APPENDIX B

Construction Specification
**SPECIFICATION**

The document revision number indicated below. Please replace all revised pages of this document and destroy the superseded copies.

<table>
<thead>
<tr>
<th>PROJECT:</th>
<th>SNAP LAKE MINE</th>
<th>NO.:</th>
<th>REV. 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE BEERS PROJECT No.:</td>
<td>[TO BE CONFIRMED BY DE BEERS]</td>
<td>GOLDER PROJECT No.:</td>
<td>1785666-033-SP-Rev0-7000</td>
</tr>
<tr>
<td>TITLE:</td>
<td>NORTH PILE CLOSURE COVER SPECIFICATION</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ISSUED FOR</th>
<th>REV. No.</th>
<th>ORIGIN</th>
<th>DATE</th>
<th>ISSUED- PAGES / SECTIONS</th>
<th>INITIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water License Renewal</td>
<td>0</td>
<td>HNL</td>
<td>11Mar2019</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>New Issue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Revised Sheet Only Attached</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entire Document Re-issued</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FINAL DOCUMENT APPROVAL**

<table>
<thead>
<tr>
<th>DE BEERS APPROVAL</th>
<th>GOLDER APPROVAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine Manager:</td>
<td>Review: Bjorn Weeks</td>
</tr>
<tr>
<td>Date:</td>
<td>Date: 11 March 2019</td>
</tr>
<tr>
<td>Plant Superintendent:</td>
<td>Project Manager: Abdul Sattar Khan</td>
</tr>
<tr>
<td>Date:</td>
<td>Date: 11 March 2019</td>
</tr>
<tr>
<td>Metallurgical Process Engineer:</td>
<td>Originator: Heather Lammers</td>
</tr>
<tr>
<td>Date:</td>
<td>Date: 11 March 2019</td>
</tr>
<tr>
<td>Engineering Lead:</td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td></td>
</tr>
</tbody>
</table>
All users are responsible for ensuring that they are using the most recent revision of this document.
Distribution List

Electronic Copy - De Beers Group of Companies

Electronic Copy - Golder Associates Ltd.
# Table of Contents

## 1.0 SCOPE OF WORK
   1.1 General ................................................................. 1
   1.2 Project Coordination .................................................. 2
   1.3 Definitions ............................................................... 2
   1.4 Abbreviations ............................................................ 3
   1.5 Codes and Standards .................................................. 4
   1.6 Construction Drawings ................................................. 5
   1.7 Submissions ............................................................... 6
   1.8 Protection ................................................................ 8
   1.9 Dust Control ............................................................... 8
   1.10 Construction Quality Control / Assurance ......................... 9
   1.10.1 Inspection and Testing ............................................. 9
   1.10.2 Laboratory Testing Services .................................... 10
   1.11 Description of Items .................................................. 10
   1.12 Dimensional Tolerances .............................................. 11
   1.13 Mobilization / Demobilization ..................................... 11
   1.14 Field Engineering ...................................................... 11
   1.14.1 Survey Control and Documentation ............................ 11
   1.14.2 Examination ........................................................ 12
   1.14.3 Alterations to Construction Drawings and Specification 12

## 2.0 CARE OF WATER ............................................... 13

## 3.0 FOUNDATION PREPARATION .................................. 14
   3.1 Work Sequence ....................................................... 14
   3.2 Products .................................................................. 14
   3.3 Execution ............................................................... 14
4.0 WEST PERIMETER EMBANKMENT REGRADE .................................................................16
  4.1 Work Sequence ...........................................................................................................16
  4.2 Products .......................................................................................................................16
  4.3 Execution ....................................................................................................................17

5.0 IN-PLACE MATERIAL EXCAVATION .........................................................................20
  5.1 Work Sequence ...........................................................................................................20
  5.2 Products .......................................................................................................................20
  5.3 Execution ....................................................................................................................20

6.0 STARTER CELL REGRADE .........................................................................................22
  6.1 Work Sequence ...........................................................................................................22
  6.2 Products .......................................................................................................................22
  6.3 Execution ....................................................................................................................22

7.0 LANDFILL WASTE PLACEMENT ..............................................................................25
  7.1 Work Sequence ...........................................................................................................25
  7.2 Products .......................................................................................................................25
  7.3 Execution ....................................................................................................................25

8.0 EAST CELL REGRADE ..............................................................................................27
  8.1 Work Sequence ...........................................................................................................27
  8.2 Products .......................................................................................................................27
  8.3 Execution ....................................................................................................................27

9.0 CLOSURE COVER CONSTRUCTION ......................................................................30
  9.1 Work Sequence ...........................................................................................................30
  9.2 Products .......................................................................................................................30
  9.3 Execution ....................................................................................................................31

10.0 SWALE AND OUTLET CHANNEL ARMOURING ......................................................34
  10.1 Work Sequence .........................................................................................................34
  10.2 Products .....................................................................................................................34
  10.3 Execution ..................................................................................................................34
11.0 INSTRUMENTATION INSTALLATION ..................................................................................36

11.1 Work Sequence..................................................................................................................36
11.2 Products ..............................................................................................................................36
11.3 Execution.............................................................................................................................36

TABLES
Table 1: Codes and Standards.................................................................................................4
Table 2: Snap Lake Mine North Pile Closure Cover Construction Drawings..........................5
Table 3: Type 4 Fill Gradation Specification.............................................................................16
Table 4: Type 5 Fill Gradation Specification.............................................................................16
Table 5: Typical Coarse and Grits Particle Size......................................................................17
Table 6: Combined Coarse and Grits Processed Kimberlite Fraction Gradation Specification ..................................................................................................................17
Table 7: Transition Material Gradation ....................................................................................30
Table 8: Erosion Protection Cover Gradation Specification ....................................................31
1.0 SCOPE OF WORK

1.1 General

1.1.1 This Specification defines the requirements for the construction and development of the North Pile closure cover as specified herein for De Beers Group of Companies’ Snap Lake Mine in the Northwest Territories of Canada.

1.1.2 Modifications or deviations from this Specification and/or corresponding Construction Drawings listed herein shall only occur with the written approval of Golder Associates Ltd.

1.1.3 The Scope of Work defined herein includes the construction and development of the North Pile closure cover as indicated in the Construction Drawings. The Contractor shall provide all materials and equipment required to execute and perform the Scope of Work, unless specifically noted otherwise.

1.1.4 The Contractor is expected to cooperate and coordinate construction with the Owner’s Representative(s). The expected general sequence for the North Pile closure cover is presented below. The construction schedule and sequence shall be proposed by the Contractor and approved by the Owner’s Representative(s); the Owner’s Representative(s) shall provide updates to the Contractor as required.

a. west perimeter embankment foundation preparation
b. west perimeter embankment side slope regrade
c. west perimeter embankment closure cover construction
d. East Cell in-place material excavation
e. East Cell landfill waste placement
f. Starter Cell top surface regrade
g. Starter Cell closure cover construction
h. Starter Cell swale armouring
i. East Cell top surface regrade
j. East Cell closure cover construction
k. East Cell swale and outlet channel armouring

1.1.5 The Contractor shall perform the Scope of Work such that no damage to existing infrastructure occurs. The Contractor shall coordinate with the Geotechnical Engineer to identify existing infrastructure prior to construction and determine protection measures to implement during construction. The Contractor shall report any damage to infrastructure immediately to the Owner’s Representative(s). The Contractor shall be responsible for all costs and activities necessary to repair and/or replace infrastructure to the satisfaction of the Owner’s Representative(s).

1.1.6 All work shall conform to the lines, grades, cross-sections, and details indicated in the Construction Drawings and meet the requirements of this Specification, including care and control of water, processing of materials as necessary, material stockpiling, loading, hauling, and fill placement. Excavation and backfilling of material shall include sorting or screening that may be necessary to produce the required gradations.
1.2 **Project Coordination**

1.2.1 The Contractor shall coordinate and comply with the Owner’s Representative(s) in allocation of areas for staging, access, and traffic.

1.2.2 The Contractor shall comply with the inter-project communication procedures of the Owner’s Representative(s) and the Geotechnical Engineer.

1.3 **Definitions**

1.3.1 The definitions of primary terms used in the Construction Drawings and this Specification document are listed below:

a. Owner De Beers Group of Companies
b. Owner’s Representative De Beers Group of Companies
c. Geotechnical Engineer Golder Associates Ltd.
d. CQA Official Golder Associates Ltd.

  The Construction Quality Assurance (CQA) Official reports directly to the Geotechnical Engineer. In the absence of the Geotechnical Engineer from the Work Site, responsibilities of the Geotechnical Engineer may be temporarily delegated to the CQA Official.

e. CQC Official De Beers Group of Companies

  The Construction Quality Control (CQC) Official reports directly to the Owner. The CQC Official will provide all required testing results to the Geotechnical Engineer and Owner’s Representative for review and comments.

f. Contractor De Beers Group of Companies
g. Project Site Snap Lake Mine

h. Work Site Limits of closure cover work, which is defined within the boundaries of the North Pile area as shown in the Construction Drawings.

h. CQC Construction Quality Control (CQC) is the planned system of inspections and laboratory testing carried out to standard specifications that are used to directly monitor the quality of products used in a construction project.
CQA Construction Quality Assurance (CQA) is the planned system of activities that provide the Owner, lending institutions, and permitting agencies assurance that the facilities were constructed as specified in the design. Construction Quality Assurance is composed of inspections and includes verifications and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. Construction Quality Assurance refers to measures taken by the Construction Quality Assurance organization to assess whether the Contractor is in compliance with the Construction Drawings and this Specification.

1.4 Abbreviations

1.4.1 The abbreviations commonly used in the Construction Drawings and in the Specification for this contract are listed below:

a. m  metre
b. m²  square metre
c. m³  cubic metre
d. mm  millimetre
e. 3H:1V  slope of 3 horizontal units to 1 vertical unit
f. %  percent
g. ASTM  ASTM International; originally known as American Society for Testing and Materials
i. CQA  Construction Quality Assurance
j. CQAP  Construction Quality Assurance Plan
k. CQCP  Construction Quality Control Plan
l. De Beers  De Beers Group of Companies
m. Golder  Golder Associates Ltd.
n. PEP  Project Execution Plan
o. PK  processed kimberlite
p. t  tonne
1.5 Codes and Standards

1.5.1 Work shall conform to, but not be limited to, the requirements of the most recent revisions of the following standards and codes that are part of this Specification. It is important to note that additional standards may be referenced by those listed in Table 1; it is the responsibility of the user of this Specification to be familiar with all the applicable standards.

Table 1: Codes and Standards

<table>
<thead>
<tr>
<th>Organization</th>
<th>Standard / Code</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM</td>
<td>D422</td>
<td>Standard Test Method for Particle-Size Analysis of Soils</td>
</tr>
<tr>
<td>ASTM</td>
<td>D698</td>
<td>Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ [600 kN-m/m³])</td>
</tr>
<tr>
<td>ASTM</td>
<td>D1140</td>
<td>Standard Test Method for Amount of Material in Soils Finer than the No. 200 (75 µm) Sieve</td>
</tr>
<tr>
<td>ASTM</td>
<td>D1556</td>
<td>Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method</td>
</tr>
<tr>
<td>ASTM</td>
<td>D2167</td>
<td>Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method</td>
</tr>
<tr>
<td>ASTM</td>
<td>D2216</td>
<td>Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass</td>
</tr>
<tr>
<td>ASTM</td>
<td>D6938</td>
<td>Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)</td>
</tr>
<tr>
<td>ASTM</td>
<td>E1915</td>
<td>Standard Test Methods for Analysis of Metal Bearing Ores and Related Materials for Carbon, Sulfur, and Acid-Base Characteristics</td>
</tr>
<tr>
<td>Government of the Northwest Territories</td>
<td>R-039-2015</td>
<td>Occupational Health and Safety Regulations under the Safety Act of the Northwest Territories</td>
</tr>
</tbody>
</table>
1.6 **Construction Drawings**

1.6.1 This Specification defines the requirements for performing the work as outlined in the most recent revision of the Construction Drawings presented in Table 2. Should a discrepancy or omission be identified by the Contractor, the Contractor shall request, in writing, clarification from the Geotechnical Engineer, through the Owner’s Representative(s). The Contractor shall proceed only upon receipt of written clarification from the Owner’s Representative(s).

### Table 2: Snap Lake Mine North Pile Closure Cover Construction Drawings

<table>
<thead>
<tr>
<th>Construction Drawing Number</th>
<th>Construction Drawing Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1-142221-6200-121-0800</td>
<td>COVER SHEET</td>
</tr>
<tr>
<td>A1-142221-6200-121-0801</td>
<td>GENERAL ARRANGEMENT PLAN: EXISTING 2018 LAYOUT WITH BORROW LOCATIONS</td>
</tr>
<tr>
<td>A1-142221-6200-121-0802</td>
<td>NORTH PILE FACILITY PERFORMANCE MONITORING: INSTRUMENTATION PLAN FOR CLOSURE</td>
</tr>
<tr>
<td>A1-142221-6200-121-0803</td>
<td>NORTH PILE FACILITY BASELINE AND FREEZE-BACK MONITORING: INSTRUMENTATION PLAN FOR CLOSURE</td>
</tr>
<tr>
<td>A1-142221-6200-121-0804</td>
<td>NORTH PILE CELL 2 EXCAVATION PLAN</td>
</tr>
<tr>
<td>A1-142221-6200-121-0805</td>
<td>NORTH PILE CELL 2 EXCAVATION DEPTH PLAN</td>
</tr>
<tr>
<td>A1-142221-6200-121-0806</td>
<td>NORTH PILE CLOSURE COVER SURFACE GRADING PLAN</td>
</tr>
<tr>
<td>A1-142221-6200-121-0807</td>
<td>NORTH PILE CLOSURE COVER GRADING ELEVATION CHANGE: OCTOBER 2018 TO POST CLOSURE COVER CONSTRUCTION</td>
</tr>
<tr>
<td>A1-142221-6200-121-0808</td>
<td>NORTH PILE CLOSURE COVER GRADING PLAN WITH CONTROL POINT LOCATIONS</td>
</tr>
<tr>
<td>A1-142221-6200-121-0809</td>
<td>NORTH PILE CLOSURE COVER GRADING PLAN SEQUENTIAL CONTROL POINT TABLES (1 of 2)</td>
</tr>
<tr>
<td>A1-142221-6200-121-0810</td>
<td>NORTH PILE CLOSURE COVER GRADING PLAN SEQUENTIAL CONTROL POINT TABLES (2 of 2)</td>
</tr>
<tr>
<td>A1-142221-6200-121-0811</td>
<td>NORTH PILE CLOSURE COVER GRADING PLAN CONTROL POINT TABLES GROUPED BY COVER PROFILE (1 of 2)</td>
</tr>
<tr>
<td>A1-142221-6200-121-0812</td>
<td>NORTH PILE CLOSURE COVER GRADING PLAN CONTROL POINT TABLES GROUPED BY COVER PROFILE (2 of 2)</td>
</tr>
<tr>
<td>A1-142221-6200-121-0813</td>
<td>NORTH PILE CROSS-SECTIONS (1 OF 2)</td>
</tr>
<tr>
<td>A1-142221-6200-121-0814</td>
<td>NORTH PILE CROSS-SECTIONS (2 OF 2)</td>
</tr>
<tr>
<td>A1-142221-6200-121-0815</td>
<td>NORTH PILE SWALE AND OUTLET CHANNEL PROFILES</td>
</tr>
<tr>
<td>A1-142221-6200-121-0816</td>
<td>NORTH PILE TYPICAL CROSS-SECTIONS AND DETAILS</td>
</tr>
</tbody>
</table>
1.7 **Submissions**

1.7.1 The Contractor shall prepare and submit a Project Execution Plan (PEP) to the Owner’s Representative for review and approval within 15 days of receipt of Notice to Proceed. The Contractor shall revise the PEP to the satisfaction of the Owner’s Representative following review. The Owner’s Representative shall provide a copy of the PEP to the Geotechnical Engineer for review and comment. The Contractor shall commence with the Scope of Work only upon written authorization from the Owner’s Representative.

1.7.2 The PEP shall contain details describing:

a. Detailed Health, Safety and Environmental Plan for all tasks within the Scope of Work: The Health, Safety and Environmental Plan shall satisfy all Project Site requirements of the Owner.

b. Contractor understanding of the Scope of Work.

c. Methods for performing the Scope of Work.

d. Equipment list for performing the Scope of Work.

e. Dust control measures to be used.

f. A Construction Quality Control Plan (CQCP). The Contractor is responsible for controlling the quality of the work, including that performed by its subcontractors and suppliers, and for assuring that the specified quality is achieved. The Contractor shall be responsible for developing and maintaining a CQCP that satisfies requirements of this Specification. Updates to the CQCP shall be provided to the Owner’s Representative by the Contractor.

g. Schedule for performing the Scope of Work, including work activities and milestones. The schedule shall be revised and updated throughout the performance of work. Weekly updates of the schedule shall be submitted by the Contractor in hardcopy and electronic formats for review and comment by the Owner’s Representative. The weekly updates shall identify upcoming dates for approvals and Construction Quality Assurance inspection requirements in support of the Contractor’s work. The Contractor shall use commonly available standard software to maintain the schedule and present a Gantt chart (original baseline target schedule versus current progress with actual dates), budget, and percent complete (effort and budget). Schedule information shall be presented by the Contractor at weekly progress meetings to be held with the Owner’s Representative and the Geotechnical Engineer.

h. List of personnel performing the Scope of Work. Resumes and time allocation to support construction of the North Pile closure cover for all supervisors and management personnel shall also be submitted.

i. Additional requirements presented in the Specification.
1.7.3 The Contractor shall submit weekly as-built survey information in hardcopy and electronic formats to the Owner’s Representative for review and comment. All as-built survey information may be checked by the Owner’s Representative with input provided by the Geotechnical Engineer. The Contractor shall revise as-built survey information as directed by the Owner’s Representative. All as-built information mutually agreed upon between the Contractor and Owner’s Representative shall not thereafter be subject to dispute. All as-built information in hardcopy and electronic formats shall be maintained and be made available by the Contractor for turnover to the Owner upon completion.

a. For earthworks: At the direction of the Owner’s Representative and with input provided by the Geotechnical Engineer, the Contractor shall survey and record limits of prepared surfaces. Longitudinal sections and cross-sections shall be obtained to define the form and elevations of prepared surfaces. In areas of fill placement, accurate surveying shall be performed at 50 m grid spacing to determine the limits of fill placement and presentation of cross-sections at no more than 25 m spacing along the swale and outlet channel centrelines, and west perimeter embankment regrade toe. All survey information may be checked at any time during the work by the Owner’s Representative and/or Geotechnical Engineer. The Owner’s Representative shall provide a minimum notification period of seven days to the Contractor prior to construction of the swale and outlet channels and/or for additional survey requirements outside of the earthwork Scope of Work.

b. The Contractor may be directed by the Owner’s Representative, with input from the Geotechnical Engineer, to collect and present survey information outside of the requirements presented in the Specification. The details of this survey information shall be mutually agreed between the Contractor and Owner’s Representative prior to start of activity.

1.7.4 The Contractor shall submit daily and weekly construction documentation to the Owner’s Representative and the Geotechnical Engineer. The reports shall include, but not be limited to:

a. health, safety, and environmental performance
b. description of work activities performed
c. equipment and personnel utilized
d. results and comments on quality of work performed
e. list of submissions, approvals requested or outstanding
f. progress relative to schedule and necessary updates and/or changes (refer to Section 1.7.2.g)
g. quantities of materials placed and hauled
1.8 Protection

1.8.1 The Contractor is responsible for the care, protection, and confirmation of locations of all existing utilities, instrumentation, and site development that may be located within the Work Site. Any damage or suspected damage shall be immediately reported by the Contractor to the Owner’s Representative(s). Any damage to utilities and/or instrumentation caused by the Contractor shall be repaired or replaced as directed by, and to the satisfaction of, the Owner’s Representative(s) with no cost to the Owner. The Contractor shall obtain approval from the Owner’s Representative(s) prior to excavation activities.

1.8.2 In areas where construction activities are carried out in or adjacent to existing site development, the location and isolation and/or relocation of buried utilities shall be completed before excavation commences. Care shall be exercised during excavation to avoid damage to existing buried pipes, structures, ducts, and power and grounding cables. If damage to any of these occurs, the Owner’s Representative shall be notified immediately, and corrective action shall be taken by the Contractor according to the instructions of the Owner’s Representative(s). Repair and corrective action shall be performed by the Contractor with no cost to the Owner. For pipelines and structures that are to remain, the Contractor shall design the temporary support systems and present the details to the Owner’s Representative(s) for review and approval prior to starting the work. The Contractor shall:

   a. Confirm the locations of the buried utilities by test pit excavations at the direction of the Owner’s Representative(s).

   b. Provide labelled surface markers for buried lines.

   c. Record the location of maintained, rerouted, and abandoned buried lines.

   d. Provide corrected Construction Drawing and as-built survey information to the Owner’s Representative(s) after verification by the Owner’s Representative(s) of the accuracy.

1.9 Dust Control

1.9.1 The dust resulting from construction activities shall be controlled by the Contractor to prevent the spreading of dust and to avoid creation of a nuisance in the surrounding area. The requirement and judgement of acceptability of dust control measures shall be at the discretion of the Owner’s Representative. The Contractor shall include a description of the dust control measures in the PEP (refer to Section 1.7.2.e).
1.10 Construction Quality Control / Assurance

1.10.1 Inspection and Testing

1.10.1.1 The Owner will retain the Geotechnical Engineer to provide a Construction Quality Assurance Plan (CQAP) to describe monitoring activities for compliance with the Construction Drawings and Specification requirements. Performance and Construction Quality Assurance monitoring shall be performed throughout the major work activities. During periods of minor construction activities, the Owner’s Representative(s) and Geotechnical Engineer shall develop a plan for part-time Construction Quality Assurance coverage by the Geotechnical Engineer. If the Geotechnical Engineer is not on the Work Site, the Owner’s Representative and/or CQA Official is required to report observations to the Geotechnical Engineer.

1.10.1.2 The Contractor shall perform activities to meet the requirements of the CQCP. The results of these activities shall be provided to the Owner’s Representative and Geotechnical Engineer in hardcopy and electronic format.

1.10.1.3 The Contractor shall identify Construction Quality Control and Construction Quality Assurance monitoring requirements to enable the Contractor to continue with the work. The Contractor shall submit written requests, including expected timing, for Construction Quality Control and Construction Quality Assurance monitoring to the Owner’s Representative.

1.10.1.4 The Owner’s Representative shall provide a minimum notification period of 24 hours to the Geotechnical Engineer on the Work Site to perform Construction Quality Assurance monitoring. All notifications to the Geotechnical Engineer shall be submitted in writing.

1.10.1.5 The Contractor shall cooperate and assist with the Construction Quality Assurance monitoring activities including, but not limited to:

a. obtaining samples of materials
b. field testing of materials
c. provision and reviewing of documentation
d. surveying the testing locations

1.10.1.6 The Contractor and the Owner’s Representative shall be made aware of the Construction Quality Assurance monitoring results. The Geotechnical Engineer shall provide recommendations, if appropriate, to the Owner’s Representative regarding corrective measures required by the Contractor. At the written direction of the Owner’s Representative, the Contractor shall address the identified deficiencies.

1.10.1.7 Construction checklist forms are required for documenting the Construction Quality Control and other aspects of the construction activities as detailed in the CQCP. The checklists shall be developed and signed off by Construction Quality Control Personnel or the Owner’s Representative, and by the Geotechnical Engineer for acceptance of the construction activities. If the Geotechnical Engineer is not on the Work Site, the Owner’s Representative and/or CQA Official is required to report observations to the Geotechnical Engineer.
1.10.2 Laboratory Testing Services

1.10.2.1 The Owner will appoint, employ, and pay for services of an independent third party to perform laboratory testing. The Geotechnical Engineer may act as an independent third-party laboratory at the discretion of the Owner.

1.10.2.2 The independent third party shall perform laboratory tests under the supervision and control of the Owner or Owner’s Representative.

1.10.2.3 The Contractor shall cooperate with the independent third party and furnish material samples as required. The Contractor shall provide a minimum notification period of 24 hours to the Owner’s Representative on the Work Site to perform Construction Quality Control laboratory testing. A minimum notification of one week is required otherwise. All notifications to the Owner or Owner’s Representative shall be submitted in writing.

1.10.2.4 The independent third party shall provide the Geotechnical Engineer with a copy of the testing report, indicating observations and results of tests and indicating compliance or non-compliance with the Specification.

1.10.2.5 Retesting required due to non-compliance to the Specification shall be performed by the same independent third party on instructions from the Geotechnical Engineer. The Contractor shall be responsible for the costs of retesting.

1.11 Description of Items

1.11.1 The North Pile closure cover construction consists of:

a. foundation preparation
b. west perimeter embankment regrade
c. in-place material excavation (from Cell 2)
d. North Pile regrade
e. landfill waste placement (within Cell 1 and Cell 2)
f. closure cover construction
g. swale and outlet channel armouring
h. instrumentation installation

1.11.2 Closure cover materials will be obtained from regrade activities. Additional closure cover materials may be obtained from identified borrow sources for placement at the North Pile. These materials shall be excavated, loaded, and hauled from the stockpiles as directed by the Owner’s Representative.
1.12 Dimensional Tolerances

1.12.1 All excavations and fill shall be completed to be within ±0.1 m horizontally and +0.1 m vertically of specified lines and grades unless otherwise approved by the Geotechnical Engineer. Fill placement and/or removal to meet these tolerances to the lines and limits shown in the Construction Drawings shall be performed by the Contractor at no additional cost to the Owner.

1.12.2 Slopes shall not be steeper than those shown in the Construction Drawings unless otherwise approved by the Geotechnical Engineer.

1.12.3 Temporary excavation and temporary fill slopes shall not be steeper than 4 horizontal to 1 vertical (4H:1V), as requested by the Owner, unless otherwise approved by the Geotechnical Engineer and Owner’s Representative(s). Temporary excavations and fill slopes shall not be larger than 5 m in vertical height without benching for stability.

1.13 Mobilization / Demobilization

1.13.1 Upon receipt of Approval to Proceed, the Contractor shall furnish, mobilize, and install temporary support systems as necessary to complete the Scope of Work. Designs for the temporary support system must submitted to the Geotechnical Engineer for approval prior to installation. The Contractor shall also maintain the temporary support systems throughout the performance of work.

1.13.2 Demobilization consists of repairing all slopes disturbed during construction, removing all construction debris and temporary support systems, and returning the Work Site to a suitable condition for permanent stabilization of disturbed surfaces as required by the Owner’s Representative(s) and Geotechnical Engineer.

1.14 Field Engineering

1.14.1 Survey Control and Documentation

1.14.1.1 Survey control and documentation shall be provided by the Contractor for confirmation of existing ground conditions, grade control during construction, and as-built conditions.

1.14.1.2 As-built survey documentation shall be provided by the Contractor weekly and upon completion of construction activities listed in Section 1.11.1.

1.14.1.3 The Contractor shall use a minimum of three survey monuments to layout the vertical control for the work and provide the elevation, northing, and easting coordinates of each monument.

1.14.1.4 The Contractor shall use staking at no more than 25 m spacing along the swale and outlet channel centrelines, as shown in the Construction Drawings.

1.14.1.5 The Contractor shall perform an as-built survey weekly and upon completion of each construction item (refer to Section 1.11.1). Elevation, northing, and easting coordinates shall be provided to the Owner’s Representative(s) and Geotechnical Engineer for verification of design compliance. As-built surveys shall include swale and outlet channel crest and toes, grade changes, and depressions sufficient to develop a triangulated irregular network (TIN) surface that is accurate to 0.1 m.
1.14.1.6  The Contractor shall provide as-built drawings to the Owner’s Representative(s) and Geotechnical Engineer. As-built drawings shall show site topography at a 0.5 m contour interval. Each as-built surveyed area shall have sufficient overlap with adjacent, previous as-built surveyed areas to avoid survey gaps.

1.14.1.7  The Contractor is responsible for maintaining a complete and accurate log of survey control and documentation.

1.14.2  Examination

1.14.2.1  The Contractor shall notify the Owner’s Representative(s) and Geotechnical Engineer of any discrepancies with the Construction Drawings discovered in the as-built survey.

1.14.3  Alterations to Construction Drawings and Specification

1.14.3.1  Alterations made by the Geotechnical Engineer to either the Construction Drawings or Specification shall be subject to approval by the Owner’s Representative(s) and, where applicable, to the approval of regulatory agencies. Alterations shall be issued under an Owner-approved Scope of Work prior to construction of the alteration. Alterations made by the Contractor to either the Construction Drawings or Specification are not allowed.
2.0 CARE OF WATER

2.0.1 Excavation, fill, and landfill work areas shall be continually and effectively drained by the Contractor. Excessive water shall not be permitted to accumulate in excavations or fill areas. The Contractor shall construct suitable temporary dykes or provide pumping equipment, as required, to divert flows away from work areas. The proposed point of discharge shall be reviewed and approved by the Owner’s Representative. The Contractor must also ensure that sediments contained in diverted water will not enter a natural watercourse and that all pumping meets the requirements of the Owner.

2.0.2 The Contractor shall be responsible for the design and construction of all temporary measures, dewatering systems, pumping facilities, siphons, and ice removal required for satisfactory management of water and ice at the Work Site. A surface water / drainage management plan shall be submitted by the Contractor for review and approval by the Owner’s Representative(s) prior to commencing construction.

2.0.3 Landfill operations may not commence until all water has been drained or otherwise removed from the excavation and the Geotechnical Engineer has approved the commencement of landfilling operations.
3.0 FOUNDATION PREPARATION

3.1 Work Sequence

3.1.1 Start work only upon receipt of approval to proceed from the Owner’s Representative.

3.1.2 Start work following receipt of approval from the Owner’s Representative of as-built survey information submission for pre-work conditions (i.e., existing conditions survey).

3.1.3 Start work following completion of temporary dykes or pumping equipment placement, as required, to divert flows away from the Work Site.

3.2 Products

3.2.1 “Unsuitable material” includes topsoil, organic soils, vegetation, and boulders to a depth or in a location that will impede the placement and compaction of competent material. Unsuitable material may be frozen in situ. Within the foundation preparation limits of the structure, unsuitable material may include mineral soil that has high silt, clay, water, and/or ice content.

Determination of unsuitable material and competent material will be made by the Geotechnical Engineer. The Contractor may be required to assist during the determination by performing such work as proof rolling, test pit excavation, and sampling as directed by the Geotechnical Engineer.

3.2.2 “Mineral soil” is the near-surface layer of earth materials generally composed of till-like soil, including but not limited to varying proportions of sand, gravel, silt, clay, cobbles, and boulders. Thawed mineral soil materials are normally suitable for mechanical excavation. Frozen mineral soil materials may require the use of drilling, blasting, ripping, and/or other techniques approved by the Owner’s Representative (with input from the Geotechnical Engineer) to prepare the materials for excavation.

3.2.3 “Competent material” includes mineral soil, existing embankment fill material, and the underlying bedrock as determined by the Geotechnical Engineer.

3.2.4 “Existing fill material” included existing granular pads and stockpiles. The materials underlying the existing fill material may not be known and may be the subject of investigation by the Contractor as directed by the Geotechnical Engineer.

3.3 Execution

3.3.1 The Contractor Shall remove unsuitable material in the west perimeter embankment regrade area indicated in the Construction Drawings and/or as directed by the Geotechnical Engineer.

3.3.2 In areas where existing fill material and/or unsuitable material are within the limits of the work, the Contractor shall advance test pit excavations as directed by the Geotechnical Engineer. The materials encountered shall be inspected by the Geotechnical Engineer. A determination of competent material of the excavated and underlying materials shall be made and recorded by the Geotechnical Engineer.
3.3.3 The Contractor shall allow the Geotechnical Engineer to review the prepared foundation to evaluate conformance to the Specification. Acceptance of foundation preparation shall be performed and recorded by the Geotechnical Engineer.

3.3.4 The Contractor shall dispose of excavated unsuitable materials at a location indicated by the Owner’s Representative.

3.3.5 The Contractor shall provide as-built survey throughout foundation preparation, providing weekly as-built survey data on a 3 m grid pattern.

3.3.6 Consistent with Section 3.3.5 above, the Contractor shall be responsible for collecting and maintaining as-built survey data throughout the foundation preparation. The Contractor shall provide as-built survey data to the Geotechnical Engineer as follows:

   a. Existing conditions survey.

   b. Weekly as-built survey data on a 3 m grid, sending to the Geotechnical Engineer within 48 hours of collection.

   c. All data shall be collected in the Snap Lake Mine site referenced grid system.

3.3.7 The Contractor shall complete appropriate checklists according to Section 1.10.1.7.
4.0 WEST PERIMETER EMBANKMENT REGRADE

4.1 Work Sequence

4.1.1 Start work only upon receipt of approval to proceed from the Owner's Representative.

4.1.2 Start work following receipt of approval from the Owner’s Representative of as-built survey information submission for pre-work conditions (i.e., existing conditions survey, foundation preparation survey).

4.1.3 Start work following completion of temporary dykes or pumping equipment placement, as required, to divert flows away from the Work Site.

4.2 Products

4.2.1 “Waste rock material” from underground sources. Placement of waste rock material will be within the areas shown in the Construction Drawings, described in this Specification, and/or as directed by the Geotechnical Engineer. In general, the waste rock material will meet the gradation specification for Type 4 Fill (Table 3) and/or Type 5 Fill (Table 4).

<table>
<thead>
<tr>
<th>Table 3: Type 4 Fill Gradation Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sieve Designation (mm)</strong></td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>4.75</td>
</tr>
<tr>
<td>0.850</td>
</tr>
<tr>
<td>0.425</td>
</tr>
<tr>
<td>0.180</td>
</tr>
<tr>
<td>0.075</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4: Type 5 Fill Gradation Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sieve Designation (mm)</strong></td>
</tr>
<tr>
<td>600</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>4.75</td>
</tr>
<tr>
<td>0.850</td>
</tr>
<tr>
<td>0.425</td>
</tr>
<tr>
<td>0.180</td>
</tr>
<tr>
<td>0.075</td>
</tr>
</tbody>
</table>
4.2.2 "Coarse and grits material" comprises the coarse and grit fractions of the processed kimberlite (PK) used to construct the west perimeter embankment of the North Pile. In general, coarse and grits material will meet the particle size listed in Table 5 and the gradation specification listed in Table 6.

### Table 5: Typical Coarse and Grits Particle Size

<table>
<thead>
<tr>
<th>Processed Kimberlite (PK) Fraction</th>
<th>Particle Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>1.5–6.0</td>
</tr>
<tr>
<td>Grits</td>
<td>0.125–1.5</td>
</tr>
</tbody>
</table>

### Table 6: Combined Coarse and Grits Processed Kimberlite Fraction Gradation Specification

<table>
<thead>
<tr>
<th>Sieve Designation (mm)</th>
<th>Percent Passing by Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5</td>
<td>100</td>
</tr>
<tr>
<td>4.75</td>
<td>90–100</td>
</tr>
<tr>
<td>2</td>
<td>62–97</td>
</tr>
<tr>
<td>0.85</td>
<td>42–75</td>
</tr>
<tr>
<td>0.425</td>
<td>28–55</td>
</tr>
<tr>
<td>0.25</td>
<td>16–40</td>
</tr>
<tr>
<td>0.15</td>
<td>6–25</td>
</tr>
<tr>
<td>0.075</td>
<td>0–10</td>
</tr>
</tbody>
</table>

### 4.3 Execution

4.3.1 Complete west perimeter embankment regrade. No fill material is to be placed on prepared foundation surface without approval from the Geotechnical Engineer. The checklist shall be completed according to Section 1.10.1.7 before fill material can be placed. If the Geotechnical Engineer is not on the Work Site, the CQA Official or Owner’s Representative is required to report observations to the Geotechnical Engineer.

4.3.2 Develop and document a traffic pattern to achieve required compaction densities of fill material to the satisfaction of the Geotechnical Engineer.

4.3.3 Perform the west perimeter embankment regrade as a local cut to fill operation. The regrade is expected to be a top excavation and push down to the extent shown in the Construction Drawings. The Geotechnical Engineer shall, with the cooperation of the Contractor, conduct field trials to assess the material placement techniques and achieved placement densities to assess possible variation to the loose lift thickness.
4.3.4 Oversize particles shall be removed from the fill material.

4.3.5 Adjust water content of waste rock and coarse and grits materials to within 3% of optimum water content.

4.3.6 Waste rock and coarse and grits materials shall be compacted using a vibratory smooth drum compactor with a minimum mass of 10 t. All material shall be placed and compacted prior to the material freezing.

   a. Coarse and grits material and waste rock material shall be compacted to at least 95% standard Proctor maximum dry density. The Contractor shall perform placement density and moisture content measurements of these materials for every 500 m³ of embankment regrade material placed. The Contractor shall perform one standard Proctor test and one grain size analysis for every 25 field density measurements.

   b. Waste rock Type 4 and Type 5 Fill material shall be compacted using a performance-based requirement. It is expected that a minimum of six passes of the compaction equipment will be required.

   c. The compaction method and degree of compaction achieved in the field will be monitored by the Geotechnical Engineer. The Contractor shall cooperate with the Owner’s Representative and Geotechnical Engineer to develop methods to achieve a satisfactory degree of compaction for the fill materials.

4.3.7 Any embankment regrade material that has become saturated, softened, or loosened or has undergone a reduction in density by precipitation, ponded water, construction traffic, or frost action is to be excavated and replaced with suitable material. The Geotechnical Engineer shall identify areas from which material shall be removed. This work shall be performed to the satisfaction of the Geotechnical Engineer. The excavated material may be dried and/or thawed and used for fill material upon approval from the Owner’s Representative using recommendations provided by the Geotechnical Engineer.

4.3.8 Shape the west perimeter embankment to a dense, uniform surface free of ruts or loose material at a slope sufficient to promote free drainage or surface water at all times.

4.3.9 West perimeter embankment material shall not be used as cover material.

4.3.10 Before suspension of operations each day or before inclement weather, the in-place material shall be compacted and the surface rolled smooth and crowned to promote runoff of precipitation.

4.3.11 Hauling and spreading equipment shall be routed and the traffic patterns shall be varied to prevent rutting. Any damage to the west perimeter embankment or to the fill material already placed shall be repaired to the satisfaction of the Geotechnical Engineer. This may include, but shall not be limited to, the removal of ruts and repairs to fill boundaries.

4.3.12 The west perimeter embankment regrade shall be uniform and constructed to the lines, grades, and cross-sections shown in the Construction Drawings.

4.3.13 Water shall not be permitted to pond on the west perimeter embankment surface. All surfaces shall be graded to promote drainage of water.
4.3.14 Fill material placed in the west perimeter embankment regrade shall be free from lenses, pockets, or layers of materials that are significantly different in gradation from the surrounding material. The Contractor shall employ methods to limit the amount and zones of segregated materials. The Contractor shall work with the Geotechnical Engineer to develop such methods, which may include, but shall not be limited to, material blending. The Geotechnical Engineer shall provide recommendations to the Owner’s Representative as to the acceptability of the results of the placed materials. Fill materials shall be placed to the satisfaction of the Geotechnical Engineer.

4.3.15 Provide field survey staking at a maximum spacing of 25 m along the toe of the west perimeter embankment regrade presenting, but not necessarily limited to:

a. embankment station
b. offset from station reference line
c. elevation

4.3.16 The Contractor shall provide as-built survey throughout foundation preparation, providing weekly as-built survey data on a 3 m grid pattern.

4.3.17 Consistent with Section 4.3.15 above, the Contractor shall be responsible for collecting and maintaining as-built survey data throughout the west perimeter embankment regrade. The Contractor shall provide as-built survey data to the Geotechnical Engineer as follows:

a. Existing conditions survey.
b. Weekly as-built survey data on a 3 m grid, sending to the Geotechnical Engineer within 48 hours of collection.
c. The Contractor shall prepare, based on AutoCAD Civil 3D drawings provided by the Geotechnical Engineer, the existing conditions survey and a surface for each subsequent as-built survey collected, and calculate west perimeter embankment regrade quantities.
d. All data shall be collected in the Snap Lake Mine site referenced grid system.

4.3.18 Complete appropriate checklists according to Section 1.10.1.7.
5.0 IN-PLACE MATERIAL EXCAVATION

5.1 Work Sequence

5.1.1 Start work upon receipt of approval to proceed from the Owner's Representative.

5.1.2 Start work following receipt of approval from the Owner’s Representative of as-built survey information submission for pre-work conditions (i.e., existing conditions survey).

5.1.3 Start work following completion of temporary surface water control construction, as required.

5.2 Products

5.2.1 “Waste rock material” as defined in Section 4.

5.2.2 “Coarse and grits material” as defined in Section 4.

5.2.3 “Rib berm material” includes non-frozen, competent, run-of-mine waste rock and coarse and grits materials approved in writing by the Geotechnical Engineer for rib berm construction.

5.2.3 “Deposited PK material” includes the fines fraction of the PK material placed within the North Pile during deposition activities. Fine fractions were deposited as a slurry or thickened slurry. The homogeneity, consistency, and strength of the deposited PK material may be spatially variable.

5.2.4 “Run-of-Mine” material includes waste rock material from underground sources as two types: Potentially Acid Generating (PAG) and Non-Acid Generating (Non-AG). Placement of PAG and Non-AG materials will be within the areas as shown on the Drawings, described in this Specification and/or as directed by the Geotechnical Engineer. In general, the run-of-mine material meets the gradation specifications for Type 4 Fill and/or Type 5 Fill.

5.3 Execution

5.3.1 Excavate rib berm material from Rib Berm 1, located between Cell 1 and Cell 2 of the East Cell, and Rib Berm 2, located between Cell 2 and Cell 3 to the bottom of cover elevations as shown in the Construction Drawings.

5.3.2 Load, transport, and stockpile excavated rib berm material for use as fill during closure cover construction at a location identified by the Owner’s Representative. Where rib berm material is comprised of PAG (metavolcanics or high sulphide granite rockfill), the final placement of this material shall be at a location at least 3 m deep below the final top-of-grade cover surface elevation, unless geochemical testing or other validation has been carried out to demonstrate to the satisfaction of the CQA official and Owner’s Representative that the material is non-acid generating. This demonstration will normally require laboratory testing of representative samples.

5.3.3 Push stockpiled rib berm material from the crest of Rib Berm 2 and the perimeter embankment into Cell 2 at a slope of 4H:1V to the top of the deposited PK material.
5.3.4 Excavate deposited PK material from Cell 2 of the East Cell to the depths as shown in the Construction Drawings. The deposited PK material will be excavated from Cell 2 in horizontal layers of approximately 1 m thickness, leaving a 4H:1V slope against the upstream perimeter of Cell 2 as the deposited PK material is removed.

5.3.5 Load and transport the excavated deposited PK material from Cell 2 for placement within Cell 3 of the East Cell.

5.3.6 Spread the excavated deposited PK material in horizontal lifts of maximum 0.3 m loose lift thickness. Modifications to maximum loose lift thicknesses shall be at the direction of the Geotechnical Engineer. The Geotechnical Engineer shall, with the cooperation of the Contractor, conduct field trials to assess the material placement techniques and possible variation to the loose lift thickness.

5.3.7 Place excavated rib berm material to a thickness of 0.3 m over the 4H:1V slope of exposed deposited PK material within Cell 2 for erosion protection as the Cell 2 excavation is advanced.

5.3.8 Excavate the remaining rib berm material from Rib Berm 1 to the depths as shown in the Construction Drawings.

5.3.9 Water shall not be permitted to pond on surfaces. Ponded water shall be removed from within the North Pile.

5.3.10 The Contractor shall provide as-built survey throughout the in-place material excavation, providing weekly as-built survey data on a 3 m grid pattern.

5.3.11 Consistent with Section 5.3.7 above, the Contractor shall be responsible for collecting and maintaining as-built survey data throughout the in-place material excavation. The Contractor shall provide as-built survey data to the Geotechnical Engineer as follows:

   a. Existing conditions survey.

   b. Weekly as-built survey data on a 3 m grid, sending to the Geotechnical Engineer within 48 hours of collection.

   c. The Contractor shall prepare, based on AutoCAD Civil 3D drawings provided by the Geotechnical Engineer, the existing survey and a surface for each subsequent as-built survey collected, and calculate the in-place material excavation quantities.

   d. All data shall be collected in the Snap Lake Mine site referenced grid system.

5.3.12 Complete appropriate checklists according to Section 1.10.1.7.
6.0 STARTER CELL REGRADE

6.1 Work Sequence

6.1.1 Start work upon receipt of approval to proceed from the Owner's Representative.

6.1.2 Start work following receipt of approval from the Owner's Representative of as-built survey information submission for pre-work conditions (i.e., existing conditions survey).

6.1.3 Start work following completion of temporary surface water control construction, as required.

6.2 Products

6.2.1 "Rib berm material" as defined in Section 5.

6.2.2 "Deposited PK material" as defined in Section 5.

6.2.3 "Embankment fill material" includes non-frozen, competent, and non-acid generating run-of-mine, coarse and grits, and quarry material and/or other material approved in writing by the Geotechnical Engineer for embankment construction

6.2.4 "Embankment / rib berm material" includes non-frozen, competent, and non-acid generating embankment fill and/or rib berm materials.

6.3 Execution

6.3.1 Complete the Starter Cell regrade. No fill material is to be placed without approval from the Geotechnical Engineer. The checklist shall be completed according to Section 1.10.1.7 before fill material can be placed. If the Geotechnical Engineer is not on the Work Site, the CQA Official or Owner's Representative is required to report observations to the Geotechnical Engineer.

6.3.2 Develop and document a traffic pattern to achieve required compaction densities of fill material to the satisfaction of the Geotechnical Engineer.

6.3.3 Perform the Starter Cell regrade as a local cut to fill operation to the extent shown in the Construction Drawings. The Geotechnical Engineer shall, with the cooperation of the Contractor, conduct field trials to assess the material placement techniques and achieved placement densities to assess possible variation to the loose lift thickness.

6.3.4 Where rib berm material is to be used as fill in the regrade, any rib berm material comprised of PAG (metavolcanics or high sulphide granite rockfill) shall be placed in locations at a depth of at least 3 m deep below the final top-of-grade cover surface elevation, unless geochemical testing or other validation has been carried out to demonstrate to the satisfaction of the CQA official and Owner's Representative that the material is non-acid generating. This demonstration will normally require laboratory testing of representative samples.
6.3.5 Excess excavated non-acid generating embankment / rib berm material may be stockpiled for use during closure cover construction at a location identified by the Owner’s Representative. The non-acid generating characteristics of PAG (metavolcanics or high sulphide granite rockfill) previously used for rib berm construction should be demonstrated through geochemical testing. If testing shows the material to be acid generating, it should be placed as fill at a depth of at least 3 m below the final cover elevation.

6.3.6 Deposited PK material will remain contained within the individual cell footprints of the North Pile.

6.3.7 Oversize particles shall be removed from the deposited PK and embankment / rib berm materials.

6.3.8 Adjust water content of coarse and grits and waste rock fill material to within 3% of optimum water content.

6.3.9 Embankment / rib berm material shall be compacted using a vibratory smooth drum compactor with a minimum mass of 10 t. All fill material shall be placed and compacted prior to the material freezing.

   a. Embankment / rib berm material shall be compacted to at least 95% standard Proctor maximum dry density. The Contractor shall perform placement density and moisture content measurements of these materials for every 500 m³ of embankment regrade material. The Contractor shall perform one standard Proctor test and one grain size analysis for every 25 field density measurements.

   b. Type 4 and Type 5 Fill material shall be compacted using a performance-based requirement. It is expected that a minimum of six passes of the compaction equipment will be required.

   c. The compaction method and degree of compaction achieved in the field will be monitored by the Geotechnical Engineer. The Contractor shall cooperate with the Owner’s Representative and Geotechnical Engineer to develop methods to achieve a satisfactory degree of compaction for the fill materials.

6.3.10 Any embankment / rib berm and/or deposited PK materials that have become saturated, softened, or loosened or have undergone a reduction in density by precipitation, ponded water, construction traffic, or frost action are to be excavated and replaced with suitable material. The Geotechnical Engineer shall identify areas from which material is to be removed. This work shall be performed to the satisfaction of the Geotechnical Engineer. The excavated material may be dried and/or thawed and used for fill material upon approval from the Owner’s Representative using recommendations provided by the Geotechnical Engineer.

6.3.11 Shape the Starter Cell regrade to a dense, uniform surface free of ruts or loose material at a slope sufficient to promote free drainage or surface water at all times.

6.3.12 Before suspension of operations each day or before inclement weather, the in-place material shall be compacted, and the surface rolled smooth and crowned to promote runoff of precipitation.

6.3.13 Hauling and spreading equipment shall be routed and the traffic patterns shall be varied to prevent rutting. Any damage to the Starter Cell regrade shall be repaired to the satisfaction of the Geotechnical Engineer prior to the placement of the next lift. This may include, but shall not be limited to, the removal of ruts and repairs to fill boundaries.
6.3.14 Water shall not be permitted to pond on surfaces. All surfaces shall be graded to promote drainage of water. Ponded water shall be removed from the North Pile.

6.3.15 Embankment / rib berm material placed in the Starter Cell regrade shall be free from lenses, pockets, or layers of materials that are significantly different in gradation from the surrounding material. The Contractor shall employ methods to limit the amount and zones of segregated materials. The Contractor shall work with the Geotechnical Engineer to develop such methods, which may include, but shall not be limited to, material blending. The Geotechnical Engineer shall provide recommendations to the Owner's Representative as to the acceptability of the results of the placed materials. Fill materials shall be placed to the satisfaction of the Geotechnical Engineer.

6.3.16 Provide field survey staking at a maximum grid spacing of 50 m over the Starter Cell regrade area presenting, but not necessarily limited to the station and elevation.

6.3.17 The Contractor shall provide as-built survey throughout the Starter Cell regrade, providing weekly as-built survey data on a 3 m grid pattern.

6.3.18 Consistent with Section 6.3.16 above, the Contractor shall be responsible for collecting and maintaining as-built survey data throughout the Starter Cell regrade. The Contractor shall provide as-built survey data to the Geotechnical Engineer as follows:

a. Existing conditions survey.

b. Weekly as-built survey data on a 3 m grid, sending to the Geotechnical Engineer within 48 hours of collection.

c. The Contractor shall prepare, based on AutoCAD Civil 3D drawings provided by the Geotechnical Engineer, the existing conditions survey and a surface for each subsequent as-built survey collected, and calculate Starter Cell regrade quantities.

d. All data shall be collected in the Snap Lake Mine site referenced grid system.

6.3.19 Complete appropriate checklists according to Section 1.10.1.7.
7.0 LANDFILL WASTE PLACEMENT

7.1 Work Sequence

7.1.1 Start work upon receipt of approval to proceed from the Owner’s Representative.

7.1.2 Start work following receipt of approval from the Owner’s Representative of as-built survey information submission for pre-work conditions (i.e., existing conditions survey, in-place material excavation survey).

7.1.3 Start work following completion of temporary surface water control construction, as required.

7.2 Products

7.2.1 “Landfill waste material” includes non-hazardous waste from facility decommissioning and demolition. Landfill waste material shall be sized prior to placement in landfill, with steel / aluminum and similar materials sheared to a 600 mm minus size. Wood is to be cut reduced to less than 2.3 m maximum length.

7.2.2 “Deposited PK material” as defined in Section 5.

7.3 Execution

7.3.1 Complete landfill waste material placement. No landfill waste material is to be placed into Cell 2 until excavation of the deposited PK has been completed as shown in the Construction Drawings (Drawing A1-142221-6200-121-0804), and review and approval of the Cell 2 excavation is obtained from the Geotechnical Engineer. The checklist shall be completed in accordance with Section 1.10.1.7, prior to placement. In the absence of the Geotechnical Engineer, CQA official or designated Owner’s Representative are required to report observations to the Geotechnical Engineer.

7.3.2 Landfill waste placement shall be restricted to the existing landfill Cell 1 and excavated Cell 2 of the East Cell to limit the extent of non-hazardous waste placement in the North Pile (Drawing A1-142221-6200-121-0806).

7.3.3 Develop and document a traffic pattern to achieve required compaction densities of landfill material to the satisfaction of the Geotechnical Engineer.

7.3.4 Landfill waste material shall meet the maximum size specification in Section 7.2.1. Oversize particles shall be removed and resized prior to placement as landfill waste material.

7.3.5 Landfill waste material shall be track compacted with a bulldozer in lifts of no more than 600 mm. A layer of suitable deposited PK or other material approved by the Geotechnical Engineer may be used to facilitate compaction, and shall also be track compacted if placed. All landfill waste material and daily cover material shall be placed and compacted prior to the material freezing.

7.3.6 The compaction method and degree of compaction achieved in the field will be monitored by the Geotechnical Engineer. The Contractor shall cooperate with the Owner’s Representative and Geotechnical Engineer to develop methods to achieve a satisfactory degree of compaction for the landfill waste materials.
7.3.7 Landfill waste and daily cover materials shall be placed such that Cell 1 and Cell 2 shed water appropriately, and no water ponding occurs over, or directly adjacent to Cell 1 or Cell 2.

7.3.8 The Contractor shall provide as-built survey throughout landfill waste material placement within Cell 1 and Cell 2, providing weekly as-built survey data of the initial Cell 1 and Cell 2 configuration on a 3 m grid pattern to track landfill waste placement volumes through the progression of the North Pile closure cover construction.

7.3.9 Consistent with Section 7.3.8 above, the Contractor shall be responsible for collecting and maintaining as-built survey data throughout landfill waste placement operations within Cell 1 and Cell 2. The Contractor shall provide as-built survey data to Geotechnical Engineer as follows:

a. Initial Cell 1 and Cell 2 surface (i.e., existing conditions survey); upon completion and approval of Rib Berm 1 and deposited PK material excavation from Cell 2, prior to landfill waste placement.

b. Weekly as-built survey data on a 3 m grid (including top and bottom of slopes) – sending to Geotechnical Engineer within 48 hours of collection.

c. The Contractor shall prepare, based on AutoCAD Civil 3D drawing provided by Geotechnical Engineer, the initial Cell 1 and Cell 2 surface (i.e., existing conditions survey) and a surface for each subsequent as-built survey collected, and calculate landfill waste placement volumes through the North Pile closure cover construction.

d. All data shall be collected in the Snap Lake Mine site referenced grid system.

7.3.10 Complete appropriate checklists according to Section 1.10.1.7.
8.0 EAST CELL REGRADE

8.1 Work Sequence

8.1.1 Start work upon receipt of approval to proceed from the Owner’s Representative.

8.1.2 Start work following receipt of approval from the Owner’s Representative of as-built survey information submission for pre-work conditions (i.e., existing conditions survey, landfill waste placement survey).

8.1.3 Start work following completion of temporary surface water control construction, as required.

8.2 Products

8.2.1 “Deposited PK material” as defined in Section 5.

8.2.2 “Embankment / rib berm material” as defined in Section 6.

8.2.3 “Landfill waste material” as defined in Section 7.

8.3 Execution

8.3.1 Complete the East Cell regrade. No fill material is to be placed without approval from the Geotechnical Engineer. The checklist shall be completed according to Section 1.10.1.7 before fill material can be placed. If the Geotechnical Engineer is not on the Work Site, the CQA Official or Owner’s Representative is required to report observations to the Geotechnical Engineer.

8.3.2 Develop and document a traffic pattern to achieve required compaction densities of fill material to the satisfaction of the Geotechnical Engineer.

8.3.3 Perform the East Cell regrade as a local cut to fill operation, post-landfill waste placement, to the extent shown in the Construction Drawings. The Geotechnical Engineer shall, with the cooperation of the Contractor, conduct field trials to assess the material placement techniques and achieved placement densities to assess possible variation to the loose lift thickness.

8.3.4 Where rib berm material is to be used as fill in the regrade, any rib berm material comprised of PAG (metavolcanics or high sulphide granite rockfill) shall be placed in locations at a depth of at least 3 m deep below the final top-of-grade cover surface elevation, unless geochemical testing or other validation has been carried out to demonstrate to the satisfaction of the CQA official and Owner’s Representative that the material is non-acid generating. This demonstration will normally require laboratory testing of representative samples.

8.3.5 Excess excavated non-acid generating embankment / rib berm material may be stockpiled for use during closure cover construction at a location identified by the Owner’s Representative. The non-acid generating characteristics of PAG (metavolcanics or high sulphide granite rockfill) previously used for rib berm construction should be demonstrated through geochemical testing. If testing shows the material to be acid generating, it should be placed as fill at a depth of at least 3 m below the final cover elevation.
8.3.6 Deposited PK and landfill waste materials will remain contained within the individual cell footprints of the North Pile.

8.3.7 Oversize particles shall be removed from the deposited PK and embankment / rib berm materials.

8.3.8 Adjust water content of the embankment / rib berm material to within 3% of optimum water content.

8.3.9 Embankment / rib berm material shall be compacted using a vibratory smooth drum compactor with a minimum mass of 10 t. All fill material shall be placed and compacted prior to the material freezing.

   a. Embankment / rib berm material shall be compacted to at least 95% standard Proctor maximum dry density. The Contractor shall perform placement density and moisture content measurements of these materials for every 500 m³ of embankment regrade material. The Contractor shall perform one standard Proctor test and one grain size analysis for every 25 field density measurements.

   b. Type 4 and Type 5 Fill material shall be compacted using a performance-based requirement. It is expected that a minimum of six passes of the compaction equipment will be required.

   c. The compaction method and degree of compaction achieved in the field will be monitored by the Geotechnical Engineer. The Contractor shall cooperate with the Owner’s Representative and Geotechnical Engineer to develop methods to achieve a satisfactory degree of compaction for the fill materials.

8.3.0 Any embankment / rib berm, deposited PK, and/or landfill waste materials that have become saturated, softened, or loosened or have undergone a reduction in density by precipitation, ponded water, construction traffic, or frost action are to be excavated and replaced with suitable material or ripped in place and allowed to dry. The Geotechnical Engineer shall identify areas from which material shall be removed. The excavated material may be dried and/or thawed and used for fill material upon approval from the Owner’s Representative using recommendations provided by the Geotechnical Engineer.

8.3.11 Shape the East Cell regrade to a dense, uniform surface free of ruts or loose material at a slope sufficient to promote free drainage or surface water at all times.

8.3.12 Before suspension of operations each day or before inclement weather, the in-place material shall be compacted, and the surface rolled smooth and crowned to promote runoff of precipitation.

8.3.13 Hauling and spreading equipment shall be routed and the traffic patterns shall be varied to prevent rutting. Any damage to the East Cell regrade shall be repaired to the satisfaction of the Geotechnical Engineer prior to the placement of the next lift. This may include, but shall not be limited to, the removal of ruts and repairs to fill boundaries.

8.3.14 Water shall not be permitted to pond on surfaces. All surfaces shall be graded to promote drainage of water. Ponded water shall be removed from the North Pile.
8.3.15  Embankment / rib berm material placed in the East Cell regrade shall be free from lenses, pockets, or layers of materials that are significantly different in gradation from the surrounding material. The Contractor shall employ methods to limit the amount and zones of segregated materials. The Contractor shall work with the Geotechnical Engineer to develop such methods, which may include, but shall not be limited to, material blending. The Geotechnical Engineer shall provide recommendations to the Owner’s Representative as to the acceptability of the results of the placed materials. Fill materials shall be placed to the satisfaction of the Geotechnical Engineer.

8.3.16  Provide field survey staking at a maximum grid spacing of 50 m over the East Cell regrade area presenting, but not necessarily limited to the station and elevation.

8.3.17  The Contractor shall provide as-built survey throughout the East Cell regrade, providing weekly as-built survey data on a 3 m grid pattern.

8.3.18  Consistent with Section 8.3.16 above, the Contractor shall be responsible for collecting and maintaining as-built survey data throughout the East Cell regrade. The Contractor shall provide as-built survey data to the Geotechnical Engineer as follows:

a.  Existing conditions survey.

b.  Weekly as-built survey data on a 3 m grid, sending to the Geotechnical Engineer within 48 hours of collection.

c.  The Contractor shall prepare, based on AutoCAD Civil 3D drawings provided by the Geotechnical Engineer, the existing conditions survey and a surface for each subsequent as-built survey collected, and calculate East Cell regrade quantities.

d.  All data shall be collected in Snap Lake Mine site referenced grid system.

8.3.19  Complete appropriate checklists according to Section 1.10.1.7.
9.0 CLOSURE COVER CONSTRUCTION

9.1 Work Sequence

9.1.1 Start work only upon receipt of approval to proceed from the Owner's Representative.

9.1.2 Start work following receipt of approval from the Owner’s Representative of as-built survey information submission for pre-work conditions (i.e., existing conditions survey, west perimeter embankment regrade survey, landfill waste placement survey, North Pile regrade survey). Closure cover placement may be advanced upon approval of pre-work conditions for a work area, independent of adjacent work areas (e.g., cover placement may be advanced for the west perimeter embankment prior to completion of landfill waste placement in the East Cell).

9.1.3 Start work following completion of temporary surface water control construction, as required.

9.1.4 Start work following review of cover profile construction locations presented in the Construction Drawings.

9.2 Products

9.2.1 “Deposited PK material” as defined in Section 5.

9.2.2 “Embankment / rib berm material” as defined in Section 6.

9.2.3 “Landfill waste material” as defined in Section 7.

9.2.4 “Transition Material” is non-acid generating material that shall consist of clean, hard, durable, angular stones with a nominal 80 mm minus size and gradation specification listed in Table 7, and shall be free of organics and other unsuitable material.

Table 7: Transition Material Gradation

<table>
<thead>
<tr>
<th>Sieve Designation (mm)</th>
<th>Percent Passing by Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>33</td>
<td>60</td>
</tr>
<tr>
<td>25</td>
<td>45</td>
</tr>
<tr>
<td>9.5</td>
<td>25</td>
</tr>
<tr>
<td>4.75</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>0.85</td>
<td>0</td>
</tr>
</tbody>
</table>

9.2.5 “Erosion protection cover material” is non-acid generating rockfill material sourced locally from identified stockpiles and borrow sources with a nominal 150 mm minus size and gradation specification listed in Table 8.
### Table 8: Erosion Protection Cover Gradation Specification

<table>
<thead>
<tr>
<th>Sieve Designation (mm)</th>
<th>Percent Passing by Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>60–100</td>
</tr>
<tr>
<td>25</td>
<td>45–90</td>
</tr>
<tr>
<td>4.75</td>
<td>25–70</td>
</tr>
<tr>
<td>0.850</td>
<td>10–30</td>
</tr>
<tr>
<td>0.425</td>
<td>5–20</td>
</tr>
<tr>
<td>0.180</td>
<td>0–10</td>
</tr>
<tr>
<td>0.075</td>
<td>0–5</td>
</tr>
</tbody>
</table>

### 9.3 Execution

9.3.1 Complete closure cover construction. No closure cover material is to be placed on prepared foundation surface without approval from the Geotechnical Engineer. The checklist shall be completed according to Section 1.10.1.7 before embankment fill material can be placed. If the Geotechnical Engineer is not on the Work Site, the CQA Official or Owner’s Representative is required to report observations to the Geotechnical Engineer.

9.3.2 Develop and document a traffic pattern to achieve required compaction densities of transition and erosion protection cover materials to the satisfaction of the Geotechnical Engineer.

9.3.3 Place transition material over the landfill waste and deposited PK materials in horizontal lifts with a maximum loose lift thickness of 0.3 m as shown in the Construction Drawings, provided that compaction of at least 95% standard Proctor maximum dry density is achieved.

9.3.4 Modifications to maximum loose lift thicknesses shall be at the direction of the Geotechnical Engineer. The Geotechnical Engineer shall, with the cooperation of the Contractor, conduct field trials to assess the material placement techniques and achieved placement densities to assess possible reduction in the total transition zone thickness.

9.3.4 Adjust water content of transition material to within 3% of optimum water content.

9.3.5 Transition material shall be compacted using a vibratory smooth drum compactor with a minimum mass of 10 t. All fill material shall be placed and compacted prior to the material freezing. Transition material shall be compacted to at least 95% standard Proctor maximum dry density. The Contractor shall perform placement density and moisture content measurements of these materials for every 500 m³ or 1,700 m² lift of in-place material. The Contractor shall perform one standard Proctor test and one grain size analysis for every 25 field density measurements.

9.3.6 Place erosion protection cover material over the entire North Pile closure cover area, after placement of transition material, in a single uniform lift thickness of 0.3 m as shown in the Construction Drawings.
9.3.7 Oversize particles shall be removed from the transition and erosion protection cover materials.

9.3.8 The Contractor shall obtain grab samples from the borrow source for every 500 m³ of transition material and erosion protection cover material obtained for construction of the closure cover. Acid base accounting tests will be performed on each sample to validate the transition and erosion protection cover materials are non-acid generating. If a sample obtained is found to be acid generating, the Contractor shall avoid using the borrow source until additional inspections by the Owner and Geotechnical Engineer.

9.3.9 Any transition or erosion protection cover material that has become saturated, softened, or loosened or has undergone a reduction in density by precipitation, ponded water, construction traffic, or frost action is to be excavated and replaced with suitable material. The Geotechnical Engineer shall identify areas from which material shall be removed. This work shall be performed to the satisfaction of the Geotechnical Engineer. The excavated material may be dried and/or thawed and used for fill material upon approval from the Owner's Representative using recommendations provided by the Geotechnical Engineer.

9.3.10 Shape the closure cover to a dense, uniform surface free of ruts or loose material at a slope sufficient to promote free drainage or surface water at all times.

9.3.11 Before suspension of operations each day or before inclement weather, the closure cover shall be compacted and the surface rolled smooth and crowned to promote runoff of precipitation.

9.3.12 Hauling and spreading equipment shall be routed approximately parallel to the axis of the embankment and the traffic patterns shall be varied to prevent rutting. Any damage to the fill material already placed shall be repaired to the satisfaction of the Geotechnical Engineer prior to the placement of the next lift. This may include, but shall not be limited to, the removal of ruts and repairs to fill boundaries.

9.3.13 The North Pile closure cover shall be constructed to the lines, grades, and cross-sections shown in the Construction Drawings.

9.3.14 Water shall not be permitted to pond on surfaces. All surfaces shall be sealed and crowned to promote drainage of water. Ponded water shall be removed from the embankment.

9.3.15 Slope exterior embankment surfaces to be plane and uniform and to the lines and grades shown in the Construction Drawings. This will require the placement and compaction of fill material beyond the lines and grades shown in the Construction Drawings followed by trimming to the lines and grades.

9.3.16 The closure cover shall be free from lenses, pockets, or layers of materials that are significantly different in gradation from the surrounding material. The Contractor shall employ methods to limit the amount and zones of segregated materials. The Contractor shall work with the Geotechnical Engineer to develop such methods, which may include, but shall not be limited to, the placement of parallel strips of fill materials within a given lift and/or material blending. The Geotechnical Engineer shall provide recommendations to the Owner's Representative as to the acceptability of the results of the placed materials. Fill materials shall be placed to the satisfaction of the Geotechnical Engineer.

9.3.17 Provide field survey staking at a maximum grid spacing of 50 m over the closure cover placement area presenting, but not necessarily limited to the station and elevation.
9.3.18 The Contractor shall provide as-built survey throughout the closure cover construction, providing weekly as-built survey data on a 3 m grid pattern.

9.3.19 Consistent with Section 9.3.17 above, the Contractor shall be responsible for collecting and maintaining as-built survey data throughout the closure cover construction. The Contractor shall provide as-built survey data to the Geotechnical Engineer as follows:

a. Existing conditions survey.

b. Weekly as-built survey data on a 3 m grid, sending to the Geotechnical Engineer within 48 hours of collection.

c. The Contractor shall prepare, based on AutoCAD Civil 3D drawings provided by the Geotechnical Engineer, the existing conditions survey and a surface for each subsequent as-built survey collected, and calculate the closure cover construction quantities.

d. All data shall be collected in Snap Lake Mine site referenced grid system.

9.3.20 Complete appropriate checklists according to Section 1.10.1.7.
10.0 SWALE AND OUTLET CHANNEL ARMOURING

10.1 Work Sequence

10.1.1 Start work only upon receipt of approval to proceed from the Owner’s Representative.

10.1.2 Start work upon completion of the closure cover construction as required and as shown in the Construction Drawings.

10.1.3 Start work following receipt of approval from the Owner’s Representative of as-built survey information submission for pre-work conditions (i.e., existing conditions survey, closure cover construction survey).

10.2 Products

10.2.1 “Erosion protection cover material” as defined in Section 9.

10.2.2 “Riprap” shall conform to the following requirements:

a. No fragments shall be larger than the nominal size specified in the Construction Drawings (i.e., 150 mm, 300 mm, or 600 mm).

b. At least 50% of the material, by weight, shall consist of fragments larger than half the nominal size specified in the Construction Drawings (i.e., 75 mm, 150 mm, or 300 mm).

c. At least 85% of the material, by weight, shall consist of fragments larger than 4.75 mm (US Standard No. 4 sieve).

d. Of the fraction passing the 75 mm US Standard sieve, not more than 5% of the material, by weight, shall pass the US Standard No. 200 sieve.

10.3 Execution

10.3.1 Riprap particles shall be placed to provide adequate interlock of individual pieces. Care shall be taken to reduce segregation of material during placement on the prepared surface. Segregation material shall be removed and replaced. The compaction requirement will be defined by the Geotechnical Engineer.

10.3.2 Keep placement surfaces free of water, debris, and foreign material during placement of riprap.

10.3.3 Place riprap on the prepared surface by approved means as a single uniform lift thickness over the entire swales and outlet channels to the lines and grades as shown in the Construction Drawings.

10.3.4 Riprap particles shall be placed to provide adequate interlock of individual pieces. Care shall be taken to reduce segregation of materials during placement. Segregated material shall be removed and replaced as directed by the Geotechnical Engineer.

10.3.5 Riprap shall be inspected by the Geotechnical Engineer for conformity with the specified requirements. Approval shall not be given until the riprap is in the final position on the slope, and work and materials are in accordance with the Specification.

10.3.6 The Contractor shall provide as-built survey throughout swale and outlet channel armouring.
10.3.7 Consistent with Section 10.3.6 above, the Contractor shall be responsible for collecting and maintaining as-built survey data throughout the swale and outlet channel armouring. The Contractor shall provide as-built survey data to the Geotechnical Engineer as follows:

a. Existing conditions survey.
b. Weekly as-built survey data at 3 m spacing, including the channel centreline, toe, and crest.
c. The Contractor shall prepare, based on AutoCAD Civil 3D drawings provided by the Geotechnical Engineer, the existing conditions survey and a surface for each subsequent as-built survey collected, and calculate swale and outlet channel armouring quantities.
d. All data shall be collected in Snap Lake Mine site referenced grid system.

10.3.8 Complete appropriate checklists according to Section 1.10.1.7.
11.0 INSTRUMENTATION INSTALLATION

11.1 Work Sequence

11.1.1 Start work only upon receipt of approval to proceed from the Owner’s Representative.

11.1.2 The instrumentation installation sequence is dependent on the construction sequence for the North Pile closure cover.

11.1.3 The Geotechnical Engineer shall prepare and submit a Work Plan for instrumentation to the Owner’s Representative for review and approval within 15 days of receipt of Notice to Proceed. The Work Plan shall include method of installation, length of instrumentation, and other materials and requirements. The Contractor shall commence with the Scope of Work only upon written authorization from the Owner’s Representative.

11.1.4 The Geotechnical Engineer may adjust the requirements of the instrumentation program based on the field conditions encountered during construction and results of the instrumentation monitoring.

11.2 Products

11.2.1 The Contractor is responsible for providing the instrumentation for the North Pile closure cover as shown in the Construction Drawings, including the following:

a. monitoring prisms
b. thermistors

11.3 Execution

11.3.1 Proposed instrumentation locations are shown in the Construction Drawings. Purchasing and calibration of the instruments shall be directed by the Owner’s Representative and completed prior to field installation. The installation of the instruments shall be overseen by the Geotechnical Engineer. The Contractor shall cooperate with the Owner’s Representative and Geotechnical Engineer for the installation of the instruments during the construction.

11.3.2 Priority of instrumentation installation shall be given by the Geotechnical Engineer and discussed and agreed upon with the Owner’s Representative prior to field installation.

11.3.3 Monitoring prisms and thermistors shall be installed at locations shown in the Construction Drawings. Regular measurement collection shall be carried out as directed by the Owner’s Representative (with input from the Geotechnical Engineer).

11.3.4 The Geotechnical Engineer will verify that the instrument is functioning properly and according to manufacturer’s specifications prior to installation by the Contractor.

11.3.5 The Contractor shall avoid damaging the instruments prior to, during, and installation. Instruments damaged by the Contractor shall be repaired at the expense of the Contractor.
Signature Page

Golder Associates Ltd.

Abdul Sattar Khan, M.A.Sc.
Project Manager

Bjorn Weeks, Ph.D., P.Eng.
Principal, Geo-environmental Engineer

ASK/BW/HNL/cr/cfrs/no

Golder and the G logo are trademarks of Golder Associates Corporation

APPENDIX C

Construction Quality Assurance Plan (CQAP)
REPORT

North Pile Closure Cover Construction Quality Assurance Plan

Snap Lake Mine

Submitted to:

**De Beers Group of Companies**
1601 Airport Road NE, Suite 300
Calgary, BC
T2E 6Z8

Attention: Sean Whitaker

Submitted by:

**Golder Associates Ltd.**
Suite 200 - 2920 Virtual Way, Vancouver, British Columbia, V5M 0C4, Canada

+1 604 296 4200

Reference No. 1785666-032-R-Rev0-4000

11 March 2019
Distribution List
Electronic Copy - De Beers Group of Companies

Electronic Copy - Golder Associates Ltd.
Study Limitations

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of De Beers Group of Companies. It represents Golder’s professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by De Beers Group of Companies, and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. De Beers Group of Companies may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.
Table of Contents

STUDY LIMITATIONS.............................................................................................................................................. ii

1.0 INTRODUCTION............................................................................................................................................. 1

2.0 PERSONNEL .................................................................................................................................................. 2
   2.1 Principal Organizations and Responsible Personnel ...................................................................................... 2
      2.1.1 Permitting Agency ................................................................................................................................ 3
      2.1.2 Owner ............................................................................................................................................... 3
      2.1.3 Geotechnical Engineer ..................................................................................................................... 3
      2.1.4 Construction Quality Assurance Official ............................................................................................ 3
      2.1.5 Construction Quality Assurance Inspection Personnel ....................................................................... 4
      2.1.6 Construction Quality Control Official .................................................................................................. 5
      2.1.7 Contractor ......................................................................................................................................... 6
   2.2 Meetings ............................................................................................................................................... 6
      2.2.1 Pre-construction Meeting ................................................................................................................ 6
      2.2.2 Daily Tailgate Meetings ................................................................................................................... 7
      2.2.3 Weekly Progress Meetings ............................................................................................................. 7
      2.2.4 Construction or Design Issues and Deficiencies Meetings ............................................................. 8

3.0 INSPECTION AND MONITORING ACTIVITIES ............................................................................................ 9
   3.1 Air, Dust, and Noise Monitoring ........................................................................................................... 10
   3.2 Construction Activity Inspections .......................................................................................................... 10

4.0 SAMPLING AND LABORATORY TESTING REQUIREMENTS ......................................................................... 11

5.0 DOCUMENTATION AND REPORTING ....................................................................................................... 12
   5.1 Photo Documentation ............................................................................................................................... 12
   5.2 Surveying ............................................................................................................................................... 12
   5.3 Daily Construction Progress Reports .................................................................................................... 12
   5.4 Weekly Construction Progress Reports .................................................................................................. 13
   5.5 Design Deficiencies and Modifications ................................................................................................ 13
5.6  Construction Record Report............................................................................................................. 14

6.0  CLOSURE............................................................................................................................................. 15

TABLES
Table 1: Personnel Responsibility and Authority......................................................................................... 2
Table 2: Inspection and Monitoring Activities............................................................................................... 9
Table 3: Construction Quality Control Sample Collection and Laboratory Testing Frequency.................. 11

APPENDICES

APPENDIX A
Construction Quality Assurance Form
1.0 INTRODUCTION

The De Beers Group of Companies (De Beers) owns and maintains Snap Lake Mine, a diamond mine located about 220 km northeast of Yellowknife, Northwest Territories, Canada. The mine operated from 2007 to 2015 and entered a care and maintenance phase on 4 December 2015. On 14 December 2017, De Beers notified the Mackenzie Valley Land and Water Board that it is preparing for final closure of the mine.

De Beers retained Golder Associates Ltd. (Golder) to prepare closure cover designs for the North Pile facility at Snap Lake Mine. The North Pile Facility includes the Starter Cell and East Cell, and was constructed for the disposal of processed kimberlite (PK), waste rock, and non-hazardous solid waste (landfill waste) materials. This report presents the Construction Quality Assurance Plan (CQAP) for the North Pile closure cover.

The closure cover design for the North Pile includes excavation and infilling of the interior cells and regrading of the Starter Cell and East Cell surfaces promote drainage away from the North Pile. It also includes placement of a closure cover composed of an erosion protection layer over the entire facility, as well as a transition layer in areas of deposited PK and landfill waste materials. This transition layer is needed for physical material compatibility (grain size) between the erosion protection cover and the underlying deposited PK and to achieve the total closure cover thickness required over the landfill waste.

Landfill waste associated with mine facility demolition will be deposed of in Cell 1 and Cell 2 of the East Cell. Deposited PK material will be excavated from Cell 2 to provide additional landfill waste capacity. The excavated material will be placed in Cell 3. Two swales will be constructed to convey flow from the Starter Cell and the east portion of the East Cell toward a channel outlet located east of Cell 5, and one swale will convey flow from the west portion of the East Cell toward a channel outlet located west of Cell 1.

This CQAP was prepared to assure that the techniques and procedures used during construction of the North Pile closure cover meet the design intent presented in the Construction Drawings and Specification. A general description of Construction Quality Control (CQC) activities is provided herein, and a separate Construction Quality Control Plan (CQCP) will be prepared by the Contractor (De Beers).

The reader is referred to the Study Limitations section, which precedes the text and forms an integral part of this report.
2.0 PERSONNEL

Execution of the CQAP relies on coordination and collaboration between principal organizations and personnel involved in permitting, design, and construction of the North Pile closure cover. Responsibilities of each organization are clearly delineated to establish lines of communication that will facilitate effective decision making during implementation of the CQAP.

2.1 Principal Organizations and Responsible Personnel

Snap Lake Mine is owned, operated, and managed by De Beers. De Beers also serves as Contractor for the North Pile closure cover. As the Contractor, De Beers is responsible for developing and executing an independent CQCP. Golder is the designer and Geotechnical Engineer for the North Pile closure cover. Responsible personnel for construction of the North Pile closure cover are listed in Table 1.

Table 1: Personnel Responsibility and Authority

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Title</th>
<th>Organization</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Beers to provide contact information</td>
<td>De Beers</td>
<td>Owner Representatives</td>
<td>Permitting Agency</td>
</tr>
<tr>
<td>Sean Whitaker</td>
<td>Owner Representatives</td>
<td>MVLWB</td>
<td>De Beers</td>
</tr>
<tr>
<td>Michelle Peters</td>
<td></td>
<td></td>
<td>Owner</td>
</tr>
<tr>
<td>Jeffrey Kwok</td>
<td>Engineer of Record</td>
<td>Golder</td>
<td>Geotechnical Engineer</td>
</tr>
<tr>
<td>Björn Weeks</td>
<td>Closure Cover Design Lead</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBD</td>
<td>Project Engineers</td>
<td>Golder</td>
<td>CQA Official</td>
</tr>
<tr>
<td>TBD</td>
<td>Golder Engineers/Geologists</td>
<td>Golder</td>
<td>CQA Inspection Personnel</td>
</tr>
<tr>
<td>TBD</td>
<td>TBD</td>
<td>De Beers</td>
<td>CQC Official</td>
</tr>
<tr>
<td>TBD</td>
<td>De Beers Operators</td>
<td>De Beers</td>
<td>Contractor</td>
</tr>
</tbody>
</table>

Notes:
Personnel for the Permitting Agency and Owner will be provided by De Beers.
Personnel for the CQA Official and Inspection Personnel, CQC Official, and the Contractor will be identified prior to construction of the North Pile closure cover.
Changes in personnel will be at the approval of the Owner with input from the Geotechnical Engineer.
MVLWB = Mackenzie Valley Land and Water Board; TBD = to be determined; CQA = Construction Quality Assurance; CQC = Construction Quality Control.
### 2.1.1 Permitting Agency

Responsible personnel for the Permitting Agency are the official representatives of the Mackenzie Valley Land and Water Board, responsible for overseeing compliance of the North Pile closure cover with regulatory requirements.

### 2.1.2 Owner

Responsible personnel for the Owner are the official representatives of De Beers, responsible for overseeing and coordinating with the North Pile closure cover Contractor and the Geotechnical Engineer.

### 2.1.3 Geotechnical Engineer

Responsible personnel for the Geotechnical Engineer are representatives from Golder, responsible for the design and preparation of the North Pile closure cover Construction Drawings and Specification. The Geotechnical Engineer will be a registered professional engineer with the Northwest Territories. The Geotechnical Engineer has the authority to stop any aspect of the work that is not in compliance with the CQAP. Work would resume once a corrective action has been approved by the Geotechnical Engineer. The Geotechnical Engineer will travel to the Work Site quarterly throughout construction, and as needed at the request of the Owner.

Responsibilities of the Geotechnical Engineer include, but are not limited to:

- Review the Construction Drawings, Specification, and related construction documents to confirm the CQAP can be implemented safely.
- Review, coordinate, and approve CQA activities to assure testing and documentation are complete, accurate, and in accordance with the Specification and CQAP.
- Assure that required CQA testing has been performed in accordance with the Construction Drawings, Specification, CQAP, and to the satisfaction of the CQA Official.
- Review and approve, if appropriate, deficiencies and design modifications during construction when deviations from the design, Specification, or CQAP are proposed or identified.
- Oversee preparation and certification of the Construction Record Report upon completion of construction.

When the Geotechnical Engineer is absent from the Work Site, responsibilities of the Geotechnical Engineer will be delegated to the CQA Official.

### 2.1.4 Construction Quality Assurance Official

Personnel for the CQA Official are representatives from Golder, responsible for assisting the Geotechnical Engineer and CQA Inspection Personnel. The CQA Official reports directly to the Geotechnical Engineer. In the absence of the Geotechnical Engineer from the Work Site, responsibilities of the Geotechnical Engineer may be temporarily delegated to the CQA Official. The CQA Official will travel to the Work Site quarterly throughout construction, and as needed at the request of the Owner.
Responsibilities of the CQA Official include, but are not limited to:

- Review the Construction Drawings, Specification, CQAP, and related construction documents.
- Review the Contractor submittals and make recommendations as required for compliance with the construction documents.
- Train CQA Inspection Personnel on CQA requirements and procedures.
- Schedule, coordinate, and support CQA inspection activities.
- Assure required CQA testing has been performed in accordance with the Construction Drawings, Specification, CQAP, and to the satisfaction of the CQA Inspection Personnel.
- Confirm CQA test data are accurately recorded, validated, interpreted, and summarized.
- Oversee the quality control activities performed by the Contractor.
- Review daily construction documentation and complete weekly construction documentation.
- Develop and maintain a project file to store original or copies of original CQA data sheets and reports generated during construction and following project completion.
- Prepare the Construction Record Report and coordinate Construction Record Drawing development following completion of construction.

Minimum qualifications and expectations of the CQA Official are:

- formal academic training in engineering, engineering geology, or other closely associated discipline
- practical, technical, and managerial experience to oversee and implement CQA activities
- detailed understanding of the Construction Drawings, Specification, CQAP, and related construction documents
- proven oral and written communication skills
- registered professional engineer in the Northwest Territories is preferred, and is required if responsibilities of the Geotechnical Engineer are temporarily delegated to the CQA Official.

2.1.5 Construction Quality Assurance Inspection Personnel

CQA Inspection Personnel are representatives from Golder, responsible for performing the tasks outlined in the CQAP and Specification. The CQA Inspection Personnel report directly to the CQA Official. The CQA Inspection Personnel will be at the Work Site throughout construction.

Responsibilities of the CQA Inspection Personnel include, but are not limited to:

- Review the Construction Drawings, Specification, CQAP, and related construction documents.
Observe and document all construction activities including but not limited to the following:

- foundation preparation
- west perimeter embankment regrade
- in-place material excavation
- North Pile regrade
- landfill waste placement
- closure cover construction
- swale and outlet channel armouring
- instrumentation installation

Assure testing equipment used and tests performed are conducted in accordance with the Specification and industry standards.

Perform or observe documentation and reporting of test results.

Relay all documentation from the Contractor to the CQA Official.

Report deficiencies to the CQA Official.

Complete daily construction documentation.

Assist with coordination of Construction Record Drawing development.

Minimum qualifications and expectations of the CQA Inspection Personnel are:

- formal academic training in engineering, engineering geology, or other closely associated discipline preferred, but practical work experience can substitute for academic training
- practical, technical, and administrative experience to execute and record inspection activities
- demonstrated knowledge of specific field practices relating to construction techniques for mine waste facilities, codes and regulations concerning earthwork construction, observation and testing procedures, equipment, documentation requirements, and site safety practices

2.1.6 Construction Quality Control Official

Personnel for the CQC Official are representatives from De Beers, responsible for the quality control activities as part of the North Pile closure cover construction, including but not limited to sampling and testing of materials to determine suitability for construction.
2.1.7 Contractor
Relevant personnel for the Contractor are representatives from De Beers, responsible for earthwork construction of the North Pile closure cover.

2.2 Meetings
Regular meetings during construction of the North Pile closure cover will strengthen accountability, responsibility, and authority by maintaining communication between responsible personnel and principal organizations. A pre-construction meeting will be held prior to construction of the North Pile closure cover. Daily tailgate meetings will be held on site between the CQA and CQC Personnel, Contractor, and any visitors to the Work Site. Weekly progress meetings will be held throughout construction of the North Pile closure cover. Additional meetings to address potential construction or design issues and deficiencies may also be held as required by the Geotechnical Engineer or Owner.

2.2.1 Pre-construction Meeting
A pre-construction meeting will be held on site at Snap Lake Mine to resolve any discrepancies and to provide additional clarification for construction of the North Pile closure cover design. The Owner, Geotechnical Engineer, CQA Official, CQA Inspection Personnel, CQC Official, Contractor, and other stakeholders designated by the Owner will be in attendance. The pre-construction meeting will be documented by the designated party and minutes transmitted to all parties associated with construction of the North Pile closure cover.

Pre-construction meeting attendees will:
- Review security and safety protocol.
- Review constructability of the North Pile closure cover and health, safety, and environmental risks and controls to be implemented.
- Determine any changes or clarifications to the Construction Drawings, Specification, CQAP, and related construction documents needed to meet the North Pile closure cover design intent.
- Review responsibilities of each principal organization.
- Establish lines of authority and communication for each principal organization.
- Establish procedures or protocol for handling construction deficiencies, repairs, and retesting.
- Review methods for documenting and reporting inspection data.
- Review methods for distributing and filing documents and reports.
- Discuss procedures for the location and protection of construction materials from damage due to inclement weather or other adverse events.
Conduct a walk-around of the Work Site to review existing site conditions, construction materials, and equipment storage locations.

- Review the project schedule.
- Establish a regular day and time for the weekly progress meetings.

### 2.2.2 Daily Tailgate Meetings

Tailgate meetings will be held daily at the Work Site, prior to commencement of work activities. At a minimum, the CQA Inspection Personnel and Contractor will be in attendance. The meeting will be documented by the CQA Inspection Personnel as part of the required daily documentation.

The purpose of daily tailgate meetings is to:

- Discuss health and safety procedures.
- Review the previous day’s activities and accomplishments.
- Review the work location and activities planned for the day.
- Identify the Contractor’s personnel and equipment assignments for the day.
- Discuss any potential construction and design issues or deficiencies.

### 2.2.3 Weekly Progress Meetings

Progress meetings will be held weekly, at an established regular day and time. At a minimum, the Owner, Geotechnical Engineer, CQA Official, CQA Inspection Personnel, and Contractor will be in attendance. The Owner is responsible for conducting and documenting weekly progress meetings and preparing minutes to be transmitted to all parties associated with the North Pile closure cover construction but may delegate that responsibility to the Geotechnical Engineer.

The purpose of weekly progress meetings is to:

- Discuss health and safety procedures.
- Review the previous week’s activities and accomplishments.
- Review the work location and activities planned for the week.
- Identify the Contractor’s personnel and equipment assignments for the week.
- Discuss any potential construction and design issues or deficiencies.
- Review the schedule.
2.2.4 Construction or Design Issues and Deficiencies Meetings

Additional meetings will be held when an issue or deficiency is presented or expected to occur during construction of the North Pile closure cover. At a minimum, the Owner, Geotechnical Engineer, CQA Official, CQA Inspection Personnel, and Contractor will be in attendance. Construction or design issues and deficiencies meetings will be documented by the Geotechnical Engineer, and minutes will be transmitted to all parties associated with construction of the North Pile closure cover.

The purpose of construction or design issues and deficiencies meetings is to:

- Define and discuss the problem or deficiency.
- Review the possible solutions.
- Implement a plan to resolve the problem or deficiency.
3.0 INSPECTION AND MONITORING ACTIVITIES

Inspection and monitoring activities will be performed by the CQA Inspection Personnel to assure the North Pile closure cover is constructed to meet the design intent and comply with the Construction Drawings, Specification, CQAP, and other design documents. A list of inspection and monitoring activities and corresponding Specification sections is presented in Table 2.

Table 2: Inspection and Monitoring Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Specification/CQAP Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air, dust, and noise monitoring</td>
<td>3.1 (CQAP)</td>
</tr>
<tr>
<td>Foundation preparation</td>
<td>3.0 (Specification)</td>
</tr>
<tr>
<td>West perimeter embankment regrade</td>
<td>4.0 (Specification)</td>
</tr>
<tr>
<td>In-place material excavation</td>
<td>5.0 (Specification)</td>
</tr>
<tr>
<td>Starter Cell regrade</td>
<td>6.0 (Specification)</td>
</tr>
<tr>
<td>Landfill waste placement</td>
<td>7.0 (Specification)</td>
</tr>
<tr>
<td>East Cell regrade</td>
<td>8.0 (Specification)</td>
</tr>
<tr>
<td>Closure cover construction</td>
<td>9.0 (Specification)</td>
</tr>
<tr>
<td>Swale and outlet channel armouring</td>
<td>10.0 (Specification)</td>
</tr>
<tr>
<td>Instrumentation installation</td>
<td>11.0 (Specification)</td>
</tr>
</tbody>
</table>

CQAP = Construction Quality Assurance Plan.

The overall closure of the North Pile facility will be a balance cut/fill operation and will not require disposal of PK or waste materials outside of the existing footprint. Additional waste material generated from construction of the North Pile closure cover will be identified in the Contractor’s health and safety plan and disposed of accordingly.

Prior to commencement of construction activities, the CQA Official and CQA Inspection Personnel will review the closure cover Construction Drawings and Specification. If closure cover documents are unclear, the Geotechnical Engineer will be notified and will provide design clarification or modification. A pre-construction training program for QC may be implemented as directed by the Owner’s Representative and Geotechnical Engineer.
3.1 Air, Dust, and Noise Monitoring

Air containing hazardous substances is not anticipated to be present within the Work Site. Should hazardous conditions be suspected, the Contractor and the CQA Inspection Personnel will stop work and notify the Owner’s Representative and Geotechnical Engineer immediately. The Owner and Geotechnical Engineer will assess the Work Site and determine whether personal air monitoring devices are required. Personal air monitoring devices will be supplied by the Contractor, Geotechnical Engineer, and Owner for each of their individual personnel / representatives. Additionally, the Contractor will minimize exposure to exhaust from equipment.

The Contractor is responsible for furnishing and replacing water for dust suppression on roads and construction areas. The Contractor and CQA Inspection Personnel will assess dust conditions periodically throughout each work day and record conditions in the daily construction documentation. Dust monitoring equipment is not anticipated to be required within the Work Site. Should heavy dust conditions be suspected, the Contractor and CQA Inspection Personnel will stop work and notify the Owner and Geotechnical Engineer immediately. The Owner and Geotechnical Engineer will assess the Work Site and determine an appropriate suppression method to be implemented by the Contractor.

The Contractor and CQA Inspection Personnel will assess noise conditions within the Work Site. Should excessive noise conditions be present, a noise measurement will be provided by the Contractor, and appropriate ear protection will be provided by the Contractor, Geotechnical Engineer, and Owner for each of their individual personnel / representatives.

3.2 Construction Activity Inspections

CQA Inspection Personnel will observe each of the construction activities listed in Table 2 and summarize observations in the daily construction activity reports for submission to and review by the CQA Official. The CQA Official will summarize the daily construction documentation and submit weekly construction activity reports to the Owner’s Representative and the Geotechnical Engineer. CQA observations typically include fill placement and compaction methods, excavation and fill placement locations, and lift thickness of fill placement.

CQA Inspection Personnel will notify the Geotechnical Engineer and Owner’s Representative immediately should the following action items be observed:

- unsuitable material within the foundation preparation area and/or used as fill materials
- material placement extends beyond the design grading limits as shown in the Construction Drawings
- discrepancy between field conditions and the design documents

The Geotechnical Engineer and Owner’s Representative will assess the action item and develop a specific remediation.

The expected general sequence for construction of the North Pile closure cover is presented in the Section 9.1 of the Specification. The Contractor will prepare and submit as-built information for each construction activity to the Geotechnical Engineer and Owner’s Representative for review and approval prior to subsequent construction activities.
4.0 SAMPLING AND LABORATORY TESTING REQUIREMENTS

Samples will be collected by the Contractor for laboratory testing of fill materials to assess particle size distribution, water content, and the maximum dry density of construction materials. The CQC Official will coordinate sample collection and laboratory testing and will provide results of the laboratory testing to the Geotechnical Engineer and Owner’s Representative for review. CQA Inspection Personnel will observe sample collection and document laboratory testing performed in the daily construction documentation. Sampling requirements are presented in the Specification and summarized Table 3.

Table 3: Construction Quality Control Sample Collection and Laboratory Testing Frequency

<table>
<thead>
<tr>
<th>Material</th>
<th>CQC Test</th>
<th>CQC Test Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankment / rib berm</td>
<td>field density, field water content</td>
<td>every 500 m³ of material placed</td>
</tr>
<tr>
<td></td>
<td>standard Proctor</td>
<td>1 for every 25 field density measurements</td>
</tr>
<tr>
<td></td>
<td>grain size analysis</td>
<td>1 for every 25 field density measurements</td>
</tr>
<tr>
<td>Erosion protection cover</td>
<td>screen analysis</td>
<td>1 for every 10,000 m³ of material placed</td>
</tr>
<tr>
<td>Landfill waste</td>
<td>to be determined prior to construction(a)</td>
<td></td>
</tr>
</tbody>
</table>

(a) Information regarding the landfill demolition plan was unavailable at the time of reporting.

CQC = construction quality control.
5.0 DOCUMENTATION AND REPORTING

Documentation of CQC inspection and monitoring and of CQC sampling and laboratory testing activities is required to assure that construction techniques and procedures are followed by the Contractor and that the design intent is met. Results of CQA and CQC activities will be documented in the Construction Record Report prepared under direction of the Geotechnical Engineer and submitted to the Owner. Construction checklist forms will be developed by the CQA Inspection Personnel and provided to the Geotechnical Engineer and Owner’s Representative for review.

5.1 Photo Documentation

All construction activities will be photo-documented to demonstrate construction progress and compliance with the Construction Drawings. Daily photographs will be taken from several consistent vantage points throughout the Work Site and include close-ups within the Work Site. A digital date stamp will be included to identify the location, time, date, and initials of the person taking the photograph.

5.2 Surveying

Construction control and as-built survey and documentation will be provided and performed by the Contractor in accordance with the Specification. CQA Inspection Personnel will conduct daily spot checks, using a global positioning system (GPS) receiver calibrated to the local mine site network, to assure compliance with the Construction Drawings. Additional survey may be requested by the Geotechnical Engineer where additional topography data are needed to confirm the construction meets the design intent.

5.3 Daily Construction Progress Reports

Daily construction progress reports will be prepared by the CQA Inspection Personnel following the format shown in Appendix A and submitted to the CQA Official for review. Field notes, observations, testing data sheets, on-site meetings, and design issues or deficiencies and resolutions will be summarized. A complete set of all daily reports for the North Pile closure cover construction will be kept on site by the CQA Inspection Personnel.

Daily construction progress reports will include:

- date, project name, location, and weather data
- summary of on-site meetings
- a reduced-scale site plan showing Work Site and test locations
- photo documentation of daily construction activities
- description of ongoing construction activities
- estimation of material quantities placed
- summary of test results and samples taken with locations and results of all retests for failed tests with remarks showing the corrective action implemented before the retest
test equipment calibrations, as required
review of schedule and document discrepancies between schedule and actual work performed
CQA Inspection Personnel signature

5.4 Weekly Construction Progress Reports
Weekly construction progress reports will be prepared by the CQA Official and submitted weekly to all parties associated with construction of the North Pile closure cover.

Weekly construction progress reports will include:
- date, project name, location, work hours, known project personnel, and visitors on site and within the Work Site
- summary of construction activities including equipment used, material placed, and quantity estimates
- summary of samples taken and test results
- summary of deficiencies, design modifications, and resolutions
- photographs of the construction process

5.5 Design Deficiencies and Modifications
During construction, the need to request design and Specification clarification, modification, or changes may arise. In such cases, the CQA Inspection Personnel will notify the CQA Official and Geotechnical Engineer. Design and Specification clarifications, modifications, or changes will only be made with written agreement from the Owner’s Representative and Geotechnical Engineer. All construction/design issues and deficiencies, and any design clarifications, modifications, or changes that solve the issue, will be documented in the daily construction progress reports prepared by the CQA Inspection Personnel.

Design deficiency and modification documentation will include:
- detailed description of the issue or deficiency including location, cause, and how and when the issue or deficiency was identified
- how the issue or deficiency was resolved
- any measures taken to prevent similar issues or deficiencies in the future
- signature of the Owner’s Representative, Geotechnical Engineer, and Contractor
- sealed certification by the Geotechnical Engineer for any design modifications or design changes
5.6 **Construction Record Report**

Upon completion of the North Pile closure cover construction, the Geotechnical Engineer will submit a Construction Record Report and Construction Record Drawings to De Beers. The report will certify that the construction work associated with the North Pile closure cover was completed in compliance with the Construction Drawings, Specification, CQAP, and other design documents.

The Construction Record Report will include:

- summary of all construction activities
- all daily and weekly progress reports and test data sheets
- all sampling locations, tests performed, and test results
- Summary of significant deficiencies, design modifications, and resolutions
- all CQA Inspection Personnel documentation
- Construction Record Drawings that accurately locate all construction items, dimensions, features, etc.
6.0 CLOSURE

The reader is referred to the Study Limitations section, which precedes the text and forms an integral part of this report.

We trust the above meets your present requirements. If you have any questions or require additional information, please contact the undersigned.
Signature Page

Golder Associates Ltd.

Abdul Sattar Khan, M.A.Sc.
Project Manager

Bjorn Weeks, Ph.D., P.Eng.
Principal, Geo-Environmental Engineer

ASK/BW/HNL/cf/no/cr

Golder and the G logo are trademarks of Golder Associates Corporation

https://golderassociates.sharepoint.com/sites/1785666-032-4-rev0-4000/1785666-032-4-rev0-4000-northpiple closurecover cpap 11mar_19.docx
APPENDIX A

Construction Quality Assurance Form
<table>
<thead>
<tr>
<th>DISCUSSIONS, COMMENTS, MEETINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>•</td>
</tr>
<tr>
<td>DOCUMENTS</td>
</tr>
<tr>
<td>•</td>
</tr>
<tr>
<td>CONSTRUCTION ACTIVITIES</td>
</tr>
<tr>
<td>•</td>
</tr>
<tr>
<td>FIELD TESTING</td>
</tr>
<tr>
<td>•</td>
</tr>
<tr>
<td>SURVEY</td>
</tr>
<tr>
<td>•</td>
</tr>
<tr>
<td>GEOTECHNICAL INSPECTION</td>
</tr>
<tr>
<td>•</td>
</tr>
<tr>
<td>ATTACHMENTS</td>
</tr>
<tr>
<td>•</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Engineer</th>
<th>Signature</th>
<th>Title</th>
<th>Date</th>
</tr>
</thead>
</table>

**DATE:**

**DAILY REPORT NO.:**

**PREPARED BY:**

**PROJECT:** North Pile Closure Cover

**DISTRIBUTION:**

**GOLDER ON-SITE STAFF:**

**DE BEERS ON-SITE STAFF:**

**SHIFT:**

**WORK HOURS:**

**WEATHER:**

---

Project No.: 1785666-4000
APPENDIX D

Surface Water Analysis
1.0 INTRODUCTION
This technical memorandum presents the detailed design of the surface water management structures to support the closure cover design of the North Pile facility at De Beers Group of Companies’ Snap Lake Mine, located approximately 220 km northeast of Yellowknife, Northwest Territories. The water management structures are designed to collect surface runoff and to route it off the North Pile via outlet channels.

The collection system will include a network of swales constructed within the closure cover of the North Pile to convey surface runoff towards two outlet channels located on the west and east sides of the North Pile. The outlet channels will convey water to two passive water treatment facilities via ditches (design of the ditches and passive treatment is part of separate scopes of work).

2.0 SURFACE WATER MANAGEMENT DESIGN
The surface water management of the North Pile closure cover consists of a network of swales constructed within the North Pile closure cover to collect surface runoff and convey it off the North Pile via the outlet channels. The outlet channels will report to existing perimeter ditches (upgraded as needed) for ultimate collection in passive water treatment facilities. The scope of this design is limited to the water management structures located on the surface of the North Pile. The design of water management structures along the perimeter of the North Pile is included in a separate scope of work, which will account for the North Pile closure cover design and water management concept.

The surface water management of the North Pile closure cover includes the following structures:

- swales to collect and route surface runoff from the closure cover to the outlet channels
  - Starter Cell swale to collect and route runoff from the closure cover over the Starter Cell to the Cell 5 swale
  - east swale to collect and route runoff from the closure cover over Cell 3, 4, and 5 of the East Cell to the Cell 5 swale
- **west swale** to collect and route runoff from the closure cover over Cell 1 and 2 of the East Cell to the Cell 1 outlet channel

- **Cell 5 swale** to collect and route runoff from the Starter Cell swale and the east swale and convey it to the Cell 5 outlet channel

- **Cell 1 outlet channel** to direct runoff from the west swale off the North Pile to the existing west perimeter ditch; any upgrades to the west perimeter ditch are included in a separate scope of work focused on closure design for the North Pile perimeter water management structures

The Starter Cell swale and the east swale will merge into the Cell 5 swale and connect to the Cell 5 outlet channel for discharge off the North Pile. The Cell 5 outlet channel design is presented under a separate scope of work focused on perimeter water management structures. The west swale will connect to the Cell 1 outlet channel for discharge off the North Pile.

The layout of the North Pile closure cover water management structures is shown in Drawing A1-14221-6200-1221-0806 in Appendix A of the North Pile closure cover detailed design report.

### 3.0 DESIGN CRITERIA

The design criteria used for the detailed design of the surface water management structures comply with the criteria set out in the Canadian Dam Association *Dam Safety Guidelines* (CDA 2013), as well as the Anglo American Technical Standards (Anglo 2016), and are summarized in the North Pile closure cover detailed design report.

The CDA criteria for inflow design flood at closed facilities with a “High” classification is the probable maximum flood (PMF) event. The Anglo standard for inflow design flood at closed facilities is the 1/10,000-year or the PMF event.

According to the CDA (2013) *Dam Safety Guidelines*, the PMF is generated by the probable maximum precipitation (PMP), estimated as the greater of the summer-autumn PMF (summer-autumn PMP only) and the spring PMF (spring PMP over snowmelt). The spring PMF is the governing design flood for the Snap Lake Mine site.

The water management structures for the closure cover have been designed to pass the estimated peak flows generated during the 24-hour PMF. The 24-hour PMF depth of 460 mm was derived from 309 mm of rainfall (24-hour PMP) combined with 151 mm snowmelt (Golder 2017). The snowmelt corresponds to the most critical 100-year temperature sequence occurring during the PMP (Golder 2017).

The design event was used to estimate peak flows for sizing the surface water management structures. The sizing of the surface water management structures was completed considering conveyance of the design peak flows while providing a minimum freeboard of 0.1 m to account for possible differential settlement of the North Pile cover and underlying material and flow run up.
3.1 Hydrologic Design Method

Peak flows were estimated through a rainfall-runoff model developed using the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) software (USACE 2010).

The 24-hour PMP event hyetograph was developed using the alternating block method, which provides precipitation depths in five-minute intervals. The shape of the distribution was taken from the 100-year return period intensity-duration-frequency data from Environment and Climate Change Canada (ECCC) station Yellowknife A (station ID: 2204100). The intensity-duration-frequency data were scaled to the Snap Lake Mine site using the 24-hour PMP depth (309 mm) at site, compared to the Yellowknife A 100-year, 24-hour depth (79 mm), to develop the 24-hour PMP hyetograph for the site. The resulting hyetograph (rainfall only) for the PMP event is shown in Plot 1. The 100-year snowmelt was added at a constant rate over a duration of 16 hours.

![PMP 24h Hyetograph (mm)](image)

PMP = probable maximum precipitation.

Plot 1: Probable Maximum Precipitation 24-Hour Hyetograph

The Soil Conservation Service curve number method (USDA 1986) was used to estimate general catchment runoff and losses. A Soil Conservation Service curve number value of 95 was used for the closure cover assuming that the ground surface will be saturated or frozen during the design event (freshet event).

The catchment areas reporting to the water management structures were defined based on the North Pile closure cover detailed design. The swales and outlet channels will receive flows contributing from catchments on the surface of the North Pile. A total of three catchments were characterized for the design of the surface water management structures for the North Pile closure cover. The time of concentration for the catchments reporting to the surface water management structures was estimated using the method for estimating runoff and peak discharge in small watersheds described in United States Department of Agriculture Technical Release 55 (USDA 1986). The lag time is estimated as 60% of the time of concentration.
The input parameters for the three catchments are shown in Table 1. The Cell 5 swale has no direct catchment and represents only a short connection to the Cell 5 outlet channel.

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Area (km²)</th>
<th>Time of Concentration (min)</th>
<th>Soil Conservation Service Lag Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starter Cell swale</td>
<td>0.215</td>
<td>29</td>
<td>17</td>
</tr>
<tr>
<td>East swale</td>
<td>0.097</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>West swale</td>
<td>0.068</td>
<td>23</td>
<td>14</td>
</tr>
</tbody>
</table>

The HEC-HMS model was run with a two-minute time step and assuming no attenuation from storage on the closure cover (saturation of cover layer). The schematic for the HEC-HMS model is shown in Plot 2. The results of the hydrologic modelling of the surface water management structures are provided in Table 3 (Section 3.2).
3.2 Hydraulic Design

The swales and channels were sized assuming uniform flow conditions using the Manning's equation. The Manning coefficients for the different types of lining used for the swales and channels are presented in Table 2.

<table>
<thead>
<tr>
<th>Riprap Lining Type</th>
<th>Manning Coefficient for Capacity (n)</th>
<th>Manning Coefficient for Stability (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{50} = 150 \text{ mm}$</td>
<td>0.038</td>
<td>0.034</td>
</tr>
<tr>
<td>$D_{50} = 300 \text{ mm}$</td>
<td>0.042</td>
<td>0.037</td>
</tr>
<tr>
<td>$D_{50} = 600 \text{ mm}$</td>
<td>0.046</td>
<td>0.042</td>
</tr>
</tbody>
</table>

The Manning coefficient values for capacity were used for channel sizing. The Manning coefficient values for stability were used for riprap lining sizing.

Sizing of the riprap lining dimensions was completed using the shear stress equation (ASCE 1982a), with the exception of channels with longitudinal slopes greater than 20%. For these steep channel sections, the riprap sizing was completed using the Olivier method (ASCE 1982b). The Starter Cell swale includes a steeper section as it transitions from Cell D (Starter Cell) to Cell 5 (East Cell). This section of the Starter Cell swale and the Cell 1 outlet channel will require a larger riprap class due to the higher flow velocities. The thickness of riprap lining is assumed to be twice the $D_{50}$ size.

The sizing of the surface water management structures is provided in Table 3.

The existing east perimeter ditch and west perimeter ditch will require upgrades to convey the estimated peak flows from the North Pile outlet channels. As mentioned in Section 2.0, the design of the required upgrades to these ditches is included in a separate scope of work.

The general layout of the surface water management structures is shown in Drawing A1-14221-6200-1221-0806 (Appendix A of the North Pile closure cover detailed design report). Profiles and typical sections of the surface water management structures are shown in Drawings A1-14221-6200-1221-0815 and A1-14221-6200-1221-0816 (Appendix A of the North Pile closure cover detailed design report).
# Table 3: Water Management Structures Design Summary

<table>
<thead>
<tr>
<th>Structure</th>
<th>Peak Design Flow (24-hour PMP) (m³/s)</th>
<th>Longitudinal Slope (%)</th>
<th>Side Slope (H:V)</th>
<th>Base Width (m)</th>
<th>Minimum Depth (m)</th>
<th>Flow Depth (m)</th>
<th>Velocity (m/s)</th>
<th>Riprap Lining Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>West swale</td>
<td>4.0</td>
<td>2</td>
<td>10:1</td>
<td>5</td>
<td>0.5</td>
<td>0.3</td>
<td>1.6</td>
<td>D$_{50} = 150$ mm</td>
</tr>
<tr>
<td>Cell 1 outlet channel (maximum slope)</td>
<td>4.0</td>
<td>30</td>
<td>3:1</td>
<td>5</td>
<td>0.5</td>
<td>0.2</td>
<td>3.9</td>
<td>D$_{50} = 600$ mm$^{(b)}$</td>
</tr>
<tr>
<td>Cell 1 outlet channel (minimum slope)</td>
<td>4.0</td>
<td>11</td>
<td>3:1</td>
<td>5</td>
<td>0.5</td>
<td>0.3</td>
<td>2.8</td>
<td>D$_{50} = 600$ mm$^{(b)}$</td>
</tr>
<tr>
<td>East swale</td>
<td>5.8</td>
<td>2</td>
<td>10:1</td>
<td>10</td>
<td>0.5</td>
<td>0.3</td>
<td>1.6</td>
<td>D$_{50} = 150$ mm</td>
</tr>
<tr>
<td>Starter Cell swale (shallow)</td>
<td>10.9</td>
<td>2</td>
<td>10:1</td>
<td>10</td>
<td>0.5</td>
<td>0.4</td>
<td>1.9</td>
<td>D$_{50} = 150$ mm</td>
</tr>
<tr>
<td>Starter Cell swale (steep, Cell D to Cell 5)</td>
<td>10.9</td>
<td>7</td>
<td>10:1</td>
<td>10</td>
<td>0.5</td>
<td>0.3</td>
<td>3.0</td>
<td>D$_{50} = 300$ mm</td>
</tr>
<tr>
<td>Cell 5 swale (east swale and Starter Cell swale combined)</td>
<td>16.3</td>
<td>2</td>
<td>10:1</td>
<td>10</td>
<td>1.0</td>
<td>0.6</td>
<td>2.0</td>
<td>D$_{50} = 300$ mm</td>
</tr>
<tr>
<td>Cell 5 outlet channel$^{(a)}$ (across embankment crest)</td>
<td>16.3</td>
<td>2</td>
<td>3:1</td>
<td>10</td>
<td>1.0</td>
<td>0.6</td>
<td>2.4</td>
<td>D$_{50} = 300$ mm</td>
</tr>
</tbody>
</table>

$^{(a)}$ The Cell 5 outlet channel design is presented under a separate scope of work focused on perimeter water management structures.

$^{(b)}$ Riprap size estimated based on Olivier method (ASCE 1982b).

PMP = probable maximum precipitation.
4.0 CLOSING

The reader is referred to the Study Limitations section, which follows the text and forms an integral part of this memorandum.

We trust the information in this report is sufficient for your present needs. Should you have any additional questions regarding this report, please contact the undersigned.

Golder Associates Ltd.

Aaron Brisbin  
Mine Water Management Group

Paolo Chiaramello, P.Eng.  
Associate, Senior Water Resources Engineer

Attachment: Study Limitations


[Permit to practice Golder Associates LTD.]

Signature: [Signature]

Date: Mar 11, 2019

PERMIT NUMBER: P 049

NT/NU Association of Professional Engineers and Geoscientists
REFERENCES


ASCE. 1982b. Sedimentation engineering processes, measurements, modeling and practice B.8.5.2.


STUDY LIMITATIONS

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with the level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of the De Beers Group of Companies. It represents Golder’s professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by the De Beers Group of Companies, and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. The De Beers Group of Companies may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.
APPENDIX E

Slope Stability Analysis
1.0 INTRODUCTION

This slope stability analysis has been completed by Golder Associates Ltd. (Golder) in support of the North Pile closure cover detailed design at Snap Lake Mine for the De Beers Group of Companies (De Beers).

The stability analysis was conducted for one of the East Cell rib berms and the perimeter embankment for the following aspects:

- Rib Berm 2 and perimeter embankment slope stability for fine processed kimberlite (PK) excavation in Cell 2 during care and maintenance.
- Cell 1 west perimeter downstream slope stability for closure.

This technical memorandum presents the methodology, criteria, foundation conditions and material strength parameters, and the results of the stability analysis.

2.0 SITE OVERVIEW

The North Pile is the permanent surface storage facility for PK and other mine waste materials at Snap Lake Mine, located approximately 220 km northeast of Yellowknife, Northwest Territories. The facility is composed of the Starter Cell, East Cell, and West Cell. The West Cell was not fully developed, leaving the west perimeter embankment of the Starter Cell and East Cell exposed. Snap Lake Mine operated from 2007 to 2015 and entered care and maintenance on 4 December 2015.
3.0 BACKGROUND
The detailed design and supporting grading plans have been developed such that the North Pile closure cover:

- complies with the design criteria listed in the North Pile Closure Cover Detailed Design report (Golder 2019)
- accommodates approximately 114,000 m³ (Whitaker 2018) landfill waste material, which includes 20% increase for additional landfill waste material placement
- reduces construction earthworks and revetment quantities to the extent practicable
- keeps landfill footprint as small as practicable

The North Pile closure cover detailed design is inclusive of the East Cell, Starter Cell, and west perimeter embankment, and incorporates a partial excavation of the deposited fine PK within Cell 2 and Rib Berm 1 of the East Cell to accommodate the required additional landfill material storage of up to 114,000 m³. The closure cover design for the East Cell and Starter Cell will be constructed as a cut to fill operation that maintains a minimum 2% gradient directed away from the North Pile perimeter embankment crest. The west perimeter embankment is located along the western portion of the East Cell and Starter Cell and was intended to be covered as the West Cell construction advanced. However, the West Cell was not fully developed, leaving the west perimeter embankment sloped at approximately 1.5H:1V. The North Pile closure cover detailed design includes regrading the west perimeter embankment to a 3H:1V slope in order to promote long-term stability of the embankment.

The construction sequence for partial excavation of the deposited fine PK within Cell 2 is anticipated to be as follows:

- Excavate Rib Berm 1 and Rib Berm 2 to the bottom of cover elevations as shown in the construction drawings and stockpile locally at a location identified by the Owner.
- Push stockpiled rib berm material from the crest of Rib Berm 2 and the perimeter embankment into Cell 2 at slope of 4H:1V to the top of the existing deposited fine PK.
- Excavate deposited fine PK from Cell 2 to the depths shown in the construction drawings and place within Cell 3. The deposited fine PK is expected to be excavated from Cell 2 in horizontal layers of approximately 1 m thickness, leaving a 4H:1V slope along the upstream perimeter of Cell 2.
- Place excavated Rib Berm 1 and Rib Berm 2 material to a thickness of 0.3 m over the 4H:1V slope of exposed deposited fine PK within Cell 2 for erosion protection as the Cell 2 excavation is advanced.
- Excavate the remaining Rib Berm 1 to the depths shown in the construction drawings and stockpile locally on the North Pile perimeter embankment for future use during closure cover construction.
4.0 STABILITY ANALYSIS

4.1 Methodology

Two-dimensional limit equilibrium stability analyses were performed on three cross-sections within the East Cell where deposited fine PK excavation will take place (Cell 2) and where the west perimeter embankment will be regraded. The computer software GeoStudio 2016, Slope/W Version 8.16, developed by GEO-SLOPE International Ltd., was used for the analyses. The Morgenstern-Price (Morgenstern 1965) method of slices was used for calculations of factors of safety (FoS). The phreatic surface in the deposited materials is expected to be low and was assumed for the models.

4.1.1 Cross-Section Locations

The current configuration (October 2018) of the North Pile was reviewed to evaluate the location of critical cross-sections for the stability assessment. Critical cross-sections for the East Cell selected for the slope stability assessment are summarized below. Cross-section locations are shown in Figure 1.

- **Rib Berm 2**—Cross-Section A at Rib Berm 2, through Cell 2 and Cell 3.
- **Cell 2 Perimeter Embankment**—Cross-Section B at North Pile perimeter embankment Stn. 35+890, through Cell 2.
- **Cell 1 West Perimeter Embankment**—Cross-Section C at North Pile perimeter embankment Stn. 36+275, through Cell 1.

4.1.2 Geometry

The upstream slope stability was assessed for Rib Berm 2 and the Cell 2 perimeter embankment located within the East Cell of the North Pile to determine whether the required FoS could be reached when the deposited fine PK is excavated from Cell 2 and placed within Cell 3.

The construction sequence for partial excavation of the deposited fine PK to a 4H:1V slope and subsequent placement into Cell 3 is described in Section 3.0. The geometry to assess the partial excavation of Rib Berm 2, and the excavation and placement of fine PK material from Cell 2 to Cell 3, is shown in Figure 2. Additionally, geometry to assess the upstream stability of the Cell 2 embankment is shown in Figure 3.

The west perimeter embankment will be regraded as a cut to fill operation to achieve a downstream slope of 3H:1V. Landfill waste material will be placed within Cell 1 of the Starter Cell. The geometry to assess the downstream stability of the Cell 1 embankment is shown in Figure 4.
4.2 Factor of Safety Criteria

Based on the Canadian Dam Association (CDA) *Dam Safety Guidelines* (CDA 2013, 2014), the North Pile perimeter embankments are currently classified as “High” consequence (Golder 2005, 2014b, 2015). The rib berms are non-structural berms for deposition and help facilitate containment of deposited PK slurry. The rib berms are considered to have the same High consequence classification as the perimeter embankments when the fine PK excavation occurs during the care and maintenance period.

Based on Anglo American (Anglo 2016) standards, the North Pile facility was rated as a Moderate to High consequence classification considering workers’ safety and health during the excavation activities and landfill backfilling. The adopted criteria for the stability analyses of the facility are summarized in Table 1.

**Table 1: Summary of Design Criteria from the Canadian Dam Association and Anglo American for Closure – Passive Care Phase**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam classification</td>
<td>Moderate to High</td>
<td>High</td>
</tr>
<tr>
<td>Earthquake design ground motion</td>
<td>1-in-10,000-year or MCE</td>
<td>1-in-2,475-year or MCE (construction, operation, and transition phases)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/2 between 1-in-2,475-year and 1-in-10,000-year or MCE (closure – passive care phase)</td>
</tr>
<tr>
<td>Slope Stability Analysis Factors of Safety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Pseudo-static</td>
<td>1.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

CDA = Canadian Dam Association; MCE = maximum credible earthquake.

The design criteria for the slope stability assessment for the current configuration of the North Pile for the excavation during the care and maintenance phase include a minimum FoS of 1.5 for static and 1.2 for pseudo-static conditions.

For the downstream stability for the North Pile perimeter embankments, the adopted minimum FoS for closure configuration are 1.5 for static and 1.2 for pseudo-static. The Cell 1 west embankment downstream stability was examined for the proposed regrading using these criteria. For other perimeter embankments in East Cell and Starter Cell, the stability analyses were carried out during the detailed design for the North Pile surface water management (Golder 2019). The static and pseudo-static FoS exceeded the closure requirements. The current closure design does not change the downstream layout of the embankments, and the stability is expected to remain satisfactory. Therefore, no stability updates were carried out for these downstream slopes of the perimeter embankments at this stage of the closure design.
The selected earthquake design ground motion is the 1-in-10,000-year return period for both the excavation and closure scenarios. Site-specific earthquake-induced seismic loading was obtained from the 2015 National Building Code Seismic Hazard Calculator by Natural Resources Canada (NRC 2018; Attachment 1). The 500- and 2,500-year return periods provided by Natural Resources Canada were plotted in log-log scale to create a linear extrapolation for a 1-in-10,000-year annual exceedance probability event, and this approach resulted in a design peak ground acceleration of 0.092 g. According to Hynes-Griffin and Franklin (1984), the horizontal seismic coefficient should be halved from the design peak ground acceleration when evaluating the seismic stability of slopes not considering liquefaction. For this reason, the horizontal seismic coefficient used in the pseudo-static stability analyses is 0.046 g.

4.3 Foundation Conditions and Material Properties

A series of site investigation programs were carried out in the East Cell perimeter embankment foundation between 2000 and 2013 and are summarized in the East Cell reconfiguration detailed design report (Golder 2014b). The organic soil was observed to be less than 0.4 m thick overlying mineral soil between 1 and 2 m thick (Golder 2005) and organics up to 1.3 m thick (Golder 2009). The mineral soils comprise silt and sand to cobbles and boulders.

Foundation preparation was completed below the footprint of the East Cell perimeter embankment (Golder 2016) and was not completed within the footprint of the deposited material.

The material strength parameters selected for the stability analysis are consistent with recent stability modelling conducted for the North Pile embankments (Golder 2018a) and are presented in Table 2. Material properties for the landfill waste and cover system have been assumed.

One test pit, TP18-01 (Figure 1), was excavated in June 2018 within the fine PK deposited into Cell 2 to a depth of 5 m. The fine PK was observed to be 1 m of soft silty clay overlying 1 m of frozen silty clay. Firm to stiff clay was encountered at a depth of 2 to 5 m. In addition, in situ field vane shear testing was undertaken during summer of 2018 by De Beers and Golder. Undrained in situ shear strength profiles for deposited fine PK material in the East cell were developed for Cells 2, 3, 4, and 5 (Golder 2018b). Based on field vane shear test data, an undrained shear strength of 50 kPa is used for deposited fine PK material below 5 m from the current surface elevation.
Table 2: Slope Stability Analyses Material Parameters

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Friction Angle (°)</th>
<th>Cohesion (kPa)</th>
<th>Undrained Shear Strength (kPa)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine PK (0 to 5 m depth)</td>
<td>15.5</td>
<td>n/a</td>
<td>n/a</td>
<td>20</td>
<td>BGC (2015)</td>
</tr>
<tr>
<td>Fine PK (&gt;5 m depth)</td>
<td>15.5</td>
<td>n/a</td>
<td>n/a</td>
<td>50</td>
<td>Golder (2018b)</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK – compacted</td>
<td>20</td>
<td>38</td>
<td>0</td>
<td>n/a</td>
<td>Golder (2014a)</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK – uncompacted</td>
<td>18</td>
<td>34</td>
<td>0</td>
<td>n/a</td>
<td>assumed</td>
</tr>
<tr>
<td>Rockfill and base rockfill drain</td>
<td>20</td>
<td>42</td>
<td>0</td>
<td>n/a</td>
<td>Golder (2015)</td>
</tr>
<tr>
<td>Internal drainage material</td>
<td>19</td>
<td>38</td>
<td>0</td>
<td>n/a</td>
<td>Golder (2015)</td>
</tr>
<tr>
<td>Mineral soil – prepared</td>
<td>19.5</td>
<td>34</td>
<td>0</td>
<td>n/a</td>
<td>Golder (2014b, 2015)</td>
</tr>
<tr>
<td>Mineral soil – unprepared</td>
<td>18.5</td>
<td>30</td>
<td>0</td>
<td>n/a</td>
<td>Golder (2007)</td>
</tr>
<tr>
<td>Landfill material</td>
<td>15</td>
<td>27</td>
<td>0</td>
<td>0</td>
<td>assumed(a)</td>
</tr>
<tr>
<td>Cover system</td>
<td>18</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>assumed the same as uncompacted combined coarse and grits fractions of the PK</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>32</td>
<td>5,000</td>
<td>n/a</td>
<td>Golder (2014b)</td>
</tr>
</tbody>
</table>

(a) Landfill material properties are representative of construction and demolition waste (Konstantopoulou and Spanou 2013; Vieira and Pereira 2015).

PK = processed kimberlite; n/a = not applicable.

5.0 RESULTS AND CONCLUSIONS

The results of the stability analyses for Cross-Sections A to C are summarized in Table 3 and 4 and presented in Figures 2 to 4. FoS are reported for static and pseudo-static analyses for slip surfaces that involve the entire regraded upstream excavation within the East Cell (Cell 2) and downstream slope of the Cell 1 west embankment.
Table 3: Summary of Fine Processed Kimberlite Excavation Slope Stability Results

<table>
<thead>
<tr>
<th>Cross-Section</th>
<th>Fine PK Excavation</th>
<th>Structure</th>
<th>Minimum Required Factor of Safety (CDA 2013; Anglo 2016)</th>
<th>Calculated Minimum Factor of Safety</th>
<th>Figure No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.5 – static 1.2 – pseudo-static</td>
<td>1.6 1.3 2</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Cell 2</td>
<td>Rib Berm 2</td>
<td>1.5 – static 1.2 – pseudo-static</td>
<td>1.6 1.3 2</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>Cell 2</td>
<td>Cell 2 embankment</td>
<td>1.7 1.4 3</td>
<td>1.7 1.4 3</td>
<td>3</td>
</tr>
</tbody>
</table>

PK = processed kimberlite.

Table 4: Summary of Perimeter Embankment Closure Downstream Slope Stability Results

<table>
<thead>
<tr>
<th>Cross-Section</th>
<th>Structure</th>
<th>Minimum Required Factor of Safety (Anglo 2016)</th>
<th>Calculated Minimum Factor of Safety</th>
<th>Figure No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cell 1 west embankment downstream slope</td>
<td>1.5 – static 1.2 – pseudo-static</td>
<td>2.9 2.5</td>
<td>4</td>
</tr>
</tbody>
</table>

The upstream slope stability assessment was completed for East Cell (Cell 2) perimeter embankment and rib berm for the fine PK excavation. The results of the analyses indicate that the excavation with a 4H:1V slope from the crest of the embankment and rib berm to cell bottom meet the required minimum static and pseudo-static FoS requirements for the rib berm and embankment cross-sections of the East Cell (Cell 2). Additionally, the 3H:1V downstream slope at the Cell 1 western embankment satisfies the minimum required FoS.
6.0 CLOSING

The reader is referred to the Study Limitations section, which follows the text and forms an integral part of this technical memorandum.

We trust the information contained in the document meets your requirements at this time. If there are any questions, or additional details are required, please contact the undersigned.

Golder Associates Ltd.

Colin McGrath, B.A.Sc.
Mine Waste Group

Abdul Sattar Khan, M.A.Sc.
Project Manager

Jeffrey Kwok, P.Eng.
Associate, Senior Geotechnical Engineer

CM/ASK/JCC/JEK/cf/cr

Attachments: Study Limitations
Figures 1 to 4

REFERENCES


STUDY LIMITATIONS

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of De Beers Group of Companies. It represents Golder’s professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by De Beers Group of Companies, and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. De Beers Group of Companies may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.
NOTES:
1. ALL UNITS ARE IN METRES UNLESS OTHERWISE NOTED.
2. COORDINATE SYSTEM IS MINE GRID.
3. ELEVATION DATA PROVIDED BY DE BEERS.
4. DRAINAGE DITCHES NOT SHOWN FOR CLARITY.
5. WATER TREATMENT AND CLOSURE WATER MANAGEMENT STRUCTURES NOT SHOWN FOR CLARITY.

REFERENCES:
4. TEST PIT TP18-04 LOCATION PROVIDED BY GOLDEN ASSOCIATES, JUNE 27, 2018.
5. TEST PIT TP18-06 TO TP18-09 LOCATIONS PROVIDED BY GOLDEN ASSOCIATES (2018).
### Cross-Section A – Rib Berm 2

**Title:** EXCAVATION OF DEPOSITED FINE PK

**Notes:**
1. Higher degree of consolidation assumed for deposited fine fractions of the PK below 5 m.
2. This condition of fine PK is not considered for Cell 3.
3. 1 in 10,000 year peak ground acceleration (PGA) selected for pseudo-static analysis.

#### Strength Parameters

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Effective Friction Angle (°)</th>
<th>Cohesion (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined coarse and grits fractions of the PK - uncompacted</td>
<td>18</td>
<td>34°</td>
<td>0</td>
</tr>
<tr>
<td>Fine PK - &lt; 5 m depth</td>
<td>15.5</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Fine PK - &gt; 5 m depth</td>
<td>15.5</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>30°</td>
<td>0</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>32°</td>
<td>5000</td>
</tr>
</tbody>
</table>

**Legend:**
- **Existing ground (July 2017)**
- **Fine PK placed in Cell 3**
- **Fine PK left in place for safety during excavation and constructability**
- **Partial Excavation of Rib Berm 2**
- **Excavated Fine PK**
- **New coarse and grits**
- **Inferred Rib Berm 2 Extent**

**Pseudo-static FoS = 1.3 (kh = ½ 0.092 g)**

**Static FoS = 1.6**
Pseudo-static FoS = 1.4 (kh = ½ 0.092 g)
Static FoS = 1.7

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Strength Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Drainage Material (50 mm minus)</td>
<td>19</td>
<td>Effective Friction Angle (φ°)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cohesion (kPa)</td>
</tr>
<tr>
<td>Fine PK - &gt; 5 m depth(1)</td>
<td>15.5</td>
<td>38°</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK - compacted</td>
<td>20</td>
<td>38°</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK - uncompacted</td>
<td>18</td>
<td>34°</td>
</tr>
<tr>
<td>Mineral soil – prepared foundation</td>
<td>19.5</td>
<td>34°</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>30°</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>32°</td>
</tr>
</tbody>
</table>

Notes:
1. Higher degree of consolidation assumed for deposited fine fractions of the PK below 5 m.
2. 1 in 10,000 year PGA selected for pseudo-static analysis.
3. For clarity, erosion protection not shown on downstream slope.

Legend
---
Existing ground (July 2017)
Notes
1. 1 in 10,000 year PGA selected for pseudo-static analysis.
2. For clarity, erosion protection not shown on downstream slope.

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Strength Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Effective Friction Angle (°)</td>
</tr>
<tr>
<td>Rockfill</td>
<td>20</td>
<td>42°</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK - compacted</td>
<td>18</td>
<td>38°</td>
</tr>
<tr>
<td>Cover System</td>
<td>18</td>
<td>34°</td>
</tr>
<tr>
<td>Landfill Material</td>
<td>15</td>
<td>27°</td>
</tr>
<tr>
<td>Mineral soil – prepared foundation</td>
<td>19.5</td>
<td>34°</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>30°</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>32°</td>
</tr>
</tbody>
</table>

Pseudo-static FoS = 2.5 (kh = ½ 0.092 g)
Static FoS = 2.9

Cell 1

CROSS-SECTION C – CELL 1 WEST EMBANKMENT CLOSURE DOWNSTREAM SLOPE
2018 National Building Code
Seismic Hazard Calculation –
Snap Lake Mine
**Site:** 63.6052 N, 110.8666 W  
**User File Reference:** Snap Lake Mine

**Requested by:** , Golder

**National Building Code ground motions:** 2% probability of exceedance in 50 years (0.000404 per annum)

<table>
<thead>
<tr>
<th>Period (s)</th>
<th>Sa(0.05)</th>
<th>Sa(0.1)</th>
<th>Sa(0.2)</th>
<th>Sa(0.3)</th>
<th>Sa(0.5)</th>
<th>Sa(1.0)</th>
<th>Sa(2.0)</th>
<th>Sa(5.0)</th>
<th>Sa(10.0)</th>
<th>PGA (g)</th>
<th>PGV (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.040</td>
<td>0.055</td>
<td>0.052</td>
<td>0.042</td>
<td>0.031</td>
<td>0.016</td>
<td>0.0066</td>
<td>0.0013</td>
<td>0.0007</td>
<td>0.030</td>
<td>0.021</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s²). Peak ground velocity is given in m/s. Values are for “firm ground” (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.

**Ground motions for other probabilities:**

<table>
<thead>
<tr>
<th>Probability of exceedance per annum</th>
<th>Probability of exceedance in 50 years</th>
<th>Sa(0.05)</th>
<th>Sa(0.1)</th>
<th>Sa(0.2)</th>
<th>Sa(0.3)</th>
<th>Sa(1.0)</th>
<th>Sa(2.0)</th>
<th>Sa(5.0)</th>
<th>Sa(10.0)</th>
<th>PGA</th>
<th>PGV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.010</td>
<td>40%</td>
<td>0.0019</td>
<td>0.0034</td>
<td>0.0040</td>
<td>0.0036</td>
<td>0.0026</td>
<td>0.0005</td>
<td>0.0002</td>
<td>0.00018</td>
<td>0.0013</td>
<td></td>
</tr>
<tr>
<td>0.021</td>
<td>10%</td>
<td>0.010</td>
<td>0.016</td>
<td>0.017</td>
<td>0.015</td>
<td>0.011</td>
<td>0.0020</td>
<td>0.0005</td>
<td>0.0085</td>
<td>0.0063</td>
<td></td>
</tr>
<tr>
<td>0.001</td>
<td>5%</td>
<td>0.019</td>
<td>0.029</td>
<td>0.028</td>
<td>0.024</td>
<td>0.018</td>
<td>0.0037</td>
<td>0.0008</td>
<td>0.016</td>
<td>0.012</td>
<td></td>
</tr>
</tbody>
</table>

**References**

- **National Building Code of Canada 2015 NRCC no. 56190;**
  - **Appendix C:** Table C-3, Seismic Design Data for Selected Locations in Canada

- **User’s Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx** (in preparation)
- **Commentary J:** Design for Seismic Effects

- **Geological Survey of Canada Open File 7893** Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be 63.5°N used with the 2015 National Building Code of Canada

  See the websites [www.EarthquakesCanada.ca](http://www.EarthquakesCanada.ca) and [www.nationalcodes.ca](http://www.nationalcodes.ca) for more information

- **Aussi disponible en français**
Distribution List
Electronic Copy - De Beers Group of Companies

Electronic Copy - Golder Associates Ltd.
Executive Summary

The De Beers Group of Companies (De Beers) owns and maintains the Snap Lake Mine, a diamond mine located about 220 km northeast of Yellowknife, Northwest Territories, Canada. The mine operated from 2007 to 2015 and entered a care and maintenance phase on 4 December 2015. On 14 December 2017, De Beers notified the Mackenzie Valley Land and Water Board that it is preparing for final closure of the mine.

This report presents the closure cover feasibility-level design for the North Pile facility at the Snap Lake Mine. The design for the North Pile considers water management, geochemical and geotechnical stability, borrow sources and availability of construction material, and post-construction monitoring and maintenance. The North Pile facility was constructed for the disposal of processed kimberlite (PK), waste rock, and non-hazardous solid waste (landfill waste) materials, and includes the Starter Cell and East Cell.

The closure cover design for the North Pile includes regrading of the pile top surface and infilling of cells to promote drainage from the North Pile. Two swales will convey flow from the Starter Cell and the east portion of the East Cell toward a channel outlet located east of Cell 5, and one swale will convey flow from the west portion of the East Cell toward a channel outlet located west of Cell 1. Minimum gradients of 2% will be targeted over the cover to reduce the risk that differential settlement could produce areas of ponding or localized drainage reversals.

The main construction materials for the North Pile cover design have been defined as an erosion protection cover material and a transition material. The erosion protection cover material, a relatively coarse rockfill, will be placed over the entire North Pile surface. The transition material will underlie the erosion protection cover material in areas of deposited PK and landfill waste materials, where it is needed for physical material compatibility (grain size) between the erosion protection cover and the underlying deposited PK and to achieve the total closure cover thickness over the landfill waste.

Surface water management, slope stability, settlement, and geochemical stability analyses were completed to support the North Pile closure cover feasibility design. A surface water management analysis of the closure cover was performed to adequately size conveyance features to accommodate peak runoff flow rates and volumes and to avoid water storage on the North Pile. Results of the analyses determined the length, width, depth, side slope, and revetment for the two channel outlets and three swales that will be constructed to convey runoff from the North Pile toward the existing Sumps SP3 and SP5.

Slope stability analyses were performed at key locations on the North Pile to confirm the stability of the closure cover for the feasibility design. Results of the stability analyses indicate the North pile closure geometry and feasibility cover design satisfies the Canadian Dam Association and Anglo American standard’s minimum static and pseudo-static factor of safety requirements for a closed facility during post-closure period. Results were also used to verify stability for the excavation of deposited PK material from Cell 2 and Cell 5 and subsequent placement in Cell 3 and Cell 4, thus allowing landfill waste material placement in Cell 1, Cell 2, and Cell 5.
A review of settlement data from the existing North Pile deposited PK and landfill waste materials was considered in developing the closure cover design basis. Results from the review indicate that the areas of greatest settlement will likely occur over the areas where landfill waste material is placed, and within the first years after cover placement. De Beers and Golder Associates Ltd. will advance trial cover test pads in the summer of 2018 to further assess total and differential settlement rates.

A geochemical stability assessment was performed to evaluate the potential for generation of acid rock drainage from the North Pile during the post-closure period, considering the measured characteristics of the material contained in the North Pile, including PK, waste rock, and rockfill materials. The assessment suggests that seepage through the North Pile would not produce significant acidity, due to the excess internal buffering capacity of the waste rock and deposited PK. However, a toe apron will be placed along the west perimeter embankment to provide additional buffering capacity and support a shallower slope regrade.

The reader is referred to the Study Limitations, which follows the text and forms an integral part of this report.
# Table of Contents

**EXECUTIVE SUMMARY** ................................................................................................................................. ii  
**LIST OF ABBREVIATIONS** ............................................................................................................................ vi  
1.0 **INTRODUCTION** ........................................................................................................................................ 1  
2.0 **DESIGN BASIS** ......................................................................................................................................... 2  
3.0 **CONCEPTUAL AND PRE-FEASIBILITY DESIGN** ......................................................................................... 3  
4.0 **FEASIBILITY DESIGN** ................................................................................................................................. 4  
   4.1 Previous Closure Activities ....................................................................................................................... 4  
   4.2 Cover Profile .............................................................................................................................................. 5  
   4.2.1 Deposited Processed Kimberlite Cover Profile .................................................................................... 6  
   4.2.2 Landfill Waste Cover Profile ................................................................................................................ 6  
   4.2.3 Embankment / Rib Berm Cover Profile ............................................................................................... 6  
   4.3 Grading Plan .............................................................................................................................................. 6  
   4.3.1 East Cell .............................................................................................................................................. 7  
   4.3.2 Starter Cell .......................................................................................................................................... 8  
   4.3.3 West Perimeter Embankment .............................................................................................................. 9  
   4.3.4 Borrow ................................................................................................................................................ 9  
   4.4 Engineering Analyses .............................................................................................................................. 10  
   4.4.1 Surface Water Management ................................................................................................................ 11  
   4.4.2 Slope Stability .................................................................................................................................... 11  
   4.4.3 Settlement .......................................................................................................................................... 12  
   4.4.4 Geochemical Stability ......................................................................................................................... 12  
4.5 Post-Closure Land Use ............................................................................................................................... 13  
5.0 **CONSTRUCTION MATERIAL QUANTITY ESTIMATE** .............................................................................. 14  
6.0 **CONSTRUCTION CONSIDERATIONS** ......................................................................................................... 17  
   6.1 Sequence .................................................................................................................................................. 17  
   6.2 Schedule ................................................................................................................................................... 18
6.3 Construction Quality Assurance / Quality Control.................................................................19
6.4 Sitewide Demolition and Landfill Waste Material Placement.............................................19

7.0 POST-CONSTRUCTION MONITORING AND MAINTENANCE...........................................20

7.1 Monitoring Areas ..................................................................................................................20
7.2 Monitoring Frequency ...........................................................................................................20
7.3 Data Assessment and Corrective Action ..............................................................................20
7.4 Reporting ...............................................................................................................................21

8.0 CLOSING ..............................................................................................................................22

REFERENCES .......................................................................................................................................24

STUDY LIMITATIONS.......................................................................................................................25

TABLES
Table 1: North Pile Closure Cover Feasibility Design Borrow Area Quantity Estimate ..................10
Table 2: North Pile Closure Cover Surface Water Management Structure Summary ......................11
Table 3: North Pile Closure Cover Feasibility Design Construction Material Quantity Estimate .........14
Table 4: North Pile Closure Cover Construction Borrow Source Material Quantity Estimate Summary ..16
Table 5: North Pile Closure Cover Design Tasks and Construction Activities Schedule .................18

APPENDICES

APPENDIX A
Design Basis and Criteria

APPENDIX B
Feasibility Design Drawings

APPENDIX C
Surface Water Analysis

APPENDIX D
Slope Stability Analysis

APPENDIX E
Geochemical Stability Analysis
List of Abbreviations

km   kilometre
m    metre
mm   millimetre
m³   cubic metre
xH:1V x horizontal to 1 vertical
%    percent
Anglo Anglo American
CDA  Canadian Dam Association
De Beers De Beers Group of Companies
FoS  Factor of Safety
Golder Golder Associates Ltd.
PK   processed kimberlite
TBD  to be determined
1.0 INTRODUCTION

The De Beers Group of Companies (De Beers) retained Golder Associates Ltd. (Golder) to prepare the feasibility-level closure cover design for the North Pile facility at the Snap Lake Mine, located approximately 220 km northeast of Yellowknife, Northwest Territories. The North Pile facility was constructed for the surface disposal of processed kimberlite (PK), waste rock, and non-hazardous waste (landfill waste) materials, and is composed of the Starter Cell, East Cell, and West Cell. The West Cell was not fully developed, leaving the west perimeter embankment of the Starter Cell and East Cell exposed.

Previous closure activities for the North Pile included placement of a 0.3 to 0.5 m thick non-acid generating waste rock material erosion protection layer on the downstream slopes of the north, south, and east perimeter embankments, at a 3 horizontal to 1 vertical (3H:1V) slope. The North Pile closure cover feasibility design addresses cover placement over the remainder of the facility, including the deposited PK materials within the East Cell and Starter Cell footprint, the west perimeter embankment, and rib berms.

The feasibility design and supporting grading plans have been developed such that the North Pile closure cover:

- complies with the North Pile Closure Design – Design Constraints and Criteria report, dated 26 September 2018 (Appendix A)
- accommodates 350,000 m³ of additional landfill waste material placement
- limits construction earthworks and revetment quantities
- meets applicable regulatory and Anglo American requirements for mineral residue facilities

The North Pile closure cover feasibility design, construction material quantity estimate, additional construction considerations, and post-construction monitoring and maintenance are summarized herein. Engineering analyses have been performed to confirm compliance with the design constraints and criteria (Appendix A). Feasibility design drawings and engineering calculations are presented in the following appendices:

- Appendix B Feasibility Design Drawings
- Appendix C Surface Water Analysis
- Appendix D Slope Stability Analysis
- Appendix E Geochemical Stability Analysis
2.0 DESIGN BASIS

De Beers and Golder representatives met on site at the Snap Lake Mine on 30 May 2018 to discuss the pre-feasibility-level closure cover design grading plan for the North Pile facility, and to get agreement on the design basis, criteria, and assumptions to be used for the feasibility-level closure cover design. Subsequently, Golder revised the design constraints and criteria report (Appendix A) for use as the basis for the North Pile closure cover feasibility design. The design objectives, basis, criteria, and cost reduction considerations included were selected based on Golder’s experience with the Snap Lake Mine, development of closure designs for similar facilities, guidelines for closure and reclamation in the Northwest Territories (MVLWB/AANDC 2013), Anglo American Standards (Anglo 2016), and additional input from De Beers.
3.0 CONCEPTUAL AND PRE-FEASIBILITY DESIGN

Previously, at the conceptual-level design, seven closure cover options for the North Pile facility were reviewed to select a preferred alternative to advance to a pre-feasibility-level design:

- Alternative 1 – No Cover
- Alternative 2 – Rock Cover
- Alternative 3 – Thick Cover
- Alternative 4 – Cover with Capillary Barrier
- Alternative 5 – Cover with Low Permeability Soil
- Alternative 6 – Geosynthetic Cover
- Alternative 7 – Revegetation Cover

Favourable characteristics for selection of an alternative included ability to meet all environmental criteria, technical suitability for site conditions, and cost. Alternative 2, placement of a rock cover, was selected for advancement to a pre-feasibility level design. A detailed description of the cover option selection process was provided in the closure cover alternatives analysis submitted to De Beers on 11 May 2018 (Golder 2018b).

A pre-feasibility design grading plan and preliminary construction material quantity estimate was presented to De Beers during a site visit at Snap Lake Mine on 30 May 2018. A description of the pre-feasibility closure cover grading plan is provided in the meeting minutes submitted to De Beers on 15 June 2018 (Golder 2018c). Based on input from De Beers, two noteworthy design modifications were made by Golder to the closure cover design during advancement from the pre-feasibility to the feasibility-level design.

The first modification was to reduce the footprint for additional landfill waste material to be placed in the North Pile. The pre-feasibility design concept included landfill waste placement within the entire East Cell footprint, while the feasibility design concept restricts placement of landfill waste material in the East Cell to within Cell 2, Cell 5, and the existing landfill Cell 1. This reduction of footprint will require excavation of the deposited PK material in Cell 2 and Cell 5 to gain the required storage capacity for landfill waste material placement. The excavated PK material would be placed in Cell 3 and Cell 4. The landfill waste material to be placed in Cell 1, Cell 2, and Cell 5 is anticipated to be mostly demolition waste from site decommissioning.

The second modification was to relocate the Cell 1 channel outlet for conveyance of excess water from the East Cell cover surface. The pre-feasibility design location west of Cell 1 was changed to the northwest corner of the East Cell. This was done to avoid placement within the Cell 1 west embankment raise footprint, which will be constructed to achieve additional storage capacity for landfill waste material.
4.0 FEASIBILITY DESIGN
The North Pile closure cover feasibility design components include the cover profile, grading plan, and supporting engineering analyses. A summary of previous closure activities is included to demonstrate the evolution of the North Pile closure design. The cover profile describes the type of rockfill and placement thickness required. The grading plan presents the top of closure cover contours and is included with the feasibility design drawings (Appendix B). Engineering analyses were performed to confirm compliance with the design constraints and criteria (Appendix A).

Key design objectives of the North Pile closure cover feasibility design include:

- convey surface water runoff away from the North Pile
- resist wind and water erosion
- physically isolate waste materials from the surrounding environment
- provide safe access and egress for wildlife
- reduce infiltration of water into the North Pile

4.1 Previous Closure Activities
The closure design presented in this report represents the culmination of an ongoing process of investigation and design refinement. The original closure cover concept presented in the 2002 environmental assessment report (EAR) for the Snap Lake Project considered placement of a non-acid generating granitic rock cover for erosion protection during reclamation (De Beers 2002).

To further assess cover options and obtain performance data, two cover test pads were constructed and thermistors installed in 2011. These cover test pads were constructed overlying the deposited PK material located in the southwest corner of the Starter Cell. Data collected from the cover test pads was used to estimate infiltration and evaluate design options (Arktis 2018). Data collected from the thermistors installed at both test pad locations to a depth of 2 m below ground surface indicated the active permafrost layer extended through the entire sensor depth.

Based on the approved cover concept presented in the EAR (De Beers 2002) and data collected from the cover test pads during operations, a 0.3 to 0.5 m thick non-acid generating rock cover was constructed on the downstream 3H:1V North Pile perimeter embankment slopes and a portion of the Starter Cell crest as part of progressive closure activities.

ERM Consultants performed a high-level cover options analysis for the North Pile using a multiple account analysis (MMA) approach (ERM 2017). Thirteen alternative closure approaches were screened, and preferred options included rock fill, low permeability cover (i.e., soil and geosynthetic), and no cover. The preferred MMA options were included in Golder’s subsequent analysis of North Pile closure cover alternatives (Golder 2018b). The recommendation from Golder’s screening of closure cover alternatives analysis was for the placement of a non-acid generating rock cover over the deposited PK, landfill waste, and embankment / rib berm materials.
Arktis Solutions presented a conceptual rock cover, consistent with the EAR (De Beers 2002), for placement over deposited PK and potentially acid generating material within the North Pile in the Interim Closure and Reclamation Plan (ICRP) (Arktis 2018). The cover profiles in the 2018 ICRP were assumed and did not include an evaluation of material gradation or placement thickness.

Placement of non-acid generating rock has been the ongoing design concept for the North Pile closure cover throughout design and operation of the pile, and in all associated approvals. This approach is also consistent with the cover that has been constructed on the 3H:1V North Pile perimeter embankment slopes and a portion of the Starter Cell crest. Geochemical and physical characteristics of the North Pile materials have been evaluated and the cover thickness optimized, resulting in the cover profiles presented in subsequent sections.

4.2 Cover Profile

The two principal materials to be used in construction of the North Pile closure cover are:

- **Erosion protection cover**—non-acid generating rockfill material sourced locally from identified stockpiles and borrow sources with a nominal 150 mm minus size, placed as erosion protection over the entire North Pile.

- **Transition**—coarse and grits PK material used for construction of the rib berms and perimeter embankments, placed between the underlying deposited PK or landfill waste materials and overlying cover material, where it is needed for physical material compatibility (grain size) between the erosion protection cover and the underlying deposited PK and to achieve the total closure thickness over the landfill waste.

Three cover design profiles have been developed for the North Pile, with different cover configurations proposed for the deposited PK, landfill waste, and embankment / rib berm areas. The different materials to be covered have slightly different technical and regulatory requirements, resulting in the different cover configurations. The placement locations for each profile are presented in Drawing 6 (Appendix B). Profile components and thicknesses for each cover design are listed in descending order from the top of cover:

- **Deposited PK**—total cover thickness of up to 600 mm:
  - 300 mm of erosion protection cover material, equivalent to twice the nominal grain size for cover material of 150 mm.
  - Nominal 300 mm of transition material. The 300 mm thickness has been carried in the feasibility design. The thickness of the transition layer will be optimized based on the results of field trials conducted in 2018/2019 and construction observations. The constructability of a thinner layer (minimum 150 mm) that still meets design intent will be evaluated during construction by the geotechnical engineer.

- **Landfill waste**—total cover thickness of 2 m to meet regulatory commitment:
  - 300 mm of erosion protection cover material, equivalent to twice the nominal size of 150 mm.
  - 1.4 m of non-acid generating material, which may be a combination of erosion protection cover and transition materials, depending on availability.
15 November 2018
Reference No. 1785666-024-R-Rev0-3000

- Nominal 300 mm of transition material (assuming landfilled material will be covered with fine PK as part of deposition).

- **Embankment / rib berm**—total cover thickness of 300 mm
  - 300 mm of erosion protection cover.
  - Transition material is not required on rib berms.

### 4.2.1 Deposited Processed Kimberlite Cover Profile

The cover profile for deposited PK material consists of the erosion protection cover material, underlain by transition material placed over the deposited PK material. The layer of transition material is required for grain size compatibility between the erosion protection cover and underlying deposited PK materials. Placing coarse erosion protection cover material directly on the deposited PK material, characterized by a particle size of less than 0.125 mm (Appendix A), could result in erosion of the cover, with filtration of fines through coarse material.

### 4.2.2 Landfill Waste Cover Profile

As per the existing site permit, a minimum non-acid generating cover thickness of 2 m will be placed over deposited landfill waste material. Similar to the deposited PK cover profile, the profile will include 300 mm of erosion protection as the uppermost layer of the cover. The remaining 1.7 m of the required 2 m thickness will be non-acid generating material. The specific composition of this 1.7 m profile will be defined based on material availability and the conditions once the landfill material has been placed. If fine PK is used to cover the landfilled waste, a minimum 150 mm layer of transition material will be required above the fine PK.

### 4.2.3 Embankment / Rib Berm Cover Profile

The embankment / rib berm material is expected to be compatible with the erosion protection cover material, and no additional transition material placement is required. The underlying embankment/rib berm materials include coarse and grits PK and waste rock. The coarse PK materials are classified by a particle size range from 1.5 to 6 mm, and the grits PK materials by a range from 0.125 to 1.5 mm (Appendix A).

### 4.3 Grading Plan

The North Pile closure cover feasibility grading plan includes the:

- East Cell
- Starter Cell
- west perimeter embankment
- borrow
The feasibility-level design grading plan (Drawing 6, Appendix B) was developed based on existing ground topography for the North Pile facility. The topography used as a basis was provided by De Beers as a contour file produced from September 2016 and July 2017 aerial surveys. The three-dimensional civil design software AutoCAD Civil 3D 2017 (Autodesk 2017) was used to evaluate alternative configurations and to develop the design and drawings for the North Pile closure cover. The design grading surface shown in the drawings represents the top-of-cover grades and elevations. Details for the closure cover and revetment requirements are included with the feasibility design drawings (Drawing 9, Appendix B).

The North Pile closure cover grading plan (Drawing 6, Appendix B) shows the configuration of the North Pile after placement of landfill waste material in selected cells of the East Cell, regrading activities to ensure positive surface water drainage away from the North Pile, and placement of the closure cover. Borrow sources identified for use as erosion protection cover and transition materials are also depicted in the North Pile closure cover grading plan (Drawing 2, Appendix B). Closure of the North Pile in accordance with the grading plan will provide a final configuration that resists erosion and conveys a majority of the surface water runoff to the east, with a small portion of runoff conveyed to the west.

Design criteria for the North Pile closure cover feasibility design are provided in Appendix A. A minimum surface gradient of 2% was established to provide positive surface water drainage away from the North Pile and to allow maintenance of positive drainage in the case of some limited differential settlement during the post-closure period. The surface gradient of the closure cover will direct surface water flows away from the embankment crest (except at designed channel outlets) to prevent surface water flows from overtopping and eroding the North Pile perimeter embankment slopes. Two channel outlets will be constructed on the East Cell to convey surface water flow off of and away from the North Pile facility. Two swales will convey flow from the Starter Cell and the east portion of the East Cell toward a channel outlet located east of Cell 5, and one swale will convey flow from the west portion of the East Cell toward a channel outlet located west of Cell 1.

As part of the design criteria, it was assumed with direction from De Beers that 350,000 m$^3$ of landfill waste will be disposed of in the North Pile. The landfill waste material quantity assumption for placement within the East Cell will be validated during detailed design based on the sitewide Demolition and Landfill Placement Plan, in development by others at the time this feasibility design was prepared. If the actual volume to be disposed of is significantly greater or lesser, the grading design will be updated.

### 4.3.1 East Cell

The East Cell is located within the northern portion of the North Pile and was constructed in five sub-cells: Cells 1, 2, 3, 4, and 5. Rib berms and perimeter embankments separate each sub-cell and were constructed using the combined coarse and grits PK, and/or waste rock materials. Cell 1 is currently used for the disposal of landfill waste material. Cells 2, 3, 4, and 5 were used to store deposited PK material.

The closure cover feasibility design for the East Cell is presented in Drawing 6 (Appendix B) and includes a minimum 2% gradient directed away from the crest, and two swales to convey surface water flows toward the Cell 1 (west) and Cell 5 (east) channel outlets.

The west swale will be constructed on the closure cover surface over Cell 1 and Cell 2 to convey surface water flow west, toward the Cell 1 channel outlet located at the northwest corner of the East Cell. The Cell 1 channel outlet will be constructed as part of the west perimeter embankment regrade.
The east swale will be constructed on the closure cover surface over Cell 3, Cell 4, and Cell 5 to convey surface water flow east, toward the Cell 5 channel outlet located at the southeast corner of the East Cell.

Riprap will be placed within the west swale, east swale, and Cell 5 channel outlet to reduce erosion potential and promote long-term stability of the cover system. Dimensions and revetment requirements for the swales and channel outlets are included in the typical sections shown in Drawing 9.

During early design iterations, options were explored to direct all surface water flow east, toward the Cell 5 channel outlet. However, to maintain the design gradient and accommodate 350,000 m³ of landfill waste material in the East Cell, the closure cover configuration would require an impractical embankment raise of approximately 10 m along the west portion of Cell 1.

To accommodate 350,000 m³ of landfill waste material within the fewest practical cells of the East Cell, the closure cover configuration incorporates an excavation of deposited PK material in Cell 2 and Cell 5, excavation of Rib Berm 1, and a raise of the Cell 1 west embankment. The excavation design for the East Cell is presented in Drawing 4 (Appendix B) and includes complete removal of Rib Berm 1 and the deposited PK material within Cell 2 and Cell 5. The excavated rib berm is composed of coarse and grits PK, and waste materials that can be stockpiled for use as transition material in the final cover. The excavated PK material from Cell 2 and Cell 5 will be placed within Cell 3 and Cell 4. The Cell 1 west embankment raise of 4 m will be constructed using excavated embankment or processed coarse granular materials from identified borrow sources.

Greater settlement is anticipated within cells where landfill waste material is placed. To avoid potential differential settlement due to consolidation of underlying landfill waste material and to maintain surface water flow direction and gradient within the cover swales, placement of landfill waste material will be excluded from the area directly beneath the cover swale in Cell 5.

4.3.2 Starter Cell

The Starter Cell is located within the southern portion of the North Pile and was constructed as eight sub-cells: Cells A, B, C, D, E, F, SQ, and LF. Rib berms and perimeter embankments separate each sub-cell and were constructed using the combined coarse and grits PK, and/or waste rock materials. Cell LF was used for the disposal of landfill waste material. Cells A, B, C, D, E, F, and SQ were used to store deposited PK material.

The closure cover feasibility design for the Starter Cell is presented in Drawing 6 (Appendix B) and includes a minimum 2% gradient directed away from the crest. In general, the closure cover construction for the Starter Cell will be performed as an earthworks local cut to fill operation. The closure cover placed above the Starter Cell will direct surface water flow from southwest to northeast at a minimum 2% gradient toward the Cell 5 channel outlet.

The Starter Cell swale will be constructed on the closure cover surface to convey surface water flow toward the Cell 5 channel outlet, located at the southeast corner of the East Cell. The gradient of the Starter Cell swale will be greatest through the Cell D to Cell 5 transition, prior to the Cell 5 channel outlet confluence. Riprap will be placed within the Starter Cell swale to reduce erosion potential and promote long-term stability of the cover system. Dimensions and revetment requirements for the swales and channel outlets are shown on the typical sections included in Drawing 9.
4.3.3 West Perimeter Embankment

The west perimeter embankment is located along the western portion of the East Cell and Starter Cell and was intended to be covered by the West Cell construction as material placement advanced. However, the West Cell was not fully developed, leaving the ~1.5H:1V west perimeter embankment of the Starter and East Cells exposed.

The closure cover feasibility design for the west perimeter embankment is presented in Drawing 6 (Appendix B) and includes a 3H:1V slope regrade to promote long-term stability of the cover system and allow for wildlife access and egress. The west perimeter embankment has been designed as a cut to fill slope regrade to the extent practicable.

The Cell 1 channel outlet will be constructed at the northwest corner of the East Cell and continue along the west perimeter embankment to convey surface water off of the East Cell, toward the existing west perimeter drainage ditch. Riprap will be placed within the Cell 1 channel outlet to reduce erosion potential and promote long-term stability of the cover system. Dimensions and revetment requirements for the channel outlet are included in Drawing 9.

4.3.4 Borrow

Transition, erosion protection cover, embankment, and riprap materials are required for construction of the North Pile closure cover.

- Transition materials will be locally sourced from the coarse and grits PK material generated by excavation of the embankment and rib berms or from suitable borrow areas surrounding the North Pile as identified in Table 1.
- Erosion protection cover and embankment construction materials will be locally sourced from the excavation of suitable borrow areas surrounding the North Pile as identified in Table 1.
- Embankment material will be locally sourced from excavation of the West Cell Divider Dyke.
- Rip rap will be locally sourced from excavation of the Organic Stockpile borrow area.

Borrow area locations for use during construction of the closure cover are presented in Drawing 2 (Appendix B). Borrow materials required for construction of the North Pile closure cover are expected to be locally available in sufficient quantities. The closure of identified borrow sources will be assessed by others during development of the overall sitewide closure plan. off-site material will be required for construction of the North Pile closure cover. Quantities have been estimated for each borrow source using the existing ground topography and are presented in Table 1.
Table 1: North Pile Closure Cover Feasibility Design Borrow Area Quantity Estimate

<table>
<thead>
<tr>
<th>Borrow Area</th>
<th>Location</th>
<th>Primary Use</th>
<th>Available Quantity Estimate (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crusher Stockpile west of North Pile</td>
<td>Erosion protection cover material</td>
<td>11,200&lt;sup&gt;(a)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Explosive Management Bunker west of East Cell</td>
<td>Erosion protection cover material</td>
<td>1,700&lt;sup&gt;(b)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Laydown Area southeast of North Pile</td>
<td>Erosion protection cover and/or transition material</td>
<td>256,000&lt;sup&gt;(c)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Organic Stockpile former AN storage facility</td>
<td>Riprap</td>
<td>29,400&lt;sup&gt;(d)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>SP5 Quarry North of East Cell, Cell 1</td>
<td>Erosion protection cover and/or transition material</td>
<td>68,200&lt;sup&gt;(e)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>West Cell Divider Dyke North Pile West Cell</td>
<td>Embankment fill and/or erosion protection cover materials</td>
<td>81,000&lt;sup&gt;(f)&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

(a) Quantities were provided by De Beers on 25 April 2018 and include the following sizes (quantities): 150 mm (5,900 m$^3$), 75 mm (2,500 m$^3$), 50 mm (900 m$^3$), and 19 mm (2,000 m$^3$).
(b) Explosive management bunker was identified as a potential borrow source during a site visit to the Snap Lake Mine on 31 May 2018.
(c) Quantity assumes only 80% of the total volume of material within the borrow area will be available and suitable for use following grizzly screening.
(d) Quantity assumes only 20% of the total volume of material within the borrow area is considered oversized and will be available and suitable for use following grizzly screening. The remaining 80% of the total volume of material estimated is assumed to be undersized and may be reserved for sitewide revegetation efforts.
(e) Quantity accounts for estimated volume of material removed during 2016 and 2017 provided by De Beers.
(f) Quantity assumes the total volume of material will be available and suitable for use.

Additional borrow areas may be considered based on feedback received from De Beers and advancement to detailed design. Activities associated with the passive treatment wetland construction may also generate borrow material for use during construction of the closure cover and will be considered during detailed design.

### 4.4 Engineering Analyses

The following sections describe the engineering analyses that were performed to confirm compliance of the North Pile closure cover feasibility design with the design constraints and criteria. Surface water management, slope stability, settlement, and geochemical stability analyses were completed to support the feasibility-level closure cover design.
4.4.1 Surface Water Management

A surface water management analysis was performed to determine the length, width, depth, side slope, and revetment for the swales and channel outlets included in the closure cover design. The probable maximum precipitation 24-hour storm event plus snowmelt was selected as the design storm event required to satisfy the criteria per the Anglo American (Anglo 2016) and Canadian Dam Association (CDA 2013) standards for the closure passive care phase. A detailed description of the surface water management analysis is included as Appendix C.

Two swales will be constructed on the East Cell closure cover surface to convey surface water toward the Cell 1 (west) and Cell 5 (east) channel outlets. One swale will be constructed on the Starter Cell closure cover surface to convey surface water toward the Cell 5 (east) channel outlet. Riprap will be placed within all three swales and both outlet channels. Channel dimensions and riprap requirements are summarized in Table 2.

Table 2: North Pile Closure Cover Surface Water Management Structure Summary

<table>
<thead>
<tr>
<th>Hydraulic Structure</th>
<th>Longitudinal Slope (%)</th>
<th>Side Slope (H: V)</th>
<th>Bottom Width (m)</th>
<th>Minimum Depth (m)</th>
<th>Riprap Size ($D_{50} = \text{mm}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Swale</td>
<td>2</td>
<td>10</td>
<td>5</td>
<td>0.6</td>
<td>150</td>
</tr>
<tr>
<td>East Swale</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>0.6</td>
<td>150</td>
</tr>
<tr>
<td>Starter Cell Swale (shallow)</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>0.7</td>
<td>150</td>
</tr>
<tr>
<td>Starter Cell Swale (Cell D to Cell 5)</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>0.7</td>
<td>300</td>
</tr>
<tr>
<td>Cell 5 Swale and Outlet Channel through embankment crest</td>
<td>2</td>
<td>2.5</td>
<td>10</td>
<td>1.0</td>
<td>600</td>
</tr>
<tr>
<td>Cell 1 Outlet Channel</td>
<td>30</td>
<td>2.5</td>
<td>5</td>
<td>0.5</td>
<td>600</td>
</tr>
</tbody>
</table>

4.4.2 Slope Stability

Development the final geometry of the closed North Pile will require excavations for the placement of landfill material within a minimum footprint, and an embankment raise of a maximum 4 m on the west embankment of Cell 1. Slope stability analysis was required to assess the permissible slopes for excavation of PK, and to confirm the long-term stability of the embankment raise. A detailed description of the slope stability analyses is included as Appendix D. Based on the results of the assessment, feasible embankment raise and excavation geometries have been developed, which meet conservatively selected factor of safety (FoS) criteria, including where applicable the Anglo American (Anglo 2016) and CDA (2013) standards for the closure passive care phase.
Results of the stability analysis indicate the planned geometry of the Cell 1 embankment raise satisfies the minimum static and pseudo-static FoS requirements. Additionally, results of the Cell 2 and Cell 5 perimeter embankments, and Rib Berms 2 and 4 stability analyses verify the excavation of deposited PK material from Cell 2 and Cell 5, and subsequent placement in Cell 3 and Cell 4 satisfies the minimum FoS requirements with the following construction considerations:

- **Rib Berm 2**—Rib berm material will be removed to the elevation of the deposited PK material in Cell 3. The deposited PK material will be subsequently excavated from Cell 2, leaving a maximum slope steepness of 4H:1V against the remaining rib berm as the deposited PK material is removed.

- **Rib Berm 4**—Rib berm material will be removed to the elevation of the deposited PK material in Cell 4. The deposited PK material will be subsequently excavated from Cell 5, leaving a maximum slope steepness of 4H:1V against the remaining rib berm as the deposited PK material is removed.

- **Cell 2 and Cell 5 perimeter embankments**—Coarse and grits PK and/or waste rock material will be excavated at a maximum steepness of 2H:1V to a depth of 10 m, leaving a 5 m excavated bench, and deposited PK material will be subsequently excavated leaving a maximum slope steepness of 4H:1V within Cell 2 and Cell 5.

### 4.4.3 Settlement

Settlement data from the existing North Pile deposited PK and landfill waste materials was reviewed during development of the closure cover design basis (Appendix A). Based on this review, it is anticipated that the areas of greatest settlement will be the cells where landfill waste material is placed (Cells 1, 2, 5), which will likely be subject to greater differential settlement than within cells where only deposited PK material is placed. Additionally, it is anticipated that the majority of the settlement will take place in the first years after cover placement, with ongoing settlement at lower, decreasing rates in subsequent years. The greatest need for cover maintenance activities to address differential settlement are likely to be in the first years after cover placement.

De Beers and Golder will advance trial cover test pads in the summer of 2018 to further assess total settlement and differential settlement rates. A report detailing construction and monitoring activities for the closure cover trial test pads will be issued in the fall of 2018.

### 4.4.4 Geochemical Stability

A geochemical stability analysis was performed to assess the acid rock drainage potential of PK, waste rock, and rockfill materials within to the North Pile (Appendix E). Data indicated that seepage through the North Pile would not produce significant acidity due to the excess internal buffering capacity of the waste rock and PK. A sitewide geochemistry review for Snap Lake Mine was submitted to De Beers on 11 September 2018 (Golder 2018d).

During construction of the North Pile, materials that had been classed as potentially acid generating materials were excluded from within 50 m of the downstream toe of the North Pile embankment, and from within 3 m of the expected closure surface, with the exception of the west perimeter embankment (Golder 2013). This was intended to provide isolation of potentially acid generating materials. The 50 m exclusion zone was not applied to the west perimeter embankment, as it was intended to be covered by the West Cell construction as material placement advanced. However, the West Cell was not fully developed, leaving the west perimeter embankment of the Starter and East cells exposed.
The geochemical assessment considered the materials previously placed in the west perimeter embankment and determined that the risk of acidic seepage was minimal.

4.5 Post-Closure Land Use

The North Pile closure cover configuration was designed to maintain physical and chemical stability post-closure. Safe access and egress for caribou and other wildlife were considered during selection of the North Pile regrade slopes. Locally sourced non-acid generating materials will be used for the construction of the North Pile closure cover and will blend in with the surrounding natural landscape. Additional input from community engagement regarding post-closure land use is ongoing and will be considered during detailed design.
5.0 CONSTRUCTION MATERIAL QUANTITY ESTIMATE

A construction material quantity estimate was developed for the North Pile closure cover feasibility design using AutoCAD Civil 3D 2017 (Autodesk 2017). Quantities have been estimated separately for the East Cell, Starter Cell, and the west perimeter embankment components of the closure cover design, and are divided into three categories:

- earthworks for grading
- earthworks for cover placement
- revetment

Earthworks and revetment quantities were calculated to estimate the amount of deposited PK, rib berm, and embankment material excavation, transition and erosion protection cover material placement, swale and channel outlet revetment placement, and borrow materials required to meet the design grades, contours, and placement locations as outlined in the design drawings (Appendix B). Earthworks and revetment quantities are presented in Table 3, and are neat line and do not account for swell, shrinkage, waste, or loss.

**Table 3: North Pile Closure Cover Feasibility Design Construction Material Quantity Estimate**

<table>
<thead>
<tr>
<th>Construction Activity</th>
<th>Quantities (m$^3$)</th>
<th>East Cell</th>
<th>Starter Cell</th>
<th>West Perimeter Embankment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Earthworks for Grading</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excavate deposited PK material from Cell 2 and Cell 5, and place in Cell 3 and Cell 4</td>
<td>129,300</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Excavate and stockpile coarse and grits from Rib Berm 1</td>
<td>21,900</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Excavate and place fill (local cut to fill)</td>
<td>100</td>
<td>63,800</td>
<td>13,100</td>
<td></td>
</tr>
<tr>
<td>Excavate and stockpile coarse and grits from rib berms (excludes Rib Berm 1)</td>
<td>17,100</td>
<td>50,800</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Excavate and stockpile waste rock/coarse and grits from the embankment</td>
<td>-</td>
<td>50,600</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Place fill for embankments</td>
<td>62,700</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Place landfill waste material in Cell 1, Cell 2, and Cell 5</td>
<td>377,200</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
### Earthworks for Cover

<table>
<thead>
<tr>
<th>Construction Activity</th>
<th>Quantities (m³)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Place erosion protection cover material over North Pile</td>
<td>East Cell: 45,400</td>
<td>Starter Cell: 68,900</td>
</tr>
<tr>
<td>Place erosion protection cover and/or transition material over landfill waste material</td>
<td>East Cell: 96,700</td>
<td>Starter Cell: 22,600</td>
</tr>
<tr>
<td>Place transition material</td>
<td>East Cell: 31,900</td>
<td>Starter Cell: 49,800</td>
</tr>
</tbody>
</table>

### Revetment

<table>
<thead>
<tr>
<th>Construction Activity</th>
<th>Quantities (m³)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Place riprap for swales (D₅₀ = 150 mm)</td>
<td>East Cell: 2,700</td>
<td>Starter Cell: 3,200</td>
</tr>
<tr>
<td>Place riprap for swales (D₅₀ = 300 mm)</td>
<td>East Cell: -</td>
<td>Starter Cell: 1,300</td>
</tr>
<tr>
<td>Place riprap for Cell 1 channel outlet (D₅₀ = 600 mm)</td>
<td>East Cell: -</td>
<td>Starter Cell: -</td>
</tr>
</tbody>
</table>

PK = processed kimberlite; D₅₀ = average particle size, where 50% is greater and 50% is less than the particle size.

The closure cover configuration will be optimized during advancement to detailed design. The current configuration accommodates 377,200 m³ of landfill waste material and exceeds the minimum 350,000 m³ assumed requirement by approximately 27,200 m³. The landfill waste material quantity assumption for placement within the East Cell will be updated during detailed design based on the sitewide Demolition and Landfill Placement Plan that is in development by others (not available at the time of the feasibility design preparation).

A summary of total earthworks and revetment quantities required for construction of the North Pile closure cover and the available borrow material sources are presented in Table 4. Excess embankment / rib berm material excavated will be used for construction of the North Pile closure cover in addition to the available borrow material sources. A material balance is demonstrated and confirms all construction material can be locally sourced.
Table 4: North Pile Closure Cover Construction Borrow Source Material Quantity Estimate Summary

<table>
<thead>
<tr>
<th>Construction Material</th>
<th>Total Construction Material Quantity (m³)</th>
<th>Available Borrow Source(s)</th>
<th>Total Available Borrow Source Quantity (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankment Fill</td>
<td>62,700</td>
<td>West Cell Divider Dyke</td>
<td>81,000</td>
</tr>
<tr>
<td>Erosion Protection Cover</td>
<td>119,200</td>
<td>Laydown Area</td>
<td>256,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SP5 Quarry</td>
<td>68,200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crusher Stockpile</td>
<td>11,200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Explosive Management Bunker</td>
<td>1,700</td>
</tr>
<tr>
<td>Erosion Protection Cover and/or Transition</td>
<td>119,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition (a)</td>
<td>81,700</td>
<td>Rib Berms</td>
<td>89,800</td>
</tr>
<tr>
<td>Riprap (D₅₀ = 150 mm)</td>
<td>5,900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riprap (D₅₀ = 300 mm)</td>
<td>1,300</td>
<td>Organic Stockpile</td>
<td>29,400</td>
</tr>
<tr>
<td>Riprap (D₅₀ = 600 mm)</td>
<td>600</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PK = processed kimberlite; D₅₀ = average particle size, where 50% is greater and 50% is less than the particle size.
(a) Transition quantity is based on a nominal 300 mm thickness and may be reduced if thinner transition layer can be constructed.
6.0 CONSTRUCTION CONSIDERATIONS

Construction activities will be performed using detailed design drawings, technical specifications, and existing equipment available on site. Detailed design drawings and technical specifications are not included with this feasibility-level design report, but will be advanced as part of the detailed design effort. Existing equipment available on site includes:

- 2 excavators: Komatsu 650 and 400
- 3 loaders: Komatsu 500, 450, and 250
- 3 haul trucks: Komatsu 350
- 1 grader: Komatsu 655
- 3 dozers: Komatsu 155, 65, John Deere 450
- 1 Bobcat: S300
- 3 Genie Man Lifts: 110 ft, 60 ft, 40 ft
- 1 crane: Knuckle Boom Fat Deck
- 2 telehandlers
- 1 forklift: 50 ton

An available water source will be identified for use during construction to control dust on the North Pile and surrounding staging, borrow, and haul road areas. Dust control management will include periodic wetting of the work areas and may be more frequent during excavation into deposited PK material on the East Cell.

6.1 Sequence

A feasibility-level construction sequence has been developed to present the order of major construction activities that will be performed to achieve the intent of the North Pile closure cover feasibility design. Construction activities are listed in progressive order:

1) **West perimeter embankment grading**—includes reducing the slope angle to 3H:1V while maintaining a cut to fill balance where practicable, constructing the Cell 1 west embankment raise for additional landfill waste material containment, and constructing a channel outlet.

2) **West perimeter embankment erosion protection cover and riprap material placement**—includes placing erosion protection cover material atop the graded footprint and placing riprap material atop the erosion protection cover to the extent outlined in the feasibility design drawings.

3) **East Cell excavation/grading**—includes excavating Rib Berm 1, and deposited PK material from Cell 2 and Cell 5, partially excavating Rib Berm 2 to the existing deposited PK material elevation within Cell 3, and local cut to fill grading.
4) **East Cell landfill waste material placement**—includes placing additional landfill waste material in Cell 1, Cell 2, and Cell 5. For feasibility-level sequencing and scheduling, landfill waste material placement is assumed to occur through much of the duration of Starter Cell and west perimeter embankment closure cover construction activities.

5) **Starter Cell grading**—includes local cut to fill grading and constructing the Starter Cell swale.

6) **Starter Cell transition material placement**—includes placing transition material atop the graded footprint to the extent outlined in the feasibility design drawings.

7) **Starter Cell erosion protection cover and riprap material placement**—includes placing erosion protection cover material atop the transition material and/or the graded footprint, and placing riprap material atop the erosion protection cover within the Starter Cell Swale to the extent outlined in the feasibility design drawings.

8) **East Cell transition material placement**—includes placing transition material atop the graded footprint and/or landfill waste material to the extent outlined in the feasibility design drawings.

9) **East Cell erosion protection cover and riprap material placement**—includes placing erosion protection cover material atop the transition material and/or the graded footprint, and placing riprap material atop the erosion protection cover within the Cell 1 and Cell 5 Outlet Channels and the East and West Swales to the extent outlined in the feasibility design drawings.

A detailed construction sequence may be required to evaluate the East Cell grading, specifically the potential for concurrent landfill waste material and closure cover placement, but has not been advanced for the North Pile closure cover feasibility design.

### 6.2 Schedule

A feasibility-level schedule for North Pile closure cover design tasks is summarized in Table 4. Cover design tasks will be completed during third quarter of 2018, and construction activities are anticipated to commence in the second quarter of 2019, after regulatory approval of the North Pile closure cover final design. Durations for the individual construction activities identified in Section 6.1 will be estimated during detailed design, considering the available site equipment and typical productivities.

**Table 5: North Pile Closure Cover Design Tasks and Construction Activities Schedule**

<table>
<thead>
<tr>
<th>Item</th>
<th>Estimated Duration (days)</th>
<th>Estimated Commencement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholder meeting – De Beers and Golder</td>
<td>-</td>
<td>Q3 2018 (16 July)</td>
</tr>
<tr>
<td>Submit Draft North Pile Closure Cover Feasibility Design Report (Rev A)</td>
<td>-</td>
<td>Q3 2018 (9 July)</td>
</tr>
</tbody>
</table>
## 6.3 Construction Quality Assurance / Quality Control

Construction monitoring and testing will be performed during the North Pile closure cover for quality control and assurance. This will be detailed in a construction quality assurance plan (CQAP) and a construction quality control plan (CQCP). The CQAP will be developed by Golder during detailed design and will be submitted with the North Pile Closure Cover Final Design Report. The CQAP will describe personnel, inspection and monitoring activities, sampling requirements, and documentation and reporting requirements for construction of the North Pile closure cover.

The CQCP will be developed by the construction contractor for the North Pile closure cover and will be submitted prior to commencement of construction activities for the North Pile closure cover.

## 6.4 Sitewide Demolition and Landfill Waste Material Placement

The North Pile closure cover feasibility design assumes 350,000 m³ of landfill waste material will be generated during sitewide demolition activities and will be placed in Cell 1, Cell 2, and Cell 5, prior to construction of the North Pile closure cover over the East Cell. The landfill waste material quantity assumption will be updated during detailed design based on the sitewide Demolition and Landfill Placement Plan. The results of that plan were not available at the time of the feasibility cover design.

The overall flow conveyance strategy for the North Pile closure cover is not expected to change with an increase or decrease in assumed landfill waste material quantity placement within the East Cell. The top of closure cover elevations, depth of excavations, and embankment / rib berm excavation elevations may vary from the feasibility design as the North Pile closure cover grading is optimized during the detailed design effort.
7.0 POST-CONSTRUCTION MONITORING AND MAINTENANCE

Post-construction monitoring and maintenance will be detailed in a closure monitoring plan (CMP). The CMP will detail monitoring areas, existing and proposed monitoring instrumentation, monitoring frequencies, inspection protocols, data collection and assessment procedures, trigger levels, corrective actions, and reporting requirements. The subsequent sections are intended to convey major elements that will be detailed in the CMP. A draft CMP was provided to De Beers on 28 September 2018.

Proposed monitoring instrumentation may be installed after the closure cover is placed to monitor thermal conditions and the anticipated freeze-back of the North Pile, piezometric levels, settlement, and other parameters. The specific instrumentation required, installation locations, and the post-construction monitoring period and frequency will be defined in the CMP during the permitting process and detailed design.

7.1 Monitoring Areas

The North Pile closure cover, embankment slopes, and surface water conveyance structures (i.e., swales, channel outlets) will be inspected by the geotechnical engineer to confirm stability and performance achieves the design intent. This monitoring will include visual inspection and review of any data obtained from instrumentation on the North Pile. Any areas of visible closure cover erosion, instability of the embankment slopes, or areas of ponded water or obstructed conveyance will be documented.

7.2 Monitoring Frequency

Visual inspection of the North Pile closure cover, embankment slopes, and surface water conveyance structures will be performed by De Beers and supported by periodic quality assurance inspections by the geotechnical engineer for a post-construction monitoring period to be defined during detailed design. Instrumentation data collection will also be performed by De Beers and provided to the geotechnical engineer for review for the post-construction monitoring period.

7.3 Data Assessment and Corrective Action

The performance of the North Pile cover will be assessed during the post-construction monitoring period based on data collected from site instrumentation and observations made during site inspections. Areas of visible closure cover erosion will be repaired if required by regrading and replacement of the transition and/or cover materials; areas of unstable embankment slopes will be flattened or supported to meet closure cover design stability requirements; and areas of ponded water or obstructed conveyance will be steepened by regrading and/or clearing of debris to achieve the surface water conveyance design intent.

If significant movement of the North Pile or closure cover is identified, the frequency of inspections may be increased to assess the extent or rate of movement. If the extent or rate of movement is considered unacceptable, such that the North Pile closure cover no longer meets the design intent, corrective action will be undertaken. The nature of the corrective actions will depend on the type of movement observed and its causes.
If surface water flow conveyance obstruction or ponded water is identified, the frequency of inspections may also be increased to assess the extent and nature of the issue. Corrective actions may include a review of the North Pile design and assessment of the closure cover construction to develop potential corrective measures.

### 7.4 Reporting

A post-construction monitoring and maintenance report will be prepared annually for a period to be defined during the permitting process and detailed design. The report will summarize all data collected, observations, and corrective action for the North Pile from the previous year.
8.0 CLOSING

The reader is referred to the Study Limitations, which follows the text and forms an integral part of this report.

We trust the information in this report is sufficient for your present needs. Should you have any additional questions regarding this report, please contact the undersigned.
Signature Page

Golder Associates Ltd.

Abdul Sattar Khan, M.A.Sc.
Project Manager

Bjørn Weeks, Ph.D., P.Eng.
Principal, Geo-Environmental Engineer

ASK/BW/HNL/cf/cmm/cr

Golder and the G logo are trademarks of Golder Associates Corporation

REFERENCES


STUDY LIMITATIONS

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with the level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of the De Beers Group of Companies. It represents Golder’s professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by the De Beers Group of Companies, and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. The De Beers Group of Companies may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.
APPENDIX A

Design Basis and Criteria
Distribution List

Electronic Copy - De Beers Group of Companies

Electronic Copy - Golder Associates Ltd.
Executive Summary

The De Beers Group of Companies (De Beers) retained Golder Associates Ltd. to prepare a closure cover design for the North Pile facility at the Snap Lake Mine. This report identifies the design basis and criteria related to the design and construction of the closure cover. This document is intended to provide a basis for input from De Beers and ensure a common understanding of the context and information that will be used in the design development. It is anticipated that this will be a living document, updated as required throughout the design of the closure cover as additional relevant information becomes available.

Key contents of the report include:

- Design objectives based on applicable guidelines and previous closure commitments.
- Design basis for the North Pile closure cover. This information includes a summary of the relevant data identified for the characterization of the regional setting (climate, hydrology, hydrogeology), physical characteristics relevant to the cover design, including the North Pile configuration and construction materials, and potential borrow sources. Relevant water management considerations are also summarized, including applicable water quality criteria and runoff volume estimates.
- Design criteria to meet the objectives set for construction of the North Pile closure cover, including cover characteristics, physical stability of the closed structure, and surface water management for the cover.
- Cost reduction considerations.

Information presented in this report has largely been compiled from other sources, including previous studies by Golder and data provide by De Beers. The sources used for information are cited throughout the design basis and criteria report.

The reader is referred to the Study Limitations section, which precedes the text and forms an integral part of this report.
Study Limitations

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with the level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of De Beers Group of Companies. It represents Golder’s professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by De Beers Group of Companies and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. De Beers Group of Companies may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.
# Table of Contents

**EXECUTIVE SUMMARY** .......................................................................................................................................... ii

**STUDY LIMITATIONS** ............................................................................................................................................. iii

1.0 **INTRODUCTION** ............................................................................................................................................. 1

2.0 **BACKGROUND** .............................................................................................................................................. 2

3.0 **DESIGN OBJECTIVES** ................................................................................................................................... 3

4.0 **DESIGN BASIS** ............................................................................................................................................... 4

4.1 **Climate** ................................................................................................................................................. 4

4.2 **Hydrology and North Pile Drainage** ..................................................................................................... 6

4.3 **Hydrogeology** ....................................................................................................................................... 6

4.4 **Water Quality** ........................................................................................................................................ 6

4.5 **Borrow Sources** .................................................................................................................................... 7

4.6 **North Pile Embankments Configuration** ............................................................................................... 9

4.7 **North Pile Embankment Construction Materials** .................................................................................. 9

4.7.1 **Processed Kimberlite** .................................................................................................................... 10

4.7.2 **Waste Rock** ................................................................................................................................... 12

4.7.2.1 **Non-acid Generating Material** .................................................................................................... 12

4.7.2.2 **Potentially Acid Generating Material** .......................................................................................... 12

4.7.3 **Rockfill** ........................................................................................................................................... 13

4.8 **Landfill Cell (Cell 1 of East Cell)** ......................................................................................................... 13

4.9 **Settlement** .......................................................................................................................................... 13

4.10 **Native Soil Foundation** .......................................................................................................................... 14

5.0 **DESIGN CRITERIA** ....................................................................................................................................... 15

5.1 **Cover** .................................................................................................................................................. 15

5.2 **North Pile Embankment Stability** ......................................................................................................... 16

5.3 **Surface Water Management** .................................................................................................................... 17

6.0 **COST REDUCTION CONSIDERATIONS** .................................................................................................... 18

7.0 **CLOSURE** ..................................................................................................................................................... 19
REFERENCES ....................................................................................................................................................... 21

TABLES
Table 1: Adjusted Precipitation Characteristics at Snap Lake .................................................................................. 4
Table 2: Summary of Rainfall, Snowmelt, and Total Event Values for 24-Hour Duration Events ............................ 5
Table 3: Potential Borrow Sources for Cover Construction ...................................................................................... 8
Table 4: Summary of Geotechnical Parameters of Processed Kimberlite ............................................................. 10
Table 5: Target Levels for Earthquake Hazards, Standard-Based Assessment for Closure – Passive Care Phase ................................................................................................................................. 16
Table 6: Summary of CDA criteria and Anglo standards for Closure – Passive Care Phase ......................... 17
1.0 INTRODUCTION

The De Beers Group of Companies (De Beers) retained Golder Associates Ltd. (Golder) to prepare closure cover designs for the North Pile facility at the Snap Lake Mine. This report identifies the design basis and criteria related to the design and construction of such cover. It is intended to be a living document that will be updated throughout the design of the closure cover as required based on additional information that may become available.
2.0 BACKGROUND

The North Pile facility is the permanent surface storage facility for processed kimberlite (PK), mine waste rock material, and non-hazardous solid waste from the mine. The facility includes the embankments, rock cover, and all waste materials deposited within it, as well as the perimeter water control structures. The facility consists of the Starter Cell and East Cell (the West Cell was partly built but not commissioned and will not be part of the North Pile closure cover).
3.0 DESIGN OBJECTIVES

The design objectives for the North Pile closure cover fall under the overarching objectives of the interim closure and reclamation plan (ICRP) for the site (Arktis 2018). The ICRP for the North Pile is based on the Guidelines for the Closure and Reclamation of Advanced Mineral Exploration and Mine Sites in the Northwest Territories (MVLWB/AANDC 2013) and its supporting principles of physical stability, chemical stability, no long-term active care, and compatibility with land use in the surrounding areas. These principles, along with stakeholder’s feedback received through environmental assessments, regulatory process, and closure-specific engagement events (Arktis 2018), have produced the following objectives applicable to the facility:

- Site-wide:
  - Dust levels are safe for people, vegetation, aquatic life, and wildlife.
  - Drainage pathways for surface runoff are physically stable.
  - Surface runoff and seepage water quality is safe for people, vegetation, aquatic life, and wildlife.
  - Landscape features (shape and vegetation) match aesthetics of the surrounding natural area.
  - Safe passage and use for caribou and other wildlife.

- North Pile specific:
  - PK is prevented from entering the surrounding terrestrial and aquatic environment.
  - The PK containment area is physically stable to limit risk of failure that would affect safety of people or wildlife.

- Closure cover specific:
  - Waste materials are physically isolated from the surrounding environment.
  - Wind and water erosion is minimized.
  - Runoff is promoted.
  - Infiltration of water into the North Pile is reduced.
4.0 DESIGN BASIS

This section presents the basis on which the North Pile cover design will be set. It includes the regional setting (climate, hydrology, and hydrogeology), current water quality conditions, potentially available borrow sources, the North Pile configuration and construction materials, and considerations for landfill cells and the native subsurface conditions.

4.1 Climate

Available climate data relevant to the site include both data from the Snap Lake Mine climate station and data from regional climate stations (managed by Environment Canada) located approximately 250 km from the site. The regional climate stations include Yellowknife A, Ekati A, Lupin A, and Lupin CS. Yellowknife A is the station with the most complete and longest set of historical records within the area.

Table 1 summarizes the long-term precipitation averages for the site, based on the 1981 to 2010 Climate Normals for the Yellowknife A station published by Environment Canada. These values have had a 3% reduction factor applied to correct for observed differences between the long-term Yellowknife A data set and available measurements from Snap Lake. The correlation for the reduction factor was developed by Golder (2017a).

Table 1: Adjusted Precipitation Characteristics at Snap Lake

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall (mm)</th>
<th>Snowfall (cm)</th>
<th>Total Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.1</td>
<td>13.8</td>
<td>10.0</td>
</tr>
<tr>
<td>February</td>
<td>0</td>
<td>14.0</td>
<td>9.9</td>
</tr>
<tr>
<td>March</td>
<td>0.1</td>
<td>13.0</td>
<td>9.7</td>
</tr>
<tr>
<td>April</td>
<td>1.8</td>
<td>7.2</td>
<td>7.9</td>
</tr>
<tr>
<td>May</td>
<td>9.7</td>
<td>3.3</td>
<td>12.9</td>
</tr>
<tr>
<td>June</td>
<td>20.2</td>
<td>0</td>
<td>20.2</td>
</tr>
<tr>
<td>July</td>
<td>28.6</td>
<td>0</td>
<td>28.6</td>
</tr>
<tr>
<td>August</td>
<td>27.4</td>
<td>0.1</td>
<td>27.5</td>
</tr>
<tr>
<td>September</td>
<td>22.9</td>
<td>2.5</td>
<td>25.4</td>
</tr>
<tr>
<td>October</td>
<td>8.5</td>
<td>14.6</td>
<td>21.2</td>
</tr>
<tr>
<td>November</td>
<td>0.2</td>
<td>25.6</td>
<td>17.4</td>
</tr>
<tr>
<td>December</td>
<td>0.1</td>
<td>16.5</td>
<td>11.3</td>
</tr>
<tr>
<td>Year</td>
<td>119.5</td>
<td>110.3</td>
<td>202.0</td>
</tr>
</tbody>
</table>

mm = millimeters; cm = centimeters.
(a) Environment Canada 1981–2010 Climate Normals for the Yellowknife A station with a 3% reduction factor added (Golder 2017a).
Golder has estimated rainfall, snowmelt, and total rainfall plus snowmelt for 24-hour design events for various return periods (up to 1:1,000-year), as well as for the probable maximum precipitation (PMP; Golder 2017a). A summary of the 24-hour design events is provided in Table 2.

Table 2: Summary of Rainfall, Snowmelt, and Total Event Values for 24-Hour Duration Events

<table>
<thead>
<tr>
<th>Return Period / Design Event (year)</th>
<th>Rainfall (mm)</th>
<th>Snowmelt (mm)</th>
<th>Total Event (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>25.1</td>
<td>53.6</td>
<td>78.7</td>
</tr>
<tr>
<td>5</td>
<td>37.0</td>
<td>65.7</td>
<td>102.7</td>
</tr>
<tr>
<td>10</td>
<td>46.0</td>
<td>73.0</td>
<td>119.0</td>
</tr>
<tr>
<td>25</td>
<td>58.5</td>
<td>81.1</td>
<td>139.6</td>
</tr>
<tr>
<td>50</td>
<td>68.6</td>
<td>86.9</td>
<td>155.5</td>
</tr>
<tr>
<td>100</td>
<td>79.3</td>
<td>92.2</td>
<td>171.5</td>
</tr>
<tr>
<td>200</td>
<td>90.8</td>
<td>95.1</td>
<td>185.9</td>
</tr>
<tr>
<td>500</td>
<td>107.0</td>
<td>99.4</td>
<td>206.4</td>
</tr>
<tr>
<td>1,000</td>
<td>120.0</td>
<td>103.0</td>
<td>223.0</td>
</tr>
<tr>
<td>PMP</td>
<td>309.0</td>
<td>151.0</td>
<td>460.0</td>
</tr>
</tbody>
</table>

Source: Golder (2017a).

PMP = probable maximum precipitation.

Two values are considered for the PMP:

- 460 mm for the spring PMP, considering rainfall on snowmelt
- 309 mm for the summer PMP, after snowpack depletion (rainfall-only PMP value)

Based on 1981 to 2010 Climate Normals for the Yellowknife climate station (Yellowknife A) published by Environment Canada, the climate in the Snap Lake Mine region generally consists of short cool summers and long cold winters, with average air temperatures of about 11°C and -20°C, respectively. The average annual air temperature is approximately -4°C (Golder 2013b).

A mean annual lake evaporation rate of 300 mm was derived for Snap Lake (Golder 2002).

Wind data recorded between the years 1998 and 2001 at the Snap Lake monitoring station indicated an average wind speed of 13.6 km/h and a maximum of 61.6 km/h (Golder 2002).
4.2 Hydrology and North Pile Drainage

The Snap Lake Mine is located within the Snap Lake catchment area, where Snap Lake is the headwater lake in the Lockhart River System, draining southwest toward Great Slave Lake. Numerous small streams ranging from less than 100 m to several kilometres in length provide local drainage to Snap Lake.

Peak flows in streams and rivers typically occur during the freshet season, due to combination of rainfall events and snowmelt. The Snap Lake Mine is located within the continuous permafrost region, with active permafrost limited to the top few metres of ground. High runoff coefficients are expected during the freshet season when ground is frozen to surface.

The North Pile facility faces Snap Lake to the north and tundra to the south, west, and east (mine facilities occupy most of the land to the east of the North Pile facility). The North Pile facility raises about 5 to 22 m above the tundra. The elevation of the deposited PK promotes surface runoff drainage toward the northeast. The total surface of the North Pile facility, including embankments, is approximately 510,000 m².

4.3 Hydrogeology

There are two main groundwater flow regimes at the project site: a shallow groundwater flow regime within the active layer and a deep groundwater flow regime located beneath the permafrost and within the talik of large water bodies. Because of the presence of thick permafrost that has low permeability, there is limited hydraulic connection between the two regimes. Within the active layer, the water table is expected to mimic variations in topography. Groundwater gradients would thus be similar to topographic gradients. Groundwater in the active layer would flow to local depressions and ponds that drain to Snap Lake or would flow directly to Snap Lake. The permafrost in the rock at Snap Lake is considered to be virtually impermeable to groundwater flow (Arktis 2018).

4.4 Water Quality

The Snap Lake mine is currently under extended care and maintenance (ECM), and effluent quality criteria (EQC) are governed by Water Licence MV2011L2-0004.

During ECM, closure and post closure, the North Pile’s run off and seepage water quality is expected to improve over time. New water inputs to the system will be limited to precipitation water, as no process water will be deposited. Contact water entering the North Pile may be affected by the geochemical composition of the material deposited in the facility. The volume of seepage through the deposited materials will be limited by the low hydraulic conductivity of the fine PK, and by the development of frozen conditions in the pile (frozen deposits are considered to be effectively impermeable).

Golder (2016d) developed water quality and quantity models to predict approximate surface water quantity and quality trends for the North Pile during ECM until 2020. Model predictions showed that the concentrations of some constituents in the discharge would begin to decline beginning in 2016, while others are expected to remain at concentrations that are similar or increase relative to historical discharge from 2013 to 2015. As monitoring data become available, further calibration of the site model may result in updates to these predictions.
4.5 Borrow Sources

Based on review of aerial photography, site reconnaissance observations, and test pit and borehole (i.e., exploratory groundwater well) information, the surficial geology of the area consists of a veneer of Quaternary morainal deposits (mineral soil) that contain cobbles and boulders mixed with a finer-grained matrix of sand and silt with some gravel underlain by bedrock. The mineral soil is generally thin (generally less than 2 m thick) but can be thicker in topographic depressions. Bedrock is also present in numerous outcrops throughout the site (Golder 2014c).

Historically, borrow material for construction of the North Pile facility (embankments, dikes, and earthen ancillary structures) has come primarily from overburden removal, kimberlite mining, and processing operations. Additionally, construction material has been obtained from identified surface borrow areas such as the SP3 quarry.

Current borrow areas that could provide material for the closure cover are listed in Table 3.
Table 3: Potential Borrow Sources for Cover Construction

<table>
<thead>
<tr>
<th>Borrow Source</th>
<th>Location</th>
<th>Material</th>
<th>Volume (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apron quarry</td>
<td>southeast of Starter Cell</td>
<td>oversized rockfill from SP5 Quarry</td>
<td>UNKNOWN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UNKNOWN. This area has been used in the past and may be exhausted as it contains water and is surrounded by existing infrastructure.</td>
<td></td>
</tr>
<tr>
<td>ANFO plant pad and access road</td>
<td>west of East Cell</td>
<td>rockfill</td>
<td>TBD</td>
</tr>
<tr>
<td>Crusher stockpile</td>
<td>west of North Pile</td>
<td>rockfill</td>
<td>TBD</td>
</tr>
<tr>
<td>East Cell rib berms</td>
<td>North Pile</td>
<td>coarse and grits PK and non-AG waste rock</td>
<td>TBD</td>
</tr>
<tr>
<td>Engineered fill pads</td>
<td>throughout the site</td>
<td>TBD both non-AG and PAG material</td>
<td>TBD</td>
</tr>
<tr>
<td>Explosive management bunker</td>
<td>west of East Cell</td>
<td>rockfill</td>
<td>TBD</td>
</tr>
<tr>
<td>Laydown area</td>
<td>southeast of North Pile</td>
<td>rockfill</td>
<td>1,700</td>
</tr>
<tr>
<td>SP5 quarry</td>
<td>north of East Cell, Cell 1</td>
<td>rockfill</td>
<td>68,200</td>
</tr>
<tr>
<td>Organics stockpile</td>
<td>former AN storage facility</td>
<td>stripped organics material (organics mixed with gravel and cobbles)</td>
<td>TBD (29,400)</td>
</tr>
<tr>
<td>Starter Cell embankment &amp; rib berms</td>
<td>North Pile</td>
<td>coarse and grits PK and non-AG waste rock</td>
<td>TBD</td>
</tr>
<tr>
<td>West Cell divider dyke</td>
<td>North Pile West Cell</td>
<td>coarse and grits PK and non-AG waste rock</td>
<td>TBD</td>
</tr>
<tr>
<td>Wetland</td>
<td>TBD</td>
<td>depending on location soil minerals to rockfill</td>
<td>TBD</td>
</tr>
<tr>
<td>WMP quarry</td>
<td>west of WMP</td>
<td>rockfill</td>
<td>TBD</td>
</tr>
</tbody>
</table>

WMP = water management pond; TBD = to be determined; PK = processed kimberlite; non-AG = non-acid generating; PAG = potentially acid-generating

(a) Volume is for gravel and cobble material in stockpile, assumed to be 20 percent of total stockpile volume. Screening would be required to separate from the organics.

WMP (a conceptual design was performed to study sump development in the area. It estimated 300,000 m$^3$ of material to be available. [Arktis 2012])
4.6 North Pile Embankments Configuration

The North Pile embankments demark the limits of the cover and may be used to some degree as material for the cover construction. The variance between ultimate design elevation and as-built elevation will provide an important insight in the amount of non-AG material available from the North Pile embankments and rib berms. Major components of the existing embankments and rib berms are identified below, with additional information available in the detailed design report and construction record report (Golder 2015, 2016a).

The facility consists of two major cells: the Starter Cell and the East Cell (a third cell, the West Cell, was designed but only a few components constructed). The Starter and East cells are divided into internal cells developed for PK deposition management. Both cells consist of three different types of embankments:

- Perimeter embankment, designed to contain the deposited PK material within the North Pile facility.
- Divider dykes, which are interior embankments that were placed to support deposition activities but do not have a structural role.
- Rib berms, which also supported deposition without contributing to the structural stability of the facility.

Starter Cell construction started in 2005. It was constructed in four phases, and deposition and development activities continued until April 2014. Approximately 140,000 m³ of capacity is still available within the Starter Cell (Golder 2017b). The current elevation of the embankments ranges from about 2 m above ultimate design at Cell LF to 1.5 m at some locations in Cell B. The current rib berms present a similar pattern of being above and below the ultimate design (with maximums of 2 m above to 3 m below).

East Cell construction started in 2008. Embankment reconfiguration construction and slurry deposition were in progress up until the mine entered the care and maintenance phase. The embankment crest has a maximum elevation that is approximately 7 m below ultimate design elevation (Golder 2016a). Rib berm elevation varies from having a surplus of material 2 to 3 m above ultimate design to falling approximately 10 m below ultimate design.

Non-hazardous solid waste from the mine is also placed in the North Pile facility. Cell LF, in the Starter Cell, was originally used for that purpose until it reached full capacity. Current non-hazardous solid waste deposition occurs in Cell 1 of the East Cell.

The battery limit of the North Pile closure cover is considered to be the outer toe of the Starter and East Cell perimeter embankments.

4.7 North Pile Embankment Construction Materials

The following construction materials are encountered in the North Pile facility:

- PK
- waste rock (non-AG and PAG) – by-products of the mining process
- rockfill (quarried material)
A summary of the material properties is presented in the following subsections.

### 4.7.1 Processed Kimberlite

PK is the material rejected from the process plant after the recoverable minerals have been extracted. PK material at the Snap Lake Mine is considered to be non-AG.

PK is classed as follows (Golder 2014c):

- coarse PK (1.5 to 6 mm)
- grits PK (0.125 to 1.5 mm)
- fine PK (<0.125 mm)

Combined coarse and grits fractions of the PK were used throughout construction of the Starter and East cells, including in the rib berms, divider dyke, and perimeter embankments. Fine PK was deposited as a slurry from 2007 to 2014 in the Starter Cell and from 2014 to 2015 in the East Cell.

A summary of PK field and laboratory testing results is presented in Table 4 (Golder 2014a), with properties measured for combined coarse and grits fractions of the PK, and for a slurry comprised solely of the fines fraction of the PK.

#### Table 4: Summary of Geotechnical Parameters of Processed Kimberlite

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Combined Coarse &amp; Grits Fractions of PK</th>
<th>Slurry</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Phi'$ (°)</td>
<td>38</td>
<td>32 to 37.5</td>
</tr>
<tr>
<td>$c'$ (kPa)</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td>$\Phi$ (°)</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>$c$ (kPa)</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.68 to 2.78</td>
<td>2.69 to 2.74</td>
</tr>
<tr>
<td>$\gamma_{wet}$ (kN/m$^3$)</td>
<td>21.3</td>
<td>14.2 to 20.2</td>
</tr>
<tr>
<td>$\gamma_{dry}$ (kN/m$^3$)</td>
<td>19.4</td>
<td>7.0 to 16.4</td>
</tr>
<tr>
<td>$\gamma_{dry}$ (kN/m$^3$) during 15 days settling</td>
<td>n/a</td>
<td>7.5 to 9.5</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>5.3 to 11.3</td>
<td>44.3 to 67.6</td>
</tr>
<tr>
<td>Residual volumetric WC (%)</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>$E$</td>
<td>n/a</td>
<td>1.30 to 0.62 (vertical stress 11 kPa to 998 kPa)</td>
</tr>
<tr>
<td>Parameters</td>
<td>Combined Coarse &amp; Grits Fractions of PK</td>
<td>Slurry</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>k (m/s)</td>
<td>1.7×10⁻⁵ to 3.6×10⁻⁶ (rigid wall constant head)</td>
<td>5.7×10⁻⁸ (50 kPa slurry consolidation test)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5×10⁻⁸ (250 kPa slurry consolidation test)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.8×10⁻⁹ (650 kPa slurry consolidation test)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0×10⁻⁸ (dissipation test)</td>
</tr>
<tr>
<td>Maximum dry density (kg/m³)</td>
<td>1895</td>
<td>1639</td>
</tr>
<tr>
<td>Optimum water content (%)</td>
<td>9.8</td>
<td>18.3</td>
</tr>
<tr>
<td>Durability index (Df)</td>
<td>45.9</td>
<td>n/a</td>
</tr>
<tr>
<td>Air-entry value (AEV)</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Thermal Conductivity (W/[mK])</td>
<td>1.54</td>
<td>1.22</td>
</tr>
<tr>
<td>Frozen thermal conductivity (W/[mK])</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Unfrozen thermal conductivity (W/[mK])</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Liquid limit (deposited)</td>
<td>n/a</td>
<td>35 to 37</td>
</tr>
<tr>
<td>Plastic limit (deposited)</td>
<td>n/a</td>
<td>18 to 23</td>
</tr>
<tr>
<td>Plastic index (deposited)</td>
<td>n/a</td>
<td>13 to 17</td>
</tr>
<tr>
<td>Liquidity index (deposited)</td>
<td>n/a</td>
<td>8.6 to 9.7</td>
</tr>
<tr>
<td>Soil classification</td>
<td>2013 sample - (SP) SAND, poor graded, trace to some fine gravel, trace silt.</td>
<td>Cell 4 sample - (SC) CLAYEY SAND, fine to coarse, low plastic fines</td>
</tr>
<tr>
<td></td>
<td>2008-2010 construction sample - (SP) SAND, fine to coarse, poorly graded, trace to some fine gravel, trace silt</td>
<td>Rib Berm 4 sample - (SW) SAND, well graded, trace to some silt and gravel</td>
</tr>
</tbody>
</table>

Source: Golder 2014a.

PK = processed Kimberlite; n/a = not applicable.
4.7.2 Waste Rock

Waste rock used in the construction of the North Pile embankments can be broken into two geochemical categories: PAG material and non-AG material. The waste rock has also been characterized based on grain size and defined as either Type 4 (300 mm minus) or Type 5 (600 mm minus) fill. The following sections discuss the sources and location of the PAG and non-AG in the facility.

4.7.2.1 Non-acid Generating Material

Non-AG waste rock has been sourced from underground mine activities located away from the metavolcanic unit. This material has been tested by De Beers (2014). Waste rock classed as non-AG contains very low amounts of sulphide minerals (less than 0.17% sulphides by weight).

Crushed and screened non-AG material has been used at the North Pile construction for the following:

- internal drainage system (75 mm minus) for the East Cell embankments and other fill materials (Golder 2016a)
- a 0.3 to 0.5 m thick erosion protection layer (250 mm minus) for 3H:1V exteriors slope of the North Pile embankments (Golder 2017b)
- Type 4 and Type 5 used in conjunction with 75 mm minus rockfill in the construction of the internal drainage (Golder 2016a)

4.7.2.2 Potentially Acid Generating Material

PAG material at the Snap Lake Mine comes from the metavolcanic unit extracted during underground development and granite rock containing. PAG material contains greater than 0.17% sulphide sulphur. All metavolcanic rock has been handled as if it were PAG (De Beers 2017b).

PAG rock was either used for construction of the North Pile rib berms, divider dykes, and perimeter embankments or deposited within the North Pile footprint (Golder 2013a).

During construction of the North Pile, PAG material was excluded from zones within 50 m of the downstream toe of any perimeter embankment and 3 m from the expected ultimate North Pile closure surface as per the design (Golder 2013a, 2014b). This was done so that PAG materials would be isolated in zones of permanent freezing.

PAG material placed for the west perimeter embankment construction of the Starter and East cells does not have this isolation. Material was placed here with the expectation that it would be completely covered and interior to the North Pile once the West Cell was constructed.

PAG material was deposited as fill along the west perimeter embankment from approximately 50 m south of the East Cell footprint to 50 m north of the Starter Cell footprint.
In addition to the west perimeter embankment, construction records (Golder 2016a) indicate PAG material has been used for the North Pile facility in other areas. The delineation between PAG zones and non-AG zones is not well established. Construction records show approximated percentages of volume corresponding to the type of material placed for a given year without delineation limits. All rib berms in the East Cell used PAG material for construction, along with the coarse and grits fraction of PK and non-AG rockfill (Golder 2017b). The quantity of PAG waste rock used in construction varied from 0% on the south embankment at cell LF to 40% at various embankments and rib berms throughout the facility.

4.7.3 Rockfill
Quarried rock fill has been obtained from the SP5 quarry. The quarry is located in a zone of massive granite-granodiorite. Rock types are expected to be non-AG based on visual inspection of quarry rock samples (Golder 2016a), but no confirmatory laboratory testing has been done to date. Rockfill uses and placement locations in the construction of the North Pile have been similar to those of the non-AG waste rock.

4.8 Landfill Cell (Cell 1 of East Cell)
Cell 1 of the East Cell is the current dedicated area for the deposition of the mine’s non-hazardous waste materials. In 2012, it replaced the now closed landfill located at the southwest corner of the Starter Cell (Cell LF). The landfill cell filling procedure has consisted of the deposition of a landfill material followed by a layer of compacted PAG rockfill.

It is expected that the remaining capacity in Cell 1 (along with other available cells) will be used for the deposition of inert solids waste generated by demolition activities. An estimated 315,000 m³ of non-hazardous demolition material will be deposited within the North Pile prior to construction of the closure cover (Arktis 2018). The closure cover design will account for a minimum number of additional cells to be used for demolition waste disposal.

4.9 Settlement
Golder (2018a) performed a settlement review of the North Pile up to July 2017. Higher rates of settlement were observed in the Starter Cell from the end of deposition to August 2014, with lower rates post August 2014. Average settlement rates from August 2014 to July 2017 range from 8 to 26 mm/month:

- Cell A = 9 mm/month
- Cell B = 14 mm/month
- Cell C = 13 mm/month
- Cell D = 9 mm/month
- Cell E = 8 mm/month
- Cell F = 8 mm/month
- Cell SQ = 26 mm/month
- Cell LF = 18 mm/month
The high rate of settlement in Cell LF may be attributed to the landfill material placed within the cell, which typically have larger void spaces that granular materials such as PK, and a subject to greater consolidation.

The East Cell also continues to settle since the end of deposition in Cells 2 through 5 in December 2015. Landfill material deposition is ongoing in Cell 1. Average settlement rates from December 2015 to July 2017 range from 16 to 77 mm/month:

- Cell 1 = landfill deposition is ongoing
- Cell 2 = 77 mm/month
- Cell 3 = 50 mm/month
- Cell 4 = 49 mm/month
- Cell 5 = 16 mm/month

4.10 Native Soil Foundation

The native soil profile beneath the facility consists of organic and peat material deposits which are typically underlain by till-like soil with varying proportions of sand, gravel, silt, clay, cobbles, and boulders (Golder 2013a). The mineral material is typically 0.3 to 1.5 m in thickness and extends 0.4 to 2.5 m below ground surface (Golder 2014b). These materials are in turn underlain by bedrock. Prior to construction of the North Pile facility, removal of unsuitable materials (e.g., vegetation, organic or saturated materials, silts, and frozen unsuitable material) was carried out (Golder 2017b); thus, no significant consolidation is expected from the remaining native foundation material.
5.0 DESIGN CRITERIA

This section presents the design criteria to meet the objectives set for the construction of the North Pile closure cover, including cover characteristics, physical stability of the closed structure, and surface water management for the cover.

5.1 Cover

The cover for the North Pile and its components will be selected through an alternatives analysis. Key design criteria are as follows:

- Dust
  - Cover will prevent wind erosion of fine PK, such that ambient air quality will not exceed the Northwest Territories Ambient Air Quality Standards and dustfall will not exceed the Alberta Ambient Air Quality Guidelines, as per existing environmental commitments.

- Chemical stability
  - PAG material will be excluded from cover construction, which includes granite rock containing greater than 0.17% sulphide sulphur and all metavolcanic rock (De Beers, 2017b).
  - PAG material will be excluded from a distance of less than 3 m from the North Pile closure surface (De Beers 2014).
  - PAG material will be excluded from the zone within 50 m of the downstream toe of the North Pile (De Beers 2014). This criterion may be re-evaluated with further geochemical analysis as part of the cover design.

- Infiltration
  - Infiltration criteria will be determined based on the site water quantity and quality criteria.

- Differential settlement
  - Differential settlement will not result in significant areas of ponding or stagnant water.
  - Specific criteria will be set depending on cover design selected.

- Thickness
  - The currently approved ICRP for North Pile includes mention of a 500 mm granular cover over the PK material (Arktis 2018).
  - For landfilled material, a 2 m thick cover is required by current permits. This thickness can be obtained through a combination of PK and coarse granular fill.
  - Based on site inspections, experience at other sites, and the performance of the cover that has been place on the outside embankments of the North Pile, a 300 mm thick granular cover over PK is expected to meet all design objectives. Over the shallow sloping surfaces within the PK deposits, a cover layer 150 mm thick is likely sufficient to provide the needed erosion control.
  - For the initial cover design cover thickness of 300 mm over the PK will be used (thinner than in the current ICRP, but thicker than the minimum needed to meet the design goals).
5.2 North Pile Embankment Stability

The closure configuration of the North Pile will be required to meet applicable dam safety criteria. The Canadian Dam Association (CDA) dam classifications for earthquake hazard criteria for the closure phase (passive) are presented in Table 5. Passive closure has been selected as the applicable criteria for the North Pile.

The current dam hazard classification for the North Pile embankments is “High” under CDA guidelines (CDA 2013).

This dam classification is assumed to be applicable in closure. The cover design is not expected to significantly alter the dam classifications, although the classifications of the dams should be re-evaluated considering the effects of all North Pile closure activities.

Table 5: Target Levels for Earthquake Hazards, Standard-Based Assessment for Closure – Passive Care Phase

<table>
<thead>
<tr>
<th>Dam Classification</th>
<th>Closure Phase – Passive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1/1,1000</td>
</tr>
<tr>
<td>Significant</td>
<td>1/2,475</td>
</tr>
<tr>
<td>High</td>
<td>½ between 1/2,475 and 1/10,000 AEP or MCE</td>
</tr>
<tr>
<td>Very High</td>
<td>1/10,000 AEP or MCE</td>
</tr>
<tr>
<td>Extreme</td>
<td>1/10,000 AEP or MCE</td>
</tr>
</tbody>
</table>

Source: CDA 2013.

AEP = annual exceedance probability; MCE = maximum credible earthquake.

Rib Berm 1 is a structural berm for containment of deposited PK slurry in the adjacent Cell 2. Rib Berm 1 would have the same “High” classification as the perimeter embankments.

The design criteria specified in the Anglo American (Anglo) Standards for mineral residue facilities and water management structures (Anglo 2016) for facilities with either a “Moderate” or “High” classification are equivalent at closure. CDA criteria and Anglo standards are presented in Table 6. The North Pile closure cover design will consider a final embankment configuration that meets the more stringent of the applicable criteria.
Table 6: Summary of CDA criteria and Anglo standards for Closure – Passive Care Phase

<table>
<thead>
<tr>
<th>Dam Classification</th>
<th>Anglo Standard</th>
<th>CDA Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquake Design Ground Motion</td>
<td>1:10,000 AEP or MCE</td>
<td>½ between 1/2,475 and 1/10,000 AEP or MCE</td>
</tr>
</tbody>
</table>

Slope Stability Analysis Safety Factors

<table>
<thead>
<tr>
<th>Type</th>
<th>Static</th>
<th>Pseudo-static</th>
<th>Dynamic (post-earthquake)</th>
<th>Static Liquefaction</th>
<th>Full or Partial Rapid Drawdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Factor</td>
<td>1.5</td>
<td>1.2</td>
<td>1.2</td>
<td>1.3</td>
<td>1.3</td>
</tr>
</tbody>
</table>


5.3 Surface Water Management

The key design criteria related to surface water management are as follows:

- **Design event**
  - The CDA criteria for inflow design flood (IDF) at closed facilities with a “high” classification is the probable maximum flood (PMF) event. The Anglo standard for IDF at closed facilities is the 1:10,000 or the PMF event.
  - The Probable Maximum Precipitation (PMP) 24-hour storm event plus snowmelt (Table 2) is selected as design event for the closure cover, to meet both CDA and Anglo criteria. This criterion is also consistent with the design basis for the ECM surface water management design (Golder 2018b).

- **Hydrologic criteria**
  - Runoff from the North Pile will be promoted and directed toward the SP3 and SP5 sump areas, and interaction between runoff and fine PK will be reduced.
  - The hydrologic parameters (e.g., runoff coefficient, time of concentration) will depend on the selected cover material.

- **Hydraulic criteria**
  - The slope of final grading and drainage pathways will be a minimum of 1% to facilitate runoff conveyance. The maximum slope will be determined based on the selected closure cover material type to prevent erosion.
  - The formation of areas of ponding or stagnant water will be avoided to the extent practicable.
6.0 COST REDUCTION CONSIDERATIONS

Considerations to minimize the cost of design and constructing the closure cover will include:

- minimizing cover thickness while meeting other criteria and objectives
- favouring locally available construction materials
- reducing haul distances
- reducing blasting requirements
- reducing ongoing maintenance needs
7.0 CLOSURE

The reader is referred to the Study Limitations section, which precedes the text and forms an integral part of this report.

We trust the above meets your present requirements. If you have any questions or additional requirements, please contact the undersigned.
Signature Page

Golder Associates Ltd.

Abdul Sattar Khan, M.A.Sc.
Project Manager

Paolo Chiaramello, P.Eng.
Associate, Senior Water Resources Engineer

Bjorn Weeks, Ph.D., P.Eng.
Principal, Senior Geo-Environmental Engineer

ASK/PC/BW/cmm/cr/ah

Golder and the G logo are trademarks of Golder Associates Corporation

REFERENCES


APPENDIX B

Feasibility Design Drawings

1 – Title Sheet
2 – General Arrangement Plan: North Pile Existing Configuration July 2017 with Borrow Locations
3 – General Arrangement Plan: North Pile Existing Configuration July 2017 with Instrumentation
4 – North Pile Cell 2 and Cell 3 Excavation Plan
5 – North Pile Cell 2 and Cell 3 Excavation Depth Plan
6 – North Pile Cover Surface Grading Plan
7 – North Pile Cover Grading Isopach Map
8 – North Pile Cross-Sections and Swale Profile
9 – North Pile Typical Cross-Sections and Details
# Snap Lake Mine
## North Pile Closure Cover Feasibility Design

## Index of Drawings

<table>
<thead>
<tr>
<th>Drawing No.</th>
<th>Drawing Sheet Title</th>
<th>Revision No.</th>
<th>Revision Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Title Sheet</td>
<td>0</td>
<td>2018-11-06</td>
</tr>
<tr>
<td>2</td>
<td>General Arrangement Borrow Locations</td>
<td>0</td>
<td>2018-11-06</td>
</tr>
<tr>
<td>3</td>
<td>General Arrangement Plan North Pile Existing Configuration July 2017</td>
<td>0</td>
<td>2018-11-06</td>
</tr>
<tr>
<td>4</td>
<td>North Pile Cell 2 and 5 Excavation Plan</td>
<td>0</td>
<td>2018-11-06</td>
</tr>
<tr>
<td>5</td>
<td>North Pile Cell 2 and 5 Excavation Depth Plan</td>
<td>0</td>
<td>2018-11-06</td>
</tr>
<tr>
<td>6</td>
<td>North Pile Cover Grading Plan</td>
<td>0</td>
<td>2018-11-06</td>
</tr>
<tr>
<td>7</td>
<td>North Pile Cover Grading Isopach Map</td>
<td>0</td>
<td>2018-11-06</td>
</tr>
<tr>
<td>8</td>
<td>North Pile Cross-Sections and Swale Profile</td>
<td>0</td>
<td>2018-11-06</td>
</tr>
<tr>
<td>9</td>
<td>North Pile Typical Cross-Sections and Details</td>
<td>0</td>
<td>2018-11-06</td>
</tr>
</tbody>
</table>
NON-ACID GENERATING BORROW SOURCES FOR COVER MATERIAL
ADDITIONAL NON-ACID GENERATING BORROW SOURCES IF NEEDED
NON-ACID GENERATING BORROW SOURCES FOR COVER MATERIAL
ADDITIONAL NON-ACID GENERATING BORROW SOURCES IF NEEDED

3. COORDINATE SYSTEM IS MINE GRID. ALL UNITS ARE IN METRES UNLESS OTHERWISE NOTED.
4. DESIGN CHANGES BASED ON JULY 2017 AND SEPTEMBER 2017 CONTOURS (REFERENCE 3)
5. NORTH PILE EXISTING CONFIGURATION JULY 2017 WITH BORROW LOCATIONS
8. LEASE BOUNDARY PROVIDED BY DE BEERS, RECEIVED JUNE 30, 2018.
LEGEND

FLOW DIRECTION

CLOSING COVER PLACEMENT OVER
ENVIRONMENTAL BARRIER
CLOSING COVER PLACEMENT OVER
PK WASTE
CLOSING COVER PLACEMENT OVER
LANDFILL WASTE

JULY 2017 AND SEPTEMBER 2017 EXISTING GROUND CONTOURS
50m SHAPING OFFSET
DESIGN FANK, COVER CONTOURS (SEE NOTE 2)
SNAP LAKE LAND (LANE BOUNDARY
WEST CELL BOUNDARY
WEST SWALE
EXISTING NORTH PERIMETER
EXISTING STARTER CELL
PERIMETER DRAINAGE DITCH
EXISTING STARTER CELL
PERIMETER DRAINAGE DITCH

NOTES:
1. ALL UNITS ARE METRES UNLESS OTHERWISE NOTED
2. COORDINATE SYSTEM IS MINE GRID
3. DETAILED IN GOLDER DOCUMENT 1668521-024-R-REVB-3000.

COORDINATE SYSTEM IS MINE GRID.

REF: 1785666/3000/100/024
3000/3100/024
REFERENCE(S)


2. CHARTERED SURVEYOR DMITRY SADOVSKY


PROJECT

SNAP LAKE MINE

NORTH PILE CLOSURE COVER

FEASIBILITY DESIGN

NORTH PILE CROSS-SECTIONS AND SWALE PROFILE

DATE

DECEMBER 20, 2017.

DESIGN INCLUDED IN GOLDEN DOCUMENT 1668521-024-R-REV-B-3000.

PERIMETER DITCH TO BE DEFINED DURING DETAILED DESIGN, AS A MODIFICATION OF PROFILE ACROSS THE EAST CELL EAST EMBANKMENT AND ALONG THE EXISTING EAST PERIMETER DITCH.
APPENDIX C

Surface Water Analysis
1.0 INTRODUCTION

This technical memorandum presents the feasibility level design of the surface water management structures to support the closure cover design of the North Pile facility at the De Beers Group of Companies’ Snap Lake Mine, located approximately 220 km northeast of Yellowknife, Northwest Territories. The water management structures are designed to collect surface runoff and to route it off the North Pile via outlet channels.

The collection system will include a network of swales constructed within the closure cover of the North Pile conveying surface runoff towards two outlet channels located on the west and east side of the North Pile. The outlet channels will convey water to perimeter water management structures including ditches and sumps. Some of these sumps are currently being considered as locations for passive treatment for closure and post-closure of the Snap Lake Mine (design of the passive treatment is part of a separate scope of work).

2.0 SURFACE WATER MANAGEMENT DESIGN

The surface water management of the North Pile closure cover consists of a network of swales constructed within the North Pile closure cover to collect surface runoff and convey it off the North Pile via the outlet channels. The outlet channels will report to existing perimeter ditches for ultimate collection in the existing sumps along the toe of the North Pile. The scope of this design is limited to the water management structures located on the surface of the North Pile. The design of water management structures along the perimeter of the North Pile is included in an ongoing separate scope of work, which will account for the North Pile closure cover design and water management concept.

The surface water management of the North Pile closure cover includes the following structures:

1) Swales to collect and route surface runoff from the closure cover to the outlet channels:
   a. Starter Cell Swale to collect runoff from closure cover of the Starter Cell
   b. West Swale to collect runoff from closure cover of Cell 1 and 2 of the East Cell
   c. East Swale to collect runoff from closure cover of Cell 3, 4, and 5 of the East Cell
2) **Cell 1 Outlet Channel** to direct runoff from the West Swale off the North Pile to the existing West Perimeter Ditch. Any upgrades to the West Perimeter Ditch are included in a separate scope of work focused on closure design for the North Pile perimeter water management structures.

3) **Cell 5 Outlet Channel** to direct runoff from the Starter Cell Swale and the East Swale off the North Pile to the existing East Perimeter Ditch. Scope of this design is limited to the portion of the channel located on the top of the North Pile and across the North Pile embankment. Design of the channel down the embankment, and upgrades to the East Perimeter Ditch are included in a separate scope of work focused on closure design for the North Pile perimeter water management structures.

The Starter Cell Swale and the East Swale will merge into the Cell 5 Outlet Channel for discharge off the North Pile. The West Swale will connect to the Cell 1 Outlet Channel for discharge off the North Pile.

The layout of the North Pile closure cover water management structures is shown in Drawing 6 in Appendix B of the North Pile closure cover feasibility report.

### 3.0 DESIGN CRITERIA

The design criteria used for the feasibility design of the surface water management structures comply with the criteria set out in the Canadian Dam Association Dam Safety Guidelines (CDA 2013) as well as the Anglo American Technical Standards (Anglo 2016) and are summarized in Golder (2018).

The CDA criteria for inflow design flood (IDF) at closed facilities with a “high” classification is the probable maximum flood (PMF) event. The Anglo standard for IDF at closed facilities is the 1/10,000 year or the PMF event.

According to the CDA dam safety guidelines, the PMF is generated by the probable maximum precipitation (PMP) estimated as the greater of the summer-autumn PMF (summer autumn PMP only) and the spring PMF (spring PMP over snowmelt). The spring PMF is the governing design flood for the Snap Lake Mine site.

The water management structures for the closure cover have been designed to pass the estimated peak flows generated during the 24-hour PMF. The 24-hour PMF depth of 460 mm was derived from 309 mm of rainfall (24-hour PMP) combined with 151 mm snowmelt (Golder 2017). The snowmelt corresponds to the most critical 100-year temperature sequence occurring during the PMP (Golder 2017) and is assumed to occur at a constant rate.

The design event was used to estimate peak flows for sizing the surface water management structures while allowing for a minimum of 0.3 m of freeboard during peak flows, to account for possible settlement and flow run up.

### 3.1 Hydrologic Design Method

Peak flows were estimated through a rainfall-runoff model developed using the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) software (USACE 2010).
The 24-hour PMP event hyetograph was developed using the alternating block method, which provides precipitation depths in five-minute intervals. The shape of the distribution was taken from the 100-year return period intensity-duration-frequency data from Environment and Climate Change Canada (EC) station Yellowknife A (EC climate station ID: 2204100). The intensity-duration-frequency data were scaled to the Snap Lake Mine site using the total 100-year, 24-hour depth (79.3 mm) and the 24-hour PMP depth (309 mm) at site, compared to the Yellowknife A 100-year, 24-hour depth (79 mm), to develop the 24-hour PMP hyetograph. The 1/100 year snowmelt was added at a constant rate over the entire 24 hours. The resulting hyetograph for the PMP plus snowmelt event is shown in Plot 1.

Plot 1: PMP and Snowmelt 24-Hour Hyetograph

The Soil Conservation Service curve number method (USDA 1986) was used to estimate general catchment runoff and losses. A Soil Conservation Service curve number value of 95 was used for the closure cover assuming that the ground surface will be frozen during the design event (freshet event).

The catchment areas reporting to the water management structures were defined based on the feasibility level closure cover design (Golder 2018). The swales and outlet channels will receive flows contributing from catchments on the surface of the North Pile. A total of 3 catchments were characterized for design of the surface water management structures for the North Pile closure cover. The time of concentration for the catchments reporting to the surface water management structures was estimated using the TR-55 method described by United States Department of Agriculture (USDA 2010).

The input parameters for the three catchments are shown in Table 1.

<table>
<thead>
<tr>
<th>5-Minute Rainfall (mm)</th>
<th>Time (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>10.00</td>
<td>3</td>
</tr>
<tr>
<td>20.00</td>
<td>6</td>
</tr>
<tr>
<td>30.00</td>
<td>9</td>
</tr>
<tr>
<td>40.00</td>
<td>12</td>
</tr>
<tr>
<td>50.00</td>
<td>15</td>
</tr>
<tr>
<td>60.00</td>
<td>18</td>
</tr>
<tr>
<td>70.00</td>
<td>21</td>
</tr>
<tr>
<td>80.00</td>
<td>24</td>
</tr>
</tbody>
</table>
Table 1: Catchments Characteristics

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Area (km²)</th>
<th>Time of Concentration (min)</th>
<th>Soil Conservation Service Lag Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starter Cell Swale</td>
<td>0.214</td>
<td>35</td>
<td>21</td>
</tr>
<tr>
<td>West Swale</td>
<td>0.068</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>East Swale</td>
<td>0.093</td>
<td>28</td>
<td>17</td>
</tr>
</tbody>
</table>

The HEC-HMS model was run with a two-minute time step and assuming no attenuation from storage on the closure cover. The schematic for the HEC-HMS model is shown in Plot 2. The results of the hydrologic modelling of the surface water management structures are provided in Table 3 (Section 3.2).

Plot 2: HEC-HMS Model Schematic
3.2 Hydraulic Design

The swales and outlet channels were sized assuming uniform flow conditions using the Manning equation. The Manning coefficient for the different types of riprap lining used for the surface water management structures are presented in Table 2.

**Table 2: Manning Coefficients**

<table>
<thead>
<tr>
<th>Riprap Lining Type</th>
<th>Manning Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{50} = 150$ mm</td>
<td>0.035</td>
</tr>
<tr>
<td>$D_{50} = 300$ mm</td>
<td>0.040</td>
</tr>
<tr>
<td>$D_{50} = 600$ mm</td>
<td>0.049</td>
</tr>
</tbody>
</table>

Sizing of the riprap lining was completed using the shear stress equation (ASCE 1982a) for slopes less than 20%; for steeper slopes the riprap sizing was completed using the method proposed by Olivier (ASCE 1982b).

The feasibility level sizing of the surface water management structures is provided in Table 3.

The Starter Cell Swale includes a steeper section as it transitions from Cell D (Starter Cell) to Cell 5 (East Cell). This section will require a larger riprap class due to the higher velocities on this longitudinal slope.

The existing East Perimeter Ditch and West Perimeter Ditch will require upgrades to convey the estimated peak flow for each ditch. As mentioned, the design of the required upgrades to these ditches is included in a separate scope of work.

The general layout of the surface water management structures is shown in Drawing 6 (Appendix B of the North Pile closure cover feasibility report). Profiles and typical sections of the surface water management structures are shown in Drawings 8 and 9 (Appendix B of the North Pile closure cover feasibility report).
### Table 3: Hydraulic Structures Design Summary

<table>
<thead>
<tr>
<th>Hydraulic Structure</th>
<th>Peak Design Flow (24-Hour PMP) (m³/s)</th>
<th>Longitudinal Slope (%)</th>
<th>Side Slope (H:V)</th>
<th>Base Width (m)</th>
<th>Minimum Depth (m)</th>
<th>Flow Depth (m)</th>
<th>Velocity (m/s)</th>
<th>Riprap Lining Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Swale</td>
<td>3.8</td>
<td>2</td>
<td>10:1</td>
<td>5</td>
<td>0.6</td>
<td>0.3</td>
<td>1.5</td>
<td>D&lt;sub&gt;50&lt;/sub&gt; = 150 mm</td>
</tr>
<tr>
<td>Cell 1 Outlet Channel</td>
<td>3.8</td>
<td>30</td>
<td>2.5:1</td>
<td>5</td>
<td>0.5</td>
<td>0.2</td>
<td>3.8</td>
<td>D&lt;sub&gt;50&lt;/sub&gt; = 600 mm*</td>
</tr>
<tr>
<td>East Swale</td>
<td>4.8</td>
<td>2</td>
<td>10:1</td>
<td>10</td>
<td>0.6</td>
<td>0.3</td>
<td>1.5</td>
<td>D&lt;sub&gt;50&lt;/sub&gt; = 150 mm</td>
</tr>
<tr>
<td>Starter Cell Swale (shallow)</td>
<td>9.8</td>
<td>2</td>
<td>10:1</td>
<td>10</td>
<td>0.7</td>
<td>0.4</td>
<td>1.8</td>
<td>D&lt;sub&gt;50&lt;/sub&gt; = 150 mm</td>
</tr>
<tr>
<td>Starter Cell Swale (Cell D to Cell 5)</td>
<td>9.8</td>
<td>9</td>
<td>10:1</td>
<td>10</td>
<td>0.7</td>
<td>0.3</td>
<td>2.8</td>
<td>D&lt;sub&gt;50&lt;/sub&gt; = 300 mm</td>
</tr>
<tr>
<td>Cell 5 Swale and Outlet Channel across embankment crest</td>
<td>14.4</td>
<td>2</td>
<td>2.5:1</td>
<td>10</td>
<td>1.0</td>
<td>0.6</td>
<td>2.1</td>
<td>D&lt;sub&gt;50&lt;/sub&gt; = 600 mm</td>
</tr>
</tbody>
</table>

* Riprap size estimated based on Olivier (ASCE 1982b).
PMP = probable maximum precipitation.
4.0 CLOSING

The reader is referred to the Study Limitations section, which follows the text and forms an integral part of this memorandum.

We trust the information in this report is sufficient for your present needs. Should you have any additional questions regarding this report, please contact the undersigned.

Golder Associates Ltd.

Aaron Brisbin
Mine Water Management Group

Paolo Chiaramello, P.Eng.
Associate, Senior Water Resources Engineer

Attachment: Study Limitations


PERMIT TO PRACTICE
GOLDER ASSOCIATES LTD.

Signature

Date 15 Nov 2018

PERMIT NUMBER: P 049
NT/NU Association of Professional Engineers and Geoscientists
REFERENCES


STUDY LIMITATIONS

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with the level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of the De Beers Group of Companies. It represents Golder’s professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by the De Beers Group of Companies, and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. The De Beers Group of Companies may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.
APPENDIX D

Slope Stability Analysis
1.0 INTRODUCTION

This slope stability analysis has been completed in support of the North Pile closure cover feasibility design at the Snap Lake Mine for the De Beers Group of Companies (De Beers). The stability analysis may be updated based on comments received and advancement of the detailed design.

The stability analysis was conducted for East Cell rib berms and perimeter embankments for the following aspects:

- Rib berm and perimeter embankment slope stability for potential fine PK excavation in Cells 2 and 5 during care and maintenance.
- Cell 1 west perimeter downstream slope stability for closure.

This technical memorandum presents the criteria, methodology, and results of the stability analysis.

2.0 SITE OVERVIEW

The North Pile is the permanent surface storage facility for processed kimberlite (PK) and other mine waste materials at the Snap Lake Mine in the Northwest Territories, located approximately 220 km northeast of Yellowknife. The facility is composed of the Starter Cell, East Cell, and West Cell. The West Cell was not fully developed, leaving the west perimeter embankment of the Starter Cell and East Cells exposed. The Snap Lake Mine operated from 2007 to 2015 and entered in care and maintenance phase on 4 December 2015.
3.0 BACKGROUND

The feasibility design and supporting grading plans have been developed such that the North Pile closure cover:

- complies with the *North Pile Closure Cover Feasibility Design – Design Basis and Criteria* draft Rev. 0 report, dated 15 November 2018 (Golder 2018b)
- accommodates 350,000 m³ of additional landfill waste material placement
- reduces construction earthworks and revetment quantities as much as practicable
- keeps landfill footprint as small as practicable

The North Pile closure cover feasibility grading plan is inclusive of the East Cell, Starter Cell, west perimeter embankment, and borrow.

Closure options are currently being assessed for the East Cell. The current closure concept incorporates an excavation of the deposited fine PK within Cell 2 and Cell 5, as well as a raise of the Cell 1 west embankment to accommodate the required additional landfill material storage of 350,000 m³. The excavation also includes total or partial removal of Rib Berms 2 and 4. The excavated rib berm material, consisting of combined coarse and grits fractions of the PK (coarse and grits PK), will be stockpiled for future use as cover material. The fine PK excavated from Cell 2 and Cell 5 will be placed within Cell 3 and Cell 4.

The closure cover construction design for the Starter Cell will consist of a cut to fill operation and includes a minimum 2% gradient away from the crest.

The west perimeter embankment is located along the western portion of the East Cell and Starter Cell and was intended to be covered as the West Cell construction advanced. However, the West Cell was not fully developed, leaving the ~1.5H:1V west perimeter embankment exposed. The closure cover for the feasibility design includes a 3H:1V slope regrade to promote the long-term stability of the cover system. For Cell 1, the west embankment also includes a 4 m raise of the embankment to achieve the required cover design grading.

4.0 STABILITY ANALYSIS METHODOLOGY

Two-dimensional limit equilibrium stability analyses were performed on six cross-sections within the East Cell where fine PK excavation will potentially take place (Cell 2 and Cell 5) and where the west perimeter embankment will be raised and regraded. The computer software GeoStudio 2016, Slope/W Version 8.16, developed by GEO-SLOPE International Ltd., was used for the analyses. The Morgenstern-Price (Morgenstern 1965) method of slices was used for calculations of factors of safety (FoS). The phreatic surface in the deposited materials is expected to be low and was assumed for the models.
Geometry
The upstream slope stability was assessed for rib berms and perimeter embankment in the East Cell (Cell 2 and Cell 5) to determine whether the required FoS could be reached when the fine PK is excavated.

The fine PK excavation includes an upstream slope cut and filled with coarse and grits PK at 2H:1V for the upper 5 m of fine PK, and the lower fine PK is cut at 4H:1V slope to the original ground. A 5 m wide berm at 5 m below the current elevation of fine PK was included for the perimeter embankments to improve the stability.

An analysis for an alternative approach to consider for the upstream slope was to cut and backfill with coarse and grits PK at 2.5H:1V. This option was evaluated for Rib Berm 4.

The Cell 1 west embankment will be raised by a maximum of 4 m and the downstream slope will be regraded to a slope of 3H:1V.

Section Locations
The current configuration (July 2017) of the North Pile embankments was reviewed to evaluate the location of key cross-sections for the stability assessment.

Critical cross-sections for the East Cell were identified for the slope stability assessment are summarized below and the section locations are shown in Figure 1.

Rib Berms
- Cross-Section A at Rib Berm 2
- Cross-Section B at Rib Berm 4

Perimeter Embankment
- Cross-Section C at stn. 35+890 (Cell 2)
- Cross-Section D at stn. 35+817 (Cell 3)
- Cross-Section E at stn. 35+333 (Cell 5)

West Embankment
- Cross-Section F at stn. 36+275 (Cell 1)
Factor of Safety Criteria

Based on the Canadian Dam Association (CDA) *Dam Safety Guidelines* (CDA 2013, 2014), the North Pile perimeter embankments are currently classified as “High” consequence (Golder 2005, 2014c, 2015). The rib berms are non-structural berms for deposition and help facilitate containment of deposited PK slurry. The rib berms are considered to also have the same High consequence classification as the perimeter embankments when the fine PK excavation will occur during the care and maintenance period.

Based on Anglo American (Anglo 2016) standards, the North Pile facility was rated as a Moderate to High consequence classification considering workers’ safety and health during the excavation activities and landfill backfilling. The adopted criteria for the stability analyses of the facility are summarized in Table 1.

**Table 1: Summary of Design Criteria from the Canadian Dam Association and Anglo American for Closure – Passive Care Phase**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam classification</td>
<td>Moderate to High</td>
<td>High</td>
</tr>
<tr>
<td>Earthquake design ground motion</td>
<td>1-in-10,000-year or MCE</td>
<td>1-in-2,475-year or MCE (construction, operation, and transition phases)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/2 between 1-in-2,475-year and 1-in-10,000-year or MCE (closure – passive care phase)</td>
</tr>
</tbody>
</table>

**Slope Stability Analysis Factors of Safety**

<table>
<thead>
<tr>
<th></th>
<th>Static</th>
<th>Pseudo-static</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

CDA = Canadian Dam Association; MCE = maximum credible earthquake.

The design criteria for the slope stability assessment for the current configuration of the North Pile for the excavation during the care and maintenance phase include a minimum FoS of 1.5 for static and 1.2 for pseudo-static conditions.

For the downstream stability for the North Pile perimeter embankments, the adopted minimum FoS for closure configuration are 1.5 for static and 1.2 for pseudo-static. The Cell 1 west embankment downstream stability was examined for the proposed raise and regrading using these criteria. For other perimeter embankments in East Cell and Starter Cell, the stability analyses were carried out during the detailed design for the North Pile surface water management (Golder 2018a). The static and pseudo-static FoS exceeded the closure requirements. The current closure design does not change the downstream layout of the embankments, and the stability is expected to remain satisfactory. Therefore, no stability updates were carried out for these downstream slopes of the perimeter embankments at this stage of the closure design.
The selected earthquake design ground motion is the 1-in-10,000-year return period for both the excavation and closure scenarios. Site-specific earthquake-induced seismic loading was obtained from the 2015 National Building Code Seismic Hazard Calculator by Natural Resources Canada (2018; Attachment 1). The 500- and 2,500-year return periods provided by Natural Resources Canada were plotted in log-log scale to create a linear extrapolation for a 1-in-10,000-year annual exceedance probability event, and this approach resulted in a design peak ground acceleration of 0.092 g. According to Hynes-Griffin and Franklin (1984), the horizontal seismic coefficient should be halved from the design peak ground acceleration when evaluating the seismic stability of slopes not considering liquefaction. For this reason, the horizontal seismic coefficient used in the pseudo-static stability analyses is 0.046 g.

Foundation Conditions and Material Properties

A series of site investigation programs were carried out in the East Cell perimeter embankment foundation between 2000 and 2013; and are summarized in the East Cell reconfiguration detailed design report (Golder 2014c). The organic soil was observed to be less than 0.4 m thick overlying mineral soil between 1 and 2 m thick (Golder 2005) and organics up to 1.3 m thick (Golder 2009). The mineral soils comprise silt and sand to cobbles and boulders.

Foundation preparation was completed below the footprint of the East Cell perimeter embankment (Golder 2016); and was not completed within the footprint of the deposited material.

The material strength parameters selected for the stability analysis are consistent with recent stability modelling conducted for the North Pile embankments (Golder 2018a) and are presented in Table 2. Material properties for the landfill waste and cover system have been assumed.

One test pit, TP18-01 (Figure 1), was excavated in June 2018 within the fine PK deposited into Cell 2 to a depth of 5 m. The fine PK was observed to be 1 m of soft silty clay, overlying 1 m of frozen silty clay. Firm to stiff clay was encountered at a depth of 2 to 5 m. The strength of the fine PK was therefore considered increased at a depth of 5 m or more below the current elevation of the fine PK for purposes of this assessment. Results of vane shear testing performed in August 2018 will be reviewed and material properties validated during the final design effort.
<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Friction Angle (°)</th>
<th>Cohesion (kPa)</th>
<th>Undrained Shear Strength (kPa)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine PK (0 to 5 m depth)</td>
<td>15.5</td>
<td>N/A</td>
<td>N/A</td>
<td>20</td>
<td>BGC (2015)</td>
</tr>
<tr>
<td>Fine PK (&gt;5 m depth)</td>
<td>15.5</td>
<td>N/A</td>
<td>N/A</td>
<td>50</td>
<td>inferred based on TP18-01</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK – compacted</td>
<td>20</td>
<td>38</td>
<td>0</td>
<td>N/A</td>
<td>Golder (2014b)</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK – uncompacted</td>
<td>18</td>
<td>34</td>
<td>0</td>
<td>N/A</td>
<td>assumed</td>
</tr>
<tr>
<td>Rockfill and base rockfill drain</td>
<td>20</td>
<td>42</td>
<td>0</td>
<td>N/A</td>
<td>Golder (2015b)</td>
</tr>
<tr>
<td>Internal drainage material</td>
<td>19</td>
<td>38</td>
<td>0</td>
<td>N/A</td>
<td>Golder (2015b)</td>
</tr>
<tr>
<td>Mineral soil – prepared</td>
<td>19.5</td>
<td>34</td>
<td>0</td>
<td>N/A</td>
<td>Golder (2013, 2015b)</td>
</tr>
<tr>
<td>Mineral soil – unprepared</td>
<td>18.5</td>
<td>30</td>
<td>0</td>
<td>N/A</td>
<td>Golder (2007)</td>
</tr>
<tr>
<td>Landfill material</td>
<td>15</td>
<td>27</td>
<td>0</td>
<td>0</td>
<td>Assumed(a)</td>
</tr>
<tr>
<td>Cover system</td>
<td>18</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>Assumed the same as uncompacted combined coarse and grits fractions of the PK</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>32</td>
<td>5,000</td>
<td>N/A</td>
<td>Golder (2014c)</td>
</tr>
</tbody>
</table>

PK = processed kimberlite; N/A = not applicable.

(a) Landfill material properties are representative of construction and demolition waste (Konstantopoulou 2013; Vieria 2015). Landfill waste material properties will be reviewed to consider the site-specific demolition characteristics during detailed design.
5.0 RESULTS AND CONCLUSIONS
The results of the stability analyses for Cross-Sections A to F are summarized in Table 3 and presented in Figures 2 to 8. FoS are reported for static and pseudo-static analyses for slip surfaces that involve the entire regraded upstream excavation within the East Cell and downstream slope of the raised Cell 1 west embankment.

Table 3: Summary of Fine PK Excavation Slope Stability Results

<table>
<thead>
<tr>
<th>Cross-section</th>
<th>Fine PK Excavation</th>
<th>Structure</th>
<th>Minimum Required Factor of Safety (CDA 2013; Anglo 2016)</th>
<th>Factor of Safety</th>
<th>Figure No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Cell 2</td>
<td>Rib Berm 2</td>
<td>1.5 – static 1.2 – pseudo-static</td>
<td>2.2 1.9</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>Cell 5</td>
<td>Rib Berm 4</td>
<td>1.8 1.6</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rib Berm 4 (coarse and grits replacement)</td>
<td>1.8 1.6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Cell 2</td>
<td>Cell 2 embankment</td>
<td>1.8 1.6</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>Cell 3</td>
<td>Cell 3 embankment</td>
<td>1.6 1.4</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>E</td>
<td>Cell 5</td>
<td>Cell 5 embankment</td>
<td>2.1 1.8</td>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

Table 4: Summary of Perimeter Embankment Closure Downstream Slope Stability Results

<table>
<thead>
<tr>
<th>Cross-section</th>
<th>Structure</th>
<th>Minimum Required Factor of Safety (Anglo 2016)</th>
<th>Factor of Safety</th>
<th>Figure No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>Cell 1 west embankment downstream slope</td>
<td>1.5 – static 1.2 – pseudo-static</td>
<td>2.4 2.1</td>
<td>8</td>
</tr>
</tbody>
</table>

The upstream slope stability assessment was completed for East Cell perimeter embankments and rib berms for the fine PK excavation. The results of the analyses indicate that the excavation with a 4H:1V fine PK slope starting 5 m beneath the current fine PK elevation meet the required minimum static and pseudo-static FoS requirements for the rib berm and embankment cross-sections of the East Cell.
Alternatively replacing the fine PK with coarse and grits PK to support the slopes would also satisfy the minimum design criteria. However, this option requires additional coarse and grits PK material and is not preferred.

A stability assessment was completed for the downstream slope of the Cell 1 west embankment with the proposed 4 m raise and regrading to 3H:1V. The stability FoS meets the minimum FoS requirements for closure under static and pseudo-static conditions.

Excavation of fine PK in Cell 5 is preferred over Cell 3 or Cell 4 as the Cell 5 embankment was generally raised using a downstream method (with an upstream widened section in some locations above elev. 456 m) and the stability FoS is higher than the Cell 3 embankment after the excavation.

In-situ field testing was performed during the summer of 2018 by De Beers and Golder. The undrained in situ shear strength profile for deposited materials in the East cell will be developed based on results of the field testing and used to validate the undrained shear strength of the deposited fine PK during the detailed design effort.
6.0 CLOSING

The reader is referred to the Study Limitations, which follow the text and forms an integral part of this technical memorandum.

We trust the information contained in the document meets your requirements at this time. If there are any questions, or additional details required, please contact the undersigned.

Golder Associates Ltd.

Colin McGrath, B.A.Sc.
Mine Waste Group

Abdul Sattar Khan, M.A.Sc.
Project Manager

Paul Bedell, M.E.Sc., P.Eng.
Principal, Senior Geotechnical Engineer

Attachments: Study Limitations
Figures 1 to 8

REFERENCES


STUDY LIMITATIONS

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of De Beers Group of Companies. It represents Golder’s professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by De Beers Group of Companies, and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. De Beers Group of Companies may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.
Notes:
1. Higher degree of consolidation assumed for deposited fine fractions of the PK below 5 m
2. This condition of fine PK is not considered for Cell 3.
3. 1 in 10,000 year PGA selected for pseudo-static analysis.

### Material Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Strength Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined coarse and grits fractions of the PK - uncompacted</td>
<td>18</td>
<td>Effective Friction Angle (°)</td>
</tr>
<tr>
<td>Fine PK - &lt; 5 m depth</td>
<td>15.5</td>
<td>34°</td>
</tr>
<tr>
<td>Fine PK - &gt; 5 m depth</td>
<td>15.5</td>
<td>30°</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>30°</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>50°</td>
</tr>
</tbody>
</table>

**Excavated Fine PK**

- Pseudo-Static FoS = 1.9 (kh = ½ 0.092 g)
- Static FoS = 2.2

**Excavated Fine PK**

- Elevation (m): 435, 440, 445, 450, 455, 460, 465, 470, 475, 480
- Distance (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120

**Cross-Section A – Rib Berm 2**

**Extraction of Fine PK**

**Cell 2**

**Cell 3**

**Title:** CROSS-SECTION A – RIB BERM 2

**Extraction of Fine PK**

**Appendix D – Stability Analysis**

**De Beers**

**Golder**

**Client:**

**Project Title:** NORTH PILE CLOSURE COVER FEASIBILITY DESIGN

**Prepared By:** CM

**Design By:** CM

**Review By:** ASK

**Approved By:** PMD

**Project No.:** 1785666

**Phase/Task/Doc:** 3000/3100/022

**Rev.:** 0

**Figure:** 2
### Table: Strength Parameters

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Effective Friction Angle (°)</th>
<th>Cohesion (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined coarse and grits fractions of the PK - uncompacted</td>
<td>18</td>
<td>34&quot;</td>
<td>0</td>
</tr>
<tr>
<td>Fine PK - &lt; 5 m depth</td>
<td>15.5</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Fine PK - &gt; 5 m depth</td>
<td>15.5</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>30&quot;</td>
<td>0</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>32&quot;</td>
<td>5000</td>
</tr>
</tbody>
</table>

### Notes

1. Higher degree of consolidation assumed for deposited fine fractions of the PK below 5 m.
2. This condition of fine PK is not considered for Cell 4.
3. 1 in 10,000 year PGA selected for pseudo-static analysis.
Notes:
1. 1 in 10,000 year PGA selected for pseudo-static analysis.

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Strength Parameters</th>
<th>Cohesion (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined coarse and grits fractions of the PK</td>
<td>18</td>
<td>Friction Angle (°)</td>
<td>34</td>
</tr>
<tr>
<td>Deposited fine fractions of the PK</td>
<td>15.5</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>Friction Angle (°)</td>
<td>30</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>Friction Angle (°)</td>
<td>32</td>
</tr>
</tbody>
</table>

Pseudo-Static FoS = 1.6 (kh = ½ 0.092 g)
Static FoS = 1.8
Pseudo-Static FoS = 1.6 (kh = ½ 0.092 g)

Excavated Fine PK

Cell 2 Embankment

### Notes
1. Higher degree of consolidation assumed for deposited fine fractions of the PK below 5 m.
2. 1 in 10,000 year PGA selected for pseudo-static analysis.

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m²)</th>
<th>Strength Parameters</th>
<th>Cohesion (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Drainage Material (50 mm minus)</td>
<td>19</td>
<td>Effective Friction Angle (°')</td>
<td>0</td>
</tr>
<tr>
<td>Fine PK - &gt; 5 m depth(^1)</td>
<td>15.5</td>
<td>38°</td>
<td>0</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK - compacted</td>
<td>20</td>
<td>38°</td>
<td>50</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK - uncompacted</td>
<td>18</td>
<td>34°</td>
<td>0</td>
</tr>
<tr>
<td>Mineral soil – prepared foundation</td>
<td>19.5</td>
<td>34°</td>
<td>0</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>30°</td>
<td>0</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>32°</td>
<td>5000</td>
</tr>
</tbody>
</table>

\(^1\) In the above table, PGA stands for Peak Ground Acceleration.
Cell 3

Pseudo-Static FoS = 1.4 (kh = \(\frac{1}{2} 0.092 \, g\))

Static FoS = 1.6

Excavated Fine PK

Cell 3 Embankment

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Strength Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Drainage Material (50 mm minus)</td>
<td>19</td>
<td>(38^\circ)</td>
</tr>
<tr>
<td>Fine PK - &gt; 5 m depth(^{(1)})</td>
<td>15.5</td>
<td>0</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK - compacted</td>
<td>20</td>
<td>(38^\circ)</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK - uncompacted</td>
<td>18</td>
<td>(34^\circ)</td>
</tr>
<tr>
<td>Mineral soil – prepared foundation</td>
<td>19.5</td>
<td>(34^\circ)</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>(30^\circ)</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>(32^\circ)</td>
</tr>
</tbody>
</table>

Notes:
1. Higher degree of consolidation assumed for deposited fine fractions of the PK below 5 m.
2. 1 in 10,000 year PGA selected for pseudo-static analysis.
Cell 5

Pseudo-Static FoS = 1.8 (kh = ½ 0.092 g)

Static FoS = 2.1

Excavated Fine PK

Cell 5 Embankment

Distance (m)

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Strength Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rockfill</td>
<td>20</td>
<td>Effective Friction Angle (°)</td>
</tr>
<tr>
<td>Fine PK - &gt; 5 m depth[1]</td>
<td>15.5</td>
<td>38°</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK</td>
<td>20</td>
<td>Cohesion (kPa)</td>
</tr>
<tr>
<td>- compacted</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK</td>
<td>18</td>
<td>34°</td>
</tr>
<tr>
<td>- uncompacted</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mineral soil – prepared foundation</td>
<td>19.5</td>
<td>34°</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>30°</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>22°</td>
</tr>
</tbody>
</table>

Notes:
1. Higher degree of consolidation assumed for deposited fine fractions of the PK below 5 m.
2. 1 in 10,000 year PGA selected for pseudo-static analysis.
### Notes

1. Higher degree of consolidation assumed for deposited fine fractions of the PK below 5 m.
2. 1 in 10,000 year PGA selected for pseudo-static analysis.

### Table

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (kN/m³)</th>
<th>Effective Friction Angle (°)</th>
<th>Cohesion (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rockfill</td>
<td>20</td>
<td>42°</td>
<td>0</td>
</tr>
<tr>
<td>Combined coarse and grits fractions of the PK - compacted</td>
<td>18</td>
<td>38°</td>
<td>0</td>
</tr>
<tr>
<td>Cover System</td>
<td>18</td>
<td>34°</td>
<td>0</td>
</tr>
<tr>
<td>Landfill Material</td>
<td>15</td>
<td>27°</td>
<td>0</td>
</tr>
<tr>
<td>Mineral soil – prepared foundation</td>
<td>19.5</td>
<td>34°</td>
<td>0</td>
</tr>
<tr>
<td>Mineral soil – unprepared foundation</td>
<td>18.5</td>
<td>30°</td>
<td>0</td>
</tr>
<tr>
<td>Bedrock</td>
<td>26</td>
<td>32°</td>
<td>5000</td>
</tr>
</tbody>
</table>

### Graph

- **Graph Title:** Pseudo-Static FoS = 2.1 (kh = ½ 0.092 g)
- **Equation:** Static FoS = 2.4

### Diagram

- **Diagram:** Cross-Section F – Cell 1 West Embankment Closure Downstream Slope

---

**De Beers**

**Golder**

**Title:** CROSS-SECTION F – CELL 1 WEST EMBANKMENT CLOSURE DOWNSTREAM SLOPE

**Project:** NORTH PILE CLOSURE COVER FEASIBILITY DESIGN

**Appendix D – Stability Analysis**
2018 National Building Code
Seismic Hazard Calculation –
Snap Lake Mine
Site: 63.6052 N, 110.8666 W  User File Reference: Snap Lake Mine
Requested by: , Golder

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

<table>
<thead>
<tr>
<th>Sa(0.05)</th>
<th>Sa(0.1)</th>
<th>Sa(0.2)</th>
<th>Sa(0.3)</th>
<th>Sa(0.5)</th>
<th>Sa(1.0)</th>
<th>Sa(2.0)</th>
<th>Sa(5.0)</th>
<th>Sa(10.0)</th>
<th>PGA (g)</th>
<th>PGV (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.040</td>
<td>0.055</td>
<td>0.052</td>
<td>0.042</td>
<td>0.031</td>
<td>0.016</td>
<td>0.0066</td>
<td>0.0013</td>
<td>0.0007</td>
<td>0.030</td>
<td>0.021</td>
</tr>
</tbody>
</table>

**Notes.** Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. *These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.*

Ground motions for other probabilities:

<table>
<thead>
<tr>
<th>Probability of exceedance per annum</th>
<th>Sa(0.05)</th>
<th>Sa(0.1)</th>
<th>Sa(0.2)</th>
<th>Sa(0.3)</th>
<th>Sa(0.5)</th>
<th>Sa(1.0)</th>
<th>Sa(2.0)</th>
<th>Sa(5.0)</th>
<th>Sa(10.0)</th>
<th>PGA</th>
<th>PGV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.010</td>
<td>0.0019</td>
<td>0.0034</td>
<td>0.0040</td>
<td>0.0036</td>
<td>0.0026</td>
<td>0.0011</td>
<td>0.0005</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0018</td>
<td>0.0013</td>
</tr>
<tr>
<td>0.0021</td>
<td>0.010</td>
<td>0.016</td>
<td>0.017</td>
<td>0.015</td>
<td>0.011</td>
<td>0.0051</td>
<td>0.0020</td>
<td>0.0005</td>
<td>0.0003</td>
<td>0.0085</td>
<td>0.0063</td>
</tr>
<tr>
<td>0.001</td>
<td>0.019</td>
<td>0.029</td>
<td>0.028</td>
<td>0.024</td>
<td>0.018</td>
<td>0.0092</td>
<td>0.0037</td>
<td>0.0008</td>
<td>0.0005</td>
<td>0.016</td>
<td>0.012</td>
</tr>
</tbody>
</table>

**References**

National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada


Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be 63.5°N used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

*Aussi disponible en français*
APPENDIX E

Geochemical Stability Analysis
1.0 INTRODUCTION
The De Beers Group of Companies (De Beers) retained Golder Associates Ltd. (Golder) to prepare closure cover designs for the North Pile facility at the Snap Lake Mine. As part of this work, the acid rock drainage (ARD) potential of the main rock types in the existing configuration North Pile was reviewed. This memorandum provides the data and results of this ARD review and provides updated geochemical considerations for use in developing closure cover design.

2.0 BACKGROUND
The North Pile facility is the permanent surface storage facility for processed kimberlite (PK), mine waste rock material, and limited quantities of nonhazardous solid waste for the mine. The facility includes the surface embankments, rock cover, and all waste materials deposited within it. It does not include the associated sumps and water management structures external to the perimeter of the facility. The facility consists of the Starter and East cells (the West Cell was partly built but not commissioned and will not be part of the closure cover system) and has an approximate area to be covered of 315,000 m².

2.1 Geochemistry
Geochemical testing was conducted during the environmental assessment process as reported in the environmental assessment report (EAR; De Beers 2002). In addition, over 100 confirmation geochemistry samples and over 900 run-of-mine (ROM) samples of waste rock material were collected and analyzed as part of the annual ARD monitoring program between 2004 and 2015 (see annual ARD reports, for example De Beers 2015). Testing included acid base accounting (ABA), as well as short-term leach testing, net acid generation (NAG) testing, and mineralogy. Annual reporting included results of geochemical testing and an assessment of the seepage quality from the facilities. Based on the seepage water quality review (De Beers 2015), the materials in the North Pile have not generated acidic seepage or runoff.
Geochemical evaluation of acid generation potential includes consideration of existing conditions on site, coupled with an evaluation of ABA. For individual samples, ABA results are evaluated including neutralization potential (NP) to acidification potential (AP) ratios (NP:AP ratio) and net neutralization potential (net NP) (determined by subtracting AP from NP). Following criteria described in Mine Environment Neutral Drainage (MEND 2009), samples with NP:AP ratio values of greater than 2 are considered non-acid generating (non-AG). Further, as determined during the environmental assessment (De Beers 2002), samples with less than 0.17% (by weight) of sulphide minerals (assumed to be represented by total sulphur) have insufficient acid generation potential to produce appreciable acidity and are considered non-AG. Samples with positive net NP are considered to contain excess neutralization capacity.

Sample results from a given unit are combined to develop an overall acid generation potential and NP of the unit or deposition area. This is considered reasonable in the case of the North Pile of Snap Lake when considering that materials were deposited over a long period of time and well mixed through the blasting, trucking, dumping, and dozing processes.

### 2.2 North Pile Embankments Configuration

The North Pile facility consists of two major cells: the Starter Cell and the East Cell. (A third cell, the West Cell, was designed however construction was initiated on only a few components in 2015, prior to the cease of operations in December 2015.) The Starter and East cells are divided into internal cells developed for PK deposition management. Both cells consists of three different types of embankments:

- the perimeter embankment
- divider dykes, which are interior embankments that were placed to support deposition activities but do not have a structural role
- rib berms, which also supported deposition without contributing to the structural stability of the facility

Starter Cell construction started in 2005. It was constructed in four phases, and deposition and development activities continued until April 2014. East Cell construction started in 2008. Embankment reconfiguration construction and slurry deposition were in progress up until the mine entered the care and maintenance phase in December 2015.

### 3.0 NORTH PILE CONSTRUCTION MATERIALS

The following construction materials are encountered in the North Pile facility:

- PK—combined coarse and grits factions of the PK
- waste rock (non-AG and potentially acid generating [PAG])—by-products of the mining process
- rockfill (quarried material).
3.1 Processed Kimberlite

PK is the material rejected from the process plant after the recoverable minerals have been extracted.

PK is classed as follows:
- coarse PK (1.5 to 6 mm)
- grits PK (0.125 mm to 1.5 mm)
- fine PK (<0.125 mm)

Combined coarse and grits fractions of the PK were used for the construction of the perimeter embankments of the Starter and East cells and for portions of the internal rib berms in the East Cell. Fine fractions of the PK was deposited in the cells as a slurry from 2007 to 2014 in the Starter Cell and from 2014 to 2015 in the East Cell.

Substantial geochemical testing of PK materials and kimberlite from underground was completed over the life of mine. ABA results including NP:AP ratio and net NP (determined by subtracting AP from NP) are available from 2004 through 2015 as presented in Attachment 1 and as summarized in Table 1.

Table 1: Summary of Acid Base Accounting and Net Acid Generation Potential for Kimberlite

<table>
<thead>
<tr>
<th>Year</th>
<th>NP:AP Ratio Count</th>
<th>NP:AP Ratio Average</th>
<th>NP:AP Ratio Median</th>
<th>Net NP Average</th>
<th>Net NP Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006-2015</td>
<td>286</td>
<td>91.6</td>
<td>130.2</td>
<td>121.1</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>3</td>
<td>137.8</td>
<td>126.1</td>
<td>349.5</td>
<td>307.5</td>
</tr>
<tr>
<td>2007</td>
<td>13</td>
<td>67.1</td>
<td>51.7</td>
<td>150.9</td>
<td>95.1</td>
</tr>
<tr>
<td>2008</td>
<td>17</td>
<td>33.7</td>
<td>41.6</td>
<td>92.0</td>
<td>101.6</td>
</tr>
<tr>
<td>2009</td>
<td>60</td>
<td>138.3</td>
<td>145.2</td>
<td>138.8</td>
<td>134.1</td>
</tr>
<tr>
<td>2010</td>
<td>14</td>
<td>123.6</td>
<td>124.0</td>
<td>134.1</td>
<td>115.3</td>
</tr>
<tr>
<td>2011</td>
<td>41</td>
<td>116.6</td>
<td>142.4</td>
<td>132.1</td>
<td>132.5</td>
</tr>
<tr>
<td>2012</td>
<td>17</td>
<td>105.8</td>
<td>166.7</td>
<td>125.7</td>
<td>99.4</td>
</tr>
<tr>
<td>2013</td>
<td>44</td>
<td>65.3</td>
<td>95.4</td>
<td>114.9</td>
<td>122.7</td>
</tr>
<tr>
<td>2014</td>
<td>36</td>
<td>164.3</td>
<td>190.0</td>
<td>129.7</td>
<td>113.4</td>
</tr>
<tr>
<td>2015</td>
<td>41</td>
<td>72.6</td>
<td>96.9</td>
<td>143.3</td>
<td>124.7</td>
</tr>
</tbody>
</table>

NP = neutralization potential; AP = acidification potential.

As can be observed in the results, this material is non-AG with substantial excess neutralizing capacity (NP:AP ratio of greater than 3 with Net NP greater than 20).

For closure construction, from a geochemical perspective, PK can be used for cover material, internal, and external embankments, and as a buffering material to be placed downgradient of potential embankment seepage from the North Pile.

3.2 Waste Rock Geochemistry

Waste rock used in the construction of the North Pile embankments can be broken into two categories: PAG material and non-AG material.
Non-acid Generating Material

Non-AG waste rock has been sourced from underground mine activities located away from the metavolcanic unit. This material has been tested by De Beers (2014). Waste rock classed as non-AG contains very low amounts of sulphide minerals (less than 0.17% sulphides by weight).

Crushed and screened non-AG material has been used at the North Pile construction for the following:

- internal drainage system (75 mm minus) for the East Cell embankments and other fill materials
- a 0.3 to 0.5 m thick erosion protection layer (150 to 250 mm minus) for the 3H:1V exteriors slope of the North Pile embankments
- Type 4 and Type 5 used in conjunction with 75 mm minus rockfill in the construction of the internal drainage

Refer to construction record information in Golder (2016 and 2017) for details.

Materials Handled as Potentially Acid Generating Material

Based on the geochemical testing, materials that are truly PAG contains greater than 0.17% sulphide sulphur (based on testing as completed for the EAR [De Beers 2002]) and has an NP:AP ratio of less than 2 (MEND 2009).

It is important to note the distinction between materials “handled” as PAG and actual PAG materials. Just because it was easier to handle the small volumes of metavolcanics rock as if it were PAG, or because a blast with a small amount of sulphide is treated and handled as PAG, does not make the material PAG. Geochemical test results must be used to determine if this material is actually PAG.

Metavolcanic Rock

Small amounts of metavolcanic rock were mined over a long period of time and resulted in blended material, often mixed with granite or containing kimberlite. For the purposes of material handling on site, all metavolcanic rock extracted during underground development and granite rock containing visually observable sulphide minerals was handled as if it were PAG. ROM samples of this material were routinely collected and analyzed as part of the ARD monitoring program (Attachment 2, Attachment 3, and annual reports, of which the latest is De Beers 2015).

A review of the ROM samples evaluated for ABA is provided in Table 2.
Results of the data review indicate:

- Seventy-five of the 109 samples are non-AG.
- Overall blended metavolcanic material (excluding granite or kimberlite) is net neutralizing with excess neutralization potential.

It is possible that small pockets of metavolcanic rock may have some acid generating potential; however, when considering the overall distribution of metavolcanic rock within the pile, and deposition history, it is unlikely that any acidity from this rock will be released. Nevertheless, it is prudent to include some mitigation as described in Section 4.

**Granitic Waste Rock from Underground**

For the purposes of material handling, on-site granite rock containing visually observable sulphide minerals was treated as if it were PAG (De Beers 2017). ROM samples (555 samples) of this material were routinely collected and analyzed as part of the ARD monitoring program (Attachment 2, Attachment 3, and annual reports, of which the latest is De Beers 2015).

A review of the ROM granite samples evaluated for ABA is provided in Table 3.
Table 3: Summary of Acid Base Accounting and Net Acid Generation Potential for Granitic Waste Rock

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>Median</td>
<td></td>
<td></td>
<td>Average</td>
<td>Median</td>
</tr>
<tr>
<td>2004</td>
<td>2</td>
<td>4.2</td>
<td>4.2</td>
<td>2004</td>
<td>2</td>
<td>4.2</td>
<td>4.2</td>
</tr>
<tr>
<td>2005</td>
<td>7</td>
<td>5.3</td>
<td>5.4</td>
<td>2005</td>
<td>7</td>
<td>8.7</td>
<td>6.8</td>
</tr>
<tr>
<td>2006</td>
<td>10</td>
<td>5.7</td>
<td>10.1</td>
<td>2006</td>
<td>10</td>
<td>7.9</td>
<td>8.6</td>
</tr>
<tr>
<td>2007</td>
<td>10</td>
<td>3.5</td>
<td>5.8</td>
<td>2007</td>
<td>10</td>
<td>4.1</td>
<td>3.8</td>
</tr>
<tr>
<td>2008</td>
<td>23</td>
<td>3.0</td>
<td>3.5</td>
<td>2008</td>
<td>23</td>
<td>4.0</td>
<td>3.2</td>
</tr>
<tr>
<td>2009</td>
<td>75</td>
<td>4.8</td>
<td>4.6</td>
<td>2009</td>
<td>75</td>
<td>4.9</td>
<td>3.4</td>
</tr>
<tr>
<td>2010</td>
<td>30</td>
<td>6.1</td>
<td>7.2</td>
<td>2010</td>
<td>30</td>
<td>7.7</td>
<td>3.9</td>
</tr>
<tr>
<td>2011</td>
<td>61</td>
<td>8.5</td>
<td>7.7</td>
<td>2011</td>
<td>61</td>
<td>7.1</td>
<td>4.0</td>
</tr>
<tr>
<td>2012</td>
<td>169</td>
<td>3.8</td>
<td>8.3</td>
<td>2012</td>
<td>169</td>
<td>3.9</td>
<td>4.4</td>
</tr>
<tr>
<td>2013</td>
<td>99</td>
<td>4.0</td>
<td>8.3</td>
<td>2013</td>
<td>99</td>
<td>3.8</td>
<td>4.4</td>
</tr>
<tr>
<td>2014</td>
<td>49</td>
<td>9.0</td>
<td>10.5</td>
<td>2014</td>
<td>49</td>
<td>7.4</td>
<td>5.7</td>
</tr>
<tr>
<td>2015</td>
<td>20</td>
<td>5.9</td>
<td>4.9</td>
<td>2015</td>
<td>20</td>
<td>10.4</td>
<td>5.7</td>
</tr>
</tbody>
</table>

NP = neutralization potential; AP = acidification potential.

Results of the data review indicate:

- Five-hundred thirty-seven of 555 ROM samples are non-AG.
- Overall blended granitic material (excluding metavolcanic and kimberlite) is net neutralizing with excess neutralization potential.

Given the observed prevalence of non-AG samples, it is unlikely that small pockets of granitic rock have acid generating potential; nevertheless, it is prudent to include some mitigation as described in Section 4.

4.0 ROCK PLACEMENT

The quantity of material handled as PAG waste rock used in construction varied from 0% on the south embankment at Cell LF to 40% at various embankments and rib berms throughout the facility.

During construction of the North Pile, materials handled as PAG were to be excluded from zones within 50 m of the downstream toe of any perimeter embankments and 3 m from the expected ultimate North Pile closure surface (Golder 2013, 2014). This was done to reduce the potential for release of acidity by decreasing potential oxygen influx and increasing the water flow path (thus increasing the potential for internal buffering of any acidity produced), and to take advantage of eventual freezing conditions to slow or eliminate oxidation reactions.

All rib berms in the East Cell used some proportion of PAG material for construction, along with the combined coarse and grits fraction of the PK and non-AG rockfill (Golder 2017). The materials handled as PAG placed along the west perimeter embankment of the Starter and East cells are not currently isolated as there was the expectation that it would be completely covered when the West Cell was built. These materials were deposited as fill along the west perimeter embankment from approximately 50 m south of the East Cell footprint to 50 m north of the Starter Cell footprint. The approximate location of this material is shown in Figure 1.
Although materials in the west perimeter embankment may remain in the active zone and undergo freeze–thaw cycles, a review of the ROM geochemical data collected on the metavolcanic and granite samples that were handled as PAG rock indicates that these materials overall are non-AG with excess neutralizing potential (Table 2, Table 3, Attachment 2, Attachment 3).

The data indicate that vertical seepage through this material within the North Pile will not be able to produce appreciable acidity (due to the excess internal buffering capacity within the blended waste rock, and relative to the substantial excess buffering capacity of the surrounding PK) even if all of the sulphide minerals were to oxidize in a short time frame. For the west perimeter embankment, similar calculations show that oxidation and vertical seepage through this material will not be able to produce appreciable acidity internally within the blended waste rock even if all of the sulphide minerals were to oxidize in a short time frame.

As an added mitigation measure for the west perimeter embankment, a small amount of PK (toe berm of approximately 1 m in thickness extending 3 m laterally at the base of any seepage faces) should be placed which will supply excess buffering capacity in this area.

5.0 COVER DESIGN CRITERIA SUMMARY – CHEMICAL STABILITY

To maintain chemical stability of the North Pile at closure, the following measures are recommended for inclusion in the cover design criteria:

- Exclude possible PAG material from cover construction both on surface and on side slopes (rock containing more than 0.17% sulphide sulphur).
- As an added mitigation measure for the west perimeter embankment, place a small amount of PK (toe berm of approximately 1 m in thickness extending 3 m laterally, at the base of any seepage faces) to supply excess buffering capacity in this area.
6.0 CLOSING

The reader is referred to the Study Limitations, which follows the text and forms an integral part of this memorandum.

We trust the above meets your present requirements. If you have any questions or comments, please contact the undersigned.

Golder Associates Ltd.

Ken De Vos, M.Sc., P.Geo.
Principal, Senior Hydrogeochemist

Jeffrey Kwok, P.Eng.
Associate, Project Manager

KJD/EJK/cr

Attachments: Study Limitations
Attachment 1: ABA Results from Kimberlite for Run-of-mine Samples (2006 – 2015)
Attachment 2: ABA Results from Metavolcanic for Run-of-mine Samples (2004 – 2015)
Attachment 3: ABA Results from Granite for Run-of-mine Samples (2004 – 2015)

REFERENCES


STUDY LIMITATIONS

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of The De Beers Group of Companies. It represents Golder’s professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by The De Beers Group of Companies, and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. The De Beers Group of Companies may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.
ABA Results from Kimberlite for Run-of-mine Samples (2006 – 2015)
<table>
<thead>
<tr>
<th>SAMPLE ID</th>
<th>Year</th>
<th>Sample Type  (Product Samples)</th>
<th>Source</th>
<th>Rock Type</th>
<th>Sample Origin</th>
<th>MLA I D</th>
<th>Pk</th>
<th>CV (%)</th>
<th>Total Sulphur (wt %)</th>
<th>Hydrocarbons Potential (kg CO₂/ha)¹</th>
<th>Sulphate N P ¹</th>
<th>Acidity Potential (kg CO₂/ha)¹</th>
<th>Substrate Sulphur (wt %)</th>
<th>Substrate Acidity (wt %)</th>
<th>N, P, K Potential (kg CO₂/ha)¹</th>
<th>CAWP ¹</th>
<th>Mnl-pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-GC-70</td>
<td>2008</td>
<td>PK Coarse and Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00250</td>
<td>24.8</td>
<td>0.02</td>
<td>1.87</td>
<td>93.01</td>
<td>0.625</td>
<td>0.02</td>
<td>128.69</td>
<td>HKM</td>
<td>136.01</td>
<td>8.47</td>
<td></td>
</tr>
<tr>
<td>2008-GC-71</td>
<td>2008</td>
<td>PK Coarse and Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00249</td>
<td>121.4</td>
<td>0.02</td>
<td>1.6</td>
<td>90.25</td>
<td>0.625</td>
<td>0.02</td>
<td>147.78</td>
<td>HKM</td>
<td>133.3</td>
<td>8.48</td>
<td></td>
</tr>
<tr>
<td>2008-GC-72</td>
<td>2008</td>
<td>PK Coarse and Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00352</td>
<td>154.0</td>
<td>0.02</td>
<td>1.6</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>143.1</td>
<td>HKM</td>
<td>165.68</td>
<td>8.96</td>
<td></td>
</tr>
<tr>
<td>2008-GC-73</td>
<td>2008</td>
<td>PK Coarse and Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00356</td>
<td>145.61</td>
<td>0.04</td>
<td>1.7</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>142.0</td>
<td>HKM</td>
<td>260.1</td>
<td>9.40</td>
<td></td>
</tr>
<tr>
<td>2008-GC-74</td>
<td>2008</td>
<td>PK Coarse and Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00273</td>
<td>24.8</td>
<td>0.02</td>
<td>1.87</td>
<td>93.01</td>
<td>0.625</td>
<td>0.02</td>
<td>124.0</td>
<td>HKM</td>
<td>123.26</td>
<td>8.12</td>
<td></td>
</tr>
<tr>
<td>2008-GC-75</td>
<td>2008</td>
<td>PK Fines</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00922</td>
<td>9.78</td>
<td>0.02</td>
<td>1.87</td>
<td>93.01</td>
<td>0.625</td>
<td>0.02</td>
<td>111.3</td>
<td>HKM</td>
<td>97.41</td>
<td>7.04</td>
<td></td>
</tr>
<tr>
<td>2008-GC-76</td>
<td>2008</td>
<td>PK Fines</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00926</td>
<td>151.35</td>
<td>0.03</td>
<td>1.6</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>138.3</td>
<td>HKM</td>
<td>151.4</td>
<td>9.33</td>
<td></td>
</tr>
<tr>
<td>2008-GC-77</td>
<td>2008</td>
<td>PK Fines</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00940</td>
<td>111.45</td>
<td>0.03</td>
<td>1.6</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>134.7</td>
<td>HKM</td>
<td>147.3</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>2008-GC-78</td>
<td>2008</td>
<td>PK Fines</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00999</td>
<td>8.74</td>
<td>0.04</td>
<td>1.7</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>119.8</td>
<td>HKM</td>
<td>2011</td>
<td>8.76</td>
<td></td>
</tr>
<tr>
<td>2008-GC-79</td>
<td>2008</td>
<td>PK Fines</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A01413</td>
<td>8.28</td>
<td>0.07</td>
<td>1.6</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>8.26</td>
<td>HKM</td>
<td>8.25</td>
<td>8.43</td>
<td></td>
</tr>
<tr>
<td>2008-GC-80</td>
<td>2008</td>
<td>PK Fines</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A01419</td>
<td>7.00</td>
<td>0.07</td>
<td>1.6</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>7.00</td>
<td>HKM</td>
<td>7.00</td>
<td>8.47</td>
<td></td>
</tr>
<tr>
<td>2008-GC-81</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00250</td>
<td>22.3</td>
<td>0.02</td>
<td>1.6</td>
<td>90.25</td>
<td>0.625</td>
<td>0.02</td>
<td>123.26</td>
<td>HKM</td>
<td>128.69</td>
<td>8.18</td>
<td></td>
</tr>
<tr>
<td>2008-GC-82</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00249</td>
<td>31.8</td>
<td>0.02</td>
<td>1.6</td>
<td>90.25</td>
<td>0.625</td>
<td>0.02</td>
<td>97.41</td>
<td>HKM</td>
<td>136.01</td>
<td>8.47</td>
<td></td>
</tr>
<tr>
<td>2008-GC-83</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00352</td>
<td>121.4</td>
<td>0.02</td>
<td>1.6</td>
<td>90.25</td>
<td>0.625</td>
<td>0.02</td>
<td>147.78</td>
<td>HKM</td>
<td>133.9</td>
<td>8.98</td>
<td></td>
</tr>
<tr>
<td>2008-GC-84</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00356</td>
<td>145.61</td>
<td>0.04</td>
<td>1.7</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>144.7</td>
<td>HKM</td>
<td>248.2</td>
<td>9.45</td>
<td></td>
</tr>
<tr>
<td>2008-GC-85</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00273</td>
<td>9.78</td>
<td>0.02</td>
<td>1.87</td>
<td>93.01</td>
<td>0.625</td>
<td>0.02</td>
<td>8.26</td>
<td>HKM</td>
<td>118.7</td>
<td>8.48</td>
<td></td>
</tr>
<tr>
<td>2008-GC-86</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00922</td>
<td>151.35</td>
<td>0.03</td>
<td>1.6</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>138.3</td>
<td>HKM</td>
<td>151.4</td>
<td>9.33</td>
<td></td>
</tr>
<tr>
<td>2008-GC-87</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00926</td>
<td>111.45</td>
<td>0.03</td>
<td>1.6</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>134.7</td>
<td>HKM</td>
<td>147.3</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>2008-GC-88</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00940</td>
<td>8.74</td>
<td>0.04</td>
<td>1.7</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>119.8</td>
<td>HKM</td>
<td>2011</td>
<td>8.76</td>
<td></td>
</tr>
<tr>
<td>2008-GC-89</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A00999</td>
<td>7.00</td>
<td>0.07</td>
<td>1.6</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>7.00</td>
<td>HKM</td>
<td>7.00</td>
<td>8.47</td>
<td></td>
</tr>
<tr>
<td>2008-GC-90</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A01413</td>
<td>7.00</td>
<td>0.07</td>
<td>1.6</td>
<td>90.08</td>
<td>0.625</td>
<td>0.02</td>
<td>7.00</td>
<td>HKM</td>
<td>7.00</td>
<td>8.47</td>
<td></td>
</tr>
<tr>
<td>2008-GC-91</td>
<td>2008</td>
<td>PK Grits</td>
<td>De Beers Geology</td>
<td>Kimberlite</td>
<td>2009</td>
<td>A01419</td>
<td>22.3</td>
<td>0.02</td>
<td>1.6</td>
<td>90.25</td>
<td>0.625</td>
<td>0.02</td>
<td>123.26</td>
<td>HKM</td>
<td>128.69</td>
<td>8.18</td>
<td></td>
</tr>
<tr>
<td>SAMPLE ID</td>
<td>Year</td>
<td>Source</td>
<td>Rock Type</td>
<td>Sample Origin</td>
<td>HOLE ID</td>
<td>Paste</td>
<td>Neutralization</td>
<td>Total Buffer (Kg CaCO₃/t)</td>
<td>Neutralization Potent (Kg CaCO₃/t)</td>
<td>Total Buffer (Kg CaCO₃/t)</td>
<td>Neutralization Potent (Kg CaCO₃/t)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>--------</td>
<td>-----------</td>
<td>---------------</td>
<td>---------</td>
<td>-------</td>
<td>---------------</td>
<td>--------------------------</td>
<td>----------------------------------</td>
<td>--------------------------</td>
<td>----------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142074</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142075</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142076</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142077</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142078</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142079</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142080</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142081</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142082</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142083</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142084</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142085</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142086</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142087</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142088</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142089</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142090</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142091</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142092</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142093</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142094</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142095</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20142096</td>
<td>2015</td>
<td>De Beers Geology</td>
<td>PK Coarse and Grits</td>
<td>Paste</td>
<td>2015</td>
<td>6.6</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Where laboratory values were reported as non-detect, calculations were completed using the detection limit values.
ABA Results from Metavolcanic for Run-of-mine Samples (2004 – 2015)
<table>
<thead>
<tr>
<th>ID</th>
<th>Year</th>
<th>Samples (Probe samples include)</th>
<th>Source</th>
<th>Rock Type</th>
<th>Sample Type</th>
<th>HOLE ID</th>
<th>Posts</th>
<th>pHe</th>
<th>CO2</th>
<th>Total Buffer (wt %)</th>
<th>NP</th>
<th>Calcium NP</th>
<th>Acidic Potential (kg CaO/100g)</th>
<th>Surface Buffer (wt %)</th>
<th>Balance Buffer (wt %)</th>
<th>10N Na+</th>
<th>10N Ca+</th>
<th>10N Mg+</th>
<th>10N K+</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006-GC-31</td>
<td>2006</td>
<td>2006 ARD Metavolcanic: Dilution Rock Pad</td>
<td></td>
<td>Metavolcanic: Dilution Rock Pad</td>
<td>Surface</td>
<td>8.59</td>
<td>0.19</td>
<td>0.03</td>
<td>12.16</td>
<td>4.32</td>
<td>26.19</td>
<td>0.01</td>
<td>1.93</td>
<td>18.96</td>
<td>0.41</td>
<td>0.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006-GC-32</td>
<td>2006</td>
<td>2006 ARD Metavolcanic: Dilution Rock Pad</td>
<td></td>
<td>Metavolcanic: Dilution Rock Pad</td>
<td>Surface</td>
<td>7.89</td>
<td>1.41</td>
<td>0.88</td>
<td>79.06</td>
<td>80.06</td>
<td>2.90</td>
<td>0.01</td>
<td>0.08</td>
<td>71.46</td>
<td>20.56</td>
<td>12.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008-GC-84</td>
<td>2008</td>
<td>2008 ARD Metavolcanic: Vent raise</td>
<td></td>
<td>Metavolcanic: Vent raise</td>
<td>Surface</td>
<td>8.49</td>
<td>0.30</td>
<td>0.07</td>
<td>11.66</td>
<td>4.55</td>
<td>2.10</td>
<td>0.01</td>
<td>0.07</td>
<td>8.41</td>
<td>0.38</td>
<td>2.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009-GC-5</td>
<td>2009</td>
<td>2009 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>6.1</td>
<td>0.92</td>
<td>1.90</td>
<td>15.3</td>
<td>0.5</td>
<td>30.2</td>
<td>0.03</td>
<td>0.07</td>
<td>14.9</td>
<td>0.5</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009-GC-4</td>
<td>2009</td>
<td>2009 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>6.0</td>
<td>0.31</td>
<td>0.96</td>
<td>12.1</td>
<td>0.2</td>
<td>29.0</td>
<td>0.03</td>
<td>0.09</td>
<td>15.0</td>
<td>0.4</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012-GC-7</td>
<td>2012</td>
<td>2012 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>6.8</td>
<td>0.91</td>
<td>0.99</td>
<td>11.3</td>
<td>0.2</td>
<td>1.9</td>
<td>0.03</td>
<td>0.06</td>
<td>9.4</td>
<td>0.9</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015-GC-10</td>
<td>2015</td>
<td>2015 ARD Metavolcanic: Dilution Rock Pad</td>
<td></td>
<td>Metavolcanic: Dilution Rock Pad</td>
<td>Surface</td>
<td>6.8</td>
<td>0.34</td>
<td>0.30</td>
<td>11.3</td>
<td>0.0</td>
<td>6.0</td>
<td>0.01</td>
<td>0.10</td>
<td>5.3</td>
<td>1.0</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015-GC-11</td>
<td>2015</td>
<td>2015 ARD Metavolcanic: Dilution Rock Pad</td>
<td></td>
<td>Metavolcanic: Dilution Rock Pad</td>
<td>Surface</td>
<td>8.7</td>
<td>0.36</td>
<td>0.26</td>
<td>14.9</td>
<td>1.4</td>
<td>6.1</td>
<td>0.02</td>
<td>0.26</td>
<td>6.7</td>
<td>1.8</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-GC-13</td>
<td>2016</td>
<td>2016 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>0.3</td>
<td>0.06</td>
<td>0.76</td>
<td>19.5</td>
<td>6.1</td>
<td>24.4</td>
<td>0.01</td>
<td>24.08</td>
<td>4.9</td>
<td>0.8</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-GC-14</td>
<td>2016</td>
<td>2016 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>0.3</td>
<td>0.13</td>
<td>19.9</td>
<td>2.5</td>
<td>4.1</td>
<td>0.01</td>
<td>4.06</td>
<td>15.9</td>
<td>4.9</td>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-GC-22</td>
<td>2016</td>
<td>2016 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>5.8</td>
<td>0.11</td>
<td>10.2</td>
<td>10.2</td>
<td>5.4</td>
<td>0.01</td>
<td>5.01</td>
<td>7.1</td>
<td>2.5</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-GC-30</td>
<td>2016</td>
<td>2016 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>5.6</td>
<td>0.13</td>
<td>20.1</td>
<td>11.9</td>
<td>3.0</td>
<td>0.01</td>
<td>3.19</td>
<td>5.1</td>
<td>1.9</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-GC-31</td>
<td>2016</td>
<td>2016 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>6.9</td>
<td>0.36</td>
<td>0.10</td>
<td>10.3</td>
<td>1.4</td>
<td>3.1</td>
<td>0.01</td>
<td>3.10</td>
<td>7.1</td>
<td>2.3</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-GC-32</td>
<td>2016</td>
<td>2016 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>6.8</td>
<td>0.11</td>
<td>0.16</td>
<td>10.2</td>
<td>2.5</td>
<td>5.6</td>
<td>0.01</td>
<td>5.19</td>
<td>6.0</td>
<td>2.2</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016-GC-33</td>
<td>2016</td>
<td>2016 ARD Metavolcanic: One general material near volcanoclastic rock pad</td>
<td></td>
<td>Metavolcanic: One general material near volcanoclastic rock pad</td>
<td>Surface</td>
<td>0.7</td>
<td>0.36</td>
<td>3.15</td>
<td>10.4</td>
<td>1.4</td>
<td>5.9</td>
<td>0.01</td>
<td>3.19</td>
<td>4.9</td>
<td>1.0</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Where laboratory values were reported as non-detect, calculations were completed using the detection limit values.
ABA Results from Granite for Run-of-mine Samples (2004 – 2015)
<table>
<thead>
<tr>
<th>Unit ID</th>
<th>Year</th>
<th>Source</th>
<th>Rock Type</th>
<th>Assay Origin</th>
<th>AGR</th>
<th>OBM</th>
<th>Total AGR (mg/kg)</th>
<th>Extractable AGR (mg/kg gold)</th>
<th>Oxidation AGR (mg/kg gold)</th>
<th>Sample Name</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>00001</td>
<td>2007</td>
<td>ARD</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>7.6</td>
<td>0.01</td>
<td>0.05</td>
<td>3.9</td>
<td>0.6</td>
<td>1320075149</td>
<td>A00212</td>
</tr>
<tr>
<td>00002</td>
<td>2008</td>
<td>ARD</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>8.9</td>
<td>0.1</td>
<td>0.01</td>
<td>0.02</td>
<td>0.0</td>
<td>4.7</td>
<td>A00212</td>
</tr>
<tr>
<td>00003</td>
<td>2009</td>
<td>ARD</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>8.5</td>
<td>0.1</td>
<td>0.02</td>
<td>0.02</td>
<td>0.0</td>
<td>4.7</td>
<td>A00212</td>
</tr>
<tr>
<td>00004</td>
<td>2010</td>
<td>ARD</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>8.6</td>
<td>0.1</td>
<td>0.02</td>
<td>0.02</td>
<td>0.0</td>
<td>4.7</td>
<td>A00212</td>
</tr>
<tr>
<td>00005</td>
<td>2011</td>
<td>ARD</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>8.7</td>
<td>0.1</td>
<td>0.02</td>
<td>0.02</td>
<td>0.0</td>
<td>4.7</td>
<td>A00212</td>
</tr>
</tbody>
</table>

**Note:**
- AGR: Acid-Reduced Gold
- OBM: Oxidation Background Material
- Total AGR (mg/kg): Total Acid-Reduced Gold in mg/kg
- Extractable AGR (mg/kg gold): Extractable Acid-Reduced Gold in mg gold/kg
- Oxidation AGR (mg/kg gold): Oxidation Acid-Reduced Gold in mg gold/kg
- Sample Name: Name of the sample collected for analysis.
|------------|------|--------------|--------|-----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-----------|-----------|-----------|-----------|-----------|-----------|

Note: Where laboratory values were reported as non-detect, calculations were completed using the detection limit values.
1.0 INTRODUCTION

This technical memorandum has been prepared for De Beers Group of Companies (De Beers) by Golder Associates Ltd. (Golder) to summarize a closure cover alternatives analysis performed in support of the Snap Lake Mine (Mine) North Pile facility closure cover design. The North Pile facility (Figure 1) is currently under extended care and maintenance (ECM) and is anticipated to enter closure within two years. The ERM Consultants (ERM) high level cover options analysis (ERM 2017) and Golder’s design constraints and criteria draft report (Golder 2018) were used as guidance for the development of closure cover alternatives.

The North Pile Facility was designed in three cells: the Starter Cell, East Cell, and West Cell. The West Cell was not fully developed, leaving the west perimeter embankment of the East and Starter cells exposed. Closure cover alternatives were initially screened based on technical, environmental, and economic qualitative criteria to identify those with the greatest chance to achieve the defined cover objectives and criteria summarized herein. Cover for the west perimeter embankment was screened separately from the rest of the North Pile Facility (main area) to address differing physical and chemical characteristics of the existing materials. Profile-level designs were advanced to permit a quantitative evaluation and comparison for alternatives that passed the initial screening. Preliminary recommendations are provided for the alternatives to be advanced to a pre-feasibility level design, and include input obtained from De Beers during the 29 March 2018 cover design alternatives meeting.

2.0 BACKGROUND

A summary of background information relevant to the cover design, including design objectives, design basis, and design criteria, is provided in Golder’s design constraints and criteria draft report (Golder 2018), currently under review by De Beers. Arktis Solutions (Arktis) prepared a draft revision to the site-wide interim closure and reclamation plan for the Mine (Arktis 2017). The current cover design for the North Pile Facility includes placement of a 0.5 m thick non-acid generating (non-AG) rock cover over the waste rock, processed kimberlite (PK), rockfill, and landfill materials to minimize infiltration and exposure to the environment.
The North Pile Facility includes the Starter and East cells, and covers an approximate area of 510,000 m². The Starter Cell was divided into eight sub-cells: Cell A, Cell B, Cell C, Cell D, Cell E, Cell F, Cell SQ, and Cell LF. The East Cell was divided into five sub-cells: Cell 1, Cell 2, Cell 3, Cell 4, and Cell 5. The average annual air temperature at the North Pile Facility location is -7.7°C for the period from 2001 to 2013 (Golder 2014). Average annual precipitation of 148 mm and 225 mm is based on the surrounding Yellowknife and Lupin climate stations, respectively (Golder 2014). The North Pile Facility has a Canadian Dam Association hazard classification of high, indicating that significant loss or deterioration of a habitat is a consequence of failure (CDA 2013).

2.1 Previous Closure Activities

Two cover test pads were constructed overlying the PK material located in the southwest corner of the Starter Cell to obtain performance data to estimate infiltration and evaluate design options in 2011 (Arktis 2017). Data collected from thermistors installed at both test pad locations to a depth of 2 m below ground surface indicated the active permafrost layer extended through the entire sensor depth.

A 50% rock cover design was completed for the Starter Cell in 2014 but was not advanced to a complete design level (Arktis 2017).

A 0.3 to 0.5 m thick non-AG waste rock material erosion protection layer was installed on the downstream 3 horizontal to 1 vertical (3H:1V) North Pile (Starter Cell and East Cell) perimeter embankment slopes and a portion of the Starter Cell crest.

ERM performed a high level cover options analysis using a multiple accounts analysis (MMA) approach (ERM 2017). Thirteen alternative closure approaches were screened, and preferred options included rock fill, low permeability cover (i.e., soil and geosynthetic), and no cover. The preferred MMA alternatives were included as part of this closure cover alternatives analysis.

2.2 Underlying Materials

The following materials are located within the North Pile Facility and will underlie the closure cover:

- PK
- waste rock
- rockfill
- landfill
The PK material has a low permeability, is susceptible to wind erosion, and the retained water is prone to freezing. PK is generally not reactive, considered non-AG, and is assumed to have minimal impact on contact water quality. The combined coarse and grits PK fractions were used in construction of the Starter and East cells (i.e., rib berms, divider dyke, perimeter embankments). Fine PK material was deposited as a slurry within the Starter Cell from 2007 to 2014, and in the East Cell from 2014 to 2015.

Waste rock is categorized as both potentially acid generating (PAG) and non-AG material, and was used in the construction of the North Pile Facility embankments. A combination of PAG and non-AG materials were used for construction of the west perimeter embankment, which was intended to be enclosed by the West Cell. However, the PAG and non-AG waste rock materials are currently exposed as the West Cell was not developed.

In general, Non-AG rockfill material was used for construction of the lower perimeter Starter Cell embankment and placed as an erosion protection layer on the outer embankments and portions of the crest of the Starter Cell. PAG rockfill material was used for construction on the lower west embankment of the Starter Cell.

Landfill material was placed within the closed Cell LF of the Starter Cell, and within Cell 1 of the East Cell. The remaining capacity of Cell 1 will be used for demolition waste disposal. This material is subject to differential settlement and is prone to consolidation under loading conditions.

2.3 Borrow Sources

Potential borrow sources for cover material have been identified and are classified as on-site and off-site sources. Selection of a borrow source will be dependent on the closure alternative(s) chosen for advancement to a pre-feasibility level design.

On-site borrow sources include non-AG rockfill, waste rock, PK, and organic materials. Rockfill material may be excavated from the SP5, water management pond, and apron quarries, or obtained from within wetland and fill pad locations. Waste rock and PK coarse and grits materials may be excavated from the constructed rib berms and West Cell Divider Dyke. Organics may be obtained from the stockpile located southeast of the North Pile Facility.

Off-site borrow sources include imported fills and synthetic materials. Synthetic materials such as bituminous geomembrane liner, high-density polyethylene, and geotextiles may be considered during the closure cover analysis. Off-site sources are subject to hauling transport via the winter road.

3.0 CLOSURE COVER

Closure cover alternatives were identified for the North Pile Facility and screened to identify a preferred alternative, based on their ability to meet the closure objectives and design criteria (Golder 2018). Closure cover alternatives for the west perimeter embankment were screened separately from the rest of the North Pile Facility (main area) to address differing physical and chemical characteristics of the existing materials.
3.1 Objectives and Criteria

Design objectives specific to the closure cover include the following:

- Isolate PK waste material from the environment.
- Minimize water and wind erosion.
- Promote runoff and reduce infiltration.

Design criteria specific to the closure cover include the following:

- Prevent wind erosion and minimize dust generation to not exceed the Northwest Territories Ambient Air Quality Standards and Alberta Ambient Air Quality Guidelines.
- Maintain chemical stability such that PAG material is excluded from use as cover, excluded 3 m from the closure surface, and from within 50 m of the North Pile Facility downstream toe.
- Reduce infiltration to site water quantity and quality criteria.
- Prevent ponding of water as a result of differential settlement.
- Integrate design with ECM strategies and designs.

Water, wind, and freeze–thaw cycles will influence the selection of a closure cover alternative. The closure cover must be capable of withstanding runoff generated during the peak maximum precipitation, 24-hour design storm event, while minimizing infiltration and interaction with the underlying material. Additionally, the closure cover must resist wind and water erosion to maintain the constructed closure configuration, minimize dust transport, and prevent material migration outside of the North Pile Facility footprint.

The closure cover should accommodate existing field conditions to prevent design revisions during construction. The closure cover design must be constructible using established construction techniques and account for the equipment available on site. Differential settlement of the underlying is expected to occur within localized areas, and should be accounted for to maintain integrity and preserve the design intent of the closure cover.
3.2 Placement Locations
A closure cover will be placed over the main area of the North Pile Facility and the side-slope of the west perimeter embankment. Alternatives were screened for the two areas independently to address differing physical and chemical characteristics of the existing materials. The main area includes non-AG PK and landfill materials, and extends an approximate area of 375,000 m². The review of the background information indicated that the material placed in the embankment that was handled as PAG rock are on an overall basis non-AG with excess neutralizing potential. Vertical seepage through this material would not be able to produce appreciable acidity. As an additional mitigating measure, an assessment (attachment 1) suggests providing excess buffering capacity at the toe of the embankment, using PK material. An embankment 1 m thick extending 3 m laterally from the toe could supply this excess capacity.

4.0 RESULTS
Closure cover alternatives were screened for both the main area and the west perimeter embankment of the North Pile Facility. Detailed screening results are provided in Table A-1, attached, and summarized in Sections 5.1 and 5.2.

4.1 Main Area
Five closure cover options were screened out for the main area of the North Pile Facility, while two options (Alternative 2: Rock Cover and Alternative 7: Revegetation Cover) were selected for further evaluation. Results from the main area closure cover alternatives screening are summarized in Table 1.

Table 1: Closure Cover Screening Results Summary for the Main Area

<table>
<thead>
<tr>
<th>Cover</th>
<th>Screening Criteria Rating</th>
<th>Overall Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Technical</td>
<td>Environmental</td>
</tr>
<tr>
<td>Alternative 1: No Cover</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Alternative 2: Rock Cover</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Alternative 3: Thick Cover</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Alternative 4: Cover with Capillary Barrier</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Alternative 5: Cover with Low Permeability Soil</td>
<td>Fair</td>
<td>Good</td>
</tr>
</tbody>
</table>
The options that were screened out for the main area, along with the reasons for excluding them, are listed below. The options selected for further evaluation are presented in Sections 5.1.1 and 5.1.2.

- **Alternative 1: No Cover** – This alternative is unlikely to receive regulatory support as it does not provide environmental protection from erosion or for water quality.

- **Alternative 3: Thick Cover** – This alternative provides significant isolation than is likely required for PK material, and at a high cost.

- **Alternative 4: Cover with Capillary Barrier** – This alternative is unlikely to perform better than rock cover (Alternative 2), and would require further evaluation to determine material suitability for use as a capillary barrier. Cost would also likely be higher.

- **Alternative 5: Cover with Low Permeability Soil** – This alternative is unlikely to perform better than rock cover (Alternative 2), and there are no known on-site borrow sources for clay.

- **Alternative 6: Geosynthetic Cover** – This alternative provides significant isolation than is likely required for PK material, and has a very high cost. Procurement and installation of the geosynthetic on schedule may also be challenging.

### 4.1.1 Alternative 2: Rock Cover

Alternative 2: Rock Cover was identified as a potential closure cover alternative for the main area of the North Pile Facility. The main area will be regraded to direct runoff and promote long-term stability. The drainage configuration will be advanced during profile design to be compatible with the ECM drainage design. The closure cover will include placement of an estimated 187,500 m³ non-AG waste rock and/or rockfill cover to a nominal thickness of 0.5 m. The existing rib berms may be flattened to generate 122,000 m³ of non-AG material, with the remaining 65,500 m³ cover quantity obtained from within identified borrow sources. Validation is needed to confirm the rib berm material is non-AG.
Further evaluation of the cover is needed to confirm total thickness. Differential settlement may occur within the landfill cells due to consolidation of the underlying material over time or under loading with the placement of cover material. This alternative uses conventional construction methods, provides erosion resistance and water quality protection, and is less costly than other screened alternatives.

### 4.1.2 Alternative 7: Revegetation Cover

Alternative 7: Revegetation Cover was identified as a potential closure cover alternative for the main area of the North Pile Facility. The main area will be regraded to direct runoff and promote long-term stability. The drainage configuration will be advanced during profile design to be compatible with the ECM drainage design. The closure cover will include placement of an estimated 112,500 m³ soil cover to a thickness of 30 cm. The closure cover will be revegetated to minimize erosion. Climate-suitable, fast-growing vegetation species will be considered, and temporary erosion controls will be designed for use until the cover is established. Regular cover maintenance is likely to be required until vegetation is established.

Multi-year closure cover test plots are generally used to demonstrate vegetation compatibility, prior to cover placement over an entire facility. This could delay closure cover placement and will influence construction timing. Soil loss rates under normal and extreme precipitation events will be evaluated during pre-feasibility level design if this alternative is selected for advancement. This alternative uses conventional construction methods, provides some erosion resistance and water quality protection and is less costly than other screened alternatives.

### 4.2 West Perimeter Embankment

Four closure cover options were screened out for the west perimeter embankment, while three options (Alternative 1: No Cover, Alternative 2: Rock Cover, and Alternative 3: Thick Cover) were selected for further evaluation. Results from the west perimeter embankment closure cover alternatives screening are summarized in Table 2.

Table 2: Closure Cover Screening Results Summary for the West Perimeter Embankment

<table>
<thead>
<tr>
<th>Cover</th>
<th>Screening Criteria Rating</th>
<th>Overall Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Technical</td>
<td>Environmental</td>
</tr>
<tr>
<td>Alternative 1 No Cover</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Alternative 2 Rock Cover</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Alternative 3 Thick Cover</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>
The options that were screened out for the west perimeter embankment, along with the reasons for excluding them, are listed below. The options selected for further evaluation are presented in Sections 5.2.1 to 5.2.3.

- **Alternative 4: Cover with Capillary Barrier** – The primary benefit of a capillary barrier is infiltration reduction. As the geochemical analysis showed that infiltration into the west embankment is unlikely to generate ARD, the capillary barrier is unlikely to provide benefits over the rock cover (Alternative 2), and would require further evaluation to determine material suitability for use as a capillary barrier, and would be more expensive to implement.

- **Alternative 5: Cover with Low Permeability Soil** – As a low permeability layer is not needed for chemical stability, this alternative is unlikely to perform better than rock cover (Alternative 2). Further, there is no known on-site borrow source for clay.

- **Alternative 6: Geosynthetic Cover** – This alternative provides more isolation than is required for the embankment material, and at a very high cost. Procurement the geosynthetic may negatively impact the overall project schedule, and placement of the cover on the relatively steep embankment slopes could be technically challenging.

- **Alternative 7: Revegetation Cover** – This alternative uses conventional construction methods but is unlikely to provide sufficient erosion resistance and water quality protection when placed on a steep slope.

### 4.2.1 Alternative 1: No Cover

Alternative 1: No Cover was identified as a potential closure cover alternative for the west perimeter embankment. This alternative requires no construction activities or materials, and is the least costly of the screened alternatives, but may leave embankment material vulnerable to erosion.
4.2.2 Alternative 2: Rock Cover

Alternative 2: Rock Cover was identified as a potential closure cover alternative for the west perimeter embankment. The embankment slope will be flattened (3H:1V or similar) to promote long-term stability. The closure cover will include placement of an estimated 67,500 m³ non-AG waste rock and/or rockfill cover to a thickness of 0.5 m. Further evaluation of the cover is needed to confirm total thickness, and the cover quantity will be obtained from within identified borrow sources. Validation is needed to confirm the embankment material requires cover prior to adopting this strategy. This alternative uses conventional construction methods, provides erosion resistance and water quality protection, and is less costly than other screened alternatives.

4.2.3 Alternative 3: Thick Cover

Alternative 3: Thick Cover was identified as a potential closure cover alternative for the west perimeter embankment. The embankment slope will be flattened (3H:1V or similar) to promote long-term stability. The closure cover will include placement of an estimated 405,000 m³ of non-AG waste rock and/or rockfill cover to a thickness of 3 m, in order to confine the active layer within the cover, providing a high degree of isolation. The cover quantity will be obtained from within identified borrow sources. Validation is needed to confirm the embankment material requires cover, and the degree of isolation provided by a thick cover, prior to adopting this strategy. This alternative uses conventional construction methods and provides significant isolation of the underlying embankment from runoff and infiltration.

5.0 PRELIMINARY RECOMMENDATIONS

Golder recommends placement of a closure cover over the PK, landfill, and PAG materials to promote long-term stability of the North Pile Facility. A cover constructed with non-AG waste rock should be suitable for the cover of both the main area of the North Pile, and the west embankment. Further detail on the recommended cover approaches is provided in the following subsections.

5.1 Main Area Closure Cover

Placement of a rock cover (Alternative 2) over the PK, landfill, and PAG materials is recommended to maintain geochemical stability and prevent dust generation and/or erosion of the main area. Construction of the cover will require regrading of the main area of the North Pile Facility to direct runoff and promote long-term geotechnical stability. The regrade design surface will need to accommodate placement of an additional 350,000 m³ of landfill material within Cells 1 through 5 of the East Cell. Profile design for Alternative 2: Rock Cover is in progress to minimize regrade of the existing facility and provide positive drainage.
A nominal cover thickness of 0.5 m has been considered for the comparison of cover alternatives. However, the design cover thickness will be evaluated and optimized considering gradient and runoff velocity during pre-feasibility level design. As part of the construction of this cover, it is anticipated that the existing rib berm material will be used in cover construction. The non-AG status of this material will need to be confirmed prior to its use as closure cover.

Use of a vegetative cover (Alternative 7) is not recommended due to additional design considerations beyond the rock cover (Alternative 2). Temporary erosion controls would be required until the vegetation cover is established, and significant work would be required in support of vegetation establishment, monitoring, and erosion control. There is also uncertainty with respect to the amount of organic soil available, considering construction needs (112,500 m³), plus contingency volumes for the repair of erosion damage following major storm events. Finally, multi-year closure cover test plots are generally used to select species and demonstrate the success of vegetation for erosion control, prior to revegetation of an entire facility. If implemented, a test plot program would significantly delay the start of cover placement.

5.2 West Perimeter Embankment Closure Cover

Placement of a rock cover (Alternative 2) over the embankment is recommended, similar to the recommendations for the main area. As part of the cover placement, flattening of the west perimeter embankment slope is expected to promote long-term geotechnical stability. The slope angle will be evaluated and optimized considering runoff velocity and stability during pre-feasibility level design.

Depending on the surface grain size distribution, it may be possible to opt for no cover placement (Alternative 1), if the surface materials are sufficiently coarse and durable (erosion resistant). This approach could be adopted for limited portions of the slope, with rock cover (Alternative 2) placed only where finer-grained material is present. A thick rock cover (Alternative 3) is not required, as there is no need to provide the associated degree of thermal isolation for the embankment materials.

A nominal cover thickness of 0.5 m has been considered for the comparison of cover alternatives. However, the design cover thickness will be evaluated and optimized considering gradient and runoff velocity during pre-feasibility level design. The cover thickness will be evaluated and optimized considering runoff velocity and geochemical stability during pre-feasibility level design.

Based on the results of the geochemical assessment (Attachment 1), a non-AG toe berm along the downstream face of the west embankment is also recommended to provide excess buffering capacity for any seepage. The nominal dimensions of this toe berm would be 1 m high by 3 m wide (and estimated 1,500 m³ non-AG waste rock and/or rockfill). It is possible that portions of the existing perimeter road would fulfil this function. This should be validated as part of the next stage of design.
6.0 NEXT STEPS

Profile designs are in development for regrade of the North Pile Facility. These profile designs consider the recommended cover, and a configuration that will accommodate placement of an additional 350,000 m$^3$ of landfill material within Cells 1 through 5 of the East Cell. The next steps to advance toward development of a pre-feasibility level design for the selected closure cover option are as follows:

- Review and confirm the profile design(s) achieve the desired landfill material storage, direct runoff off the North Pile, and minimize facility regrade quantities.
- Develop material take-offs for the selected options.
- Integrate the closure cover with the optimized ECM surface water management plan, mine decommissioning plan and debris landfilling schedule, and passive water treatment system.
- Incorporate predicted consolidation and settlement with the closure cover design.
- Confirm design compliance with existing conditions during a May site visit.
7.0 CLOSING

We trust the above meets your present requirements. If you have any questions or comments, please contact the undersigned.

Golder Associates Ltd.

ORIGINAL SIGNED

Jeffrey Kwok, P.Eng.
Associate, Senior Geotechnical Engineer

JEW/cr

ORIGINAL SIGNED AND SEALED

Bjorn Weeks, Ph.D., P.Eng.
Principal, Geo-Environmental Engineer

Attachments:
- Table A-1: Closure Cover Screening for the North Pile Facility
- Figure 1: Overall Site Plan: North Pile Layout and Potential Borrow Sources for Cover Construction
- Attachment 1: ARD Review

REFERENCES


## Table A-1: Closure Cover Screening for the North Pile Facility

<table>
<thead>
<tr>
<th>Cover Description</th>
<th>Criteria</th>
<th>Main Area</th>
<th>Rating</th>
<th>Overall</th>
<th>West Perimeter Embankment</th>
<th>Rating</th>
<th>Overall</th>
<th>Cost:</th>
<th>Cost:</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alternative 1</em> No Cover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$ (No Cost)</td>
<td>$ (No Cost)</td>
</tr>
<tr>
<td><em>Technical</em></td>
<td>Construction Materials: None</td>
<td>Good</td>
<td>No</td>
<td>Environmental and Regulatory Concerns</td>
<td>Construction Materials: None</td>
<td>Good</td>
<td>Yes</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td></td>
<td>Water Quality: water contact with PK (runoff and/or infiltration)</td>
<td>Poor</td>
<td>Environmental and Regulatory Concerns</td>
<td>Water Quality: water contact with PK (runoff and/or infiltration)</td>
<td>Poor</td>
<td>Environmental and Regulatory Concerns</td>
<td>$</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td><em>Economic</em></td>
<td>Cost: $ (No Cost)</td>
<td>$ (No Cost)</td>
<td>$ (No Cost)</td>
<td>$ (No Cost)</td>
<td>$ (No Cost)</td>
<td>$ (No Cost)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Alternative 2</em> Rock Cover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td><em>Technical</em></td>
<td>Construction Materials: Non-AG material estimate 187,500 m³ (375,000 m² cover area, 0.5 m thickness). On-site borrow, may supplement with excavated rib berm material.</td>
<td>Good</td>
<td>Yes</td>
<td>Environmental and Regulatory Concerns</td>
<td>Construction Materials: Non-AG material estimate 67,500 m³ (135,000 m² cover area, 0.5 m thickness). On-site borrow.</td>
<td>Good</td>
<td>Yes</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td></td>
<td>Erosion: Water and wind erosion controls, decreased potential for dust generation.</td>
<td>Good</td>
<td>Yes</td>
<td>Environmental and Regulatory Concerns</td>
<td>Erosion: Water and wind erosion controls, decreased potential for dust generation.</td>
<td>Good</td>
<td>Yes</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td></td>
<td>Water Quality: Decreased potential for water contact with PK (runoff and/or infiltration). Reduced active zone in underlying PK, proportionate to cover thickness.</td>
<td>Good</td>
<td>Yes</td>
<td>Environmental and Regulatory Concerns</td>
<td>Water Quality: Decreased potential for water contact with PK (runoff and/or infiltration). Reduced active zone in underlying PK, proportionate to cover thickness.</td>
<td>Good</td>
<td>Yes</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td><em>Economic</em></td>
<td>Cost: $ $ $ $ $</td>
<td>$ $ $ $ $</td>
<td>$ $ $ $ $</td>
<td>$ $ $ $ $</td>
<td>$ $ $ $ $</td>
<td>$ $ $ $ $</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Alternative 3</em> Thick Cover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td><em>Technical</em></td>
<td>Construction Materials: Non-AG material estimate 1.13 Mm³ (375,000 m² cover area, 3 m thickness). May require new on-site borrow source identification and development.</td>
<td>Poor</td>
<td>No</td>
<td>Environmental and Regulatory Concerns</td>
<td>Construction Materials: Non-AG material estimate 405,000 m³ (135,000 m² cover area, 3 m thickness). May require new on-site borrow source identification and development.</td>
<td>Poor</td>
<td>No</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td></td>
<td>Erosion: Water and wind erosion controls, significantly decreased potential for dust generation.</td>
<td>Good</td>
<td>Large financial investment to encapsulate fine-grained, low permeability non-AG PK material.</td>
<td>Erosion: Water and wind erosion controls, significantly decreased potential for dust generation.</td>
<td>Good</td>
<td>Yes</td>
<td>$</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water Quality: Slightly decreased potential for water contact with PK (runoff and/or infiltration). Isolation of underlying material within proymafrost.</td>
<td>Good</td>
<td>Large financial investment to encapsulate fine-grained, low permeability non-AG PK material.</td>
<td>Water Quality: Slightly decreased potential for water contact with PK (runoff and/or infiltration). Isolation of underlying material within permafrost.</td>
<td>Good</td>
<td>Yes</td>
<td>$</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td><em>Economic</em></td>
<td>Cost: $ $ $ $ $ $ $</td>
<td>$ $ $ $ $ $ $</td>
<td>$ $ $ $ $ $ $</td>
<td>$ $ $ $ $ $ $</td>
<td>$ $ $ $ $ $ $</td>
<td>$ $ $ $ $ $ $</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Alternative 4</em> Cover with Capillary Barrier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td><em>Technical</em></td>
<td>Construction Materials: Non-AG material estimate 187,500 m³ (375,000 m² cover area, 0.5 m thickness). Fine-grained soil estimate 56.250 m³ (375,000 m² cover area, 15 cm thickness). On-site borrow, may supplement with excavated rib berm material.</td>
<td>Fair</td>
<td>No</td>
<td>Environmental and Regulatory Concerns</td>
<td>Construction Materials: Non-AG material estimate 67,500 m³ (135,000 m² cover area, 15 cm thickness). On-site borrow. Geosynthetic, soil, and vegetation will cover the entire area.</td>
<td>Fair</td>
<td>No</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td></td>
<td>Erosion: Water and wind erosion controls, decreased potential for dust generation. Some risk of erosion for fine-grained cover soil depending on success of revegetation efforts. Riprap lined channels may be required for runoff conveyance.</td>
<td>Good</td>
<td>Environmental and Regulatory Concerns</td>
<td>Erosion: Water and wind erosion controls, decreased potential for dust generation. Some risk of erosion for fine-grained cover soil depending on success of revegetation efforts. Riprap lined channels may be required for runoff conveyance.</td>
<td>Good</td>
<td>Yes</td>
<td>$</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water Quality: Decreased potential for water contact with PK (runoff and/or infiltration).</td>
<td>Good</td>
<td>Environmental and Regulatory Concerns</td>
<td>Water Quality: Decreased potential for water contact with PK (runoff and/or infiltration).</td>
<td>Good</td>
<td>Yes</td>
<td>$</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td><em>Economic</em></td>
<td>Cost: $ $ $ $ $ $</td>
<td>$ $ $ $ $ $</td>
<td>$ $ $ $ $ $</td>
<td>$ $ $ $ $ $</td>
<td>$ $ $ $ $ $</td>
<td>$ $ $ $ $ $</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: Costs are approximate and subject to change based on site-specific conditions.*

**Environmental Cover:** Suitable for areas where permeability and erosion control are critical. Suitable for areas of cover placement on a slope. Layered cover placement may be required for runoff conveyance. Revegetation with geosynthetic to maintain separation. Geosynthetic, soil, and vegetation will cover the entire area. Suitable on-site materials not yet demonstrated. Long-term stability of fine-grained material uncertain.

**Technical Cover:** Suitable for areas where technical feasibility is uncertain. Long-term stability of fine-grained material uncertain.
## Table A-1: Closure Cover Screening for the North Pile Facility

<table>
<thead>
<tr>
<th>Cover</th>
<th>Description</th>
<th>Criteria</th>
<th>Main Area</th>
<th>West Perimeter Embankment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Screening</td>
<td>Rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Construction Materials: Non-AG material estimate 112,500 m^2 (375,000 m^2 cover area, 0.3 m thickness). Fine-grained material estimate 56,250 m^2 (375,000 m^2 cover area, 15 cm thickness). More complex construction, involving base preparation, placement and welding of synthetic material (with cold weather restrictions on welding), placement of protective layer and erosion control layer. Geosynthetic material subject to damage under differential settlement.</td>
<td>Technical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Construction Activities: Conventional regrade with specialized geosynthetic installation contractor, areas of cover placement on a slope. Complex construction including subgrade preparation, welding, and cold-weather installation. Layered cover placement may require geotextile to maintain separation.</td>
<td>Environmental</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Economic</td>
<td>Cost: $555 (higher due to geosynthetic procurement and installation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Construction Materials: Soil cover estimate 112,500 m^2 (375,000 m^2 cover area, 30 cm thickness). On-site borrow, availability may limit thickness.</td>
<td>Technical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Construction Activities: Conventional regrade and cover placement, areas of cover placement on a slope. Revegetation may include organic soil placement and seeding/planting. Revegetation may require test plots and ongoing maintenance, challenging due to short growing and construction season.</td>
<td>Environmental</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Economic</td>
<td>Cost: $55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Construction Materials: Soil cover estimate 40,500 m^2 (135,000 m^2 cover area, 0.3 m thickness). Fine-grained material estimate 20,250 m^2 (135,000 m^2 cover area, 15 cm thickness). More complex construction, involving base preparation, placement and welding of synthetic material (with cold weather restrictions on welding), placement of protective layer and erosion control layer. Geosynthetic material subject to damage under differential settlement.</td>
<td>Technical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Construction Activities: Conventional regrade and cover placement, areas of cover placement on a slope. Revegetation may include organic soil placement and seeding/planting. Revegetation may require test plots and ongoing maintenance, challenging due to short growing and construction season.</td>
<td>Environmental</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Economic</td>
<td>Cost: $55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative 7</td>
<td>Revegetation Cover</td>
<td>Organic Vegetated Soil 30 cm thickness</td>
<td>Technical</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Construction Materials: Soil cover estimate 112,500 m^2 (375,000 m^2 cover area, 30 cm thickness). On-site borrow, availability may limit thickness.</td>
<td>Environmental</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Economic</td>
<td>Cost: $55</td>
</tr>
</tbody>
</table>

Notes: [Link to Table A-1.xlsx](https://golderassociates.sharepoint.com/sites/17180g/Deliverables/1785666-010-TM-Rev0-2000/Table%20A-1.xlsx)
ARD Review
1.0 INTRODUCTION
The De Beers Group of Companies (De Beers) retained Golder Associates Ltd. (Golder) to prepare closure cover designs for the North Pile facility at the Snap Lake Mine. As part of this work, the acid rock drainage (ARD) potential of the main rock types in the existing configuration North Pile was reviewed. This memorandum provides the data and results of this ARD review and provides updated geochemical considerations for use in developing closure cover design.

2.0 BACKGROUND
The North Pile facility is the permanent surface storage facility for processed kimberlite (PK), mine waste rock material, and limited quantities of nonhazardous solid waste for the mine. The facility includes the surface embankments, rock cover, and all waste materials deposited within it. It does not include the associated sumps and water management structures external to the perimeter of the facility. The facility consists of the Starter and East cells (the West Cell was partly built but not commissioned and will not be part of the closure cover system) and has an approximate area to be covered of 315,000 m².

2.1 Geochemistry
Geochemical testing was conducted during the environmental assessment process as reported in the environmental assessment report (EAR; De Beers 2002). In addition, over 100 confirmation geochemistry samples and over 900 run-of-mine (ROM) samples of waste rock material were collected and analyzed as part of the annual ARD monitoring program between 2004 and 2015 (see annual ARD reports, for example De Beers 2015). Testing included acid base accounting (ABA), as well as short-term leach testing, net acid generation (NAG) testing, and mineralogy. Annual reporting included results of geochemical testing and an assessment of the seepage quality from the facilities. Based on the seepage water quality review (De Beers 2015), the materials in the North Pile have not generated acidic seepage or runoff.
Geochemical evaluation of acid generation potential includes consideration of existing conditions on site, coupled with an evaluation of ABA. For individual samples, ABA results are evaluated including neutralization potential (NP) to acidification potential (AP) ratios (NP:AP ratio) and net neutralization potential (net NP) (determined by subtracting AP from NP). Following criteria described in Mine Environment Neutral Drainage (MEND 2009), samples with NP:AP ratio values of greater than 2 are considered non-acid generating (non-AG). Further, as determined during the environmental assessment (De Beers 2002), samples with less than 0.17% (by weight) of sulphide minerals (assumed to be represented by total sulphur) have insufficient acid generation potential to produce appreciable acidity and are considered non-AG. Samples with positive net NP are considered to contain excess neutralization capacity.

Sample results from a given unit are combined to develop an overall acid generation potential and NP of the unit or deposition area. This is considered reasonable in the case of the North Pile of Snap Lake when considering that materials were deposited over a long period of time and well mixed through the blasting, trucking, dumping, and dozing processes.

2.2 North Pile Embankments Configuration

The North Pile facility consists of two major cells: the Starter Cell and the East Cell. (A third cell, the West Cell, was designed however construction was initiated on only a few components in 2015, prior to the cease of operations in December 2015.) The Starter and East cells are divided into internal cells developed for PK deposition management. Both cells consists of three different types of embankments:

- the perimeter embankment
- divider dykes, which are interior embankments that were placed to support deposition activities but do not have a structural role
- rib berms, which also supported deposition without contributing to the structural stability of the facility

Starter Cell construction started in 2005. It was constructed in four phases, and deposition and development activities continued until April 2014. East Cell construction started in 2008. Embankment reconfiguration construction and slurry deposition were in progress up until the mine entered the care and maintenance phase in December 2015.

3.0 NORTH PILE CONSTRUCTION MATERIALS

The following construction materials are encountered in the North Pile facility:

- PK—combined coarse and grits factions of the PK
- waste rock (non-AG and potentially acid generating [PAG])—by-products of the mining process
- rockfill (quarried material).
3.1 Processed Kimberlite

PK is the material rejected from the process plant after the recoverable minerals have been extracted.

PK is classed as follows:

- coarse PK (1.5 to 6 mm)
- grits PK (0.125 mm to 1.5 mm)
- fine PK (<0.125 mm)

Combined coarse and grits fractions of the PK were used for the construction of the perimeter embankments of the Starter and East cells and for portions of the internal rib berms in the East Cell. Fine fractions of the PK was deposited in the cells as a slurry from 2007 to 2014 in the Starter Cell and from 2014 to 2015 in the East Cell.

Substantial geochemical testing of PK materials and kimberlite from underground was completed over the life of mine. ABA results including NP:AP ratio and net NP (determined by subtracting AP from NP) are available from 2004 through 2015 as presented in Attachment 1 and as summarized in Table 1.

Table 1: Summary of Acid Base Accounting and Net Acid Generation Potential for Kimberlite

<table>
<thead>
<tr>
<th>Year</th>
<th>Count</th>
<th>NP:AP Ratio</th>
<th>Net NP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>Median</td>
</tr>
<tr>
<td>2006-2015</td>
<td>286</td>
<td>91.6</td>
<td>130.2</td>
</tr>
<tr>
<td>2006</td>
<td>3</td>
<td>137.8</td>
<td>126.1</td>
</tr>
<tr>
<td>2007</td>
<td>13</td>
<td>67.1</td>
<td>51.7</td>
</tr>
<tr>
<td>2008</td>
<td>17</td>
<td>33.7</td>
<td>41.6</td>
</tr>
<tr>
<td>2009</td>
<td>60</td>
<td>138.3</td>
<td>145.2</td>
</tr>
<tr>
<td>2010</td>
<td>14</td>
<td>123.6</td>
<td>124.0</td>
</tr>
<tr>
<td>2011</td>
<td>41</td>
<td>116.6</td>
<td>142.4</td>
</tr>
<tr>
<td>2012</td>
<td>17</td>
<td>105.8</td>
<td>166.7</td>
</tr>
<tr>
<td>2013</td>
<td>44</td>
<td>65.3</td>
<td>95.4</td>
</tr>
<tr>
<td>2014</td>
<td>36</td>
<td>164.3</td>
<td>190.0</td>
</tr>
<tr>
<td>2015</td>
<td>41</td>
<td>72.6</td>
<td>96.9</td>
</tr>
</tbody>
</table>

NP = neutralization potential; AP = acidification potential.

As can be observed in the results, this material is non-AG with substantial excess neutralizing capacity (NP:AP ratio of greater than 3 with Net NP greater than 20).

For closure construction, from a geochemical perspective, PK can be used for cover material, internal, and external embankments, and as a buffering material to be placed downgradient of potential embankment seepage from the North Pile.

3.2 Waste Rock Geochemistry

Waste rock used in the construction of the North Pile embankments can be broken into two categories: PAG material and non-AG material.
Non-acid Generating Material

Non-AG waste rock has been sourced from underground mine activities located away from the metavolcanic unit. This material has been tested by De Beers (2014). Waste rock classed as non-AG contains very low amounts of sulphide minerals (less than 0.17% sulphides by weight).

Crushed and screened non-AG material has been used at the North Pile construction for the following:

- internal drainage system (75 mm minus) for the East Cell embankments and other fill materials
- a 0.3 to 0.5 m thick erosion protection layer (150 to 250 mm minus) for the 3H:1V exteriors slope of the North Pile embankments
- Type 4 and Type 5 used in conjunction with 75 mm minus rockfill in the construction of the internal drainage

Refer to construction record information in Golder (2016 and 2017) for details.

Materials Handled as Potentially Acid Generating Material

Based on the geochemical testing, materials that are truly PAG contains greater than 0.17% sulphide sulphur (based on testing as completed for the EAR [De Beers 2002]) and has an NP:AP ratio of less than 2 (MEND 2009).

It is important to note the distinction between materials “handled” as PAG and actual PAG materials. Just because it was easier to handle the small volumes of metavolcanics rock as if it were PAG, or because a blast with a small amount of sulphide is treated and handled as PAG, does not make the material PAG. Geochemical test results must be used to determine if this material is actually PAG.

Metavolcanic Rock

Small amounts of metavolcanic rock were mined over a long period of time and resulted in blended material, often mixed with granite or containing kimberlite. For the purposes of material handling on site, all metavolcanic rock extracted during underground development and granite rock containing visually observable sulphide minerals was handled as if it were PAG. ROM samples of this material were routinely collected and analyzed as part of the ARD monitoring program (Attachment 2, Attachment 3, and annual reports, of which the latest is De Beers 2015).

A review of the ROM samples evaluated for ABA is provided in Table 2.
Table 2: Summary of ABA, and Net Acid Generation Potential for Metavolcanic Waste Rock

<table>
<thead>
<tr>
<th>Year</th>
<th>Count</th>
<th>NP:AP Ratio</th>
<th>Net NP</th>
<th>Net NP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>Median</td>
<td>Average</td>
</tr>
<tr>
<td>2004-2015</td>
<td>109</td>
<td>3.2</td>
<td>3.2</td>
<td>14.0</td>
</tr>
<tr>
<td>2004</td>
<td>3</td>
<td>2.7</td>
<td>5.2</td>
<td>20.6</td>
</tr>
<tr>
<td>2005</td>
<td>5</td>
<td>0.9</td>
<td>1.5</td>
<td>-2.1</td>
</tr>
<tr>
<td>2006</td>
<td>8</td>
<td>1.5</td>
<td>2.0</td>
<td>5.1</td>
</tr>
<tr>
<td>2007</td>
<td>22</td>
<td>2.5</td>
<td>4.1</td>
<td>7.8</td>
</tr>
<tr>
<td>2008</td>
<td>9</td>
<td>3.7</td>
<td>5.1</td>
<td>12.3</td>
</tr>
<tr>
<td>2009</td>
<td>14</td>
<td>3.6</td>
<td>1.7</td>
<td>10.3</td>
</tr>
<tr>
<td>2010</td>
<td>2</td>
<td>0.4</td>
<td>0.4</td>
<td>-8.8</td>
</tr>
<tr>
<td>2011</td>
<td>14</td>
<td>3.4</td>
<td>3.1</td>
<td>23.9</td>
</tr>
<tr>
<td>2012</td>
<td>11</td>
<td>3.5</td>
<td>3.0</td>
<td>10.6</td>
</tr>
<tr>
<td>2013</td>
<td>3</td>
<td>1.3</td>
<td>1.8</td>
<td>2.2</td>
</tr>
<tr>
<td>2014</td>
<td>8</td>
<td>3.8</td>
<td>4.6</td>
<td>11.9</td>
</tr>
<tr>
<td>2015</td>
<td>10</td>
<td>21.2</td>
<td>14.6</td>
<td>46.8</td>
</tr>
</tbody>
</table>

NP = neutralization potential; AP = acidification potential.

Results of the data review indicate:

- Seventy-five of the 109 samples are non-AG.
- Overall blended metavolcanic material (excluding granite or kimberlite) is net neutralizing with excess neutralization potential.

It is possible that small pockets of metavolcanic rock may have some acid generating potential; however, when considering the overall distribution of metavolcanic rock within the pile, and deposition history, it is unlikely that any acidity from this rock will be released. Nevertheless, it is prudent to include some mitigation as described in Section 4.

Granitic Waste Rock from Underground

For the purposes of material handling, on-site granite rock containing visually observable sulphide minerals was treated as if it were PAG (De Beers 2017). ROM samples (555 samples) of this material were routinely collected and analyzed as part of the ARD monitoring program (Attachment 2, Attachment 3, and annual reports, of which the latest is De Beers 2015).

A review of the ROM granite samples evaluated for ABA is provided in Table 3.
Table 3: Summary of Acid Base Accounting and Net Acid Generation Potential for Granitic Waste Rock

<table>
<thead>
<tr>
<th>Year</th>
<th>Count</th>
<th>2004-2015</th>
<th>NP:AP Ratio</th>
<th>Net NP</th>
<th>Net NP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year</td>
<td>NP:AP Ratio</td>
<td>Average</td>
<td>Median</td>
<td>Average</td>
</tr>
<tr>
<td>2004-2015</td>
<td>555</td>
<td>4.9</td>
<td>8.3</td>
<td>5.2</td>
<td>4.4</td>
</tr>
<tr>
<td>2004</td>
<td>2</td>
<td>4.2</td>
<td>4.2</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>2005</td>
<td>7</td>
<td>5.3</td>
<td>5.4</td>
<td>8.7</td>
<td>6.8</td>
</tr>
<tr>
<td>2006</td>
<td>10</td>
<td>5.7</td>
<td>10.1</td>
<td>7.9</td>
<td>8.6</td>
</tr>
<tr>
<td>2007</td>
<td>10</td>
<td>3.5</td>
<td>5.8</td>
<td>4.1</td>
<td>3.8</td>
</tr>
<tr>
<td>2008</td>
<td>23</td>
<td>3.0</td>
<td>3.5</td>
<td>4.0</td>
<td>3.2</td>
</tr>
<tr>
<td>2009</td>
<td>75</td>
<td>4.8</td>
<td>4.6</td>
<td>4.9</td>
<td>3.4</td>
</tr>
<tr>
<td>2010</td>
<td>30</td>
<td>6.1</td>
<td>7.2</td>
<td>7.7</td>
<td>3.9</td>
</tr>
<tr>
<td>2011</td>
<td>61</td>
<td>8.5</td>
<td>7.7</td>
<td>7.1</td>
<td>4.0</td>
</tr>
<tr>
<td>2012</td>
<td>169</td>
<td>3.8</td>
<td>8.3</td>
<td>3.9</td>
<td>4.4</td>
</tr>
<tr>
<td>2013</td>
<td>99</td>
<td>4.0</td>
<td>8.3</td>
<td>3.8</td>
<td>4.4</td>
</tr>
<tr>
<td>2014</td>
<td>49</td>
<td>9.0</td>
<td>10.5</td>
<td>7.4</td>
<td>5.7</td>
</tr>
<tr>
<td>2015</td>
<td>20</td>
<td>5.9</td>
<td>4.9</td>
<td>10.4</td>
<td>5.7</td>
</tr>
</tbody>
</table>

NP = neutralization potential; AP = acidification potential.

Results of the data review indicate:

- Five-hundred thirty-seven of 555 ROM samples are non-AG.
- Overall blended granitic material (excluding metavolcanic and kimberlite) is net neutralizing with excess neutralization potential.

Given the observed prevalence of non-AG samples, it is unlikely that small pockets of granitic rock have acid generating potential; nevertheless, it is prudent to include some mitigation as described in Section 4.

4.0 ROCK PLACEMENT

The quantity of material handled as PAG waste rock used in construction varied from 0% on the south embankment at Cell LF to 40% at various embankments and rib berms throughout the facility.

During construction of the North Pile, materials handled as PAG were to be excluded from zones within 50 m of the downstream toe of any perimeter embankments and 3 m from the expected ultimate North Pile closure surface (Golder 2013, 2014). This was done to reduce the potential for release of acidity by decreasing potential oxygen influx and increasing the water flow path (thus increasing the potential for internal buffering of any acidity produced), and to take advantage of eventual freezing conditions to slow or eliminate oxidation reactions.

All rib berms in the East Cell used some proportion of PAG material for construction, along with the combined coarse and grits fraction of the PK and non-AG rockfill (Golder 2017). The materials handled as PAG placed along the west perimeter embankment of the Starter and East cells are not currently isolated as there was the expectation that it would be completely covered when the West Cell was built. These materials were deposited as fill along the west perimeter embankment from approximately 50 m south of the East Cell footprint to 50 m north of the Starter Cell footprint. The approximate location of this material is shown in Figure 1.
Although materials in the west perimeter embankment may remain in the active zone and undergo freeze-thaw cycles, a review of the ROM geochemical data collected on the metavolcanic and granite samples that were handled as PAG rock indicates that these materials overall are non-AG with excess neutralizing potential (Table 2, Table 3, Attachment 2, Attachment 3).

The data indicate that vertical seepage through this material within the North Pile will not be able to produce appreciable acidity (due to the excess internal buffering capacity within the blended waste rock, and relative to the substantial excess buffering capacity of the surrounding PK) even if all of the sulphide minerals were to oxidize in a short time frame. For the west perimeter embankment, similar calculations show that oxidation and vertical seepage through this material will not be able to produce appreciable acidity internally within the blended waste rock even if all of the sulphide minerals were to oxidize in a short time frame.

As an added mitigation measure for the west perimeter embankment, a small amount of PK (toe berm of approximately 1 m in thickness extending 3 m laterally at the base of any seepage faces) should be placed which will supply excess buffering capacity in this area.

5.0 COVER DESIGN CRITERIA SUMMARY – CHEMICAL STABILITY

To maintain chemical stability of the North Pile at closure, the following measures are recommended for inclusion in the cover design criteria:

- Exclude possible PAG material from cover construction both on surface and on side slopes (rock containing more than 0.17% sulphide sulphur).
- As an added mitigation measure for the west perimeter embankment, place a small amount of PK (toe berm of approximately 1 m in thickness extending 3 m laterally, at the base of any seepage faces) to supply excess buffering capacity in this area.
6.0  CLOSING

The reader is referred to the Study Limitations, which follows the text and forms an integral part of this memorandum.

We trust the above meets your present requirements. If you have any questions or comments, please contact the undersigned.

Golder Associates Ltd.

ORIGINAL SIGNED AND SEALED

Ken De Vos, M.Sc., P.Geo.
Principal, Senior Hydrogeochemist

Jeffrey Kwok, P.Eng.
Associate, Project Manager

KJD/JEK/ct

Attachments:
Study Limitations
Attachment 1: ABA Results from Kimberlite for Run-of-mine Samples (2006 – 2015)
Attachment 2: ABA Results from Metavolcanic for Run-of-mine Samples (2004 – 2015)
Attachment 3: ABA Results from Granite for Run-of-mine Samples (2004 – 2015)


PERMIT TO PRACTICE
GOLDER ASSOCIATES LTD.

Signature __________________________

Date __________________________

PERMIT NUMBER: P 049
NT/NU Association of Professional Engineers and Geoscientists
REFERENCES


STUDY LIMITATIONS

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, has been prepared by Golder for the sole benefit of The De Beers Group of Companies. It represents Golder’s professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document. All third parties relying on this document do so at their own risk.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by The De Beers Group of Companies, and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder. The De Beers Group of Companies may make copies of the document in such quantities as are reasonably necessary for those parties conducting business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.
ABA Results from Kimberlite for Run-of-mine Samples (2006 – 2015)
<table>
<thead>
<tr>
<th>SAMPLE ID</th>
<th>Year</th>
<th>Sampled Material (Probe Samples)</th>
<th>Source</th>
<th>Rock Type</th>
<th>Sample Origin</th>
<th>MOLE ID</th>
<th>Sampled pH</th>
<th>Total Sulfate (mmol/L)</th>
<th>Neutralization Potential (kg CaCO3/t)</th>
<th>Cadmium (kg/t DPCW)</th>
<th>Arsenic (kg/t DPCW)</th>
<th>Cadmium Sulfide Substrate (mmol/L)</th>
<th>Arsenic Sulfide Substrate (mmol/L)</th>
<th>Net Neutralization Potential (kg CaCO3/t)</th>
<th>NP-AR</th>
<th>CuWP-AR</th>
<th>Mo pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>A001075</td>
<td>2010</td>
<td>Kimberlite</td>
<td>HKM</td>
<td>Kimberlite</td>
<td>Kimberlite</td>
<td>A00249</td>
<td>2.10</td>
<td>1.73</td>
<td>2.35</td>
<td>15.65</td>
<td>0.00</td>
<td>1.49</td>
<td>25.22</td>
<td>181.18</td>
<td>45.4</td>
<td>4.95</td>
<td>5.8</td>
</tr>
<tr>
<td>A001081</td>
<td>2010</td>
<td>Kimberlite</td>
<td>HKM</td>
<td>Kimberlite</td>
<td>Kimberlite</td>
<td>A00250</td>
<td>1.70</td>
<td>2.13</td>
<td>2.17</td>
<td>15.61</td>
<td>0.00</td>
<td>1.49</td>
<td>25.22</td>
<td>181.18</td>
<td>45.4</td>
<td>4.95</td>
<td>5.8</td>
</tr>
<tr>
<td>A001082</td>
<td>2010</td>
<td>Kimberlite</td>
<td>HKM</td>
<td>Kimberlite</td>
<td>Kimberlite</td>
<td>A00251</td>
<td>1.70</td>
<td>2.13</td>
<td>2.17</td>
<td>15.61</td>
<td>0.00</td>
<td>1.49</td>
<td>25.22</td>
<td>181.18</td>
<td>45.4</td>
<td>4.95</td>
<td>5.8</td>
</tr>
<tr>
<td>A001083</td>
<td>2010</td>
<td>Kimberlite</td>
<td>HKM</td>
<td>Kimberlite</td>
<td>Kimberlite</td>
<td>A00252</td>
<td>1.70</td>
<td>2.13</td>
<td>2.17</td>
<td>15.61</td>
<td>0.00</td>
<td>1.49</td>
<td>25.22</td>
<td>181.18</td>
<td>45.4</td>
<td>4.95</td>
<td>5.8</td>
</tr>
<tr>
<td>A001084</td>
<td>2010</td>
<td>Kimberlite</td>
<td>HKM</td>
<td>Kimberlite</td>
<td>Kimberlite</td>
<td>A00253</td>
<td>1.70</td>
<td>2.13</td>
<td>2.17</td>
<td>15.61</td>
<td>0.00</td>
<td>1.49</td>
<td>25.22</td>
<td>181.18</td>
<td>45.4</td>
<td>4.95</td>
<td>5.8</td>
</tr>
<tr>
<td>A001085</td>
<td>2010</td>
<td>Kimberlite</td>
<td>HKM</td>
<td>Kimberlite</td>
<td>Kimberlite</td>
<td>A00254</td>
<td>1.70</td>
<td>2.13</td>
<td>2.17</td>
<td>15.61</td>
<td>0.00</td>
<td>1.49</td>
<td>25.22</td>
<td>181.18</td>
<td>45.4</td>
<td>4.95</td>
<td>5.8</td>
</tr>
<tr>
<td>A001086</td>
<td>2010</td>
<td>Kimberlite</td>
<td>HKM</td>
<td>Kimberlite</td>
<td>Kimberlite</td>
<td>A00255</td>
<td>1.70</td>
<td>2.13</td>
<td>2.17</td>
<td>15.61</td>
<td>0.00</td>
<td>1.49</td>
<td>25.22</td>
<td>181.18</td>
<td>45.4</td>
<td>4.95</td>
<td>5.8</td>
</tr>
<tr>
<td>SAMPLE ID</td>
<td>Year</td>
<td>Sample Origin</td>
<td>Source</td>
<td>Rock Type</td>
<td>MDSL ID</td>
<td>pH</td>
<td>Base (wt%)</td>
<td>Neutralization Potential (Na CO3 equiv)</td>
<td>Sulphate Neutralization Potential (Kg CaCO3/t)</td>
<td>Net Neutralization Potential (Kg CaCO3/t)</td>
<td>Ca/Mg Ratio</td>
<td>Mds/pH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>---------------</td>
<td>--------</td>
<td>----------</td>
<td>---------</td>
<td>----</td>
<td>------------</td>
<td>--------------------------------------</td>
<td>-----------------------------------------------</td>
<td>---------------------------------------------</td>
<td>-----------</td>
<td>--------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Where laboratory values were reported as non-detect, calculations were completed using the detection limit values.
ABA Results from Metavolcanic for Run-of-mine Samples (2004 – 2015)
<table>
<thead>
<tr>
<th>SAMPLE ID</th>
<th>Year</th>
<th>Date</th>
<th>Depth (cm)</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
<th>Value 5</th>
<th>Value 6</th>
<th>Value 7</th>
<th>Value 8</th>
<th>Value 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>A00837</td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>A00803</td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>A01423</td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>A01422</td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>A00934</td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>A01322</td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>A00057</td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>3.0</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Note:** Where laboratory values were reported as non-detect, calculations were completed using the detection limit values.
ABA Results from Granite for Run-of-mine Samples (2004 – 2015)
<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Source</th>
<th>Sample Type</th>
<th>Source Origin</th>
<th>HOLE</th>
<th>Total Ca (ppm)</th>
<th>Neutralization Potential (kg CaCO₃/t)</th>
<th>Exchangeable Ca²⁺ (mg/kg beds)</th>
<th>Exchangeable Mg²⁺ (mg/kg beds)</th>
<th>Acidic (mg/L)</th>
<th>Alkaline (mg/L)</th>
<th>Acid Neutralization Capacity (kg CaCO₃/t)</th>
<th>Alkalinity (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>ARD</td>
<td>2007</td>
<td>Granite</td>
<td>Granite Surface</td>
<td>ARD Granite</td>
<td>9.0</td>
<td>0.1</td>
<td>0.03</td>
<td>5.0</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>Sample Lot</td>
<td>Year</td>
<td>Batch</td>
<td>Source</td>
<td>Test Type</td>
<td>Assay Origin</td>
<td>% ABA</td>
<td>% ABA</td>
<td>% ABA</td>
<td>% ABA</td>
<td>% ABA</td>
<td>% ABA</td>
<td>% ABA</td>
<td>% ABA</td>
</tr>
<tr>
<td>------------</td>
<td>------</td>
<td>-------</td>
<td>--------</td>
<td>-----------</td>
<td>--------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>A01438</td>
<td>2004</td>
<td>A01150</td>
<td>Granite</td>
<td>A01143</td>
<td>A01128</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01089</td>
<td>2005</td>
<td>A01088</td>
<td>Granite</td>
<td>A01070</td>
<td>A01069</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01059</td>
<td>2006</td>
<td>A01069</td>
<td>Granite</td>
<td>A01068</td>
<td>A01059</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01058</td>
<td>2007</td>
<td>A01068</td>
<td>Granite</td>
<td>A01067</td>
<td>A01058</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01057</td>
<td>2008</td>
<td>A01067</td>
<td>Granite</td>
<td>A01066</td>
<td>A01057</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01056</td>
<td>2009</td>
<td>A01066</td>
<td>Granite</td>
<td>A01065</td>
<td>A01056</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01055</td>
<td>2010</td>
<td>A01065</td>
<td>Granite</td>
<td>A01064</td>
<td>A01055</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01054</td>
<td>2011</td>
<td>A01064</td>
<td>Granite</td>
<td>A01063</td>
<td>A01054</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01053</td>
<td>2012</td>
<td>A01063</td>
<td>Granite</td>
<td>A01062</td>
<td>A01053</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01052</td>
<td>2013</td>
<td>A01062</td>
<td>Granite</td>
<td>A01061</td>
<td>A01052</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01051</td>
<td>2014</td>
<td>A01061</td>
<td>Granite</td>
<td>A01060</td>
<td>A01051</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A01050</td>
<td>2015</td>
<td>A01060</td>
<td>Granite</td>
<td>A01059</td>
<td>A01050</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*Note: The table continues with additional rows.*
<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Year</th>
<th>Source</th>
<th>Sample Type</th>
<th>Sulfur</th>
<th>Neutralization Potential (Kg CaCO3/t)</th>
<th>Sulphide Sulfur Potential (Kg CaCO3/t)</th>
<th>Inorganic Matter (% dry wt)</th>
<th>Total Sulfur (mg/100g)</th>
<th>Extrinsic Hydrogen (mg vol%)</th>
<th>Hydrogen Sulfide (mg/l)</th>
<th>Extrinsic Sulfur (mg/100g)</th>
<th>Residual Sulfate (mg/100g)</th>
<th>COD (mg/100g)</th>
<th>Lead (ppm)</th>
<th>Arsenic (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AO4161</td>
<td>2014</td>
<td>Golder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AO4159</td>
<td>2014</td>
<td>Golder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AO4157</td>
<td>2014</td>
<td>Golder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AO4144</td>
<td>2014</td>
<td>Golder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AO4142</td>
<td>2014</td>
<td>Golder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Additional information regarding the samples can be found in the referenced document or database.