

**National Exams May 2013**

**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 inch, hand written both sides is allowed in the exam. This is not an open book exam, therefore only the APEO approved Sharp or Casio type calculators are permitted.
3. Compulsory Question 1 and FOUR (4) other questions constitute a complete exam paper.  
  
Only question 1 and the first four optional questions as they appear in the answer book will be marked. You must select four questions from the "optional" Questions 2 to 7. Be sure you understand that two of Questions 2 to 7 must not be answered.
4. Compulsory Question 1 is worth 40 marks. Each optional question is of equal value (15 marks). Four 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 sketches and drawings to illustrate your answers whenever possible.
6. ***If you answer Question 3, make sure you write your name on the appropriate figures and hand in with your exam answer booklets.***

**Question 1.1 (6 marks)**

*answer compulsory*

With regard to pit dewatering, discuss the use of the following. Indicate the range of volume pumped and pump head when discussing pumps.

- 1.1 Pencil pumps
- 1.2 Submersible pumps
- 1.3 Hydraulic pumps
- 1.4 Pumps with attached generator
- 1.5 Check valve
- 1.6 Water hammer

(1 mark each)

**Question 1.2 (6 marks)**

*answer compulsory*

With respect to conventional dragline mining operations, answer the following questions indicating the conditions which make such operating methods necessary. Use sketch sections/plans where appropriate.

- 1.2.1 Advanced bench
- 1.2.2 Key cut
- 1.2.3 Extended bench
- 1.2.4 Horseshoe configuration
- 1.2.5 Pullback method

(1 mark each, 2 marks for 1.2.4)

**Question 1.3 (6 marks)**

*answer compulsory*

In the optimization of open pits, the first stage is to convert grade to a block model of cash flows.

1.3.1 What do you understand by a block model, and how is each block given a single unique number which can be converted to X, Y and Z co-ordinates and vice versa.

1.3.2 How are costs defined.

1.3.3 How is a "grade" converted to a revenue and then to a cash flow..

1.3.4 What is the rule base for defining the cash flow of material which has a grade but the grade is too low to generate a positive cash flow when processed.

1.3.5 At some operations "least loss" is used to define whether material is processed or sent to waste or low grade stockpiles. Define the rule base for "least loss".

(1 mark each, 2 marks for 1.3.5)

**Question 1.4 (6 marks)**

***answer compulsory***

1.4.1 What do you understand by the Bieniawski Rock Mass Rating, how values are estimated, what the values mean in terms of slope angle, and are they applicable to slope stability.

1.4.2 Many other systems of rock classification have been developed. Name and discuss a system you are familiar with that accounts for ;

1.4.2.1 The three dimensional character of discontinuities and their relation to the slope faces.

1.4.2.2 The presence of ground water and its action on pit wall stability

1.4.2.3 The effects of blasting and how distance and delay caps affect slope stability

1.4.2.4 The effect of varying rock parameters in different elevations and different sectors of the slopes.

(2 marks for 1.4.1, 1 mark each for 1.4.2)

**Question 1.5 (6 marks)**

***answer compulsory***

1.5.1 With respect to truck dispatching used in mines, what do you understand by the terms "closed out" and "dispatched".

Truck dispatch has now become an integral part of the operation of open pit mines. Explain the methodology used in such a computerised system when applied to the following headings;

- 1.5.2.1 Maximized production
- 1.5.2.2 Minimized equipment (trucks)
- 1.5.2.3 Optimal mill head grade
- 1.5.2.4 Maintaining the stripping ratio
- 1.5.2.5 Provision of a computerised data base for production, maintenance, control of consumables and future truck purchases

(1 mark for 1.5.1, 1 mark each for 1.5.2)

**Question 1.6 (5 marks)**

***answer compulsory***

From an open pit mine perspective define the following;

- 1.6.1 Reclamation
- 1.6.2 Sustainability

(2 marks for 1.6.1, 3 marks for 1.6.2)

**Question 1.7 (5 marks)**

***answer compulsory***

In the context of mine cost estimating, what do you understand by the following terms, and describe the function and development of these terms.

- 1.7.1 The Marshall and Swift Mine/Mill cost index (M&S M/M)
- 1.7.2 The "six tenths rule" (the rule may also be referenced as the 'two thirds' or 0.7 rule depending on the practitioner)
- 1.7.3 List the cost centers on which the Marshall and Swift (and many other) indices for mining are based.

(1 mark for 1.7.1, 2 marks for 1.7.2 and 1.7.3)

**Question 2 (15 marks)**

**One of Four Optional Questions**

2.1 In the context of dragline coal mining operations what do you understand by the term "Range Diagram". (1 mark)

2.2 Draw a neat sketch section of a dragline side-casting operation showing;

2.2.1 Dragline operating radius

2.2.2 Stacking height

2.2.3 Cut depth

2.2.4 Dragline reach

(1 mark)

2.3 Indicate on your neat sketch section

2.3.1 Pit width

2.3.2 Depth of overburden

2.3.2 High-wall slope angle

2.3.3 Spoil pile angle of repose

2.3.4 Spoil pile swell factor

2.3.5 Coal seam thickness

(1 mark)

2.4 The term "dragline positioning" is used to describe the position of the dragline tub with respect to the edge of the high-wall. The term defines the percent of tub diameter from the dragline centerline to the edge of the high-wall. Draw a neat sketch section showing the dragline tub (20m diameter) and edge of high-wall when the "positioning" is 75%.

What is the distance from the edge of the high-wall to the nearest edge of the tub, and from the high-wall edge to the center line of the dragline.

(2 marks)

2.5 The term "spoil pile swell factor" is the increase in volume of unbroken overburden when stacked as broken rock (spoil). It is usually stated as a decimal rather than a percentage. If a spoil pile swell factor is 0.25, what is the volume of  $10 \text{ m}^3$  of unbroken overburden after digging and placing on the spoil pile.

(2 marks)

2.6 The following are the specifications of a walking dragline mining overburden covering a 3m thick flat coal seam using simple side casting. The machine is working about half way along the cut in an established mine.

#### Dragline specifications

Tub diameter	20m
Operating radius	90m
Positioning factor	75%
Stacking height	12m
Digging depth	35m

#### Mined material specifications

High wall angle (from horizontal)	63 degrees
Coal face angle (from horizontal)	90 degrees (to simplify calculations)
Spoil pile slope (from horizontal)	35 degrees
Spoil pile swell factor	0.25
Depth of overburden	25m
Pit width	40m

Draw a neat sketch of the operation to scale so that you can check your answers.

(2 marks)

Calculate the following for a 1m wide section of the operation

- 2.6.1 Cut area (a volume per meter wide slice)
- 2.6.2 Spoil pile area
- 2.6.3 Spoil pile height above coal seam floor
- 2.6.4 Height of the spoil pile above base of dragline tub
- 2.6.5 Operational stacking height (not stacking height specified by dragline)
- 2.6.6 Horizontal reach factor (crest of overburden to top of stacked spoil)

(3 marks)

2.7 Will the dragline be capable of mining the overburden and uncovering the coal as planned in question 2.6, i.e. can the dragline complete the operation of the mine without modifications to the mining method or machine.

(2 marks)

2.8 What auxiliary mining methods and/or extra equipment would be required to accomplish the mining if the dragline and its mining configuration were inadequate for purpose.

(1 mark)

**Question 3 (15 marks)**

**One of Four Optional Questions**

In "optimizing" the volume to be removed from an open pit the "moving" (or "floating") cone method "MC" may be used.

3.1.1 What is the rule base for the moving cone method. (2 marks)

Apply the rule base to Figure 3.1.1 which shows the "cash flows" of a two dimensional section across a pit as an (i,j) matrix. The wall slope is set at 45 degrees and the blocks are 15m square (cube). Do not use the sum of cash-flows of adjacent or close blocks to define positive values as there is no reliable computer algorithm for this in three dimensions.

3.1.2 Neatly show the pit outline on your Figure 3.1.1. Do not forget to place your name/number on the Figure 3.1.1 and hand it in with your answer booklet. Two extra copies of the cash flow matrix in Figure 3.1.1 are provided in case you need to revise your "optimally" mined out area. (2 marks)

3.1.3 What is the sum of cash flows for the MC "optimal" mined pit section. Do not forget to place your name/number on the Figure(s) 3.1.1 and hand it/them in with your answer booklet. (1 mark)

In 1968, Lerchs and Grossmann presented a method of guaranteeing the optimality of the mined pit referred to as "LG".

3.2.1 Explain the LG "graph" method and how this differs from the moving cone. Use examples of a

3.2.1.1 two bottom large pit

3.2.1.2 pit with a deep flat lying seam

3.2.1.3 pit resembling a "half donut" or "half bagel" (cut horizontally leaving only the bottom part and a mountain in the middle where the hole was) in shape.

(2 marks)

The same "cash flows" shown in Figure 3.1.1 as an  $(i,j)$  matrix are now to be used by you, the candidate, to show the LG method in two dimensions using  $P_{i,j}$  and  $M_{i,j}$  matrices. The  $M_{i,j}$  matrix is developed working left to right.

Figure 3.2.1.3.a shows the same matrix of cash flows as Figure 3.1.1. Figure 3.2.1.3.b shows the  $P_{i,j}$  matrix formed by summing the cash flows of each column starting at the top of the column going straight down.

In Figure 3.2.1.3.c, the  $P$  matrix has been transformed to the  $M$  matrix using graph theory and the maximum slope of 45 degrees. The columns  $j=8$  and  $j=9$  are left blank.

The  $M$  matrix contains the LG solution which can be read directly on the table/graph.



3.2.2 Complete the P (i,j) sub matrix for P (i=1 to 10, j=8 and j=9) shown in Figure 3.2.1.3.c and 3.2.1.3.d for P (i = 1 to 10, j = 6, 7, 10, 11) with j = 8 and 9 left blank. Note that there are two copies in Figure 3.2.1.3.d in case you make a mistake.

(2 marks)

3.2.3 Neatly show the LG pit outline on your Figure 3.2.1.3.a. Do not forget to place your name/number on the Figure 3.2.1.3.a, b, c and d and hand them in with your answer booklet. You may use an unused copy of 3.1.1 in case you need to revise your LG "optimally" mined out area, but be sure to note this on the diagram and hand in..

(2 marks)

3.2.4 Where is the "optimal" answer to the LG method shown on the Figure 3.2.1.3.c matrix, (you may indicate this on your Figure 3.2.1.3.a or c, or explain where it is), and what is the "optimal" value.

(2 marks)

3.2.5 The LG method does not include the "time value of money", and is therefore sub-optimal. What changes in methodology would make the LG method more "optimal". You may briefly describe how any commercial software you are familiar with accomplishes this.

(2 marks)

***Make sure you write your name/number on any Figures you have worked on, and hand in with your answer booklet.***

Figure 3.1.1 (original) Block Profit (Cash Flow) Matrix Section Wall Slope 45 degrees Blocks 15x15x15 m

-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	-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	-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	-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	-1	-1	-1
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

Figure 3.1.1 Copy 1 Block Profit (Cash Flow) Matrix Section Wall Slope 45 degrees Blocks 15x15x15 m

-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	-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
-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	-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
-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	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

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Figure 3.1.1.1 Copy2 Block Profit (Cash Flow) Matrix Section Wall Slope 45 degrees Blocks 15x15x15 m

-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	-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	-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	-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	-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
-2	-2	-2	-2	-2	-2	-2	3	24	4	5	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

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Figure 3.2.1.3.a Block Profit (Cash Flow) Matrix Section Wall Slope 45 degrees Blocks 15x15x15 m

-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	-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	-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	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-2	-2	-2	-2	-2	-2	24	3	24	4	5	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

Figure 3.2.1.3.b "P" Matrix (cumulative sum cash flow by column going down)

-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4
-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11

Figure 3.2.1.3.c Final Sub-Matrix of "M" Values from LG Algorithm Wall Slope 45 degrees Blocks 15x15x15 m j = 8 and 9 omitted

i	j=1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	6	5	4	3	2	1	0	-1	-1	-1	-1	10	9
2	-2	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	7	6	6	4	3	2	1	0	-1	-2	-3	-3	11	9	8
3	-3	-5	-6	-6	-6	-6	-6	-6	-6	-6	-6	9	8	8	5	3	1	0	-1	-2	-3	-4	13	10	8	6
4	-4	-7	-9	-10	-10	-10	-10	-10	-7	12	11	11	7	4	1	-1	-3	-4	-5	-6	-6	16	12	9	6	4
5	-5	-9	-12	-14	-15	-15	-15	-15	16	15	15	10	6	2	-1	-4	-6	-8	-5	-5	20	15	11	7	4	1
6	-7	-12	-16	-19	-21	-22	4	4	20	20	14	8	3	-1	-5	-8	-11	-13	-11	18	13	8	4	0	-3	-3
7	-9	-16	-21	-25	-28	-30	-5	18	18	12	12	5	-1	-6	-10	-14	-17	-20	-18	10	9	4	-1	-5	-9	-9
8	-11	-20	-27	-32	-36	-39	-15	14	14	8	8	1	-6	-12	-17	-21	-25	-28	-27	1	-1	-2	-7	-12	-16	-16

Figures 3.2.1.3.d (2 copies) Final Sub-Matrix of "M" Values from LG Algorithm for i = 1 to 8 and j = 6, 7, 10, 11

j	6	7	8	9	10	11	i = 1	6	7	8	9	10	11
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-3	-3	-3	-3	-3	-3	-3	2	-3	-3	-3	-3	-3	-3
-6	-6	-6	-6	-6	-6	-6	3	-6	-6	-6	-6	-6	-6
-10	-10	-10	-10	-10	-10	-10	4	-10	-10	-10	-10	-10	-10
-15	-15	-15	-15	-15	-15	-15	5	-15	-15	-15	-15	-15	-15
-22	4	4	4	4	4	4	6	-22	4	4	4	4	4
-30	-5	-5	-5	-5	-5	-5	7	-30	-5	-5	-5	-5	-5
-39	-15	-15	-15	-15	-15	-15	i = 8	-39	-15	-15	-15	-15	-15

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**Question 4 (15 marks)**

**One of Four Optional Questions**

4.1 Discuss the progress of slope monitoring over the period 1965 to present.

(3 marks)

4.2 Compare and contrast the use of automated survey slope stability monitoring with radar based systems.

Your answer should include

4.2.1 An assessment of accuracy and repeatability of the basic measurements, horizontal and vertical angles and slope distance.

4.2.2 An assessment of the changes (in X, Y and Z directions) occurring on a failing slope

4.2.3 A cost comparison (equipment acquisition and operating) and numbers of units required to adequately monitor all wall slopes.

4.2.4 An assessment of all-weather capabilities

4.2.5 A plan to evacuate personnel and equipment based on the measurements.

4.2.6 Both survey and radar monitoring measure face movement. How can such measurements indicate conditions inside the slope. What methods can be used to independently monitor movement inside the rock face.

(1.5 marks each, 9 total)

4.3 Discuss and compare the "Factor of Safety" and "Probability of Failure" criteria when designing pit wall slopes.

(3 marks)

**Question 5 (15 marks)**

**One of Four Optional Questions**

With respect to truck dispatch, what do you understand by the following and what does each accomplish.

5.1.1 Best path (BP)

5.1.2 Linear program (LP)

5.1.3 Dynamic program (DP)

(2 marks)

5.2.1 With respect to truck-shovel open pit operations, draw a sketch graph showing shovel production in tonnes per shift (Y axis) versus the number of trucks assigned to the shovel (X axis), and explain any curvature of the resulting relationship. (1 mark)

5.2.2 What could happen if the number of trucks assigned was (say) twice the number theoretically required. (1 mark)

5.2.3 What do you understand by the terms "spotting", "double back-up" and "drive by" in the context of open pit truck-shovel operations. Neat sketches are expected as are brief comparisons with regard to blast layout configurations. (2 marks)

5.3 In the context of truck-shovel mining, what do you understand by the term "match factor". (1 mark)

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

What is the total "theoretical" truck cycle time and match factor. (1 mark)

5.4 Figure 5.4 shows a sketch 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.

5.4.1 Referencing Figure 5.4 showing all possible routings, draw two neat diagrams showing the respective closed out and dispatched routes. (1 mark)

5.4.2 The times taken by the trucks to travel to and from the shovels and dumps are shown below, as are the load and dump times. 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 at Shovel 1	3
• Dumping Ore at Crusher	1
• Loading Waste at Shovel 2	3
• Dumping at Waste Dump	1

It is not necessary to convert numbers to integers for the following question 5.4.3.



5.4.3 What are the theoretical numbers of trucks required for “closed out” and “dispatched” operation in Figure 5.4 to obtain maximum production. (2 marks)

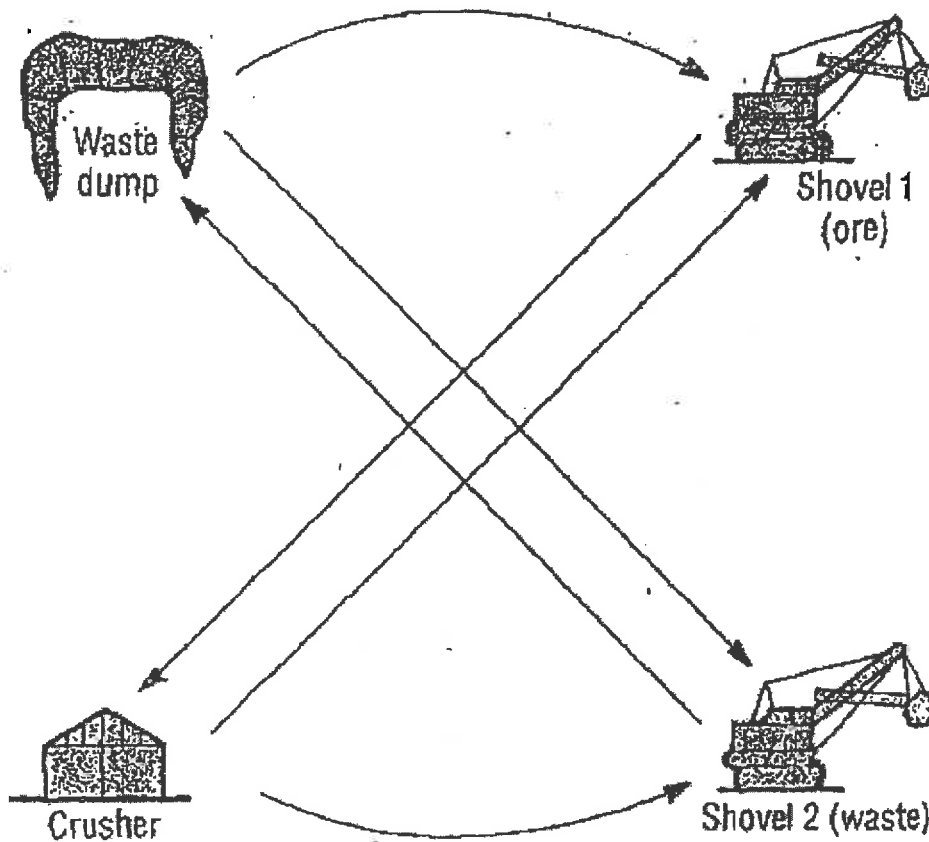


Figure 5.4 All Possible Truck Routings

5.4.4 Which trucking configuration is the most efficient, closed out or dispatched. (1 mark).

5.4.5 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. (1 mark)

5.5 All large open pits use the principles shown in Figure 5.4 and in the text of 5.4 above. Briefly describe the computer hardware employed on the shovels and trucks to achieve maximum trucking efficiency in such large pits. You may use "bullet" form headings and a brief explanation for each "bullet" in order to answer this part (5.5) of question 5.

(2 marks)

**Question 6 (15 marks)**

**One of Four Optional Questions**

6.1 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.

6.1.1 Re-vegetation and re-forestation of contoured waste dumps

6.1.2 Acid drainage remediation

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

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

6.1.5 Restoring the agricultural capabilities of the disturbed area.

6.1.6 How the abandoned open pit should be developed to provide a lake suitable for fish breeding, and alternatives.

(3 marks)

A mine has been permitted based on a 10 year mine plan and a following "reclamation" period. The cost of reclamation has been estimated as 1 million dollars based on "today's dollar".

6.2.1 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 ]

6.2.2 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%.

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

(2 marks)

6.2.3 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 mine closes unexpectedly, declaring bankruptcy. The assets are taken over and all items of salvageable value removed 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 lasting 4 years at 6%.

What is the cost of reclamation in 4 years given 6% inflation in today's dollars, i.e. the cost of reclamation in year 4 dollars as opposed to start up day's dollars or year 10 dollars.

(1 mark)

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

(2 marks)

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

(1 mark)

6.3 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)

6.4 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.

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

6.4.1 Ownership of manufacturing plants

6.4.2 Training of manufacturing/design/research employees

6.4.3 Remaining "leading edge" rather than "up-to-date" or "outdated" with mine equipment, fabrication and raw materials manufacturing is difficult. There are no local mines demanding modern innovative equipment in this case.

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

(3 marks)

Question 7 (15 marks)

One of Four Optional Questions

7.1 You have been asked by your employer to provide some quick fixed capital cost estimates for the open pit section of a mine. Who would you communicate with to provide a quick estimate +/- 40% within a day. (0.5 marks)

7.2 What do you understand by the "O'Hara Capital Cost Estimation Method" as published in the Canadian Institute of Mining Bulletin, February, 1980 and further described by Mular and Poulin in "CapCost, CIM Special Volume 47, 1998" and elsewhere in SME and other publications. (1 mark)

7.3 Working today as a capital cost estimator, how would you convert 1980 and 1998 costs to present day (2012) and say 2015 estimates. (0.5 marks)

7.4 The following are formulae for estimating the fixed capital costs of an open pit mine.

If you make an obvious, substantial and extremely large error in an estimated value, use a more logical answer in subsequent calculations and **be sure to indicate this in your exam answer.**

An open pit mine is to be located in an area of heavy tree growth and rugged terrain. Any soil will be stripped at a rate of 23,000 tonnes (metric tons, mt) per day for 60 days, and rock overburden will be stripped at a rate of 11,000 mt/day for 300 working days. The total ore plus waste to be mined per day during normal operations is 23,000 mt where the mill capacity is 9,000 mt per day. Estimate the capital cost of the mine using the following formulae.

7.4.1 What is the stripping ratio and provide a definition of this ubiquitous and well used value. (0.5 marks)

7.4.2 What is the cost of site preparation  $C_{12}$  in rough terrain given  $C_{12} = 11410 T^{0.5}$  where T is the mt/day of ore plus waste. (0.5 marks)

7.4.3 What are the costs of pre-production stripping  $C_{21}$  and  $C_{22}$  where;

Cost soil overburden  $C_{21} = 1826 \times T_S^{0.5}$  and  $T_S$  is the total mt of soil overburden

and Cost rock overburden  $C_{22} = 19395 \times T_R^{0.5}$  and  $T_R$  is the total mt of rock overburden

(0.5 marks)

7.4.4 What sizes of shovels and trucks are required where;

Shovel size  $S$  ( $m^3$ ) =  $0.1034 \times T^{0.4}$  where  $T$  is the tons/day ore plus waste in cubic meters

and truck size  $t$  (mt) =  $9.75 \times S^{1.1}$

(shovel sizes are 6, 8, 10 and 12 yd<sup>3</sup> or 4.6, 6.1, 7.6 and 9.2 m<sup>3</sup> respectively and sizes are rounded up to the next m<sup>3</sup>)

(truck sizes are 50, 60, 75, 85 and 100 st or 45, 54, 68, 77 and 91 mt respectively and sizes are rounded up to the next mt)

(2 marks)

7.4.5 What numbers of shovels ( $N_S$ ) and trucks ( $N_T$ ) are required where

$N_S = 0.0058 \times (1 / S) \times T^{0.8}$  where  $T$  is the mt/day ore plus waste

$N_T = 0.198 \times (1 / t) \times T^{0.8}$  where  $T$  is the mt/day ore plus waste

Again the numbers are rounded up to the next integer.

(2 marks)

7.4.6.1 What are the costs of the open pit equipment (auxiliary equipment e.g. graders, etc. are factored in) given;

Shovel fleet  $C_{31} = 499813 \times N_S \times (S \times 1.308)^{0.73}$  and

Truck fleet  $C_{32} = 19558 \times N_T \times (t \times 1.1023)^{0.85}$

Drilling equipment  $C_{33} = 1407359 \times N_S \times S^{0.73} \times T^{-0.2}$

(2 marks)

7.4.6.2 By dividing the cost of shovels and trucks ( $C_{31}$  and  $C_{32}$ ) by the number of units ( $N_S$  and  $N_T$ ), a rough cost per truck and shovel can be estimated. What are these unit costs, and what do you consider a good estimate for these units today.

Do these past and present values provide a good inflation index given that the cost data used by O'Hara were analyzed in the period 1978-80.

If drills and trucks cost approximately the same, how many drills are indicated (rounded up). Comment on this "rule of thumb", especially when very large trucks are involved. When the rule of thumb indicates an inappropriately high cost/drill, what can the estimator do to provide meaningful numbers of drills.

(2 marks)

7.4.7 What are the costs of maintenance  $C_4$  facilities given,

$$C_4 = 335629 \times T^{0.3}$$

(0.5 marks)

7.4.8 Electrical Power, Water, General Plant Services, Access, Town-site and Housing are dependent on location, the milling complex, and fly in-out, town-site or established towns.

Consequently this value is estimated during milling/processing infrastructure cost estimations and can be ignored when estimating open pit infrastructure costs. No calculation or estimate for  $C_5$  is required in this exam.

7.4.9 Estimate the following costs

(1 mark)

7.4.9.1 Feasibility, Engineering and Planning

5% of ( $C_{12} + C_{21} + C_{22}$ ) plus 7% of ( $C_{31} + C_{32} + C_{33} + C_4$ )

7.4.9.2 Supervision, Management, Camp, Construction Facilities

9% of ( $C_{12} + C_{21} + C_{22} + C_{31} + C_{32} + C_{33} + C_4$ )

7.4.9.3 Administration, Accounting, Key Personnel, Legal

5.5% of ( $C_{12} + C_{21} + C_{22} + C_{31} + C_{32} + C_{33} + C_4$ )

7.4.10 What is the total fixed capital cost of starting an open pit (mine only – not mill or item 7.4.8)

Total =  $C_{11} + C_{12} + C_{21} + C_{22} + C_{31} + C_{32} + C_{33} + C_4$  plus 7.4.9 (1 to 3 inclusive )

In 7.4.6.2 you estimated an inflation factor converting 1978-80 costs to present. When applied to the fixed capital cost is the answer to 7.4.10 reasonable.

(2 marks)

**Do not forget to place your name on any Figures in Question 3 and hand in with your exam booklet.**

**End of Exam**