National Exams May 2016

09-MMP-A5, Surface Mining Methods and Design

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. One only reference sheet, 8.5 " x 11", hand written both sides is allowed in the exam. This is Closed book exam, therefore only the approved Sharp or Casio approved calculators are permitted.

3. Compulsory Question 1 and THREE (3) other questions constitute a complete exam paper.

Only question 1 and the first three optional questions as they appear in the answer book will be marked. You must select three questions from the "optional" Questions 2 to 6.

4. Compulsory Question 1 is worth 40 marks. Each optional question is of equal value (20 marks). Three optional questions plus Question 1 constitute a complete exam paper.

5. Many questions require an answer in essay format. Clarity and organization of the answer are important. Use large neat sketches and drawings to illustrate your answers when possible.

6. Answers to Questions 1.4 and 1.5 must be completed on attached pages 17 and 18. Make sure you hand in Figures 1.4 and 1.5 with your number/name attached clearly in the space provided. Include any other material you may have written on.

09-MMP-A5 Surface Mining Methods and Design May 2016

Question 1 is compulsory, consists of six sections and carries 40 marks.

You must then **choose three questions** from Questions 2 to 6 which carry 20 marks each. Be sure to answer only three of the multiple choice questions 2 to 6. The maximum mark will be (40 + 3 X 20) = 100.

Answers to Question 1 and three other questions constitute a complete exam paper.

Only the **first three of the optional choice** questions (2 to 6) will be marked in the order they appear in the answer book.

Compulsory Question 1 (40 marks) you must answer all 6 parts of Question 1

1.1 block models (5 marks) 1.2 block model computer files (8 marks) 1.3 pit optimization (7 marks) 1.4 moving cone example (6 marks) 1.5 moving cone example (7marks) 1.6 range diagrams (7 marks)

Optional Questions 2 to 6 are worth 20 marks each. You must only answer three out of the five, total 60 marks. If you answer more than three, the last questions after the three required will not be marked.

Compulsory Question 1 (40 marks)

You must answer all of this question, parts 1.1 to 1.6 inclusive

Question 1.1 (5 marks) *answer compulsory*

What do you understand by the term 'block model' as used in a mining context. Differentiate between long range and short range models. Use a typical open pit gold mine and an oil sands operation to help illustrate your answer.

How is surface topography described in a block model at the mine feasibility stage.

Question 1.2 (8 marks) *answer compulsory*

A typical block model consists of a half to several million computer records representing individual blocks. In order to minimize the physical size (bytes) of the file, a special number describing the X, Y and Z co-ordinates of a block as a double precision integer can be used to describe data pertaining to a particular block (e.g. metal grade and kriging variance).

A typical record would look like '00.750 00.0038' and the records are stored in the file in order of the special number, i.e. position in the file. Note the records in the file are the same length, which makes direct access simple, but if the order of the file is changed (e.g. sorting by grade, etc.) the records in the file no longer refer to the original blocks. An advantage is that other associated files, or the block model file, could have the special number attached (included) to refer to the block model.

As an example, the origin (first) block special number is 0000000, and the size of the model is 5 x 4 x 3 in the nX, nY and nZ dimensions. Note that the model starts at 0, 0 and 0, at the centre floor Xb, Yb and Zb (x, y and z), and blocks are regular 20 x 20 x 8 meters The lower south west block floor is centred at 0, 0, 0 meters in block metric coordinates.

The block in question is given the naming convention Xb, Yb and Zb, all starting at 0 (zero). Two values, the N and IJK numbers (© Datamine), are calculated, N to improve mathematical precision and IJK as the number of the special record in the file when given block centre x, y and z calculations, or finding the x, y and z given the record number.

Question 1.2 continued ***answer compulsory***

N improves the precision of computer calculations and N = IJK - Xb*nY*nZ

In this example, the smallest special IJK number is;
IJK = Xb*nY*nZ + Yb*nZ + Zb = 0 * 4 * 3 + 0 * 3 + 0 = 0
The largest IJK is;
IJK = Xb*nY*nZ + Yb*nZ + Zb = 4 * 4 * 3 + 3 * 3 + 2 = 48 + 9 + 2 = 59
(one less than 5 * 4 * 3 as the IJK starts at 0)

What record holds the data for a block at centre floor 50, 30 and 16, x, y and z
The block is int(50/20) or 2 blocks east of the origin and Xb is 2
The block is int(30/20) or 1 block north of the origin and Yb is 1
The block is 16/8 or 2 blocks above the origin and Zb is 2
IJK = Xb*nY*nZ + Yb*nZ + Zb = 2 * 4 * 3 + 1 * 3 + 2 = 24 + 3 + 2 = 29
The special IJK number is 29 and data can be found in record 29 and note records start at zero (0).

What are the co-ordinates of record 30 (starting at zero)
Xb = int(IJK / (Ny*Nz)) = int(30/(4*3)) = int(30/12) = int(2.5) = 2
N = IJK – Xb * nY * nZ = 30 – 2 * 4 * 3 = 30 – 24 = 6
Yb = int(N/nZ) = int(6/3) = 2
Zb = N – Yb*nZ = 6 – 2 * 3 = 6 – 6 = 0

X = 10 + 2 * 20 = 50
Y = 10 + 2 * 20 = 50
Z = 0

Note block center of block 0, 0, 0 is 10, 10, 0 and south west corner floor of the south west block is 0, 0, 0.

Note record 29 is 2 1 2 and record 30 is 2 2 0 as can be interpreted from the Figure 1.2 below.

Question 1.2 continued *answer compulsory*

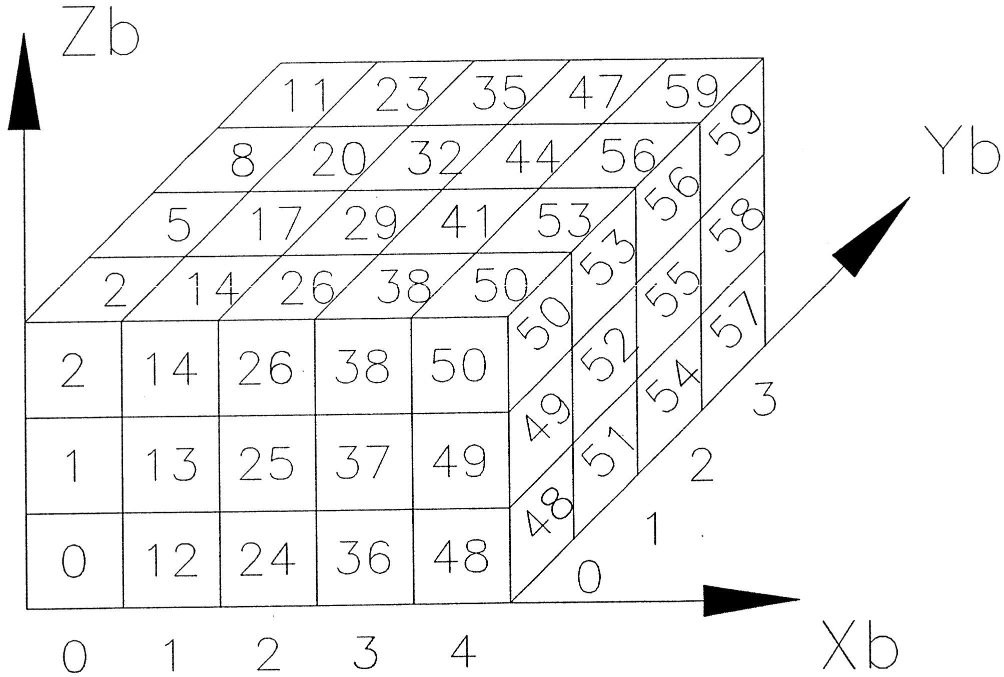

Figure 1.2 Special record numbers for individual blocks

Question 1.2.0 (8 marks as already indicated above)

Another company uses the single unique record number (IJK, a double precision integer) to describe a three dimensional block model.

The block model size is 46 nX, 56 nY and 51 nZ, and the block model starts at 1510, 1210 and 1000 meters (x, y and z) for centre floor of the south west corner block, and X Y and Z as block numbers all start at zero.

The block dimensions are 20 by 20 by 8 meters, x, y and z.

1.2.1 What is the special record location number (IJK) for the block having its centre at 1970 (x) and 1950 (y) at a floor elevation of 1208 (z).

1.2.2 What are the block centre floor coordinates of special block number (IJK) 6028.

Question 1.3 (7 marks) ***answer compulsory***

Based on Lizottes systematic description (i.e. facilitates a computer programming solution), only one positive block at any stage can potentially form an extraction cone at the cone vertex, and cones cannot be combined, reference;

The Economics of Computerized Open Pit Design, Y. Lizotte
International Journal of Surface Mining Reclamation and Environment 01/1988; Reclamation and Environment(Vol. 2):59-78. DOI:10.1080/09208118808944138
© 1988 A.A.Balkema, P.O.Box 1675,3000 BR Rotterdam. Netherlands.

This allows for other positive blocks within the cone being analysed, which could not form an extraction cone on their own, to be included in the cone economic appraisal. Cones starting independently outside the cone being analysed cannot be included as this would be extremely difficult to program on a computer.

1.3.1 What single fundamental principal governs whether an ore block is mined or not.

1.3.2 Explain how the stages of employing the "moving (or floating) cone" are used to find a near optimal open pit excavation. What values are used to describe the economics of individual blocks and give examples for ore and waste.

1.3.3 A newer method of determining "truly" optimal excavations was first described in 1967/68. What was this method and briefly describe it's mechanism. .

1.3.4 Give two examples of open pit configurations that make the moving cone (1.3.2) sub-optimal in comparison to the method you described in question 1.3.3.

Question 1.4 (6 marks) ***answer compulsory***

The following is a 2D section of an open pit block model. Using the moving cone algorithm, of 1.3.1 and 1.3.2, show each stage and find the ultimate pit excavation.

-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	+2	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	+13	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1

Two copies of question 1.4 section are attached at the end of the exam paper to prepare your answer. Do not prepare an answer on the above diagram.

Do not forget to insert your number/name on the attached page 18 and hand in with your exam paper.

Question 1.5 (7 marks) ***answer compulsory***

The following is a 2D section of an open pit block model. Using the moving cone algorithm, of 1.3.1 and 1.3.2, show each stage and find the ultimate pit excavation

-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	+4	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	+10.7	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	+19.8	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Two copies of question 1.5 section are attached at the end of the exam paper to prepare your answer. Do not prepare an answer on the above diagram.

Do not forget to insert your number/name on the attached page 19 and hand in with your exam paper.

Question 1.6 (7 marks) ***answer compulsory***

What do you understand by the term 'range diagram' as used in surface coal mining and other mining operations.

Make a list of the important parameters from the range diagram determining the feasibility of using a particular piece of equipment to mine a typical buried coal seam.

Question 2 (20 marks) One of Three Optional Questions to be Selected

A mining operation is moving ore material such as oil sands from a relatively shallow depth, and the ore is covered by overburden consisting of top soil and barren sands.

Initially the mine equipment consists of either;

2.a Large bucket wheel excavators which move lightly blasted ore or waste onto separate conveyors which carry either ore (2.a.1) onto long mobile conveyors which traverse over the mined out area and feed the concentrator or carry waste (2.a.2) to the mined out area. The excavators (2.a.1) sit on ore or the underlying barren rock or (2.a.2) on waste, overburden or ore.

2.b Large draglines which advance continually on a wide face along the ore while sitting on the overburden. The ore is placed on the bench beside the dragline and the waste, as mined, is cast back into the area already mined out. Bucket wheel excavators, on the same elevation as the dragline, re-handle the ore and place the material in hoppers feeding long conveyors which advance ahead of the dragline and feed the concentrator. No blasting takes place.

2.c When the above equipment reaches the end of its useful life, it is replaced by "conventional" truck/shovel operations.

2.1 Draw a sketch plan and section of each operation (2.a, 2.b and 2.c).

(2 marks each for 2.a, b, and c, total 6 marks)

2.2 Compare the three operations 2.a, 2.b and 2.c from the point of view of;

- 2.2.1 Mining Capital and Fleet Unit Cost
- 2.2.2 Mining Productivity
- 2.2.3 Selectivity of Mining
- 2.2.4 Grade Control
- 2.2.5 Improved Concentrator Throughput and Recovery

(2 marks each, total 10 marks)

2.3 Discuss why all newer "conventional" oil sand and other similar deposits use "conventional" truck/shovel methods (4 marks)

Question 3 (20 marks) One of Three Optional Questions to be Selected

3.1 "Pareto's Law" can be used to find the major operating cost components of drills, trucks or shovels in a typical truck/shovel hard rock open pit mine. What do you understand by Pareto's Law.

(1 mark)

Given that you have access to all accounting information for such a mine, how would you apply Pareto's Law to quickly isolate the major operating costs of items such as drilling (for blast-holes), trucks (for rock haulage) and shovels (for loading trucks).

(2 marks)

For each of the following three cost centres, list the three major cost items and their approximate percentage of the total cost of that particular cost sector.

3.1.1 Drilling (for Blast-holes)
3.1.2 Truck (Haulage)
3.1.3 Shovel (Loading)

(2 mark each, total 6 marks)

(an example answer for the blasting cost centre might be 30% ANFO, 25% Slurried Explosive, 20% Wages and Benefits, 10% Blast Hole Dewatering, 10% Detonators and Accessories and 5% "Other").

3.2 Discuss how inflation cost indexes could improve cost estimates of future operations based on your answers to questions 3.1.1, 3.1.2 and 3.1.3.

(2 marks)

3.3 A publication has produced capital cost indexes for a variety of mining purchases based on the equipment size (imperial) for the year 1997. Such information allows the mining engineer to estimate capital costs (CDN $) for potential mining projects by the various cost centres in 1997 dollars.

Question 3 (continued)

For trucks the relationship is

$P = a X^{b}$ where P is the cost of a truck, X the truck capacity in short tons and a and b are constants, 20,000 and the power 0.90 respectively

3.3.1 What is the 1997 cost of a 300 tonne truck. (2 marks)

For shovels the relationship is

$P = a X^{b}$ where P is the capital cost of a shovel, X is the shovel bucket capacity in cubic yards and a and b are constants, 540,000 and the power 0.75 respectively.

3.3.2 What is the 1997 cost of a 53 cubic meter bucket size shovel.

(2 marks)

For drills the relationship is

$P=a X^{b}$ where P is the capital cost of a drill, X is the pull-down force in pounds (lbs.), and a and b are constants, 400 and 0.67 respectively.

3.3.3 What is the 1997 cost of a 55,000 kg pull-down force rotary drill.

(2 marks)

3.4 A cost index estimates that a 1997 dollar is now worth 2.50 dollars (all Canadian $)

What are the costs of buying the drill, shovel and truck today, and are the values realistic.

(3 marks)

Question 4 (20 marks) One of Three Optional Questions to be Selected

Figure 4 shows a sketch of all possible routings with two shovels operating. One shovel is digging waste which must be trucked to the waste dump and the other shovel is loading ore which must be trucked to the crusher.

4.1 The average loading time for a truck, including truck positioning, is 3.0 minutes. The time taken for ore trucks to reach the crusher is 12.0 minutes and for waste trucks, 12.0 minutes to reach the dump. Backup and dumping take 1.0 minute and the empty return for ore or waste is 8.0 minutes.

What is the total "theoretical closed out" truck cycle time and match factor. (2 marks)

4.2 Referencing Figure 4 showing all possible routings, draw two neat diagrams showing the respective "closed out" and "dispatched" routes. (3 marks)

The times taken by the trucks to travel to and from the shovels and dumps are shown below, as are the dump times. The shovel loading time includes "spotting". All times are in minutes.

- **Shovel 1 to Crusher** **12 minutes**
- **Crusher to Shovel 1** **8**
- **Shovel 2 to Waste Dump** **12**
- **Waste Dump to Shovel 2** **8**

- **Crusher to Shovel 2** **4**
- **Waste Dump to Shovel 1** **3**
- **Loading Ore at Shovel 1** **3**

- **Dumping Ore at Crusher** **1**
- **Loading Waste at Shovel 2** **3**
- **Dumping at Waste Dump** **1 minute**

It is not necessary to convert numbers to integers for the following parts of questions 4.3, 4.4 and 4.5 below.

Question 4 (continued)

4.3 What are the theoretical numbers of trucks required for "closed out" and "dispatched" operation shown in Figure 4 to obtain maximum production. (7 marks)

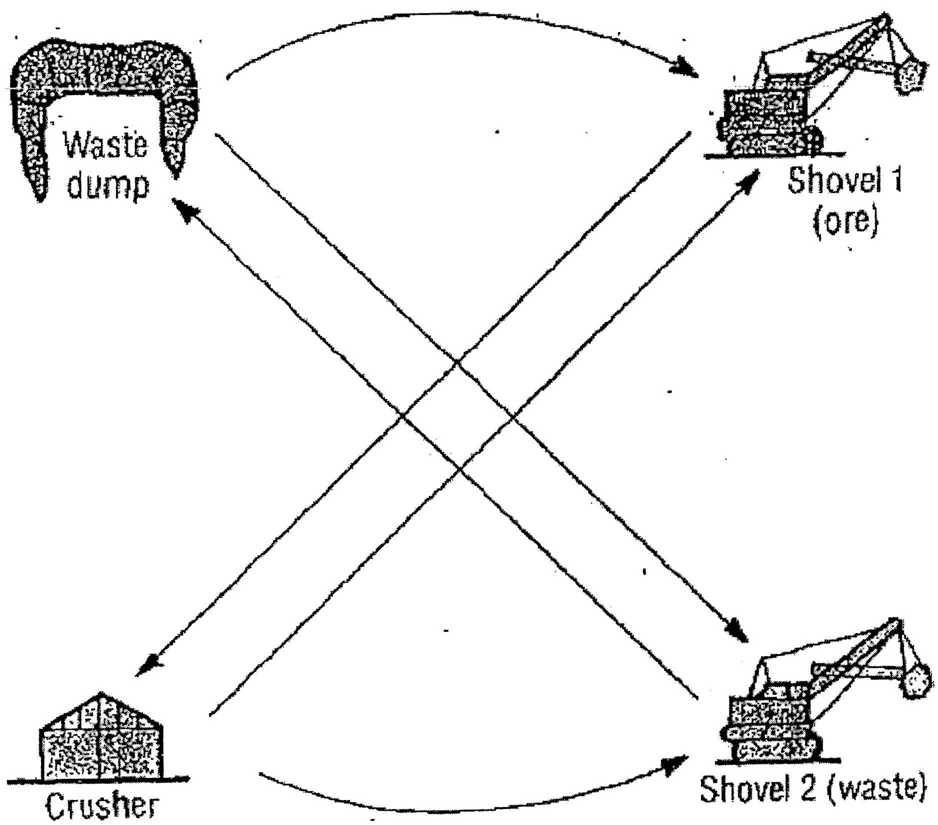

Figure 4 All Possible Truck Routings

4.4 Which trucking configuration is the most efficient, closed out or dispatched.

(3 marks).

4.5 Using the most efficient configuration, how many truckloads are delivered to the crusher and dump in an 8 hour shift and is this value realistic. (5 marks)

Question 5 (20 marks) One of Three Optional Questions to be Selected

5.1 What are the main elements of a mine closure plan and provide a brief discussion of such a plan. Include the following in your discussion.

5.1.1 Re-vegetation and re-foresting of contoured waste dumps

5.1.2 Acid drainage remediation

5.1.3 Re-vegetation of tailings dams and the selection of vegetation to accomplish this.

5.1.4 Reclamation of the "slimes" area of the tailings pond(s)

5.1.5 Restoring the agricultural capabilities of the disturbed area.

5.1.6 How an abandoned open pit should be developed to provide a lake suitable for fish breeding, and/or alternatives.

(total 6 marks)

A mine has been permitted based on a 10 year mine plan and an immediately following "reclamation" period. The cost of reclamation has been estimated as 1 million dollars based on "todays dollar", with no net salvage value.

5.2.1 According to the mining company, inflation averages 6% per year. What will the 1 million dollar reclamation cost be in 10 years. (1 mark)

(interest rate tables are not provided as $(1+r)^n$ can be easily found on the APEO approved calculator allowed in the exam)

5.2.2 Permitting of mines often includes some form of annual "sinking fund installment" to provide the cost of reclamation at a very low government secured bond interest rate. What annual amount (same every year) must the mine deposit in each of the 10 years to provide the required lump sum at the end of mine operations if the government interest rate is 2%. (2 marks)

A formulae which may be of use as is or inverted $[\ i\ /\ (((1+i)^n)-1)\ ]$

Question 5 (continued)

5.2.3 The permitting process has not allowed for the possibility that the mine might close prematurely (from low product prices, increased costs, reduced mill recovery, slope failure, etc.)

At year 4, the planned 10 year mine closes unexpectedly, declaring bankruptcy. The assets are taken over by the government and all items of salvageable value removed (at no value) leaving nothing of value. The pit, tailings and waste areas are essentially the same with respect to disturbance as if the mine had operated for its anticipated 10 years. Consequently reclamation costs are those for the 10 year mine plan but lasting only 4 years at 6% annual inflation.

What is the cost of reclamation in today's dollars, i.e. the cost of reclamation in year 4 dollars at 6% expressed in todays' dollars. (2 marks)

5.2.4 At the 2% government rate, how much has the company deposited by year 4 in today's dollars, given that the mine life was expected to be 10 years.

(2 marks)

5.2.5 How much must the taxpayer pay in year 4 to complete the reclamation.

(2 marks)

5.3 Develop a financial plan that will avoid such a taxpayer liability and which is fair to the mine and in a sense "optimal" for both mine and taxpayer.

(2 marks)

Second Part of Question 5, No Relation to the above Earlier Section

5.4 A mining district has operated several very profitable mines for a half century. During this period, specialized mining equipment has been developed, with supporting infrastructure supplying raw materials for fabrication. A skilled workforce has been trained and employed making such equipment and raw materials for worldwide consumption.

Question 5.4 (continued)

The mines eventually close. How would you ensure the continued sustainability of the mine equipment and raw material manufacturing industries which have replaced the mines as the leading employer. The following are a few headings for discussion.

5.4.1 Ownership of manufacturing plants

5.4.2 Training of future manufacturing/design/research employees

5.4.3 In old mining districts, remaining "leading edge" rather than "up-to-date" or conversely, "outdated" with mine equipment, fabrication and raw materials manufacturing is difficult. There are no local mines demanding modern innovative equipment in this case.

5.4.4 Give (discuss) an example where sustainability has been achieved (employing more personnel than the original mines) and an example where it has not (resulting in permanent un-employment rates of over 20% and a sense of hopelessness in the community).

(3 marks)

Question 6 (20 marks) One of Three Optional Questions to be Selected

6.1 An open pit mine is in the early feasibility stage.

6.1.1 Discuss the initial rock strength and discontinuity structural measurements which must be performed, and how such tasks might be undertaken. What types of equipment would be used for this work and from the point of view of pit slope design, how accurate will the results be.

(1 mark)

Question 6.1 (continued)

6.1.2 The presence of water can be detrimental to the stability of pit wall slopes. Discuss the equipment which might be used to provide measures of potential instability and the results which might be expected. What typical recommendations might be provided to the slope design process in order to improve wall slope angles. _(2 marks)

6.1.3 Typical slope design problems include the potential for wedges intersecting the pit wall. How is the presence of such structures determined and what methods can be used to graphically display the structures and the angular parameters necessary for their (in) stability to be ascertained. (2 marks)

6.1.4 Wall slopes have been suggested as per below (6.1.4.a and 6.1.4.b)

6.1.4.a It has been suggested that the pit wall slope should be designed at 45.971 degrees.

6.1.4.b It has been suggested that an open pit should be designed with a (double) bench height of 30m, a berm width of 14m and a batter slope angle of 63.435 degrees.

Discuss how these values may have been arrived at and how accurate and practical such values are. (2 marks)

What role does the presence of water in the pit walls have in the wall slope angles suggested, and how can remediation be quantified. (2 marks)

6.2 An open pit design team has been provided with a pit slope assessment from all of question 6.1 above, and is preparing a mine plan.

Discuss how the pre-ramp bench wall slopes will be determined and how the slopes post ramps and inter ramps will be determined. It can be assumed that the pit will be developed as a series of economic pushbacks around an initial high value pit. (2 marks)

Discuss the location of ramps on the various sectors of the pit walls. Include the potential for variable rock types and discontinuities in the discussion. The potential for wedges intersecting pit walls should also be part of your discussion. (2 marks)

Question 6 (continued)

6.3 The pit is now in operation and ongoing wall slopes have to be monitored as the pit deepens and pushbacks are developed.

6.3.1 What modern pit slope monitoring tools would you recommend in these circumstances. (1 mark)

6.3.2 Briefly describe how monitoring systems in 6.3.1 work and how the results are analysed in a timely manner. (2 marks)

6,4 In the event of an instability, methods of wall support are an option. A list would include

6.4.1 off-loading

6.4.2 buttressing

6.4.3 dewatering

6.4.4 mechanical support

Discuss the role of 6.4.1, 2, 3 and 4 in wall slope remediation. (2 marks)

How would you include regional destabilization such as earthquakes in your pit design. (2 marks)

End of Exam

Figures which must be handed in with your number/name attached follow (pages 17 and 18 for questions 1.4 and 1.5)

Your Number/Name ________________

Question 1.4 (5 marks) *answer compulsory*

The following is a 2D section of an open pit block model and a copy. Using the moving cone algorithm, of 1.3.1 and 1.3.2, find the ultimate pit excavation

-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	**+2**	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	**+13**	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1

-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	**+2**	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	**+13**	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1

Two copies of question 1.4 section are attached on this page 17. Use the above diagrams to prepare your answer.

Do not forget to insert your number/name on the attached page 17 and hand in with your exam paper.

Your Number/Name ____________________

Question 1.5 (6 marks) ***answer compulsory***

The following is a 2D section of an open pit block model and a copy. Using the moving cone algorithm, of 1.3.1 and 1.3.2, find the ultimate pit excavation

-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	+4	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	+10.7	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	+19.8	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	+4	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	+10.7	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	+19.8	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Two copies of question 1.5 section are attached on this page 18. Use the above diagrams to prepare your answer.

Do not forget to insert your number/name on the attached page 18 and hand in with your exam paper.