Slope Design Criteria**. Technical Memorandum, January, 2004.

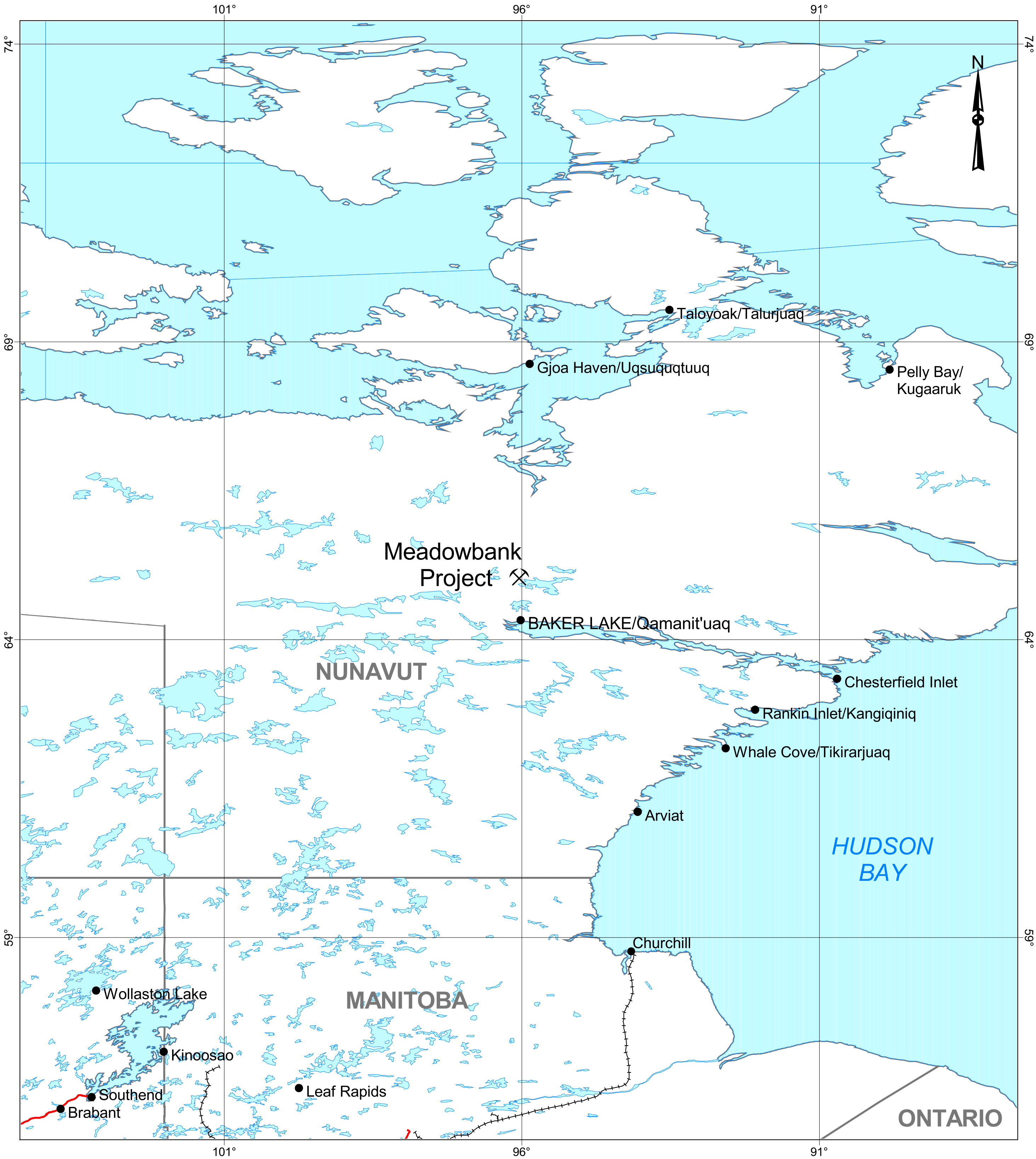
Golder Associates Ltd. **Preliminary Estimates of Peak Particle Velocity Along Meadowbank Dikes**. Technical Memorandum, November, 2003.

Golder Associates Ltd. **Summary of Rock Quality and Estimates of In-Situ Deformation Modulus and Pit Inflows – Portage Pit Area.** Technical Memorandum, October, 2003.

Hoek, E., and Bray, J.W. **Rock Slope Engineering**, Revised 3rd Edition, Institution of Mining and Metallurgy, London, 1981.

Hoek, E. and Brown, E.T. "Practical Estimates of Rock Mass Strength", International Journal of Rock Mechanics and Mining Sciences, 1997?.

Lilly, P.A. "An Empirical Method of Assessing Rock Mass Blastability", Large Open Pit Mining Conference, Newman, Australia, 1986.



LEGEND

- Meadowbank Project
- Town/Village
- Provincial Border
- Water
- Primary Highway
- Railroad

REFERENCE

Base digital data obtained from ESRI Inc.,
DATUM: WGS84 PROJECTION: Geographic

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TITLE	LOCATION PLAN MEADOWBANK PROJECT				
Golder Associates	PROJECT No. 03-1413-427			SCALE AS SHOWN	REV. 0
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	GIS	CDB	19 Dec. 2003		
	CHECK	CJC	19 Dec. 2003		
	REVIEW				

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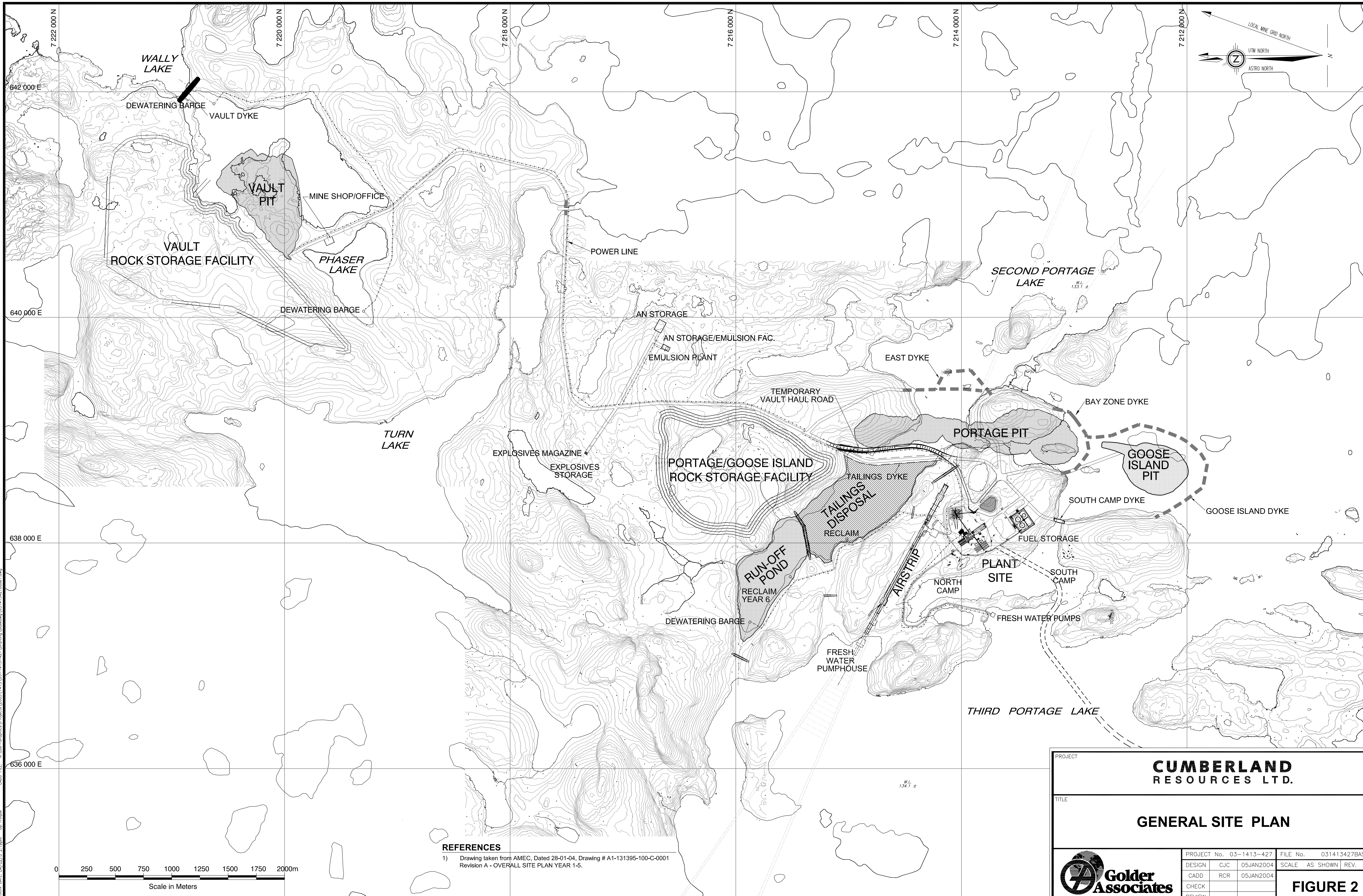

REFERENCES

1) Drawing taken from AMEC, Dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

GENERAL SITE PLAN

Golder Associates

PROJECT No. 03-1413-427			FILE No. 031413427BASE1
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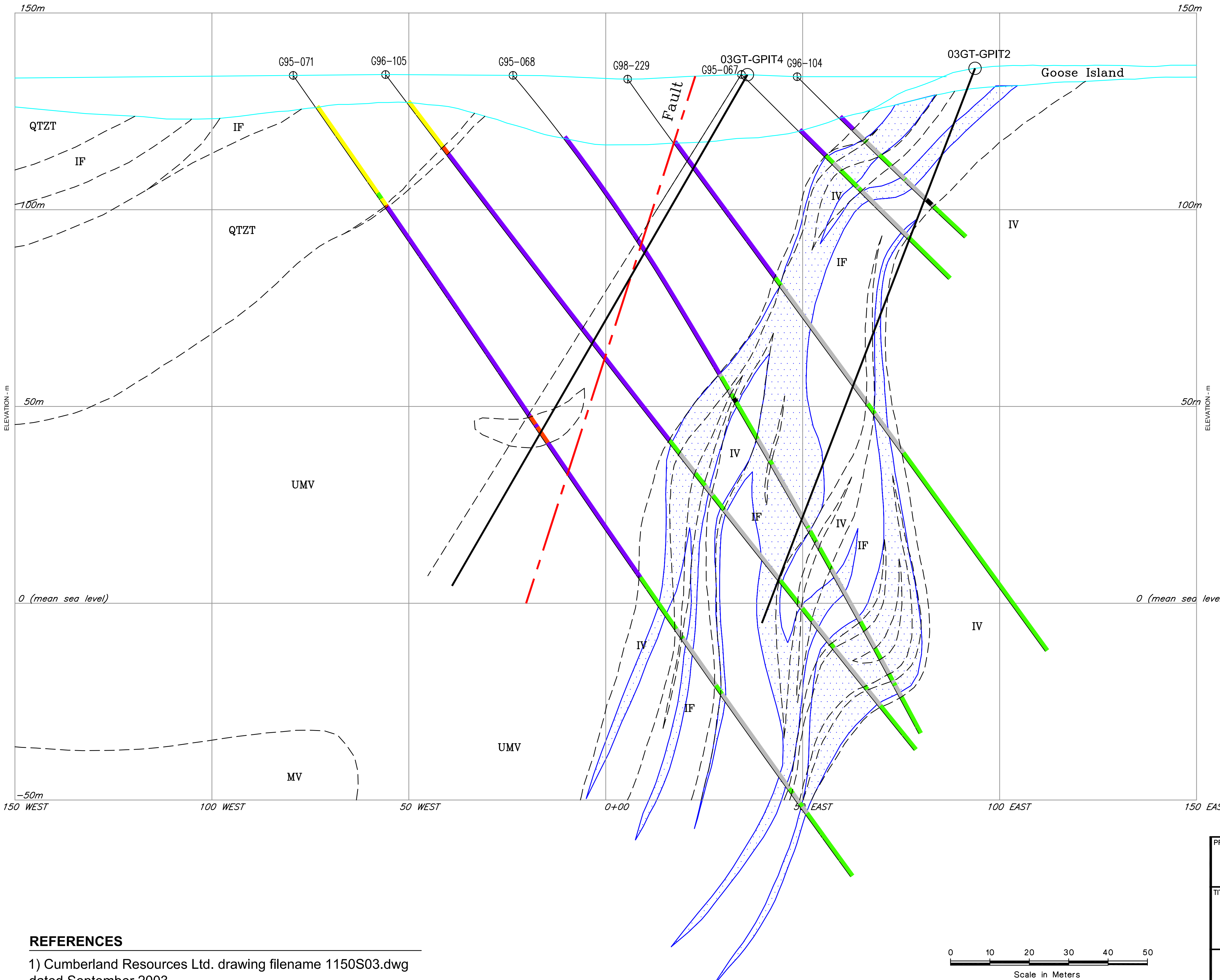
CHECK			**FIGURE 2**
REVIEW			



LEGEND

LITHOLOGY : ROCK TYPE

- IF*: iron formation
  - QM: chert > magnetite
  - MQ: magnetite > chert
- IVchl: vfg-aphanitic chl-rich sediment (transition between clastic & chemical sediments, correlates with IFQM/IFMQ along strike)
- IV*: intermediate volcaniclastics
  - c: chlorite alteration
  - cs: chlorite/sericite alteration
  - sc: sericite/chlorite alteration
- IVs: intermediate volcaniclastics, strong sericite alteration
- IVs(sil): IVs with silicification
- IVbio: intermediate volcaniclastics, biotite alteration
- IVlt: intermediate volcaniclastics, lapilli tuff
- QIVT: quartz-eye intermediate volcanic tuff
- IVT: tuffaceous felsic volcaniclastics, lapilli tuff (grain size > 2mm)
- FV: felsic volcaniclastics
- IVA: intermediate polymictic agglomerate, fragments & clasts > 4cm
- QV: quartz vein
- QCV: quartz carbonate vein
- QCCV: quartz calcite vein
- FD: felsic dyke
- QFP: quartz-feldspar porphyry
- FQP: feldspar-quartz porphyry
- QP: quartz porphyry
- FP: feldspar porphyry
- GR: granite
- QTZT: quartzite
- QPC: quartz pebble conglomerate
- LAMP: lamprophyre dyke
- CB: carbonate
- Chert: chert
- MYL: mylonite
- MV: mafic volcanic
- UM*: ultramafic volcanics
  - A: actinolitic
  - S: serpentinized
  - V: massive flow
  - f: foliated
- FLT: fault
- ORE SHELL

REFERENCES

1) Cumberland Resources Ltd. drawing filename 1150S03.dwg dated September 2003.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

GOOSE ISLAND
TYPICAL CROSS SECTION
SECTION 11+50S

Golder Associates

PROJECT No. 03-1413-427			FILE No. 031413427SK03	
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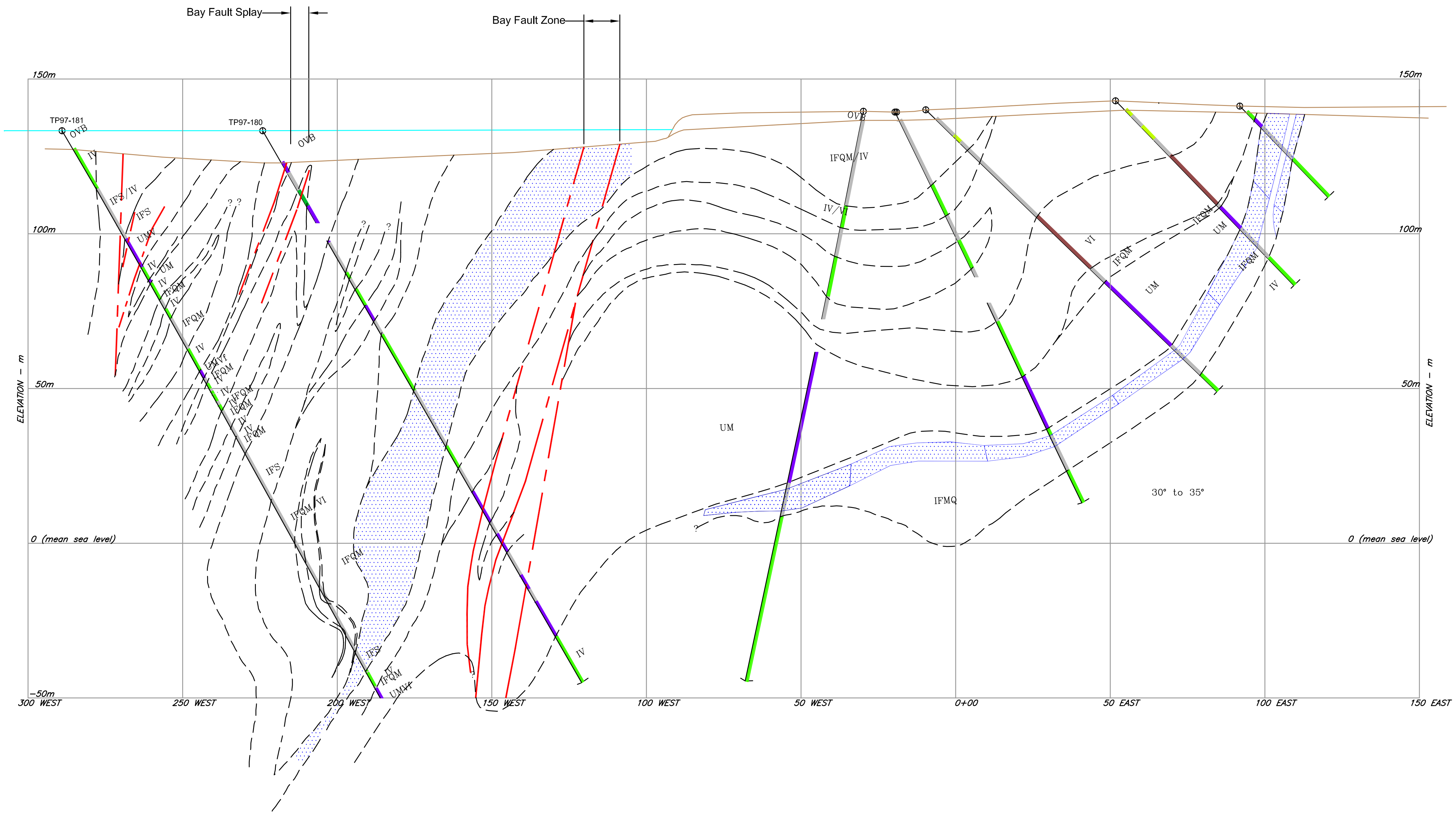

LEGEND

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- IVbio: intermediate volcaniclastics, biotite alteration
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- QCV: quartz carbonate vein
- QCCV: quartz calcite vein
- FD: felsic dyke
- QFP: quartz-feldspar porphyry
- FQP: feldspar-quartz porphyry
- QP: quartz porphyry
- FP: feldspar porphyry
- GR: granite
- QTZT: quartzite
- QPC: quartz pebble conglomerate
- LAMP: lamprophyre dyke
- CB: carbonate
- Chert: chert
- MYL: mylonite
- MV: mafic volcanic
- UM*: ultramafic volcanics
  - A: actinolitic
  - S: serpentinized
  - V: massive flow
  - f: foliated
- FLT: fault
- ORE SHELL

REFERENCES

1) Cumberland Resources Ltd. drawing filename 120SF99.dwg dated March 30, 2003.

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PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

THIRD PORTAGE DEPOSIT TYPICAL CROSS SECTION SECTION 1+20S

Golder Associates

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CHECK	CJC	27 JAN 04	FIGURE 4	
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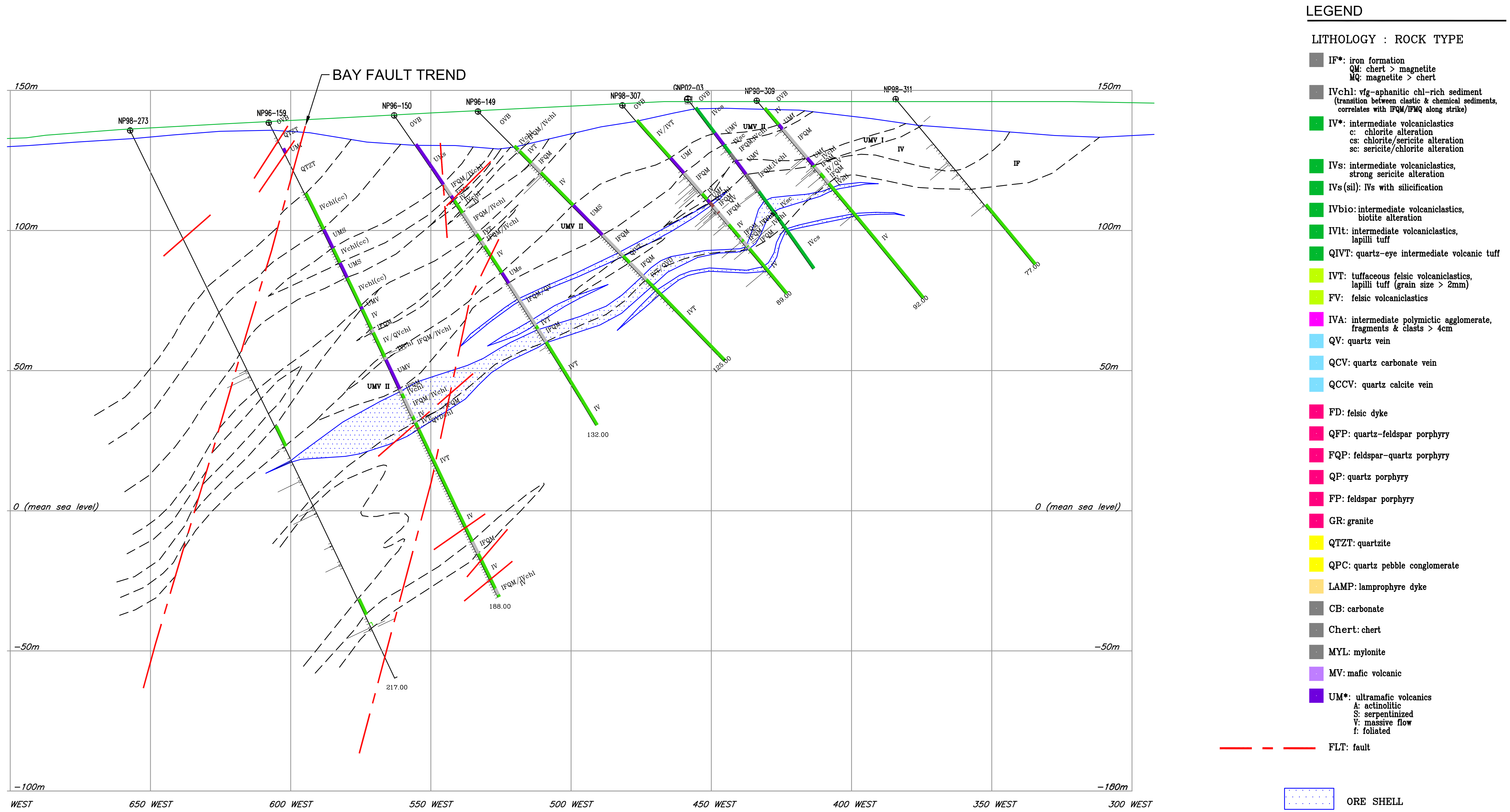

REFERENCES

1) Cumberland Resources Ltd. drawing filename 1225N02.dwg dated April 22, 2003.

PROJECT
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TITLE
NORTH PORTAGE DEPOSIT TYPICAL CROSS SECTION SECTION 12+25N

Golder Associates

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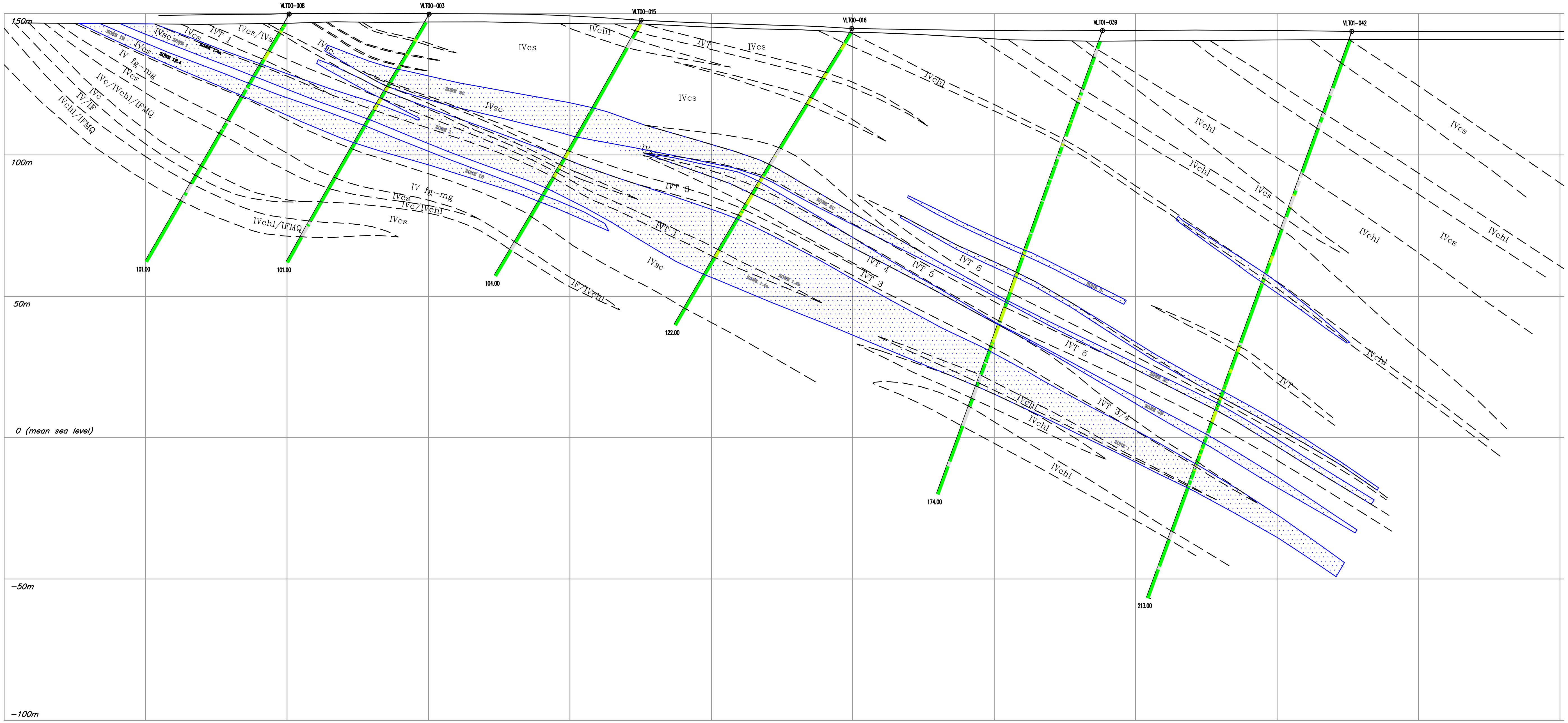

LEGEND

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  - c: chlorite alteration
  - cs: chlorite/sericite alteration
  - sc: sericite/chlorite alteration
- IVs: intermediate volcanoclstics, strong sericite alteration
- IVs(sil): IVs with silicification
- IVT: tuffaceous intermediate volcanoclstics (grain size > 2mm)
- IVA: intermediate polymictic agglomerate, fragments & clasts > 4cm
- QIVT: quartz-eye volcanic tuff
- QV: quartz vein
- FD: felsic dyke
- QFP: quartz-feldspar porphyry
- UM*: ultramafic volcanics
  - A: actinolitic
  - S: serpentinized
  - V: massive flow
  - f: foliated
- ORE SHELL

REFERENCES

1) Cumberland Resources Ltd. drawing filename 4675NO1.dwg dated December 6, 2001.

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PROJECT: CUMBERLAND RESOURCES LTD.

TITLE: VAULT DEPOSIT TYPICAL CROSS SECTION SECTION 46+75N

Golder Associates

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CADD	SRR	27 JAN 04	
CHECK	CJC	27 JAN 04	FIGURE 6
REVIEW			

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By: sreddy

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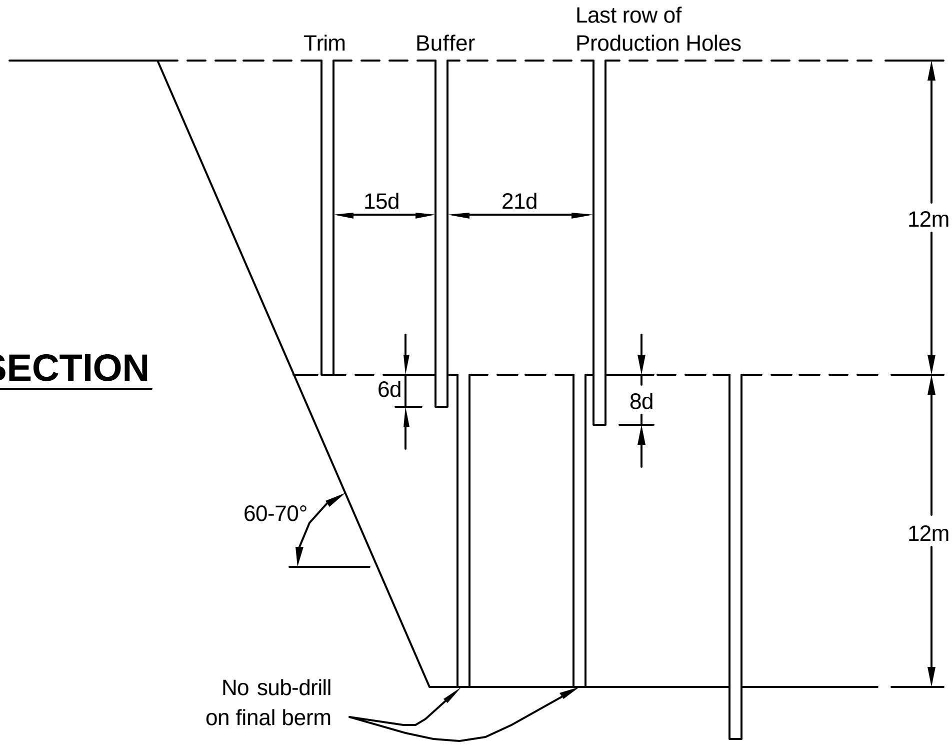

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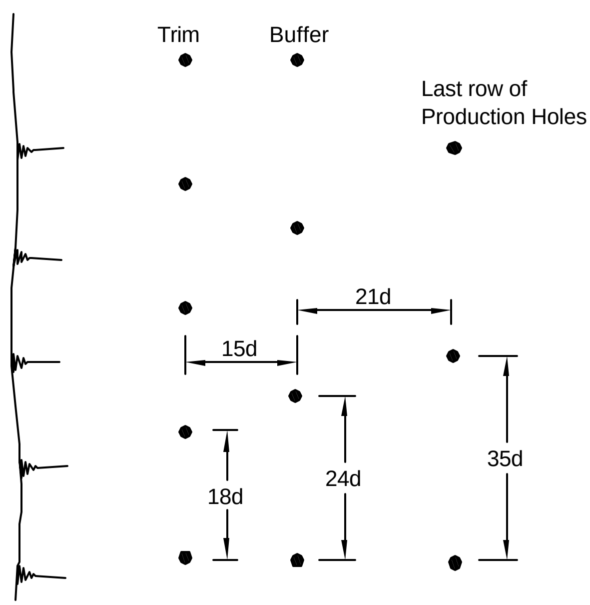
PRODUCTION	100	30d 6.9m 5.0m	35d 7.9m 5.7m
BUFFER	67	21d 4.8m 3.5m	24d 5.5m 4.0m
TRIM	33	15d 3.4m 2.5m	18d 4.1m 3.0m

PLAN



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PROJECT

CUMBERLAND RESOURCES LTD.

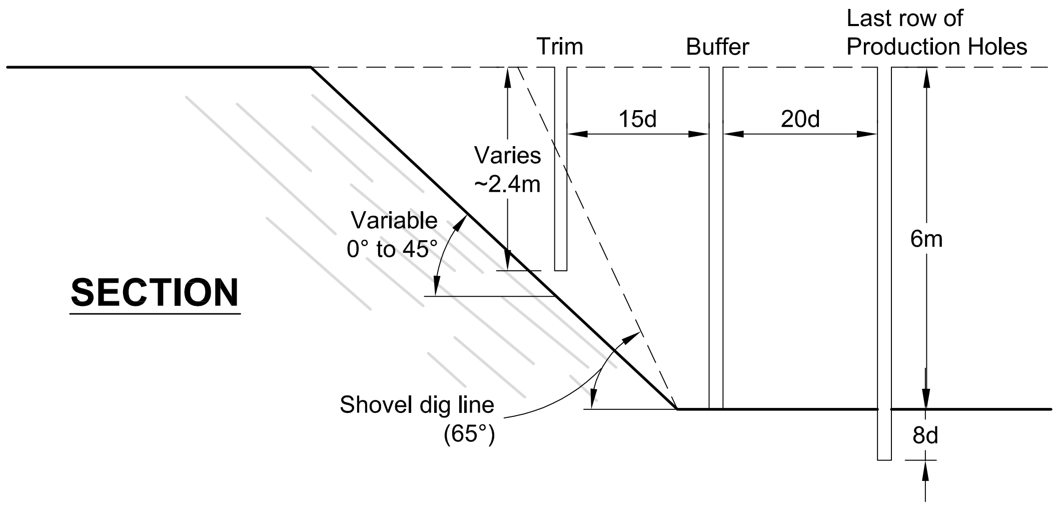
TITLE

CONCEPTUAL CONTROLLED BLAST DESIGN GENERAL CONFIGURATION

Golder Associates

PROJECT No. 03-1413-427			FILE No.	P427-01
DESIGN	CJC	02DEC03	SCALE AS SHOWN	REV. A
CADD	SS	02DEC03		
CHECK	CJC	02DEC03	**FIGURE 7**	
REVIEW				

SECTION



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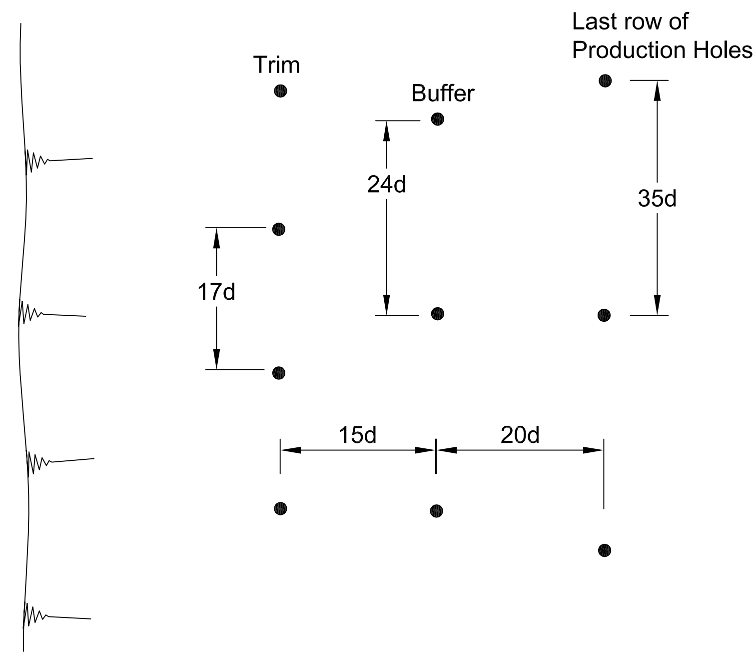
			d = 229	d = 165		d = 229	d = 165
PRODUCTION	100	30d	6.9m	5.0m	35d	8.0m	5.8m
BUFFER	67	20d	4.6m	3.3m	24d	5.5m	4.0m
TRIM	33	15d	3.4m	2.5m	17d	3.9m	2.8m

PLAN



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PROJECT
CUMBERLAND RESOURCES LTD.

TITLE
CONCEPTUAL CONTROLLED BLAST DESIGN FOR SHALLOW DIPPING ORE

Golder Associates

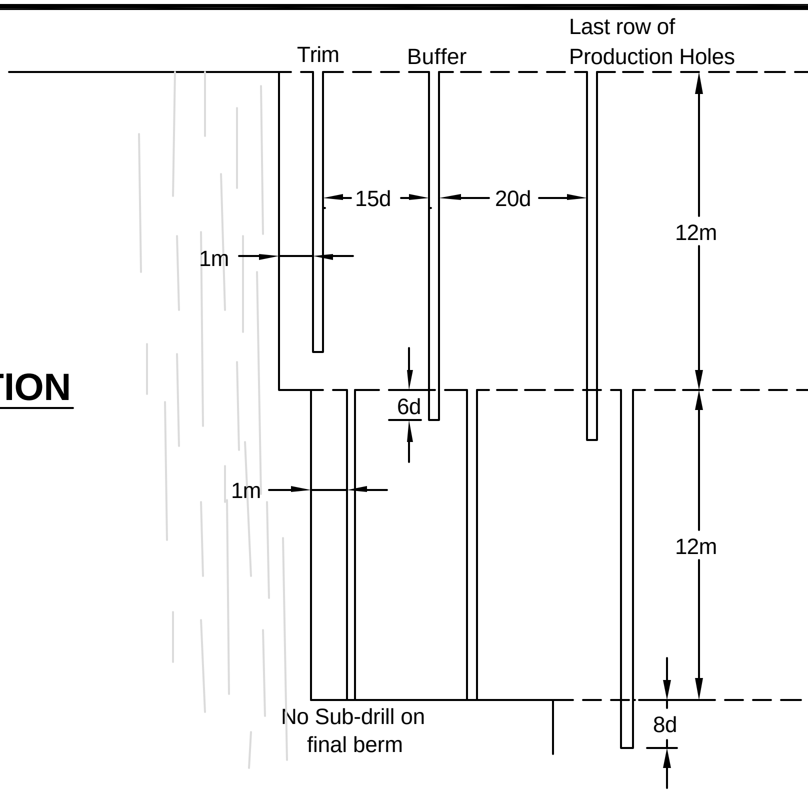
PROJECT No.	03-1413-427	
DESIGN	CJC	02DEC03
CADD	SS	02DEC03
CHECK	CJC	02DEC03
REVIEW		

FILE No. P421-01
SCALE AS SHOWN | REV. A

FIGURE 8

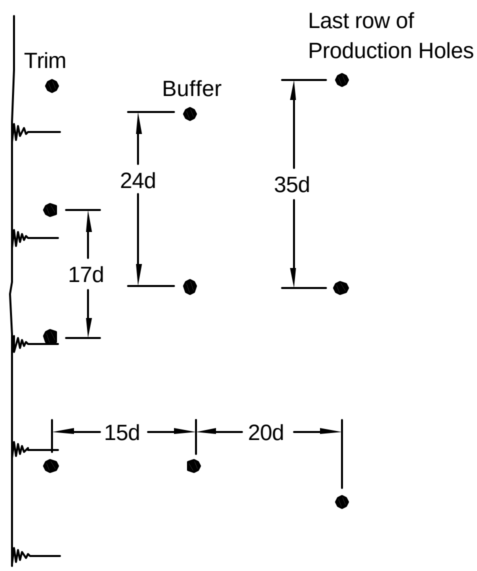
REVISION DATE: 04\02\11 By: sskermer CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\P427-01.dwg

SECTION



APPROXIMATE BLAST CONFIGURATION							
	CHARGE (%)	BURDEN	d = 229	d = 165	SPACING	d = 229	d = 165
PRODUCTION	100	30d	6.9m	5.0m	35d	8.0m	5.8m
BUFFER	67	20d	4.6m	3.3m	24d	5.5m	4.0m
TRIM	33	15d	3.4m	2.5m	17d	3.9m	2.8m

PLAN



SCHEMATIC ONLY
Not to Scale

PROJECT
CUMBERLAND RESOURCES LTD.

TITLE
CONCEPTUAL CONTROLLED BLAST DESIGN IN AREAS OF POTENTIAL TOPPLING

Golder Associates

PROJECT No. 03-1413-427			FILE No. P427-01	
DESIGN	CJC	02DEC03	SCALE AS SHOWN	REV. A
CADD	SS	02DEC03	**FIGURE 9**	
CHECK	CJC	02DEC03		
REVIEW				

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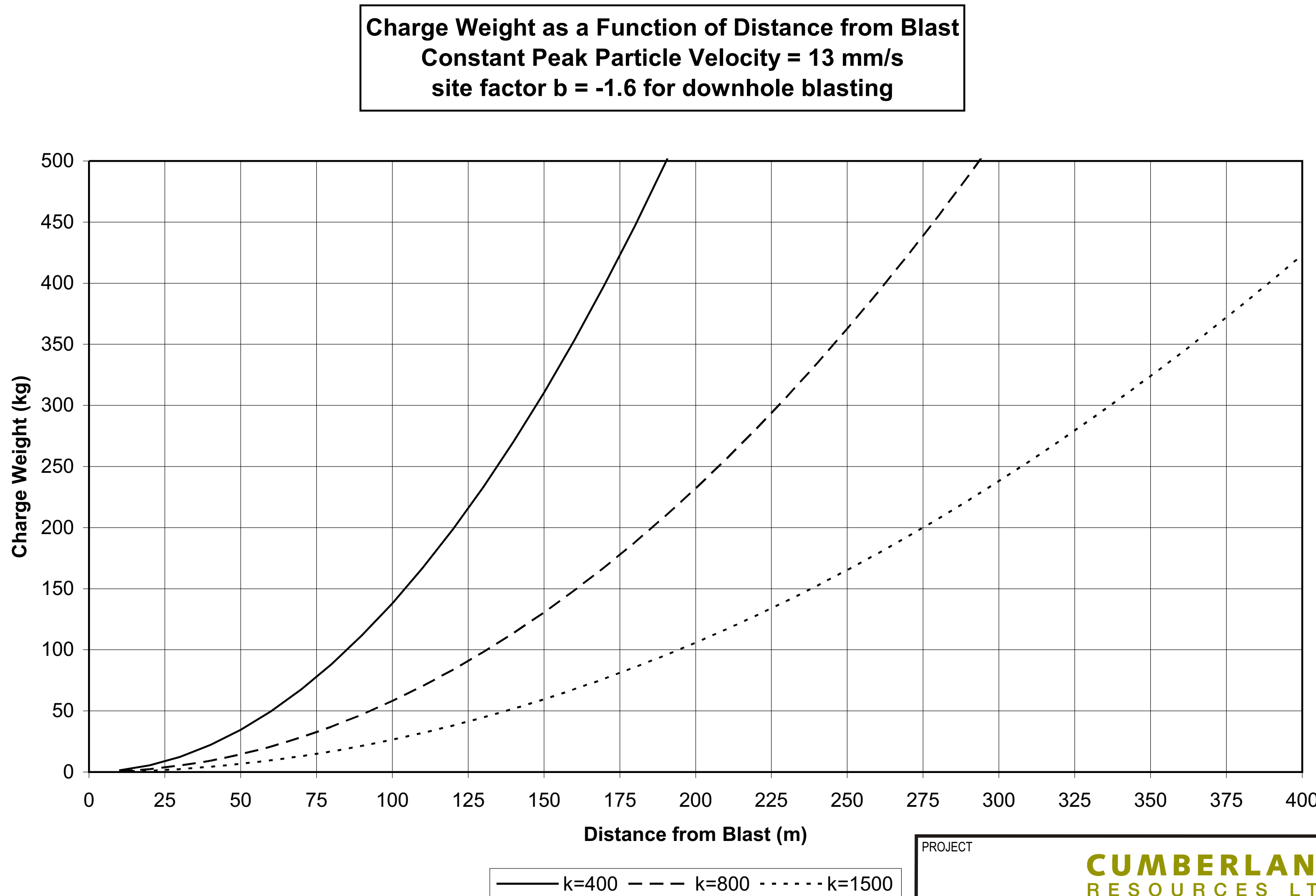

PROJECT	CUMBERLAND RESOURCES LTD.				
TITLE	CHARGE WEIGHT vs DISTANCE FROM BLAST - PPV = 13mm/s				
Golder Associates	PROJECT No.	03-1413-427		FILE No.	FIGURE 3
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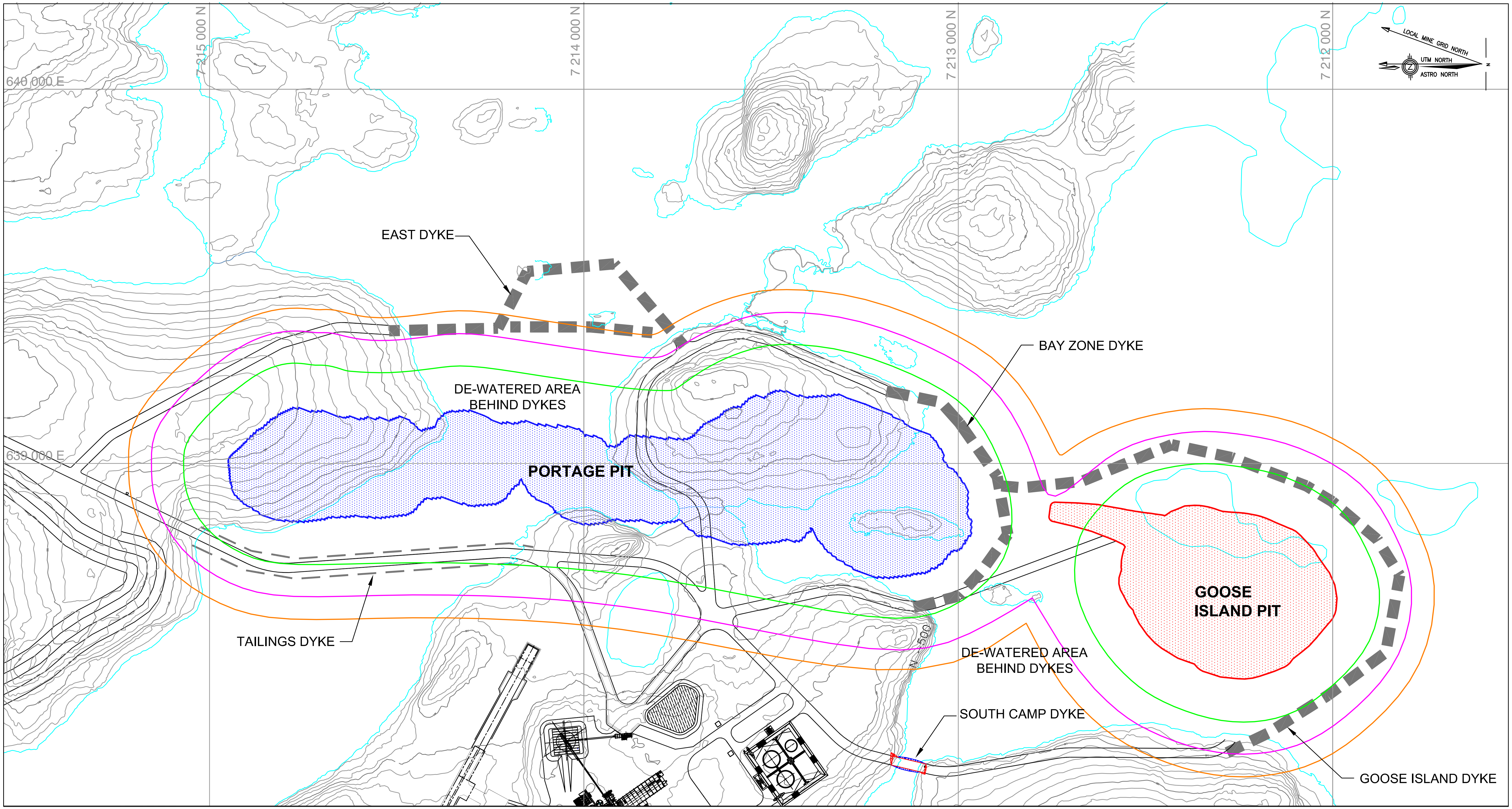
	REVIEW				



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By: sreddy

REVISION DATE: 04/01/27 4:46pm

LEGEND

green line	86 kg Charge Weight, 122m Offset
magenta line	250 kg Charge Weight, 208m Offset
orange line	420 kg Charge Weight, 269m Offset

Confinement, k = 800

NOTES

1) Area behind dykes is de-watered during operations.

REFERENCES

1) Drawing taken from AMEC, dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

0 100 200 300 400 500

Scale in Meters

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

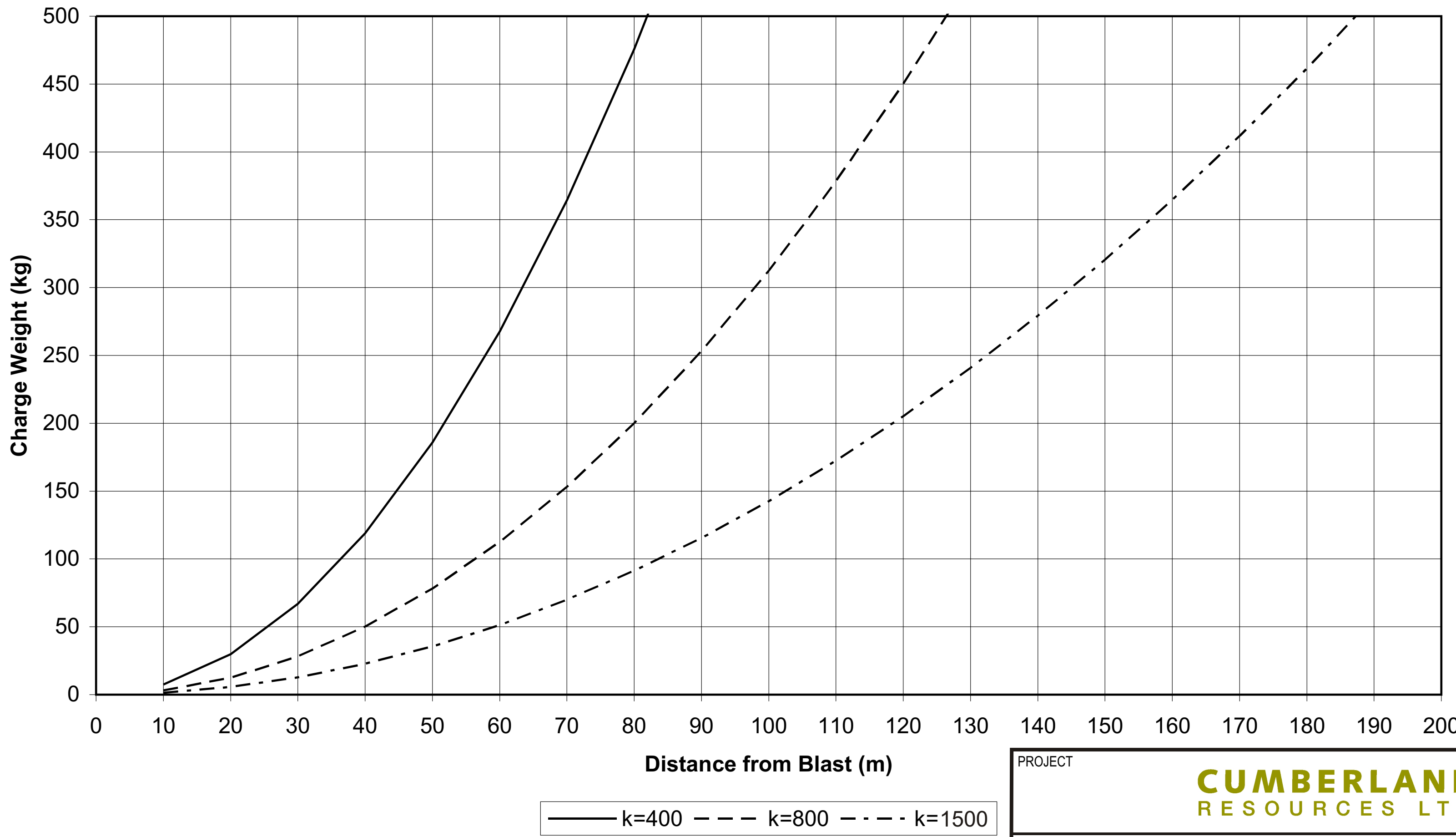
PEAK PARTICLE VELOCITY
13 mm/s ISOPLETH

Golder Associates

PROJECT No.	03-1413-427		FILE No.	031413427SK11
DESIGN	CJC	23 JAN 04	SCALE AS SHOWN	REV. A
CADD	SRR	27 JAN 04		
CHECK	CJC			
REVIEW				

FIGURE 11

Charge Weight as a Function of Distance from Blast
Constant Peak Particle Velocity = 50 mm/s
site factor b = -1.6 for downhole blasting



PROJECT	CUMBERLAND RESOURCES LTD.				
TITLE	CHARGE WEIGHT vs DISTANCE FROM BLAST - PPV = 50mm/s				
Golder Associates	PROJECT No.	03-1413-427		FILE No. FIGURE 3	
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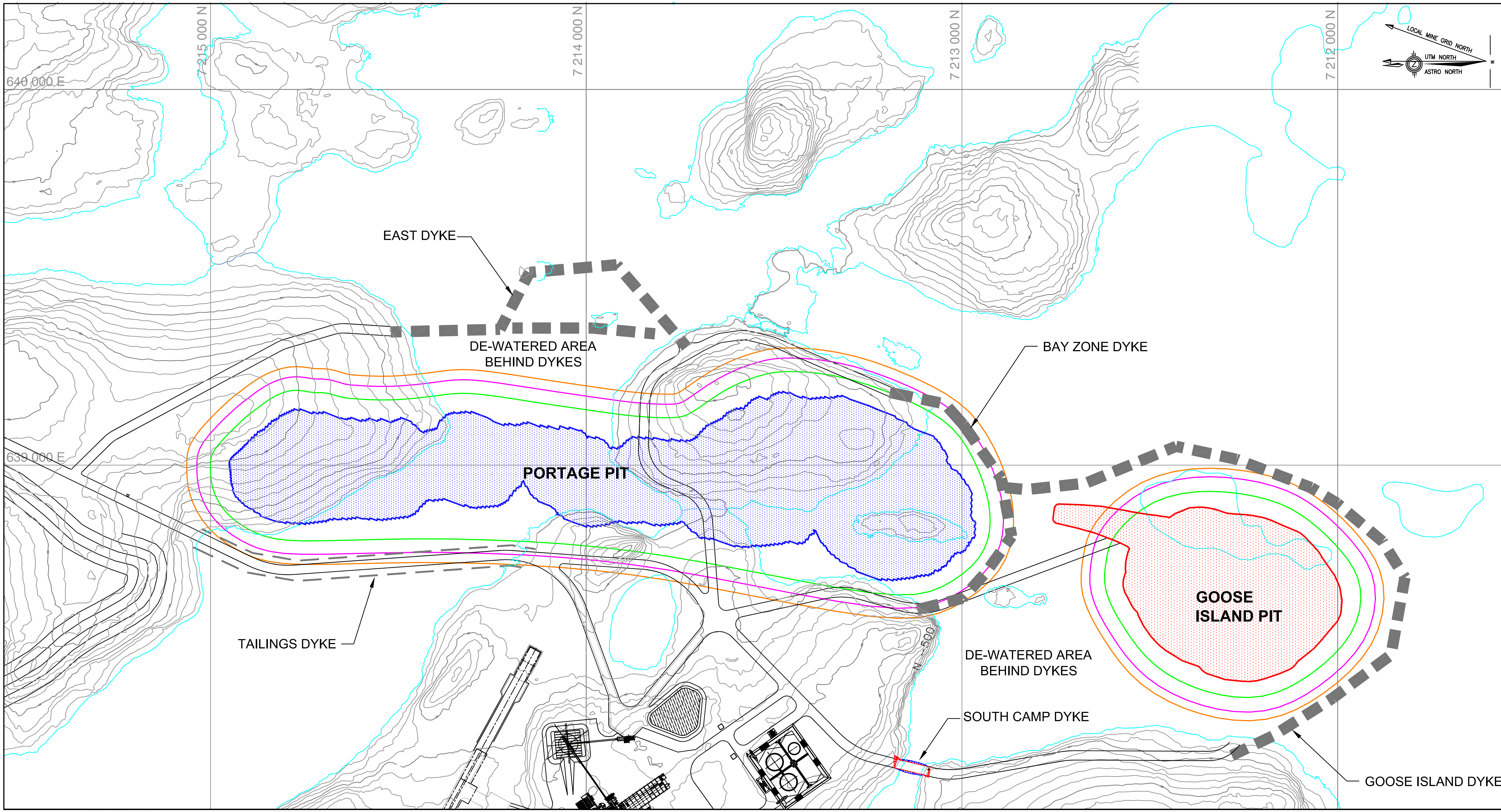
	REVIEW				



LEGEND

- 86 kg Charge Weight, 53m Offset
- 250 kg Charge Weight, 89m Offset
- 420 kg Charge Weight, 116m Offset

Confinement, k = 800

NOTES

1) Area behind dykes is de-watered during operations.

0 100 200 300 400 500

Scale in Meters

REFERENCES

1) Drawing taken from AMEC, dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

PEAK PARTICLE VELOCITY 50 mm/s ISOPLETH

Golder Associates

PROJECT No.	03-1413-427	FILE No.	031413427SK13
DESIGN	CJC 23 JAN 04	SCALE AS SHOWN	REV. A
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CHECK	CJC	FIGURE 13	
REVIEW			

REVISION DATE: 04/01/27 4:46pm By: sreddy CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\031413427SK13.dwg

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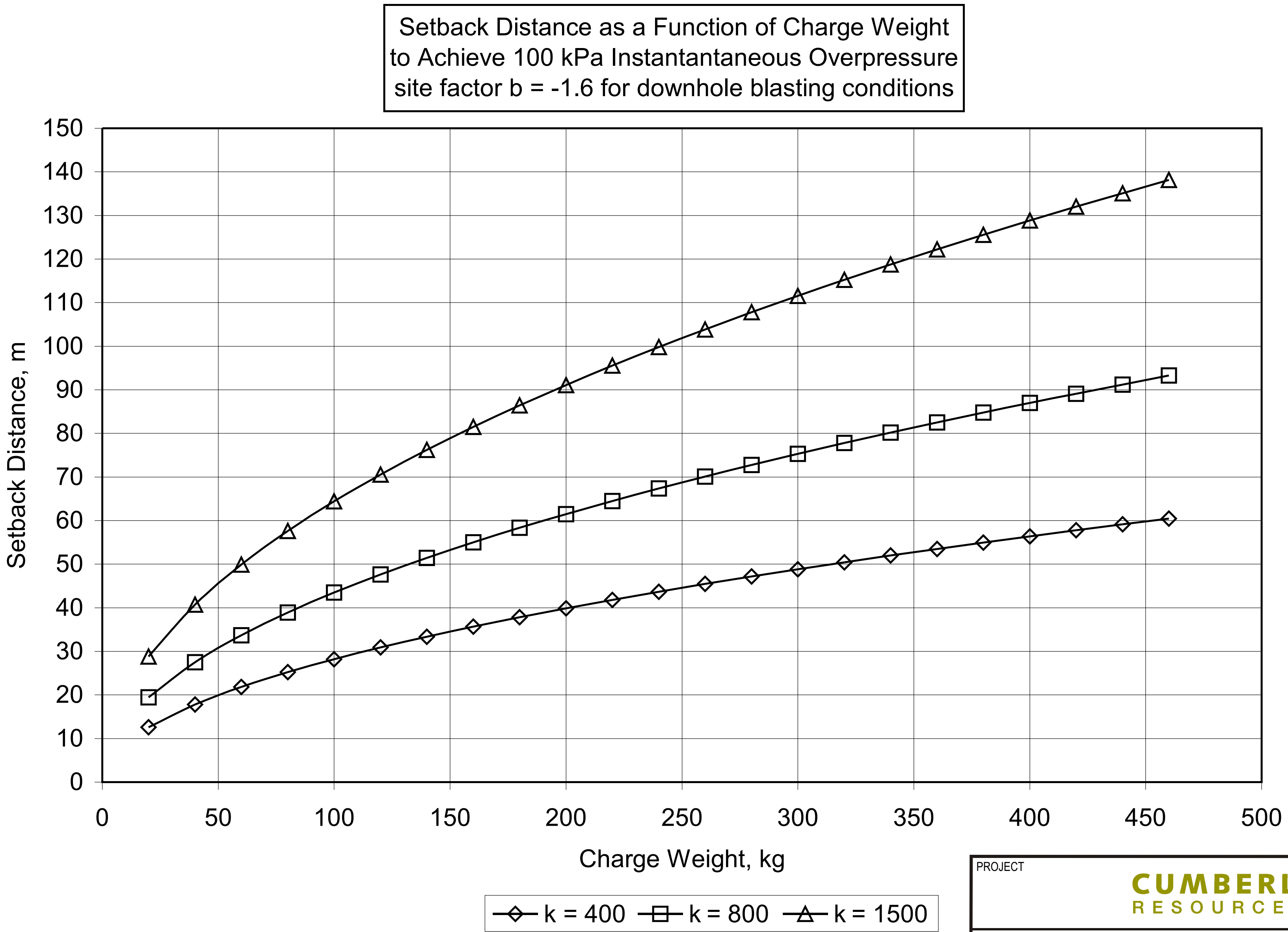


PROJECT

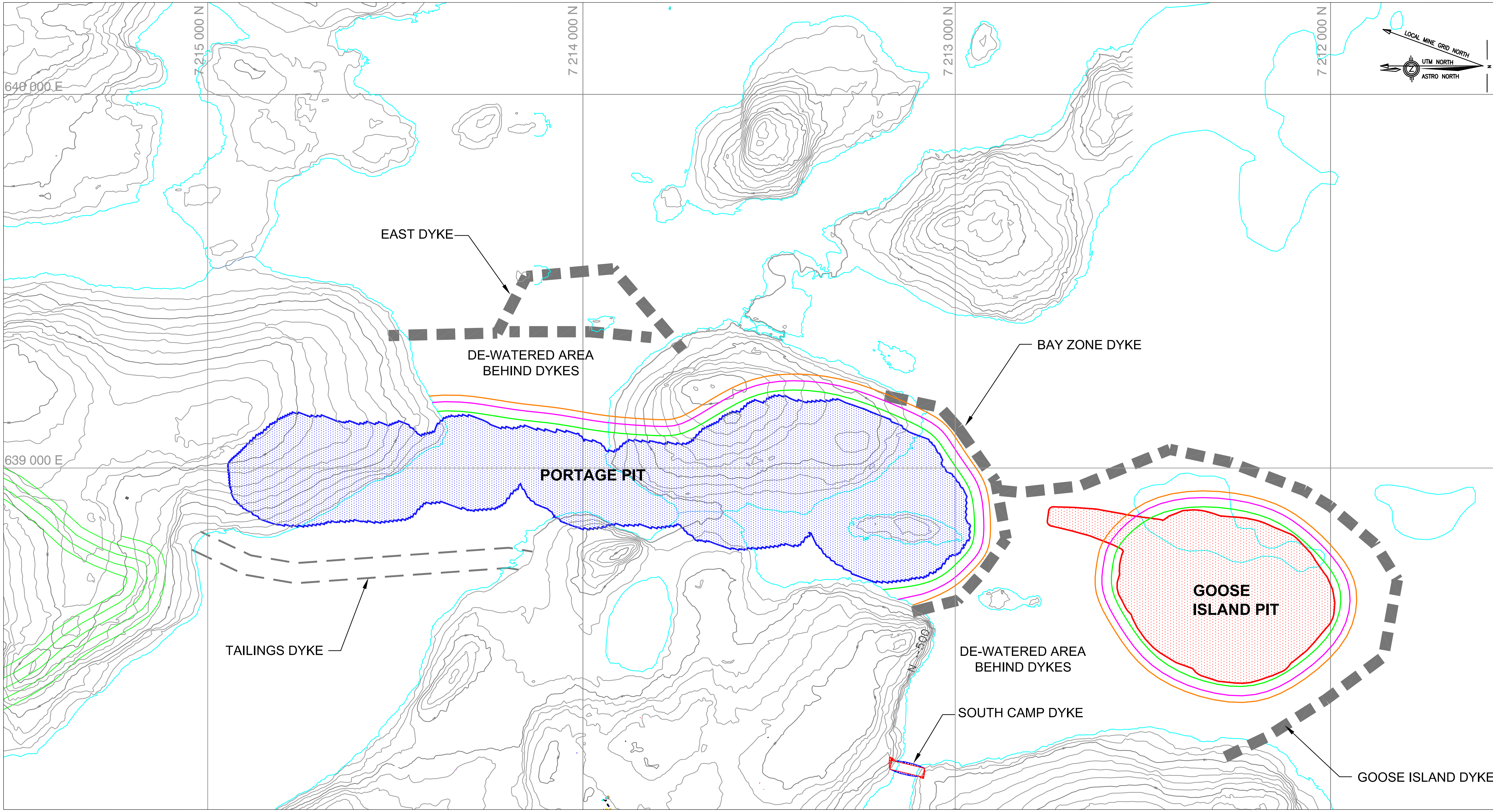
CUMBERLAND
RESOURCES LTD.

TITLE

CHARGE WEIGHT vs SETBACK DISTANCE FOR 100 kPA OVERPRESSURE

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 3	
DESIGN	CJC	28JAN04	SCALE	REV.
CADD	SS	28JAN04	**FIGURE 14**	
CHECK	CJC	28JAN04		
REVIEW				



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REVISION DATE: 04/01/27 4:04pm By: sreddy

LEGEND

86 kg Charge Weight, 40m Offset

250 kg Charge Weight, 69m Offset

420 kg Charge Weight, 89m Offset

Confinement, k = 800

NOTES

1) Area behind dykes is de-watered during operations.

0 100 200 300 400 500

Scale in Meters

REFERENCES

1) Drawing taken from AMEC, dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

INSTANTANEOUS OVERPRESSURE 100kPa ISOPLETH

Golder Associates

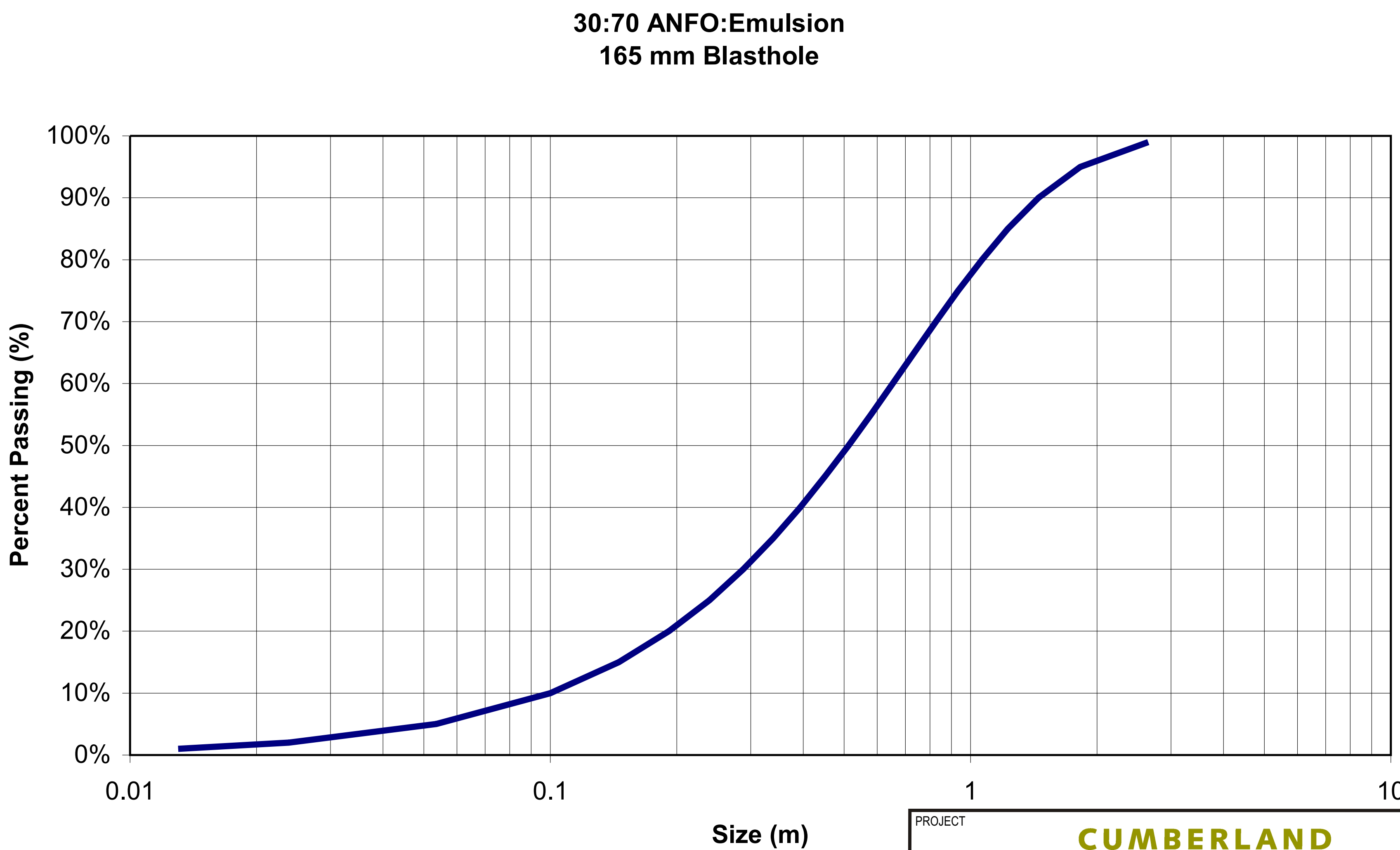
PROJECT No.	03-1413-427		FILE No.	031413427SK15
DESIGN	CJC	23 JAN 04	SCALE AS SHOWN	REV. A
CADD	SRR	27 JAN 04		
CHECK	CJC			
REVIEW				

FIGURE 15

APPENDIX I

FRAGMENTATION PREDICTIONS

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 3.cdr



PROJECT

CUMBERLAND RESOURCES LTD.

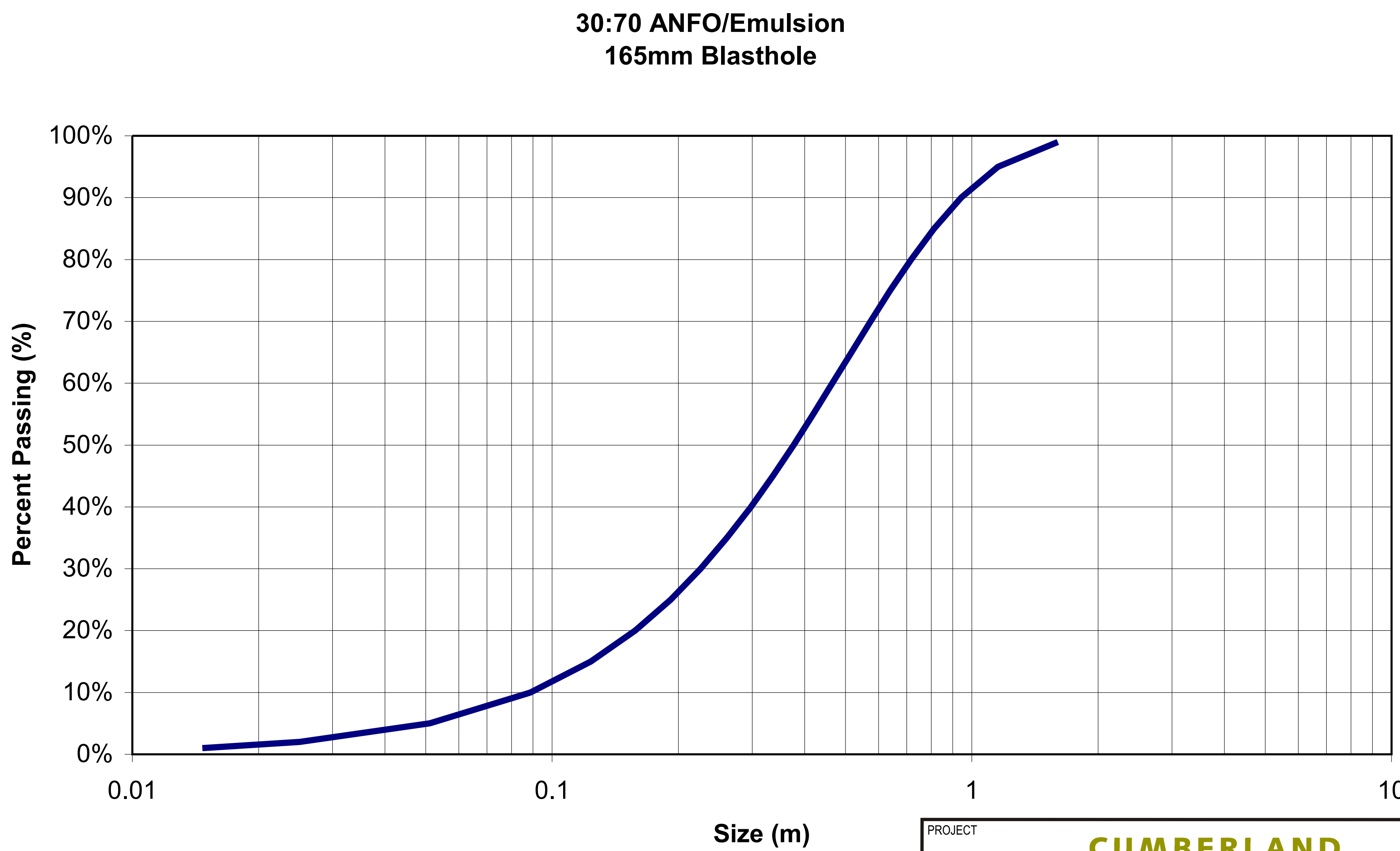
TITLE

IRON FORMATION
FRAGMENTATION PREDICTION
6m BENCH - 165mm BLASTHOLE

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 3	
DESIGN	CJC	28JAN04	SCALE	REV.
CADD	SS	28JAN04	FIGURE I-1	
CHECK	CJC	28JAN04		
REVIEW				

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 3.cdr



PROJECT

CUMBERLAND RESOURCES LTD.

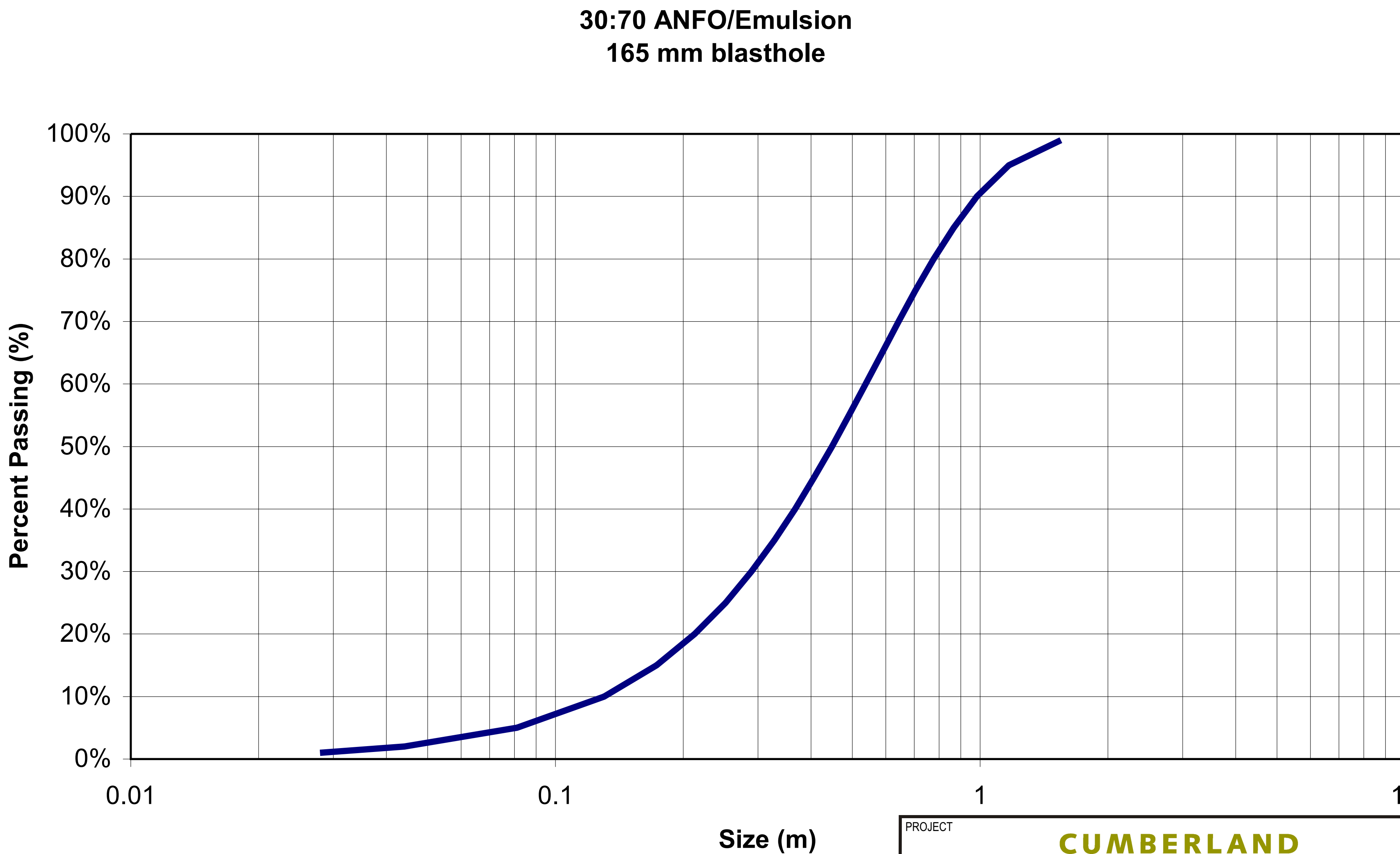
TITLE

ULTRAMAFIC VOLCANIC
FRAGMENTATION PREDICTION
12m BENCH - 165mm BLASTHOLE

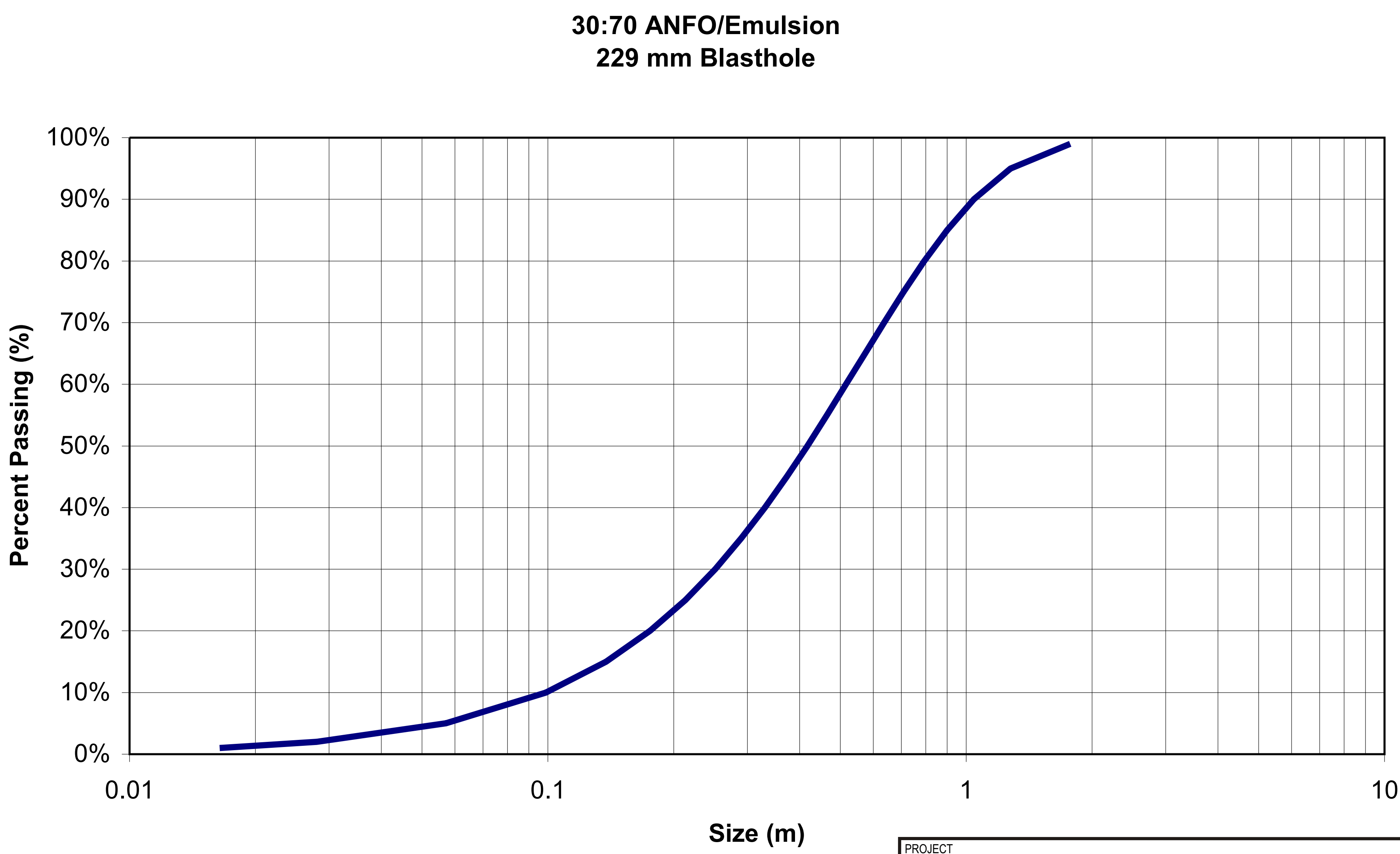
Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 3	
DESIGN	CJC	28JAN04	SCALE	REV.
CADD	SS	28JAN04	FIGURE I-2	
CHECK	CJC	28JAN04		
REVIEW				

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 3.cdr



PROJECT	CUMBERLAND RESOURCES LTD.			
TITLE	INTERMEDIATE VOLCANIC FRAGMENTATION PREDICTION 12m BENCH - 165mm BLASTHOLE			
Golder Associates	PROJECT No.	03-1413-427		FILE No. FIGURE 3
	DESIGN	CJC	28JAN04	SCALE / REV.
	CADD	SS	28JAN04	FIGURE I-3
	CHECK	CJC	28JAN04	
	REVIEW			



PROJECT	CUMBERLAND RESOURCES LTD.				
TITLE	ULTRAMAFIC VOLCANIC FRAGMENTATION PREDICTION 12m BENCH - 229mm BLASTHOLE				
Golder Associates	PROJECT No.	03-1413-427		FILE No. FIGURE 3	
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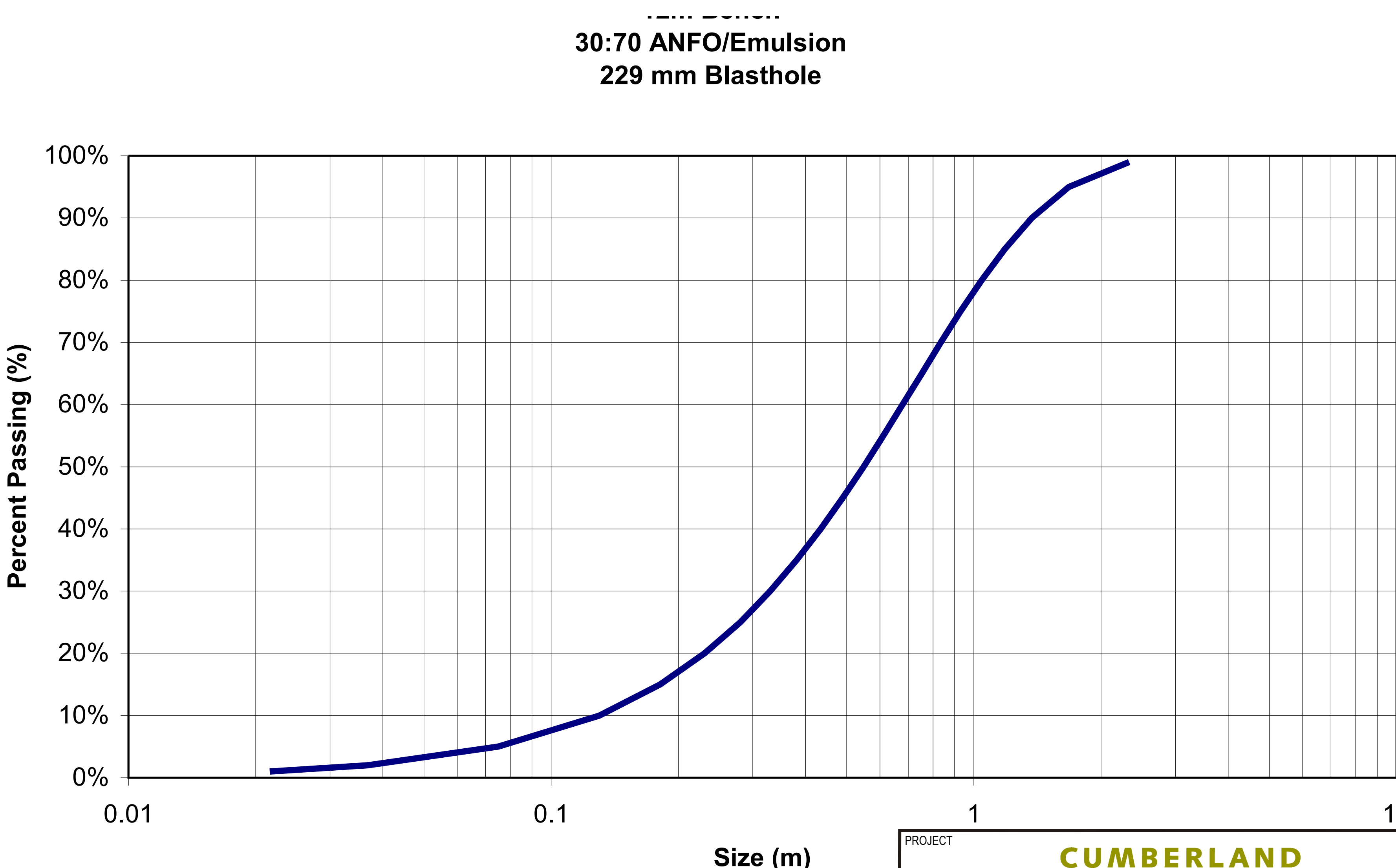
	CADD	SS	28JAN04	FIGURE I-4	
	CHECK	CJC	28JAN04		
	REVIEW				



PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

INTERMEDIATE VOLCANIC FRAGMENTATION PREDICTION 12m BENCH - 229mm BLASTHOLE

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 3	
DESIGN	CJC	28JAN04	SCALE	REV.
CADD	SS	28JAN04	**FIGURE I-5**	
CHECK	CJC	28JAN04		
REVIEW				

Golder Associates Ltd.

500 – 4260 Still Creek Drive
Burnaby, British Columbia, Canada V5C 6C6
Telephone (604) 296-4200
Fax (604) 298-5253

May 25, 2004 03-1413-427/4300

Cumberland Resources Ltd.
Suite 950, One Bentall Centre
505 Burrard Street
Vancouver, BC
V7X-1M4

Attention: Mr. Brad Thiele

RE: BLASTING REPORT ADDENDUM

Dear Mr. Thiele:

1.0 INTRODUCTION

This document is an Addendum to a more detailed report titled "Blast Design, Meadowbank Gold Project, Nunavut" issued February 10, 2004, and should be read in conjunction with that report.

A request was made by Cumberland Resources to consider the use of 3-m high benches and 76-mm (3") diameter for blasting both ore and waste at the Meadowbank Project. It is understood that issues related to grade control and blasting vibrations are the primary driving influences behind the use of smaller diameter blastholes with lower bench heights.

2.0 EXPLOSIVE TYPE

The explosive selected for blasting with the larger diameter holes would not be suitable for use with the smaller diameter blastholes due to sensitivity issues. Consequently, a more sensitive emulsion product will be required. The emulsion product would have to be sensitized (either with gas, micro-balloons or with small amounts of a molecular explosive) to ensure detonation in the smaller diameter blastholes. This will increase the cost of the explosive product. The product would be pumped directly to the bottom of the blastholes.

The following table summarizes typical properties of sensitized emulsion products.

Table 1: Typical Properties of Sensitized ANFO/Emulsion Mixtures for Small Diameter Blastholes

ANFO (%)	Emulsion (%)	Density (g/cc)	Velocity of Detonation (m/s)	RWS/RBS	Minimum Diameter (mm)	Water Resistance	Loading
	100	1.20	5700	77/113	75	Excellent	Pump
20	80	1.23	5400	82/123	90	Excellent	Pump
30	70	1.24	4800	84/127	100	Excellent	Pump
50	50	1.27	4700	93/130	125	Good	Auger

Reference: Dyno Nobel, Inc.

3.0 PRODUCTION BLAST DESIGN

The following tables summarize blast designs developed for the smaller blasthole diameter, lower bench height, and a straight emulsion product.

Table 2: Blasthole Parameters

	Units	76 mm Diameter Blasthole	
		Waste	ORE
Working Bench Height	m	3	3
Blasthole Diameter	mm	76	76
Hole Inclination	deg	90	90
Subdrill	m	0.6	0.6
TOTAL DRILLED DEPTH	**m**	**3.6**	**3.6**

Table 3: Blast Patterns

Blasthole Pattern	Staggered
Blast Sequence	En Echelon
Spacing/Burden Ratio	1:1.15
Number of Rows	5
Number of Holes per Row	10

Table 4: Charge Table – (100% Emulsion)

Blasting Variables	Units	Ore	IV and Quartzite	Ultramafic
Bench Height	m	3	3	3
Subdrill	m	0.3	0.3	0.3
Stemming Length	m	1.2	1.2	1.2
Charge Length	m	2.1	2.1	2.1
Linear Charge Density	kg/m	5.9	5.9	5.9
Burden	m	2.4	2.3	2.3
Spacing	m	2.7	2.6	2.6
Burden Volume	m^3	19	18	18
Explosives Mass per Hole, Q	kg	12.4	12.4	12.4
Powder Factor, PF	**kg/m^3**	**0.64**	**0.69**	**0.69**

The general blast configurations are the same as those proposed for the larger diameter blastholes with the obvious changes to the burden and spacing dimensions. The shorter blastholes lengths are more amenable to following a gentle sloping footwall and should not require the "stab" holes proposed for the larger bench heights.

3.1 Drilling

The change in cubic meter of rock broken per drilled meter is dramatically decreased using the smaller blasthole diameter. The change is from approximately 23 m^3 for the 165 mm holes to 5.5 m^3 for the 76 mm diameter holes. This represents a 76% reduction in the rock fragmentation volume for each meter of blasthole drilled. The smaller holes are less expensive to drill but many more are required to break the same volume of rock.

3.2 Wall Control

The general concept for wall control blasting does not change with the smaller blasthole diameter. The smaller holes will produce less damage to the wall rocks and will result in smoother, sounder wall conditions. However, the use of 3 m bench heights will result in a reduction in the overall slope angle for the final pit walls. This is because there will be a "step-out" of at least 1 m for every 3-m high bench to allow access for the drill. For example, for a design bench configuration of a 65 degree bench face angle with two 12-m high working benches to reach the final bench height of 24 m, and a 49 degree design inter-ramp angle, the effective inter-ramp angle will be approximately 47 degrees allowing for a 1 m "step-out". If a 3 m working bench height is considered, this will require eight working benches to reach the final 24 m bench height, and will result in an effective inter-ramp angle of approximately 43 degrees, allowing a 1 m "step-out" on seven of the eight working benches for drill access.

3.3 Rock Fragmentation

The fragmentation was predicted using the Kuz-Ram model defined in the main text of the report. The following table summarizes the predicted rock fragmentation for the preceding design criteria, and for a five row blast pattern with ten holes per row. The fragmentation is predictably finer given improvement in energy distribution that results from the smaller burden and spacing dimensions. However, the tonnage per blast is lower than for the greater bench heights and larger blastholes proposed in the previous report. The predicted fragmentation curves are contained in Appendix I.

Table 5: Predicted Fragmentation

Rock Type	Bench Height, m	Hole Size, mm	t/blast, t[1]	Powder Factor, kg/m^3	50% passing, m	80% passing, m	Characteristic Size, m
Iron Formation	3 m	76	3,344	0.64	0.33	0.59	0.42
Ultramafic	3 m	76	2,422	0.69	0.22	0.39	0.28
Intermediate Volcanic	3 m	76	2,512	0.69	0.28	0.51	0.37

1. Assumes 5 rows and 10 holes per row.

The impact of the smaller hole diameters and bench heights on productivity should be assessed in greater detail. As an approximate assessment of this impact, consider a stripping ratio of about 7:1 for the Portage Pit area. Approximately 39,000 t/day of waste will need to be moved to feed the 5,500 t/day milling operation. Based on the smaller blast design, this would require about 16 blasts per day in waste assuming five rows and ten holes per row. By comparison, a 6-m bench with 86 kg charge weight would move about 30,000 t/day in waste per blast, and a 12-m bench with 250 kg charge weight would move about 46,000 t/day in waste per blast.

4.0 BLAST INDUCED VIBRATION

The following sections summarize the results of previous analyses, and include additional analyses based on the revised production blast designs for the proposed 3-m bench height.

4.1 Minimum Setback Distance for Canadian Fisheries Guidelines

For the Meadowbank Site, three blast designs were previously assessed: the first assumed a charge weight per delay of 420 kg for 229 mm (9") blastholes and an operating bench height of 12 m, the second assumed a maximum charge weight of 250 kg for 165 mm (6½") blastholes and a bench height of 12 m, and the third assumed a charge weight of 86 kg for 165-mm blasthole and bench height of 6 m (see Golder Report on Blast Design, February 2004). An Emulsion:ANFO ratio of 70:30 was assumed for the first three cases. An additional scenario is considered here for a charge weight of 12 kg for a 76 mm blasthole and 3-m bench height. The fourth case assumes a sensitized emulsion product.

The PPV's were evaluated for the Second Portage Lake East Dike, the Third Portage Peninsula east shoreline, the Bay Dike, and the Goose Island east shoreline. Based on the current mine layout, estimates of the minimum distance from the estimated final production blast near the pit crest, to the point of concern (either the shoreline or the dike face), and estimates of the distance from the pit centre to the point of concern (either the shoreline or the dike face) were made. The PPV were evaluated based on these estimated distances.

By reducing the working bench height to 3 m within the waste rock and the ore, the charge weight per blasthole is reduced. The following table summarizes the estimated PPV at points of concern either along the upstream face of the dike, or along the shoreline, whichever is closest, for a 12 kg charge weight, 76 mm blasthole, and 3 m bench height.

Table 6: Preliminary Estimate of Peak Particle Velocities based on Production Blasting (12-kg charge weight per delay; 3-m bench height, 76-mm blasthole)

Location	Distance to Point of Concern (m)		PPV (mm/sec)		
			k=400	k=800	k=1500
Second Portage Lake East Dike	Pit Crest to U/S Dike Face	255	<1	1	2
	Pit Centre to U/S Dike Face	375	<1	<1	1
Third Portage Peninsula	Pit Crest to Shoreline	101	2	4	7
	Pit Centre to Shoreline	295	<1	1	1
Bay Dike	Pit Crest to U/S Dike Face	145	1	2	4
	Pit Centre to U/S Dike Face	355	<1	<1	1
Goose Island	Pit Crest to U/S Dike Face*	210*	1	1	2
	Pit Centre to U/S Dike Face*	500*	<1	<1	1

Distances are measured from approximate location of last production blast, not final trim blast.
Values of PPV in bold exceed 13 mm/sec.
*The Goose Island Dike alignment has been modified since the previous report. The new distance and results reflect the current concept for the dike alignment.

The following table summarizes the results of the analyses for the four charge weights that were considered, assuming a confinement value, k, of 800, which is considered to be appropriate for the Meadowbank Project based on experience at other northern mines.

Table 7: Summary of Estimates of Peak Particle Velocities based on Production Blasting Charge Weights (k=800)

Location	Distance to Point of Concern (m)		PPV (mm/sec)			
			12kg/3m bench	86kg/6m bench	250kg/12m bench	420kg/12m bench
Second Portage Lake East Dike	Pit Crest to U/S Dike Face	255	1	4	9	**14**
	Pit Centre to U/S Dike Face	375	<1	2	5	8
Third Portage Peninsula	Pit Crest to Shoreline	101	4	**18**	**41**	**62**
	Pit Centre to Shoreline	295	1	3	7	11
Bay Dike	Pit Crest to U/S Dike Face	145	2	10	**23**	**35**
	Pit Centre to U/S Dike Face	355	<1	2	6	8
Goose Island	Pit Crest to U/S Dike Face*	210*	1	5	**13**	**36**
	Pit Centre to U/S Dike Face*	500*	<1	1	3	9

Distances are measured from approximate location of last production blast, not final trim blast.
Values of PPV in bold exceed 13 mm/sec.
*The Goose Island Dike alignment has been modified since the previous report. The new distance and results reflect the current concept for the dike alignment.

The analysis indicates that, for the charge weight of 12 kg and bench height of 3 m, the peak particle velocity along the upstream (lake side) dike faces will not exceed 13 mm/s. With the exception of a short segment of the Third Portage Pit wall adjacent to the east shoreline of the Third Portage Peninsula, charge weights of 86 kg on 6 m benches will result in PPV less than the required 13 mm/s. Finally, with the exception of the segment of the Third Portage Pit wall just described, and short segments of the south end of the Goose Island Dike re-alignment, charge weights of 250 kg and 12 m bench heights can be used without exceeding the required 13 mm/s guideline.

For the portions of the dike or shoreline where the 13 mm/s guideline is exceeded, modified blast designs consisting of lower charge weights on lower bench heights have been shown to result in PPV that meet the guideline requirement. Alternatively, additional fill materials could be placed along the shoreline or dike upstream (lake side) face to increase the distance from the blasting area.

Figure 1 presents the relationship between charge weight and distance from blast for a constant Peak Particle Velocity of 13 mm/s for lower charge weights. The figure can be used as a guide to estimate the maximum allowable charge weight per blasthole that will not exceed a peak particle velocity of 13 mm/s at a specified distance from the blast.

The minimum setback distances to achieve a PPV of 13 mm/s have been estimated for the various values of ‘k’, and for the four potential charge weights per delay used in the above PPV estimates. The following table summarizes the estimates of minimum setback required to achieve a PPV value of 13 mm/s.

Table 8: Minimum Setback Distance for 13 mm/s Peak Particle Velocity Guideline

k	12 kg charge weight per delay (3 m bench, 76 mm hole)	86 kg charge weight per delay (6 m bench, 165 mm hole)	250 kg charge weight per delay, (12 m bench, decked charge, 229 mm hole)	420 kg charge weight per delay, (12 m bench, 229 mm hole)
	Minimum Setback Distance to Achieve PPV = 13 mm/s			
400	30 m	79 m	135 m	175 m
800	46 m	122 m	208 m	269 m
1500	67 m	180 m	308 m	399 m

The relationships presented in the above table are shown on Figure 2 for a confinement value, k, of 800.

4.2 Minimum Setback Distance for Threshold Damage Levels

General guidelines for blasting nears dams indicate vibration damage thresholds on the order of 50 mm/s to be reasonable for dams having medium to dense sand or silts within the dam or foundation materials. The following table summarizes the estimates of minimum setback required to achieve a PPV value of 50 mm/s for the charge weights considered.

Table 9: Comparison of Minimum Setback Distance for a Peak Particle Velocity of 50 mm/s for Various Blast Configurations

k	12 kg charge weight per delay (3 m bench, 76 mm hole)	86 kg charge weight per delay (6 m bench, 165 mm hole)	250 kg charge weight per delay, (12 m bench, decked charge, 229 mm hole)	420 kg charge weight per delay, (12 m bench, 229 mm hole)
	Minimum Setback Distance to Achieve PPV = 50 mm/s			
400	13 m	32 m	58 m	75 m
800	20 m	53 m	89 m	116 m
1500	29 m	78 m	133 m	172 m

Figure 3 presents the relationship between charge weight and distance from blast for a constant Peak Particle Velocity of 50 mm/s. The relationships presented in the above table are shown on Figure 4 for a confinement value, k, of 800.

The analysis indicates that for the 80-m toe setback currently assumed for the dikes at the Meadowbank Project, a charge weight of up to 200 kg per delay could be used resulting in PPV less than 50 mm/s, based on the assumptions presented in this report. Additional blast monitoring during construction will be required to confirm the assumptions on which these results are based.

4.3 Instantaneous Pressure Change for Canadian Fisheries Guidelines

The required setback distance for confined explosives to achieve the 100 kPa instantaneous pressure change guideline can be estimated from relationships presented in "Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters" (Wright and Hopky, 1998).

The following properties were used to assess the minimum setback distance.

Table 10: Properties Used to Assess Setback Distance for Instantaneous Pressure Change

Medium	Density, g/cm^3	Compressional Wave Velocity, cm/s
Water	1	146,300[1]
Rock (Intermediate Volcanic)	2.8	457,200[1]

1. Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998

Based on the above properties, the range of potential charge weights, and the range in confinement value, k, the following minimum setback distances, below which the 100 kPa overpressure guideline will not be exceeded, are estimated.

Table 11: Minimum Setback Distance for Instantaneous Pressure Change Guideline

Charge Weight per Delay	Minimum Setback Distance, m		
kg	k=400	k=800	k=1500
12	10 m	15 m	22 m
86	26 m	40 m	60 m
250	45 m	69 m	102 m
420	58 m	89 m	132 m

The relationship between charge weight per delay and minimum setback distance to achieve the 100 kPa guideline for instantaneous pressure change is shown on Figure 5. The figure can be used as a guide to optimizing the blast designs. The relationships presented in the above table are shown on Figure 6 for a confinement value, k, of 800.

Based on the currently proposed de-watering dike configuration, the average distance from the pit crest to the outside (lake side) dike face will be on the order of 160 m. In order for the instantaneous pressure change measured on the outside (lake side) face of the dike to exceed 100 kPa, a charge weight in excess of 1300 kg would be required, based on the assumptions in this report. Consequently, for the range of charge weights considered in the analyses for the Meadowbank project, none will result in an instantaneous pressure change greater than 100 kPa.

5.0 CLOSING REMARKS

Cumberland is considering mining of both ore and waste at the Meadowbank Project using 3-m bench heights and small diameter (76 mm) blastholes. The reduced bench heights and small diameter blastholes will result in lighter charge weights, and hence lower vibration levels experienced on the outside (lake side) of the dikes. Based on the proposed 3-m bench configurations and 76 mm blasthole diameter, a 12 kg charge weight will be used.

An assessment of blast induced vibration and instantaneous pressure change was carried out to assess vibration levels resulting from the lower charge weights as these relate to Canadian fisheries guidelines. The maximum acceptable Peak Particle Velocity (PPV) resulting from the use of explosives in or near fisheries waters is 13 mm/s. The maximum acceptable instantaneous pressure change is 100 kPa.

The results of the assessment indicate that for the proposed 3-m bench configuration and 12 kg charge weight, PPV on the outside (lake side) of the dikes will not exceed 13 mm/s, and that with the exception of a short segment of the Third Portage Pit wall adjacent to the east shoreline of the Third Portage Peninsula, charge weights of 86 kg on 6 m benches will result in PPV less than the guideline 13 mm/s. Furthermore, with the exception of the segment of the Third Portage Pit wall just described, and short segments of the south end of the Goose Island Dike re-alignment, charge weights of 250 kg and 12 m bench heights can be used without exceeding the required 13 mm/s guideline. For the portions of the dike or shoreline where the 13 mm/s guideline is exceeded, modified blast designs can be used to meet the guideline requirements. Alternatively, additional fill materials could be placed along the shoreline or dike upstream (lake side) face to increase the distance from the blasting area.

The instantaneous pressure change along the upstream (lake side) face of the dikes is predicted to be less than the 100 kPa guideline for all charge weights that are currently being considered for the Meadowbank Project.

An assessment of blast induced vibration as it relates to threshold damage levels for structures was carried out. General guidelines for blasting near dams indicate vibration damage thresholds on the order of 50 mm/s to be acceptable for dams having medium to dense sand or silts within the dam or foundation materials. Based on the proposed toe setback of 80 m, a 3-m bench height and 12-kg charge weight, and assumed site conditions and confinement, the analyses indicate that the 50 mm/s guideline will not be exceeded at the toe of the proposed de-watering dikes and tailings dike. The analyses indicate that for the 80-m toe setback currently assumed for the dikes at the Meadowbank Project, a charge weight of up to 200 kg per delay could be used without exceeding PPV of 50 mm/s at the toe, based on the assumptions presented in this report, and the preceding report. Where blast induced vibration is predicted to exceed general guidelines, modified blast designs can be used to reduce vibration levels.

The Vault Dike has not been considered in the analyses. The Vault Dike lies some 750 m from the nearest crest of the Vault Pit. Consequently, the proposed bench configurations and charge weights currently being considered will not exceed the Canadian fisheries guidelines for blasting induced vibration or for instantaneous pressure change.

It is recommended that the modified blast designs consisting of smaller blasthole diameter and lower bench heights only be used in those areas of the final pit walls where PPV along the lake shoreline, or along the upstream (lake side) of the dikes, is predicted to exceed guidelines, or within the ore zone where grade control is essential. The larger blast configurations (either 6 m or 12 m benches) should be adopted elsewhere within the waste rock. The smaller charge weights and lower bench heights will require more blasts on a daily basis to move the required amount of waste rock to obtain the daily ore tonnage to feed the mill. The number of blasts required per day for the lower bench heights may be impractical from a longer term operational perspective.

During mine development, a vibration monitoring program will be required in order to measure the response of the de-watering dikes and tailings dike to pit blasting, and to measure peak particle velocities on the upstream (lake side) of the dikes to assess the blast designs.

Yours very truly,

GOLDER ASSOCIATES LTD.

Cameron J. Clayton, P.Geo.
Mining Group

W.W. Forsyth, P.Eng.
Principal

CJC/WWF/vee
03-1413-427/4300

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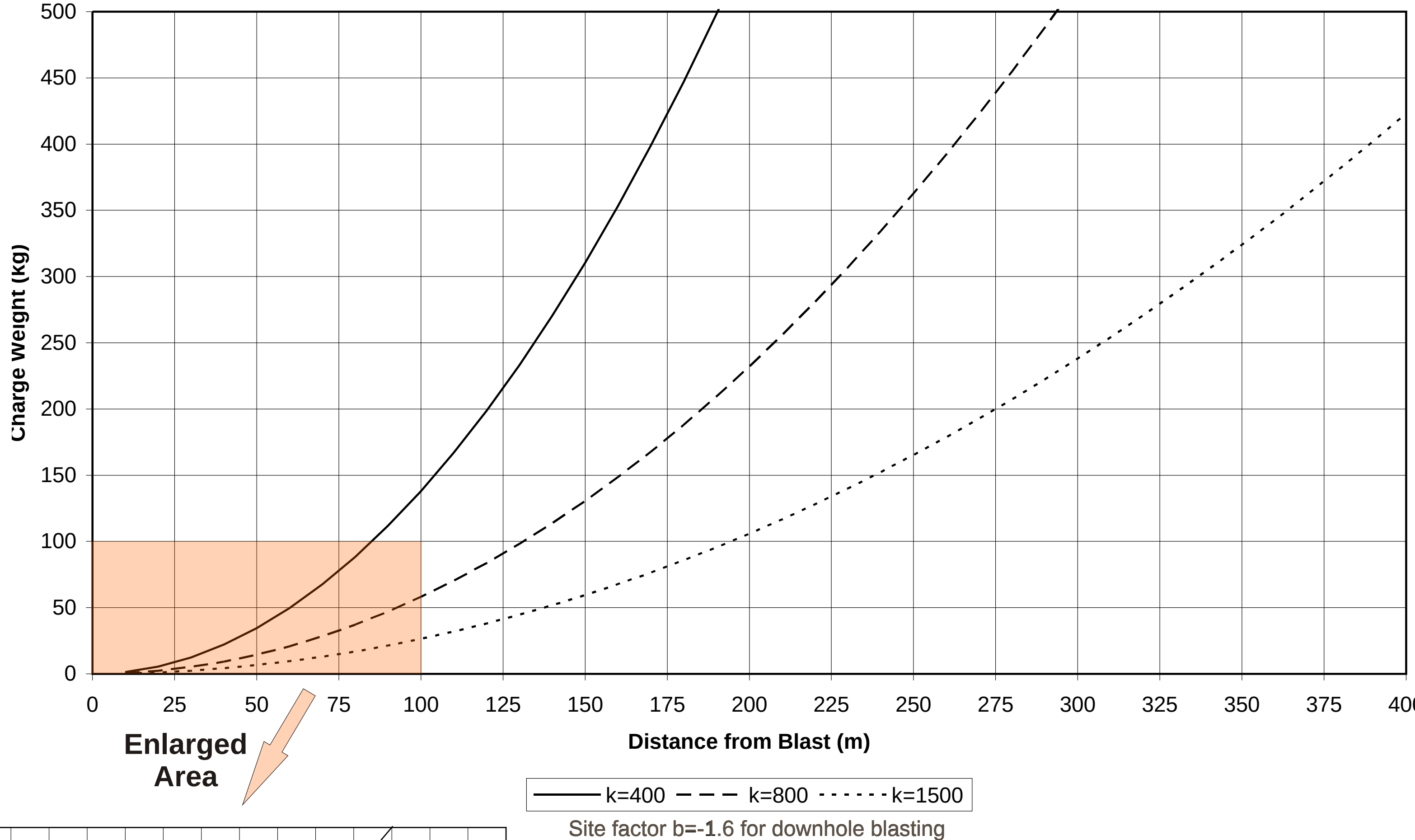

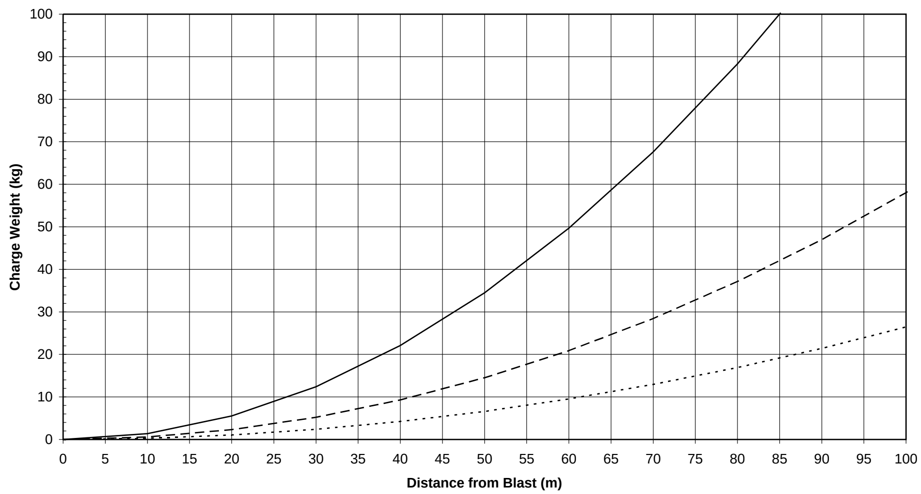

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

CHARGE WEIGHT vs DISTANCE FROM BLAST - PPV = 13mm/s

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 4	
DESIGN	CJC	28JAN04	SCALE NTS	REV. 0
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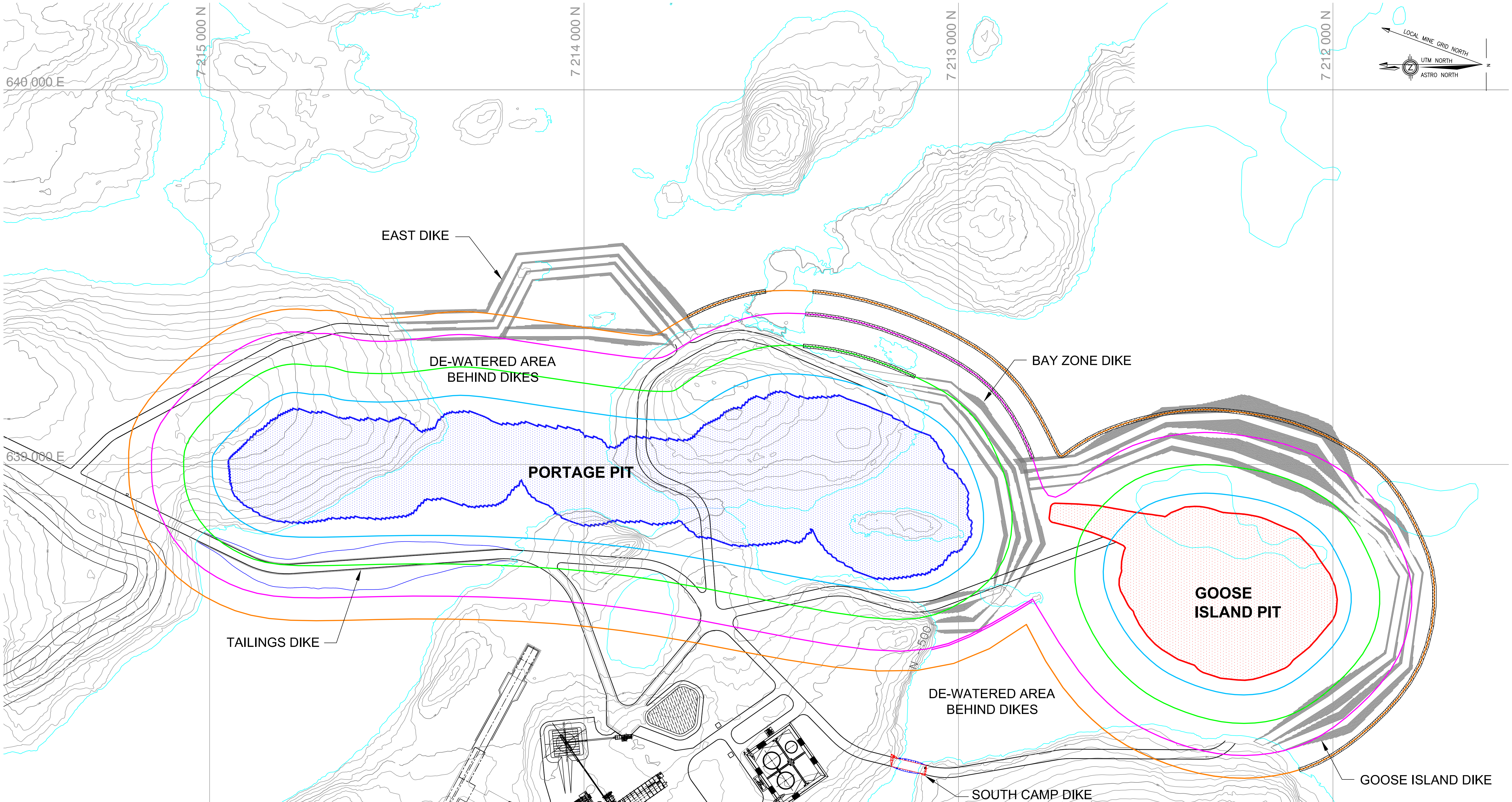
CHECK	CJC	28JAN04		
REVIEW		10MAR04		



LEGEND

12 kg Charge Weight, 46m Offset — Confinement, k = 800

86 kg Charge Weight, 122m Offset

250 kg Charge Weight, 208m Offset

420 kg Charge Weight, 269m Offset

Aquatic areas that may experience 13mm/s vibration levels for a specific charge weight.

NOTES

1) Area behind dikes is de-watered during operations.

REFERENCES

1) Drawing taken from AMEC, dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

2) Golder Report on Blast Design, Feburary, 2004.

0 100 200 300 400 500
Scale in Meters

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

REPORT ADDENDUM
PEAK PARTICLE VELOCITY
13 mm/s ISOPLETH

Golder Associates

PROJECT No.	03-1413-427		FILE No.	031413427-F02
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CADD	SRR	09 MAR 04		
CHECK	CJC	10 MAR 04	FIGURE 2	
REVIEW		10 MAR 04		

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REVISION DATE: 04/03/9 10:35am By: sreddy

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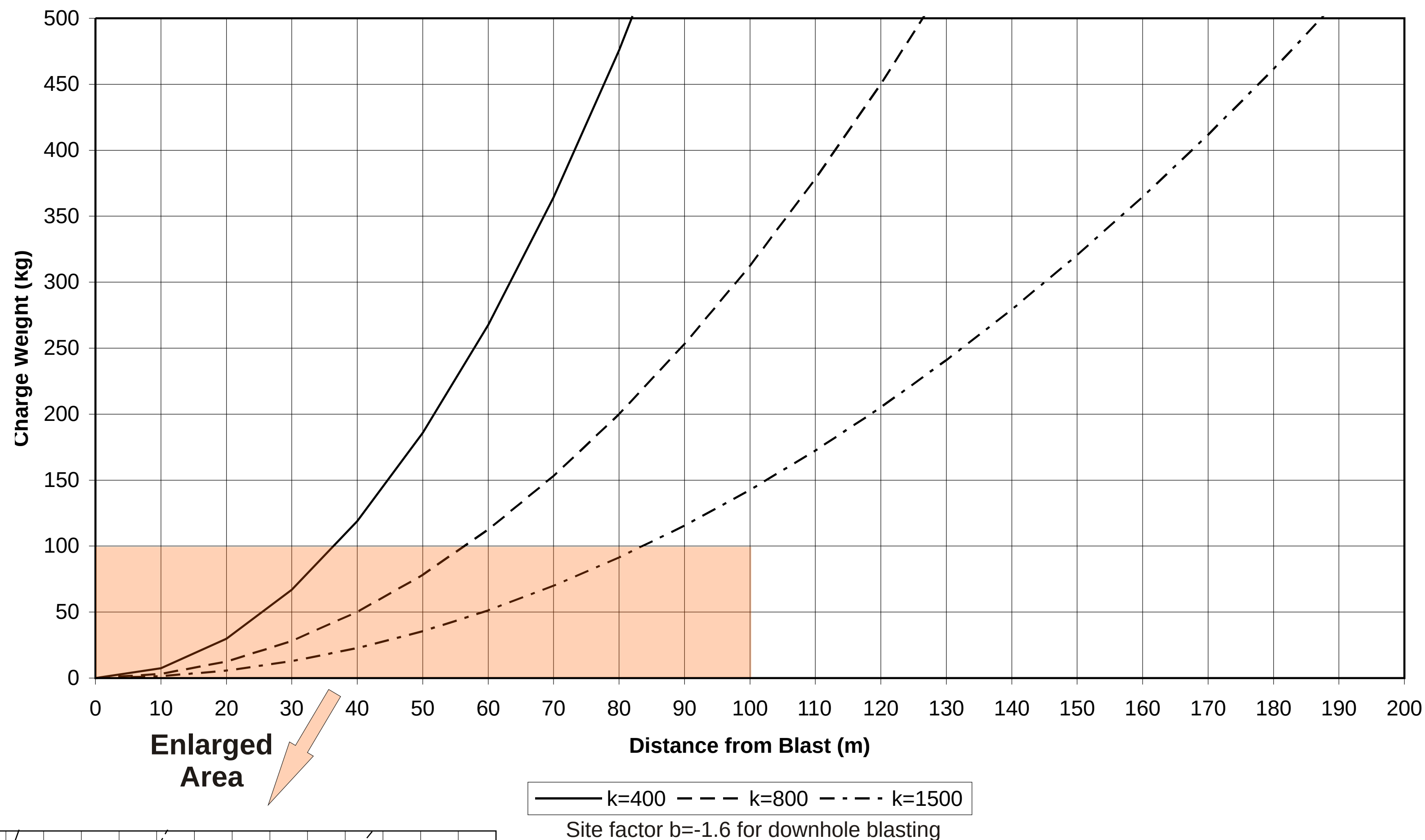

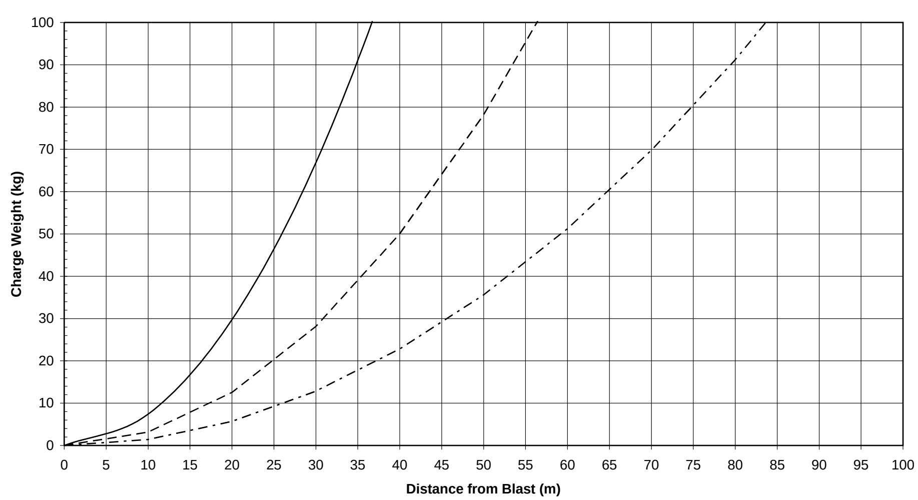

1500

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

CHARGE WEIGHT vs DISTANCE FROM BLAST - PPV = 50mm/s

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 4	
DESIGN	CJC	28JAN04	SCALE NTS	REV. 0
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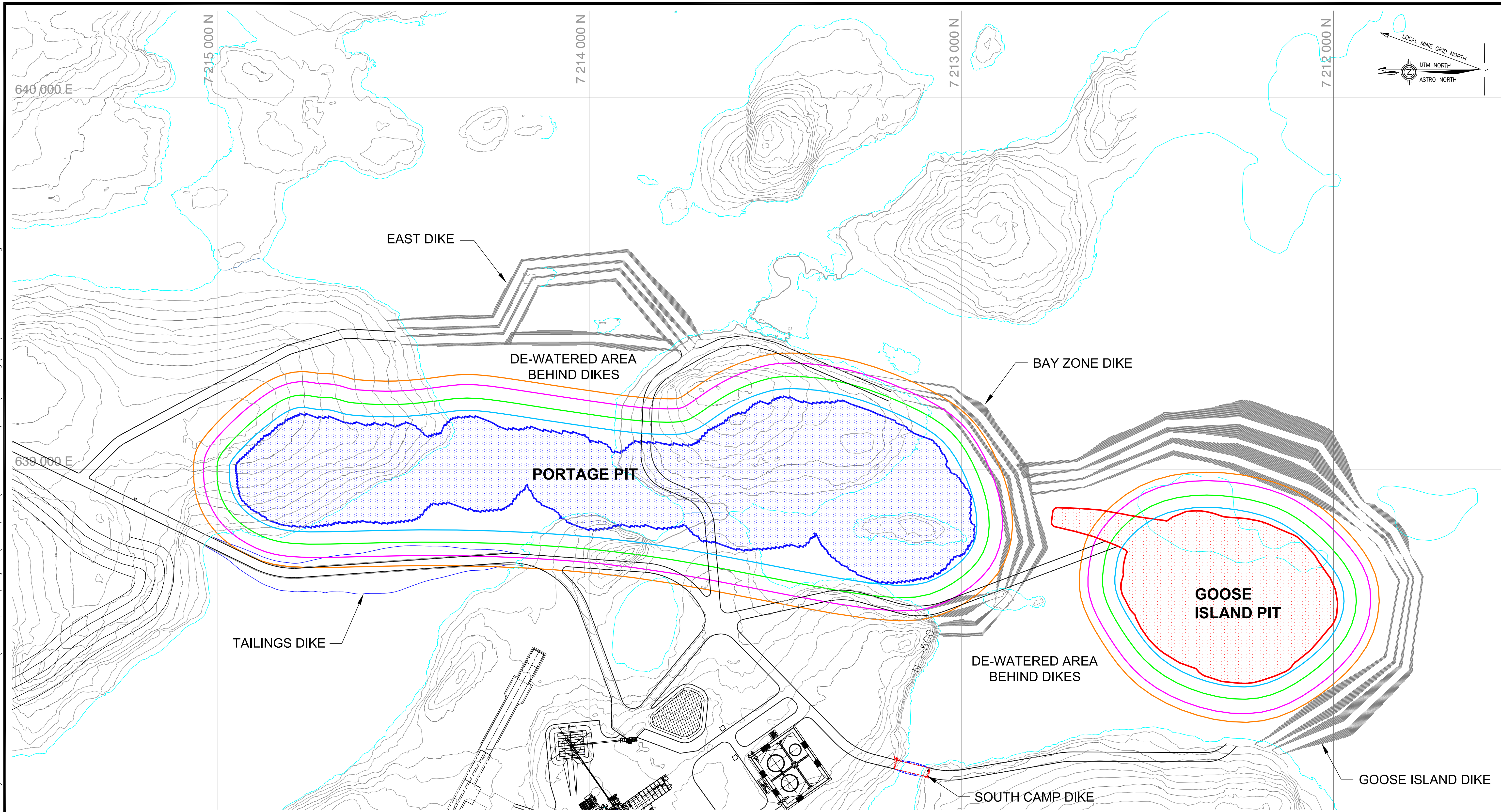
CHECK	CJC	28JAN04		
REVIEW		10MAR04		



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By: sreddy

REVISION DATE: 04/03/9 11:33am

LEGEND

- 12 kg Charge Weight, 20m Offset
- 86 kg Charge Weight, 53m Offset
- 250 kg Charge Weight, 89m Offset
- 420 kg Charge Weight, 116m Offset

Confinement, k = 800

NOTES

1) Area behind dikes is de-watered during operations.

REFERENCES

1) Drawing taken from AMEC, dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

2) Golder Report on Blast Design, Feburary, 2004.

0 100 200 300 400 500

Scale in Meters

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

**REPORT ADDENDUM
PEAK PARTICLE VELOCITY
50 mm/s ISOPLETH**

Golder Associates

PROJECT No.	03-1413-427	FILE No.	031413427-F04
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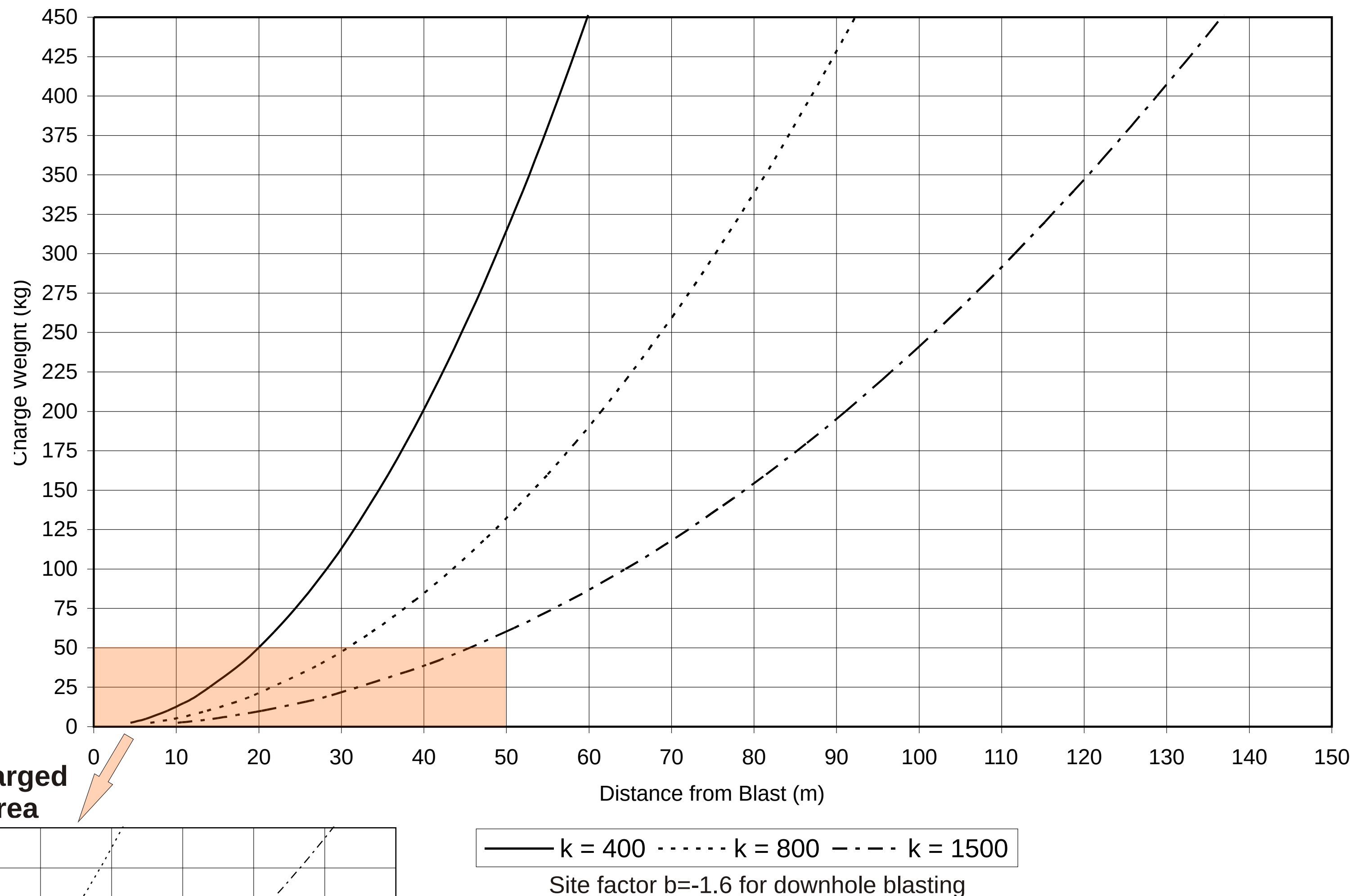
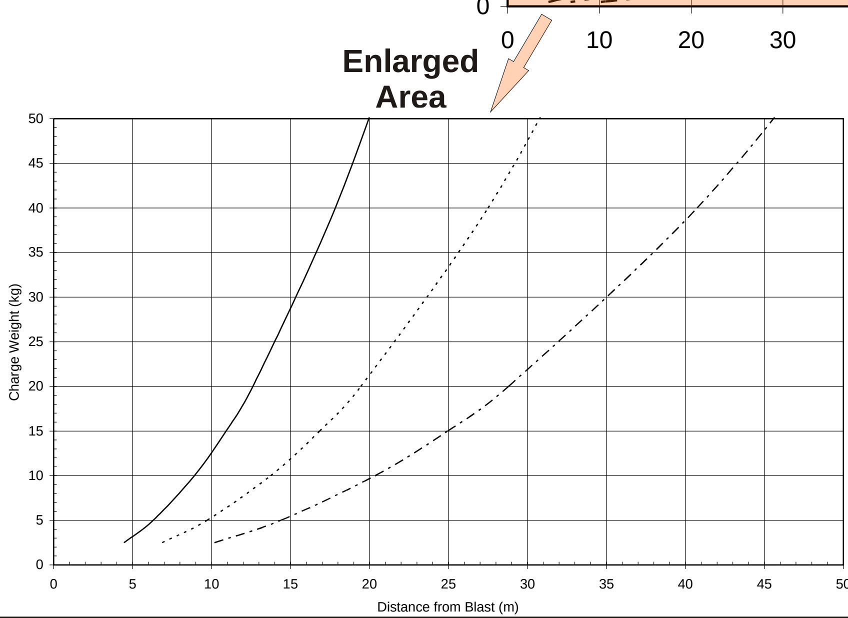
CADD	SRR	09 MAR 04	
CHECK	CJC	10 MAR 04	**FIGURE 4**
REVIEW		10 MAR 04	

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 4.cdr





PROJECT

CUMBERLAND RESOURCES LTD.

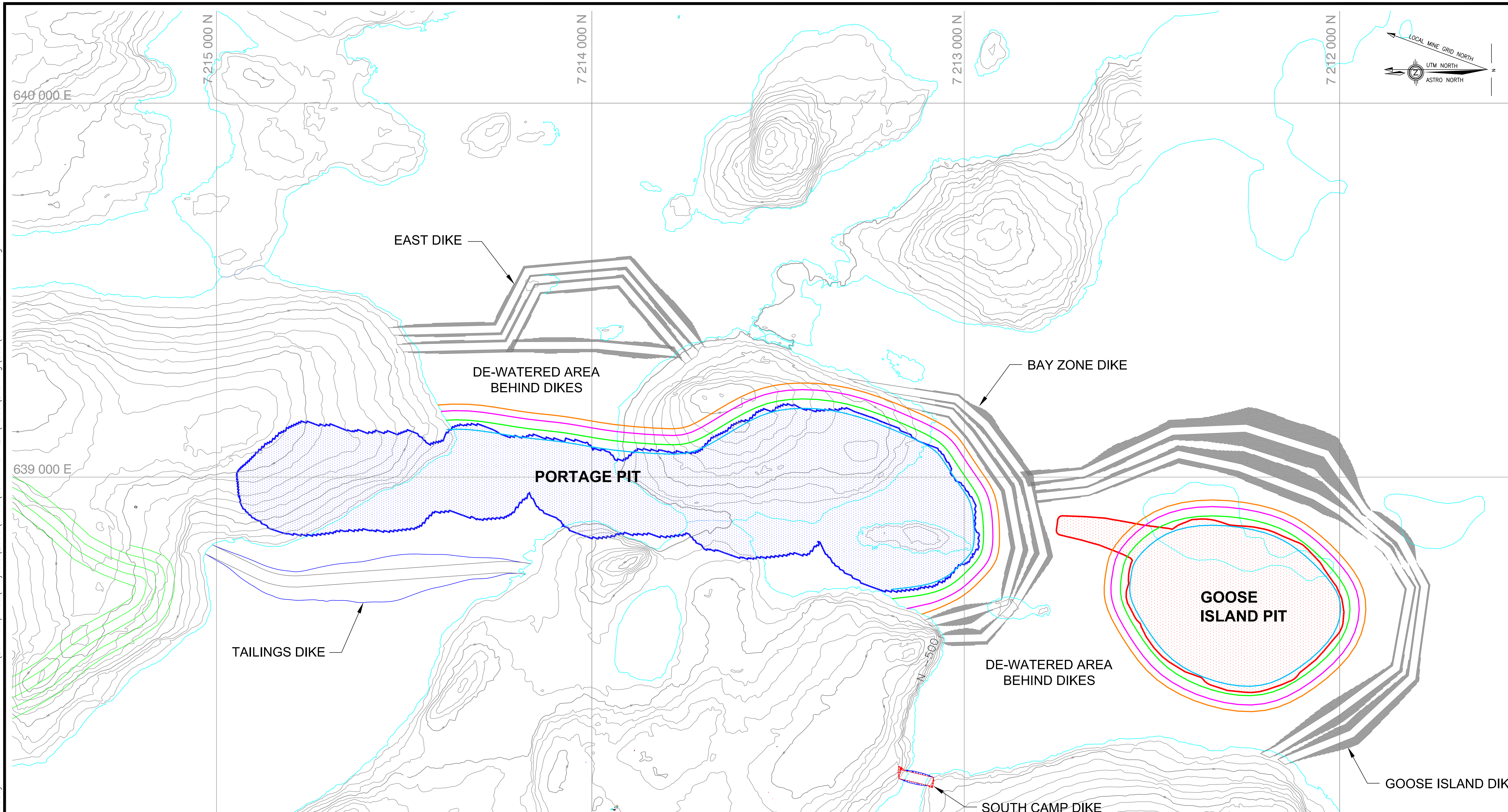
TITLE

CHARGE WEIGHT vs SETBACK DISTANCE FOR 100 kPA OVERPRESSURE

Golder Associates

PROJECT No.	03-1413-427		FILE No.	FIGURE 4
DESIGN	CJC	28JAN04	SCALE NTS	REV. 0
CADD	SS	28JAN04		
CHECK	CJC	28JAN04		
REVIEW		10MAR04		

FIGURE 5



REVISION DATE: 04/03/9 11:18am By: sreddy CADD FILE: N:\Bur-Graphics\Projects\2003\1413\03-1413-427\4300\Drafting\cad\031413427-F06.dwg

LEGEND

- 12 kg Charge Weight, 15m Offset
- 86 kg Charge Weight, 40m Offset
- 250 kg Charge Weight, 69m Offset
- 420 kg Charge Weight, 89m Offset

Confinement, k = 800

NOTES

1) Area behind dikes is de-watered during operations.

0 100 200 300 400 500
Scale in Meters

REFERENCES

1) Drawing taken from AMEC, dated 28-01-04, Drawing # A1-131395-100-C-0001 Revision A - OVERALL SITE PLAN YEAR 1-5.

2) Golder Report on Blast Design, Feburary, 2004

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

REPORT ADDENDUM
INSTANTANEOUS OVERPRESSURE
100kPa ISOPLETH

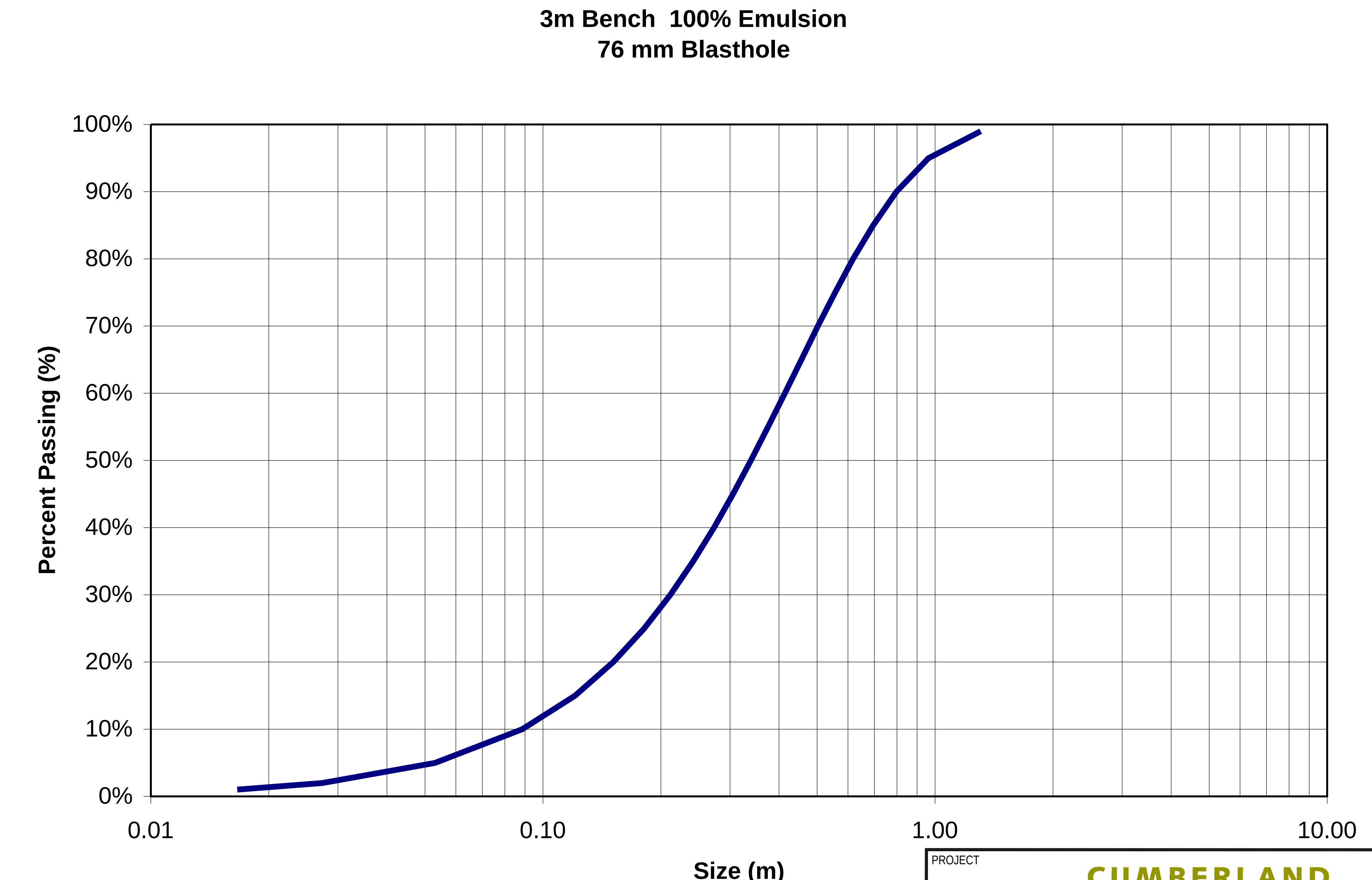
Golder Associates

PROJECT No.	03-1413-427		FILE No. 031413427-F06
DESIGN	CJC	08 MAR 04	SCALE AS SHOWN REV. 0
CADD	SRR	09 MAR 04	
CHECK	CJC	10 MAR 04	**FIGURE 6**
REVIEW		10 MAR 04	

APPENDIX I

FRAGMENTATION PREDICTIONS

REVISION DATE:28-JAN-04 BY: SS COREL FILE:N:\Bur-Graphics\Projects\2003\1413\03-1413-427\Drafting\corel\Figures 4.cdr



PROJECT

CUMBERLAND RESOURCES LTD.

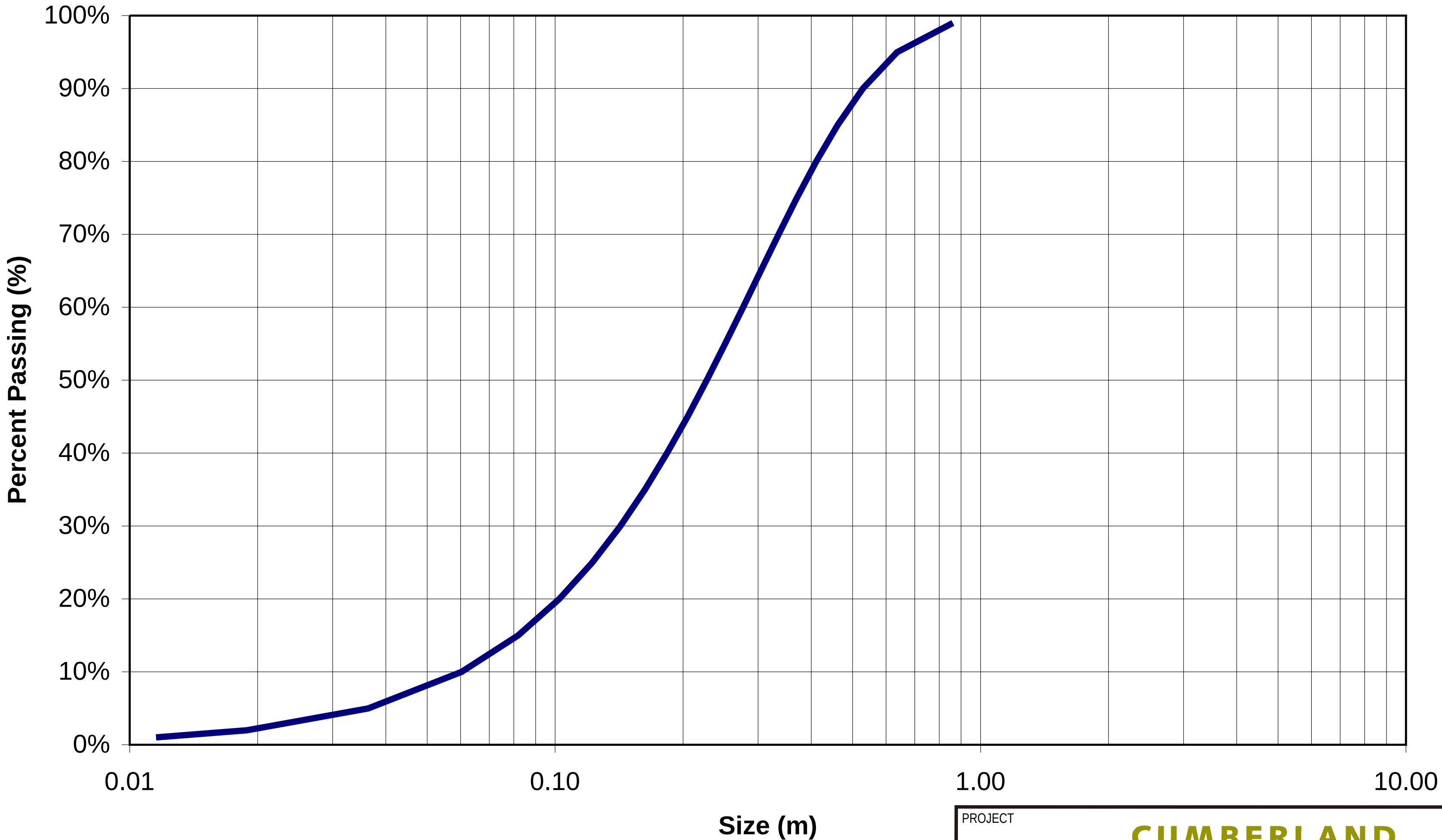
TITLE

IRON FORMATION
FRAGMENTATION PREDICTION
3m BENCH - 76mm BLASTHOLE

Golder Associates

PROJECT No.	03-1413-427		FILE No.	FIGURE 4
DESIGN	CJC	28JAN04	SCALE NTS	REV. 0
CADD	SS	28JAN04		
CHECK	CJC	28JAN04	**FIGURE I-1**	
REVIEW		10MAR04		

3m Bench 100% Emulsion
76 mm Blasthole



PROJECT

CUMBERLAND
RESOURCES LTD.

TITLE

ULTRAMAFIC VOLCANIC
FRAGMENTATION PREDICTION
3m BENCH - 76mm BLASTHOLE

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 4	
DESIGN	CJC	28JAN04	SCALE NTS	REV. 0
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CHECK	CJC	28JAN04		
REVIEW		10MAR04		

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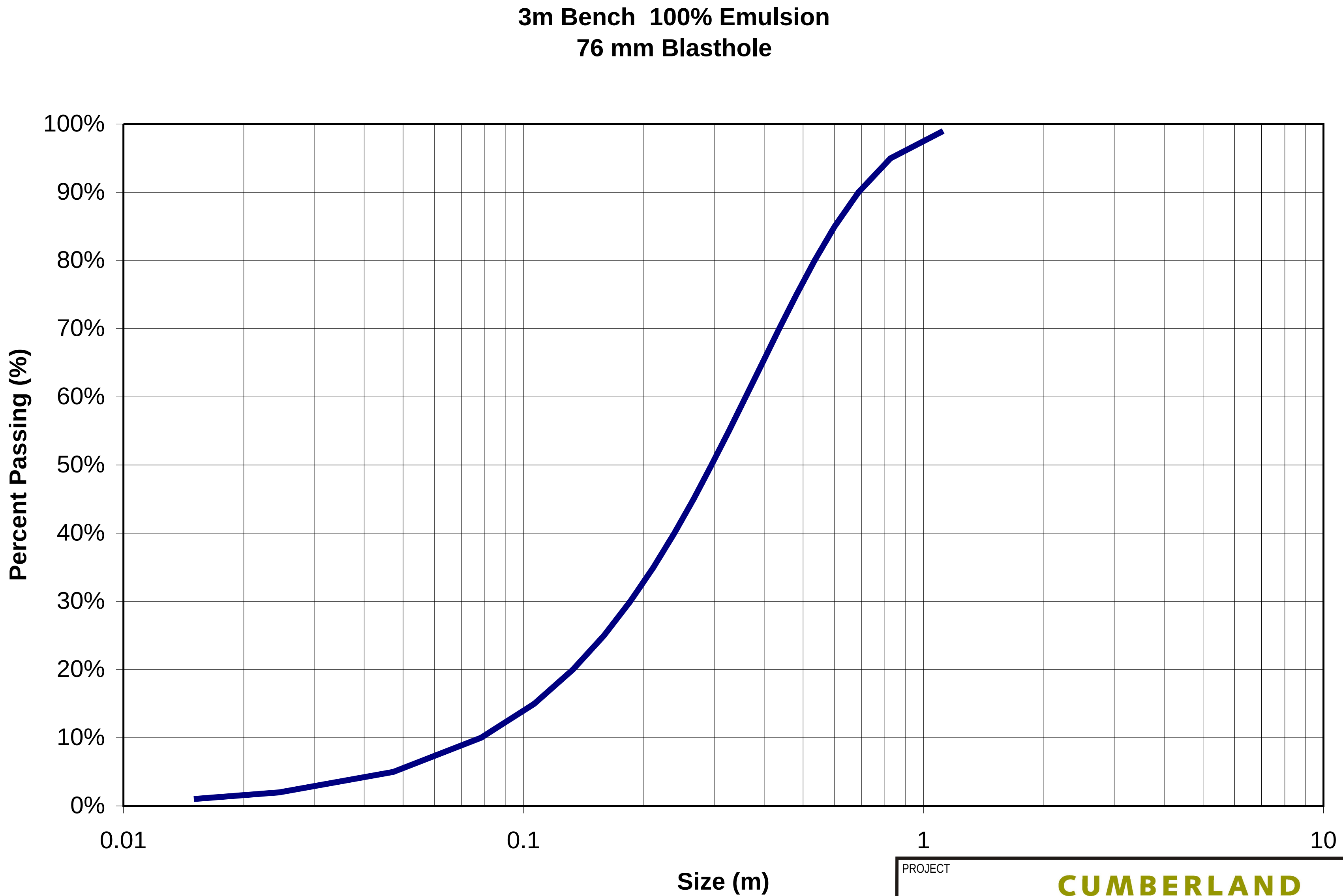

PROJECT

CUMBERLAND
RESOURCES LTD.

TITLE

INTERMEDIATE VOLCANIC
FRAGMENTATION PREDICTION
3m BENCH - 76mm BLASTHOLE

Golder Associates

PROJECT No.	03-1413-427		FILE No. FIGURE 4	
DESIGN	CJC	28JAN04	SCALE NTS	REV. 0
CADD	SS	28JAN04	**FIGURE I-3**	
CHECK	CJC	28JAN04		
REVIEW		10MAR04		

TECHNICAL MEMORANDUM

Golder Associates Ltd.
#500 - 4260 Still Creek Drive
Burnaby, B.C., Canada V5C 6C6
Telephone: 604-296-4200
Fax Access: 604-298-5253

TO: Cumberland Resources Ltd. **DATE:** October 6, 2005

FROM: Cameron Clayton **JOB NO:** 05-1413-036A

EMAIL: **cclayton@golder.com**

RE: **ITEM #85/85A – MEADOWBANK GOLD PROJECT – BLASTING ADDENDUM**

A Technical Meeting was held in Baker Lake on June 2 and 3, 2005 to review the Draft Environmental Impact Statement (DEIS) for Cumberland Resources Limited (CRL), Meadowbank Gold Project. Following the technical meeting, a list of commitments by CRL was prepared, which would either be addressed as soon as possible or appear in the Final Environmental Impact Statement. This technical memorandum responds to Items #85 and #85a from this list which requested additional information relating to the annotation of a permafrost cross section through the project area.

Specifically, Items #85 and 85a requested to:

85. "Ensure that the blast management plan in the FEIS accounts for DFO addendum relating to blast design during periods when water bodies are ice covered:
    a. A Blast Design Report will be submitted, taking into account the DFO addendum relating to blast design during frozen conditions."

1.0 INSTANTANEOUS PRESSURE CHANGE FOR CANADIAN FISHERIES GUIDELINES

Two blast design reports have been produced previously for the project:

- Golder Associates Ltd., Report on *Blast Design, Meadowbank Gold Project, Nunavut*, February 10, 2004.
- Addendum: Blasting Report Addendum, Golder Associates, May 25, 2004.

The reader is directed to review the two previous reports which describe in greater detail the development of assumptions on which the evaluations have been based, the procedures used to carry out the evaluations, and other parameters used in the evaluations that may be presented below but are not described.

The previous report, and the report addendum, included consideration of blast induced vibration from the perspective of the stability of the perimeter dikes and tailings dike, and from the perspective of the effect of blast induced vibration on fish and fish habitat. Estimates of blast induced vibration and instantaneous pressure change were presented for various charge weights based on initial evaluation of blast design. The feasibility study recently completed by Amec Americas Ltd recommended that a charge weight of 77 kg for a bench height of 6 m be used. The previously completed blast designs have been modified to reflect this recommendation, and are presented below.

The following sections are based on the previous work, and on new analyses to address additional concerns presented by Department of Fisheries and Oceans (DFO) and presented during the meetings in Baker Lake.

1.1 Blast Induced Vibration

Blast induced vibrations have the potential to reduce the stability and performance of nearby earthen structures such as dikes. Where saturated conditions exist within the foundation materials and within the earthen structural fills of the de-watering dikes and the tailings dike, blast induced vibrations could result in the development of increased pore water pressures within the foundation and structural fill materials. This could lead to potential settlement of the structures and consequently impact to the water retaining capacity of the dikes.

The effects of blasting are typically assessed in terms of Peak Particle Velocity (PPV).

1.1.1 Estimates of Peak Particle Velocity

The preliminary estimates of Peak Particle Velocity (PPV) are based on the current understanding of the site layout, mine plan, and blast design. Changes to the current site layout, mine plan, and blast design will result in changes to the estimates of PPV. Certain site specific factors that are required to calculate PPV have been estimated based on published values. However, site specific parameters can only be determined by site vibration monitoring of actual blasts. Consequently, the actual PPV values may differ from those presented here.

The US Bureau of Mines has established that the peak particle velocity, PPV, is related to the scaled distance by the following relationship:

$$PPV = k * (R/W^{0.5})^{-b}$$

Where:

PPV	= Peak Particle Velocity, mm/s
R	= Distance from blast to point of concern, m
W	= Charge weight per delay, kg
k	= confinement factor – specific to site
b	= site factor

The constants k and b are specific to the site, and can be determined by blast vibration monitoring.

For this evaluation, a value of b = 1.6 was assumed. The PPV was evaluated for a range of values of confinement, 'k', of 400, 800, and 1500, for down hole blasting. This range in values is considered to be reasonable for the site and to provide an estimate of the sensitivity of PPV to different values of confinement.

Based on the current understanding of site conditions and blast monitoring experience at two other northern sites, the confinement value of 800 is expected to be the most likely representative value for average conditions at the site. The actual value for confinement can only be determined through a detailed field monitoring program.

1.1.2 Minimum Setback Distance for Canadian Fisheries Guidelines

Design guidelines governing the use of explosives adjacent to Canadian fisheries waters (Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998) indicate that no explosive is to be detonated that produces a peak particle velocity greater than 13 mm/s in a spawning bed during the period of egg incubation.

The PPV's were evaluated for the Second Portage Lake East Dike, the Third Portage Peninsula east shoreline, the Bay Dike, and the Goose Island east shoreline.

1.1.3 Setback Distance for Peak Particle Velocity

The minimum setback distances to achieve a Peak Particle Velocity, PPV, of 13 mm/s have been estimated for various values of confinement, 'k', and for four potential charge weights per delay. The following table summarizes the estimates of minimum setback required to achieve a PPV value of 13 mm/s.

Table 1: Minimum Setback Distance for 13 mm/s Peak Particle Velocity Guideline

k	12 kg charge weight per delay (3 m bench, 76 mm hole)	77 kg charge weight per delay (6 m bench, 165 mm hole)	250 kg charge weight per delay, (12 m bench, decked charge, 229 mm hole)
	Minimum Setback Distance to Achieve PPV = 13 mm/s		
400	30 m	75 m	135 m
800	46 m	115 m	208 m
1500	67 m	171 m	308 m

The relationships presented in the above table are shown on Figure 1 for a confinement value, k, of 800.

With the exception of a short segment of shoreline adjacent to the Portage Pit wall at the south end of the pit, the proposed charge weight of 77 kg per hole on 6 m benches will result in PPV less than the required 13 mm/s.

For the portions of the dike or shoreline where the 13 mm/s guideline is exceeded, modified blast designs consisting of lower charge weights on lower bench heights have been shown to result in PPV that meet the guideline requirement. For example, the figure indicates that a charge weight of 12 kg would result in acceptable PPV in the area of concern. Alternatively, additional fill materials could be placed along the shoreline or dike upstream (lake side) face to increase the distance from the blasting area.

1.1.4 Minimum Setback Distance for Threshold Damage Levels

General guidelines for blasting nears dams indicate vibration damage thresholds on the order of 50 mm/s to be reasonable for dams having medium to dense sand or silts within the dam or foundation materials. The following table summarizes the estimates of minimum setback required to achieve a PPV value of 50 mm/s for the charge weights considered.

Table 2: Comparison of Minimum Setback Distance for a Peak Particle Velocity of 50 mm/s for Various Blast Configurations

k	12 kg charge weight per delay (3 m bench, 76 mm hole)	77 kg charge weight per delay (6 m bench, 165 mm hole)	250 kg charge weight per delay, (12 m bench, decked charge, 229 mm hole)
	Minimum Setback Distance to Achieve PPV = 50 mm/s		
400	13 m	32 m	58 m
800	20 m	50 m	89 m
1500	29 m	74 m	133 m

The analysis indicates that for the proposed 80-m toe setback for the dikes at the Meadowbank Project, and the proposed 77 kg charge weight, PPV of 50 mm/s will not be exceeded in the toe areas of the perimeter dikes or tailings dike (see Figure 2).

1.1.5 Instantaneous Pressure Change for Canadian Fisheries Guidelines – 100 kPa Criteria

The required setback distance for confined explosives to achieve the 100 kPa instantaneous pressure change guideline can be estimated from relationships presented in "Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters" (Wright and Hopky, 1998).

The following properties were used to assess the minimum setback distance.

Table 3: Properties Used to Assess Setback Distance for Instantaneous Pressure Change

Medium	Density, g/cm^3	Compressional Wave Velocity, cm/s
Water	1	146,300[1]
Rock (Intermediate Volcanic)	2.8	457,200[1]

1. Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters; Wright and Hopky, 1998

Based on the above properties, the range of potential charge weights, and the range in confinement value, k, the following minimum setback distances, below which the 100 kPa overpressure guideline will not be exceeded, are estimated.

Table 4: Minimum Setback Distance for Instantaneous Pressure Change Guideline (<100kPa)

Charge Weight per Delay (kg)	Minimum Setback Distance (m)		
	k=400	k=800	k=1500
12	10 m	15 m	22 m
77	25 m	38 m	57 m
250	45 m	69 m	102 m

The results in the above table are presented on Figure 3 for a confinement of 800. For the proposed charge weight of 77 kg the instantaneous pressure change will not exceed the guideline of 100 kPa on the outside of the dikes.

1.1.6 Instantaneous Pressure Change for Ice Covered Waters – 50 kPa Criteria

In addition to the legislated criteria Department of Fisheries and Oceans has requested that Cumberland assess the effect of blast induced vibration and instantaneous overpressure resulting from blasting adjacent to waters during ice cover periods, although this is not currently legislated. For these conditions, Department of Fisheries has recommended an additional evaluation to consider an instantaneous pressure change of 50 kPa.

For the range of potential charge weights, and for a range in confinement value, k, the following minimum setback distances, below which the 50 kPa overpressure guideline will not be exceeded, are estimated.

Table 5: Minimum Setback Distance for Instantaneous Pressure Change Guideline (50 kPa Ice Covered Water)

Charge Weight per Delay (kg)	Bench Height (m)	Hole Diameter (mm)	Minimum Setback Distance (m)		
			k=400	k=800	k=1500
12	3 m (ore)	76	15	23	34
77	6 m (ore and waste)	165	38	59	87
250	6 m (waste)	165	69	106	157

The relationships presented in the above table are shown on Figure 4 for a confinement value, k, of 800. Based on the analysis, an instantaneous pressure change of 50 kPa will not be exceeded for the proposed 77 kg charge weight per hole, and for a confinement value, ‘k’, of 800.

1.2 Conclusions

The following summarizes the conclusions of the previous and current assessment:

- With the exception of a short segment of shoreline adjacent to the southeast wall of the Portage Pit, the Peak Particle Velocity of 13 mm/s will not be exceeded for the proposed 77 kg charge weight per hole. This relates to fisheries guidelines.
- The Peak Particle Velocity of 50 mm/s will not be exceeded in the toe region of the perimeter dikes or tailings dike for the proposed 77 kg charge weight per hole. This relates to the structural stability of the dikes.
- The instantaneous pressure change along the upstream (lake side) face of the East Dike, Bay Zone Dike, and Goose Dike is predicted to be less than the 100 kPa guideline for the proposed 77 kg charge weight per hole. This relates to fisheries guidelines.
- The instantaneous pressure change along the upstream (lake side) face of the dikes during periods of ice cover is predicted to be less than 50 kPa for the proposed 77 kg charge weight per hole. This relates to an additional request by DFO to assess instantaneous pressure change for ice covered water conditions.
- For the Vault deposit, Peak Particle Velocity and instantaneous pressure change guidelines along the Vault Dike face will not be exceeded for any of the proposed blast designs or charge weights. The Vault Dike lies about 750 m from the nearest crest of the Vault Pit.

The analyses have shown that peak particle velocities and instantaneous overpressure can be effectively managed through the use of lighter charge weights, decreased blasthole diameters, and decreased operating bench heights, or a combination of these mitigative measures. During mine development and operations, a vibration monitoring program will be required in order to measure the response of the de-watering dikes and tailings dike to pit blasting, and to measure peak particle velocities on the upstream (lake side) of the dikes to assess the current blast designs. This will allow modifications to be made to the operational blast designs.

1.2.1 Monitoring

As part of the mine development, a vibration monitoring program will be required in order to measure the response of the de-watering dikes and tailings dike to pit blasting. The data from this program would be assessed in conjunction with continuous measurements from piezometers that would be installed in the dikes, and within the dike foundation materials. From this analysis, the blasting could be adjusted to minimize the impact on the dikes. Mitigative measures to the blast design to minimize the development of blast induced vibration could include modifications to the blasthole patterns, reduction in blasthole size and hence charge weight in critical areas of the pit walls within a certain distance from the proposed de-watering and tailings dike, single blasthole initiation per delay, reduction in operating bench height in critical areas, or a combination of all these measures.

A more comprehensive program of blast vibration modelling and test blasting may be required during operations if blast vibration levels remain high and their frequency (cycles per second) is low.

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05-1413-036A
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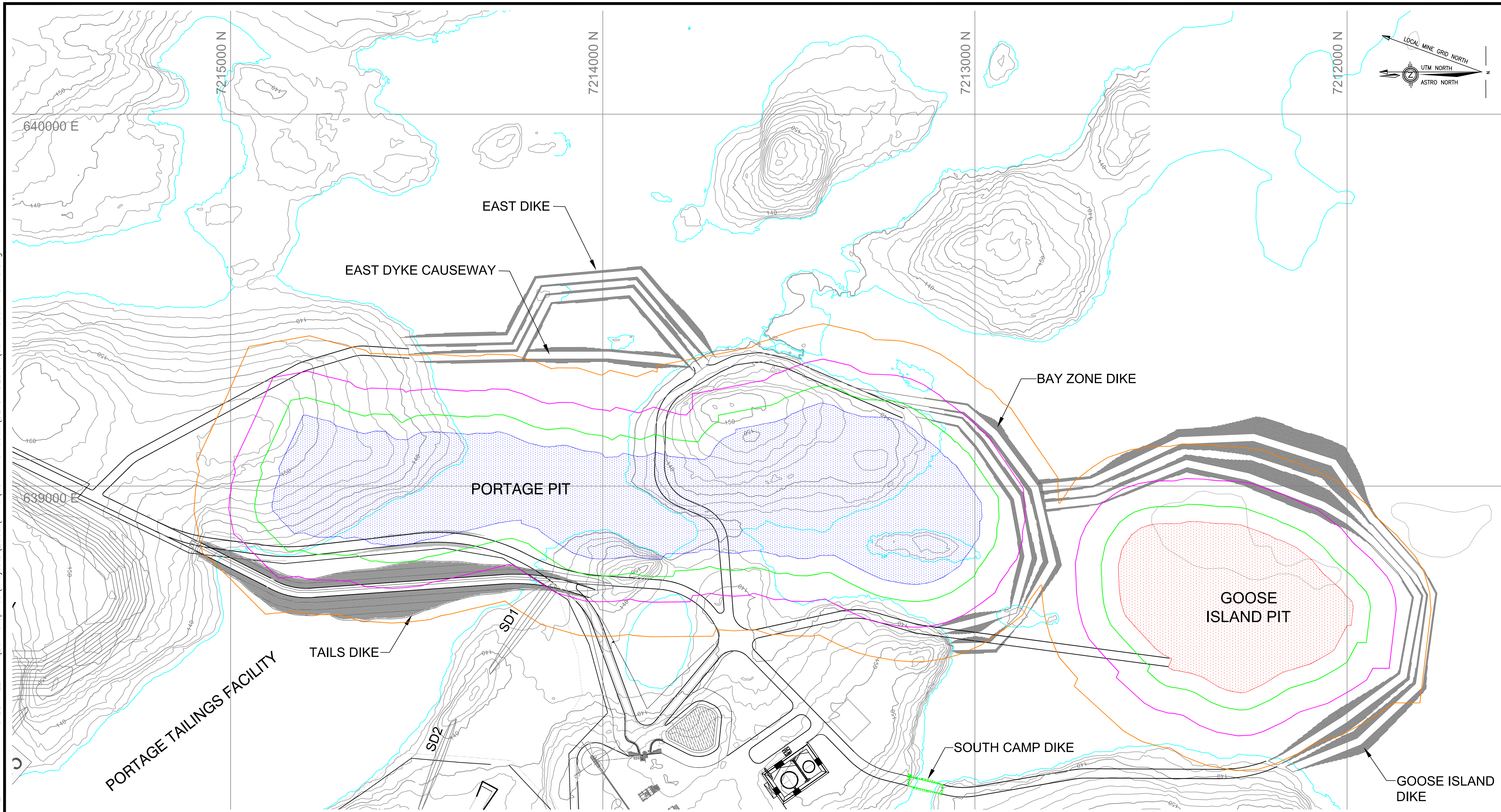


LEGEND

- 12 kg Charge Weight, 46m Offset
- 77 kg Charge Weight, 115m Offset
- 250 kg Charge Weight, 208m Offset

Confinement, k = 800

Recommended Charge Weight

NOTES

1. Contour Interval 2 Metre.
2. All Dimensions in Metres.
3. Elevations in Metres above Sea Level.
4. UTM Zone 14, NAD83.
5. Area behind Dikes is De-watered during Operations.
6. Reference: Feasibility Study Report, AMEC, June 2005.

REFERENCES

1) AMEC Americas LTD, Drawing # A1-131395-100-C-0001 (100-C-0001.dwg), Meadowbank Feasibility Study, April 2005.
2) Golder Associates: Report on Blast Design, Meadowbank Golder Project, February 2004.
3) Golder Associates: Blasting Report Addendum, May 2004.

PROJECT

CUMBERLAND RESOURCES LTD.

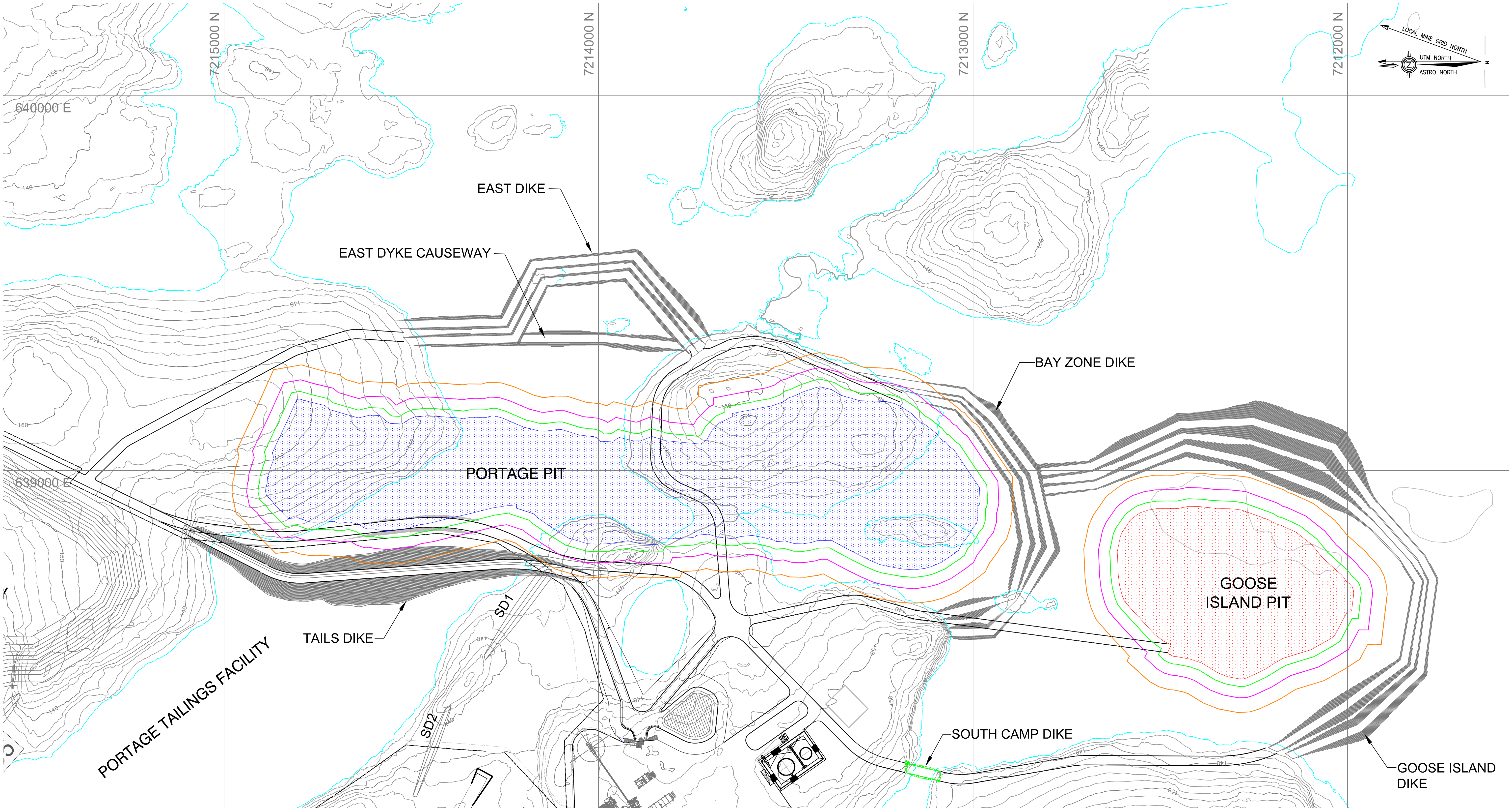
TITLE

PEAK PARTICLE VELOCITY 13 mm/s ISOPLETH

Golder Associates

PROJECT No. 05-1413-036A		FILE No. 051413036A-SK13	
DESIGN	CJC	03OCT05	SCALE AS SHOWN REV. A
CADD	WLI	03OCT05	
CHECK	CJC	03OCT05	FIGURE 1
REVIEW			

CADD FILE: N:\Bur-Graphics\Projects\2005\1413\05-1413-036A\BLAST DESIGN\051413036A-SK13.dwg By: WLi REVISION DATE: 05/10/6 8:38am



LEGEND

12 kg Charge Weight, 20m Offset

77 kg Charge Weight, 50m Offset

250 kg Charge Weight, 89m Offset

Confinement, k = 800

Recommended Charge Weight

NOTES

1. Contour Interval 2 Metre.
2. All Dimensions in Metres.
3. Elevations in Metres above Sea Level.
4. UTM Zone 14, NAD83.
5. Area behind Dikes is De-watered during Operations.
6. Reference: Feasibility Study Report, AMEC, June 2005.

REFERENCES

1) AMEC Americas LTD, Drawing # A1-131395-100-C-0001 (100-C-0001.dwg), Meadowbank Feasibility Study, April 2005.
2) Golder Associates: Report on Blast Design, Meadowbank Golder Project, February 2004.
3) Golder Associates: Blasting Report Addendum, May 2004.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

PEAK PARTICLE VELOCITY 50 mm/s ISOPLETH

Golder Associates

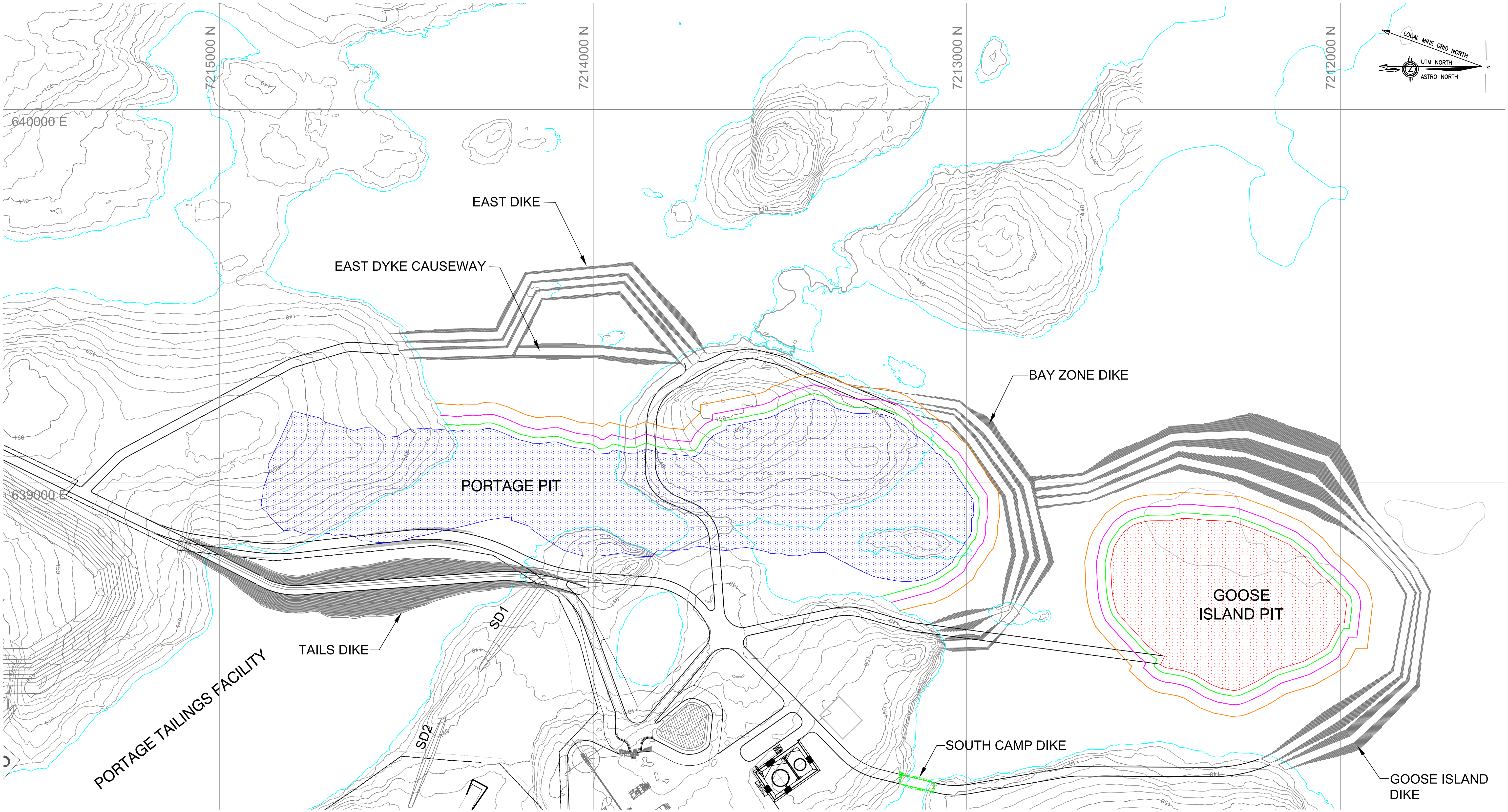
PROJECT No. 05-1413-036A		
DESIGN	CJC	03OCT05
CADD	WLI	03OCT05
CHECK	CJC	03OCT05
REVIEW		

FILE No. 051413036A-SK14

SCALE AS SHOWN | REV. A

FIGURE 2

CADD FILE: N:\Bur-Graphics\Projects\2005\1413\05-1413-036A\BLAST DESIGN\051413036A-SK14.dwg   By: WLi   REVISION DATE: 05/10/6 8:42am



0 100 200 300 400 500
Scale in Meters

CADD FILE: N:\Bur-Graphics\Projects\2005\1413\05-1413-036A\BLAST DESIGN\051413036A-SK15.dwg By: WLi REVISION DATE: 05/10/6 8:41am

LEGEND

- Green line: 12 kg Charge Weight, 15m Offset
- Magenta line: **77 kg Charge Weight, 38m Offset** (highlighted in yellow)
- Orange line: 250 kg Charge Weight, 69m Offset

Confinement, k = 800

Yellow box: Recommended Charge Weight

NOTES

1. Contour Interval 2 Metre.
2. All Dimensions in Metres.
3. Elevations in Metres above Sea Level.
4. UTM Zone 14, NAD83.
5. Area behind Dikes is De-watered during Operations.
6. Reference: Feasibility Study Report, AMEC, June 2005.

REFERENCES

1) AMEC Americas LTD, Drawing # A1-131395-100-C-0001 (100-C-0001.dwg), Meadowbank Feasibility Study, April 2005.
2) Golder Associates: Report on Blast Design, Meadowbank Golder Project, February 2004.
3) Golder Associates: Blasting Report Addendum, May 2004.

PROJECT

CUMBERLAND RESOURCES LTD.

TITLE

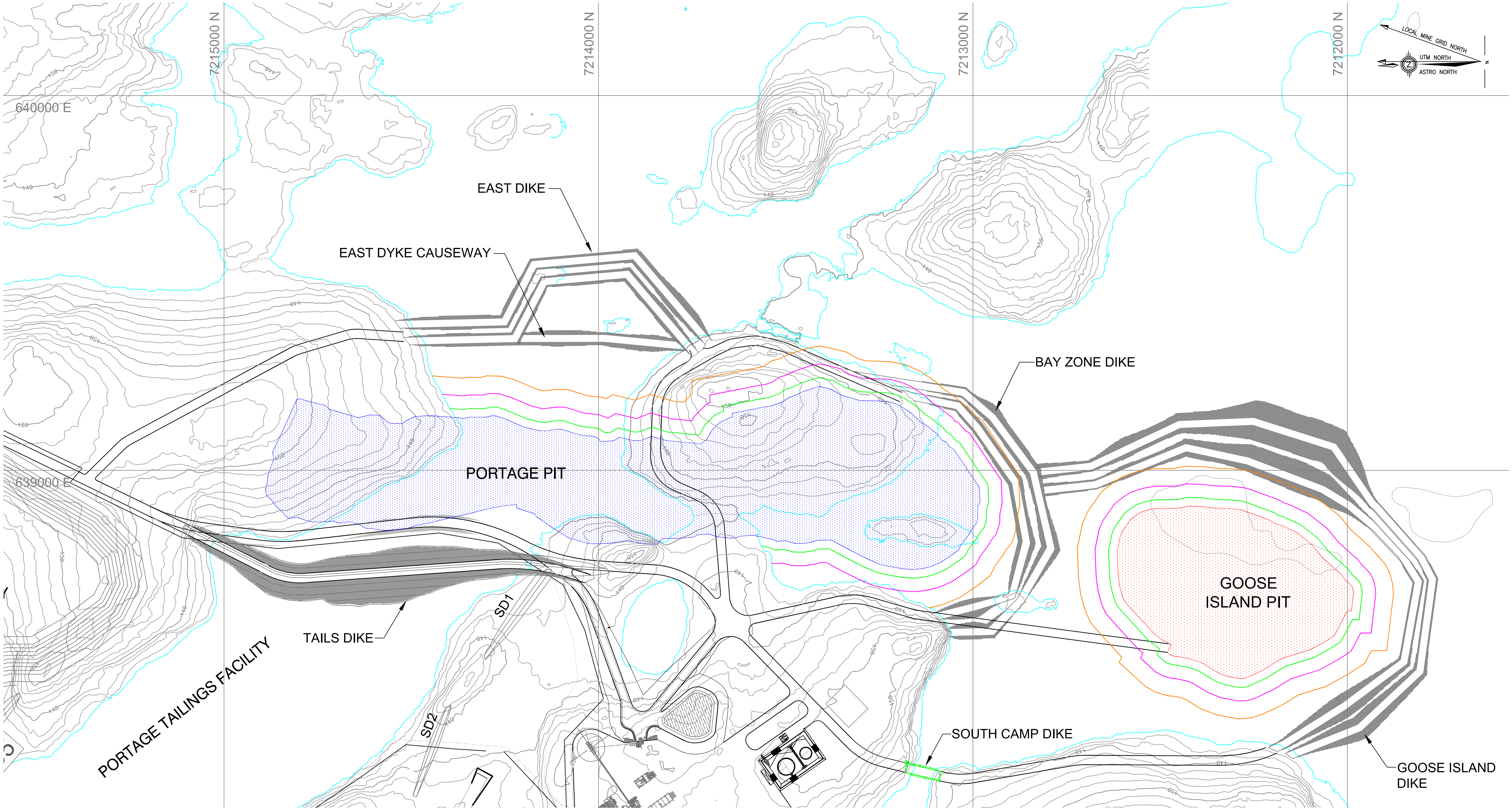
INSTANTANEOUS OVERPRESSURE 100kPa ISOPLETH

Golder Associates

PROJECT No. 05-1413-036A		
DESIGN	CJC	03OCT05
CADD	WLI	03OCT05
CHECK	CJC	03OCT05
REVIEW		

FILE No. 051413036A-SK15
SCALE AS SHOWN REV. A

FIGURE 3



0 100 200 300 400 500
Scale in Meters

LEGEND

Green line	12 kg Charge Weight, 23m Offset
Magenta line	77 kg Charge Weight, 59m Offset (highlighted in yellow)
Orange line	250 kg Charge Weight, 106m Offset
Confinement, k = 800	Yellow box: Recommended Charge Weight

NOTES

1. Contour Interval 2 Metre.
2. All Dimensions in Metres.
3. Elevations in Metres above Sea Level.
4. UTM Zone 14, NAD83.
5. Area behind Dikes is De-watered during Operations.
6. Reference: Feasibility Study Report, AMEC, June 2005.

REFERENCES

1) AMEC Americas LTD, Drawing # A1-131395-100-C-0001 (100-C-0001.dwg), Meadowbank Feasibility Study, April 2005.
2) Golder Associates: Report on Blast Design, Meadowbank Golder Project, February 2004.
3) Golder Associates: Blasting Report Addendum, May 2004.

PROJECT
CUMBERLAND RESOURCES LTD.

TITLE
INSTANTANEOUS OVERPRESSURE 50 kPa ISOPLETH UNDER ICE CONDITION

Golder Associates

PROJECT No. 05-1413-036A			FILE No. 051413036A-SK2-1	
DESIGN	CJC	03OCT05	SCALE AS SHOWN	REV. 0
CADD	WLI	03OCT05		
CHECK	CJC	03OCT05		
REVIEW				

FIGURE 4

REVISION DATE: 05/10/6 8:38am By: WLi CADD FILE: N:\Bur-Graphics\Projects\2005\1413\05-1413-036A\BLAST DESIGN\051413036A-SK02-1.dwg

APPENDIX D

Perimeter Dike Slope Stability Analyses

Table D.1: Summary of Limit Equilibrium Slope Stability Analyses – Meadowbank Dikes

Figure No. (I-)	Section Analyzed	Conditions Modelled	Calculated Minimum FOS	Calculated Yield Acceleration (g)	Maximum Required Undrained Shear Strength of Overburden Till (kPa)	
					FOS=1.0	FOS=1.3
		End of Construction				
A1	A	Failure through Cutoff Wall; Circular Surfaces			13	19
A2		Failure through Cutoff Wall; Block Surfaces			13	18
A3		Failure through Rockfill; Circular Surfaces			20	28
A4		Failure through Rockfill; Block Surfaces			18	24
B1	B	Failure through Cutoff Wall; Circular Surfaces			n/a	n/a
B2		Failure through Cutoff Wall; Block Surfaces			16	23
B3		Failure through Rockfill; Circular Surfaces			n/a	5
B4		Failure through Rockfill; Block Surfaces			20	30
C1	C	Failure through Cutoff Wall; Circular Surfaces			7	9
C2		Failure through Cutoff Wall; Block Surfaces			9	13
C3		Failure through Rockfill; Circular Surfaces			11	16
C4		Failure through Rockfill; Block Surfaces			10	14
		Long-Term Effective Strength				
A5	A	Failure through Cutoff Wall; Circular Surfaces – Static	4.1			
A6		Failure through Cutoff Wall; Block Surfaces - Static	4.3			
A7		Failure through Rockfill; Circular Surfaces – Static	2.7			
A8		Failure through Rockfill; Block Surfaces - Static	2.8			
A9		Failure through Cutoff Wall; Circular Surfaces – Pseudostatic	3.5			
A10		Failure through Cutoff Wall; Block Surfaces - Pseudostatic	3.7			
A11		Failure through Rockfill; Circular Surfaces – Pseudostatic	2.5			
A12		Failure through Rockfill; Block Surfaces - Pseudostatic	2.6			
A13		Failure through Cutoff Wall; Circular Surfaces – Yield Acceleration		0.41		

Figure No. (I-)	Section Analyzed	Conditions Modelled	Calculated Minimum FOS	Calculated Yield Acceleration (g)	Maximum Required Undrained Shear Strength of Overburden Till (kPa)	
					FOS=1.0	FOS=1.3
A14		Failure through Cutoff Wall; Block Surfaces - Yield Acceleration		0.41		
A15		Failure through Rockfill; Circular Surfaces – Yield Acceleration		0.36		
A16		Failure through Rockfill; Block Surfaces - Yield Acceleration		0.38		
B5	B	Failure through Cutoff Wall; Circular Surfaces – Static	3.5			
B6		Failure through Cutoff Wall; Block Surfaces - Static	5.9			
B7		Failure through Rockfill; Circular Surfaces – Static	1.9			
B8		Failure through Rockfill; Block Surfaces - Static	3.1			
B9		Failure through Cutoff Wall; Circular Surfaces – Pseudostatic	3.0			
B10		Failure through Cutoff Wall; Block Surfaces - Pseudostatic	4.9			
B11		Failure through Rockfill; Circular Surfaces – Pseudostatic	1.7			
B12		Failure through Rockfill; Block Surfaces - Pseudostatic	2.8			
B13		Failure through Cutoff Wall; Circular Surfaces – Yield Acceleration		0.27		
B14		Failure through Cutoff Wall; Block Surfaces - Yield Acceleration		0.40		
B15		Failure through Rockfill; Circular Surfaces – Yield Acceleration		0.16		
B16		Failure through Rockfill; Block Surfaces - Yield Acceleration		0.34		
C5	C	Failure through Cutoff Wall; Circular Surfaces – Static	5.0			
C6		Failure through Cutoff Wall; Block Surfaces - Static	3.9			
C7		Failure through Rockfill; Circular Surfaces – Static	3.4			
C8		Failure through Rockfill; Block Surfaces - Static	3.2			
C9		Failure through Cutoff Wall; Circular Surfaces – Pseudostatic	3.7			

Figure No. (I-)	Section Analyzed	Conditions Modelled	Calculated Minimum FOS	Calculated Yield Acceleration (g)	Maximum Required Undrained Shear Strength of Overburden Till (kPa)	
					FOS=1.0	FOS=1.3
C10		Failure through Cutoff Wall; Block Surfaces - Pseudostatic	3.3			
C11		Failure through Rockfill; Circular Surfaces – Pseudostatic	2.4			
C12		Failure through Rockfill; Block Surfaces - Pseudostatic	2.8			
C13		Failure through Cutoff Wall; Circular Surfaces – Yield Acceleration		0.48		
C14		Failure through Cutoff Wall; Block Surfaces - Yield Acceleration		0.37		
C15		Failure through Rockfill; Circular Surfaces – Yield Acceleration		0.42		
C16		Failure through Rockfill; Block Surfaces - Yield Acceleration		0.36		