National Exams December 2017

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 approved Sharp or Casio type 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 of 3 candidate chosen optional questions 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 Question 1.3 (page 4) and Question 3.2.2.1 to .4 (pages 9 and 10, if answered) must be completed on the exam paper and included with your answer.***

   Make sure you hand in Figure(s) 1.3 and 3.2.2.1 to .4 (if chosen as questions to answer) with your number/name attached clearly in the space provided.
7. Include any other material you may have written on.

Compulsory Question 1 (40 marks)

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

Question 1.1 (6 marks total)

O'Hara (1980 CIM Bull. No.814, 73(2): 87-99) published a well accepted method of cost estimation for mines.

$$\text{Cost} = A.T^b$$

1.1.1 Explain the formula and how A and b were estimated by O'Hara (3 marks)

1.1.2 How are cost estimates from a fixed point in time converted to "present day" and name two of the publications which facilitate the cost update. (3 marks)

Question 1.2 (6 marks total)

1.2.1 Describe typical mining bucket chain excavators (BCE's) and bucket wheel excavators (BWE's). (2 marks)

1.2.2 Include typical estimated capital cost on site and erection costs (2 marks)

1.2.3 A special emphasis on the detail of materials handling methods for these machines, from face digging tools (tooth vs lip) to material disposal from the individual machine, is required. Neat sketches must be included in your answer. (2 marks)

Question 1.3 (7 marks total)

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

1.3.1 What is the rule base for the moving cone method. (3 marks)

Apply the rule base to Figure 1.3 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.

Original

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-3|
-3|-3|
-4|-4|-4|
-4|-4|-4|-4|   | 4|
-5|-5|-5|-5|-4|-1|
-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|
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SU RF AC E

Copy

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|-1|-1|-1|
|-2|-2|-2|-2|
|-2|-2|-2|-2|-2|
|-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|
|-5|-5|-5|-5|-5|-5|-5|-5|-5|-4|-1| 2| 2| 2|-1|-4|-5|-5|
|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|-6|
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                  |-1|-1|
               |-2| 0|-1|
            |-2| 4| 4| 2|
         |-3|-3|-1| 3| 4|
      | 2|-3|-3|-3|-3|-1|
   | 3| 2|-1|-4|-4|-4|-1|
| 4| 2| 2| 2| 1|-4|-4|-4|
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1.3 Section through ope[n pit s]lope Figure

Your Name/Number ________________

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

1.3.2 Neatly show the "MC" pit outline on your Figure 1.3. Do not forget to place your name/number on the Figure 1.3 and hand it in with your answer booklet. An extra copy of the cash flow matrix in Figure 1.3 is provided in case you need to revise your "optimally" mined out area. (2 marks)

1.3.3 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 1.3 (or Copy) and hand it/them in with your answer booklet. (2 marks)

Question 1.4 (6 marks total)

Explain each of the following "modes of wall failure" (1 mark each, 1.4.4, 2 marks)

1.4.1 Circular

1.4.2 Planar (plane)

1.4.3 Toppling

1.4.4 Wedge

1.4.5 Ravelling (rubbleizing)

Question 1.5 (9 marks total)

An alternative to the pumping system described in Question 5 (in pit sump pump with pipeline to surface) is a series of deep well pumps around the pit perimeter and possibly on the ramp inside the pit.

From this perspective, described by Jacob, Theis and others, discuss;

1.5.1 How the transmissibility and storage constants of the pit wall rocks are found using a graphical solution and experimental wells. (2 marks)

1.5.2 Describe the types of pumps used in such a deep well system. (2 marks)

1.5.2 How might the pumps be laid out in plan and the pump depth determined. (1 marks)

1.5.3 What is the feasibility and cost of such a system. (2 marks)

1.5.4 The operational advantages quantified from a pit operations perspective. (2 marks)

Question 1.6 (6 marks total)

For this question, the final pit limit as defined by either the moving cone or better, Lerchs-Grossman technique with haul ramp(s) is referenced in Question 6. The outline is the assumed maximum economic pit with as steep a wall slope as practicable given that the ore-body is approximately horizontal and extends several blocks.

1.6.1 Discuss the alternatives the open pit planner has in defining a series of alternative mine plans with ramps, and whether the "final" pit is a suitable starting point in developing a 'life-of-mine" strategy. (6 marks)

Question 2 ***Syllabus "Bucket Wheel Excavators"*** **(20 marks total)**

2.1 Describe and differentiate between a typical mobile boom stacker and a conveyor bridge, and how these two units are applied to BWE's. (2 marks)

2.2 How does this auxiliary equipment affect the mine planning and layout of a typical pit operating BWE's, and how does the "side-slewable conveyor" assist in efficient mine planning and layout. Why would a telescopic discharge boom unit conveyor be useful when working with long mobile conveyors. (2 marks)

2.3 An adaptation of the bucket wheel described as a "bucket-less" bucket wheel has been patented. How does this adaptation work and how is material moved from the face, via bucket wheel to the transfer conveyor. (1 marks)

2.4 Define the term Bank Cubic Meter and how this can be used in machine productivity estimation. (1 mark)

2.5 BWE's generally dig in three configurations.

(2.5.1) block excavation; (2.5.2) bench excavation; (2.5.3) lateral block excavation

Sketch and describe the configurations, the mine planning involved and advantages of each of the three, including working floor gradients, geology and how material volumes are estimated. (3 marks)

2.6 What does the horizontal action of the bucket wheel achieve, and what does the boom length and hydraulic mechanism achieve in these (2.5) configurations (2 marks).

2.7 With respect to a typical BWE, describe in (say) 10 words each or with neat sketches each of the following (0.5 marks each, total 6 marks)

2.7.a Typical dimensions, cost, weight and crew size for a large unit

2.7.b The, cleaning (clearing) of individual bucket cells, the effect of hard abrasive boulders in the material and the desired characteristics of the material mined

2.7.c Mining production efficiency

2.7.d Machine maintainability

2.7.e Operational flexibility (include mine planning considerations)

2.7.f The effect of the capital cost of the BWE and auxiliary equipment

2.7.g Crawler design and dimensions with respect to machine weight (design kPa)

2.7.h Bench height, working and travelling gradients and digging depth

2.7.i Layout of and to multiple distant material transportation systems.

2.7.j Mining selectivity (include geological characteristics and uniformity)

2.7.k Proven reserves, horizontal stratification, material mined.

2.7.l Size of, typical production rate (speed/width) and method of moving of the long transfer conveyor

(0.5 mark each, total 6 marks)

2.8 What is the typical power consumption of a large BWE, and the annual output (as bank cubic meters and tonnes). What is the typical voltage supplied to such a BWE, and the size of and cost of the electrical cable. (3 marks)

Question 3 ***Syllabus "Design criteria for surface mines"*** **(20 marks total)**

In 1968, Lerchs and Grossman 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;

3.2.1.1 two bottom large pit (2 marks)

3.2.1.2 pit with a deep flat lying seam (2 marks)

3.2.1.3 pit resembling a "half donut" or "half bagel" of ore (leaving only the outsides and lower part and a mountain in the middle of waste i.e. in the center hole and the surrounding donut shape. (3 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 as a directed graph.

Figure 3.2.2.1 shows the matrix of cash flows. Figure 3.2.2.2 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 3.2.2.3 the P matrix has been transformed to the M matrix using graph theory and the maximum slope of 45 degrees. In Figure 3.2.2.4. 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 M (i,j) sub matrix for M (i=1 to 10, j=8 and j=9) shown in

Figure 3.2.2.1 and 3.2.2.2 for P (i = 1 to 10, j = 6, 7, 10, 11) with j = 8 and 9 left blank.

(6 marks)

Note that there is another copy in Figure 3.2.2.4 in case you make a mistake.

Figure 3.2.2.1 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	3	29	-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	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

Figure 3.2.2.2 "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	-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
-3	-3	-3	-3	-3	-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	-4	-4	-4	-4	-4
-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-1	25	-5	-5	-5	-5	-5
-7	-7	-7	-7	-7	-7	19	-2	19	-1	0	-6	-7	-7	-7	-7	-7	-7	-7	-3	23	-7	-7	-7	-7	-7
-9	-9	-9	-9	-9	-9	17	-4	17	-3	-2	-8	-9	-9	-9	-9	-9	-9	-9	-5	21	-9	-9	-9	-9	-9
-11	-11	-11	-11	-11	-11	15	-6	15	-5	-4	-10	-11	-11	-11	-11	-11	-11	-11	-7	19	-11	-11	-11	-11	-11

Print your Number/Name Here ____________________

Figure 3.2.2.3 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	6	5	5	4	3	2	1	0	-1	-1	-1	10	9
2	-2	-3	-3	-3	-3	-3	-3			-3	-3	-3	7	6	6	4	3	2	1	0	-1	-2	-3	11	9	8
3	-3	-5	-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			-7	12	11	11	7	4	1	-1	-3	-4	-5	-6	16	12	9	6	4
5	-5	-9	-12	-14	-15	-15	-15			16	15	15	10	6	2	-1	-4	-6	-8	-5	20	15	11	7	4	1
6	-7	-12	-16	-19	-21	-22	4			20	20	14	8	3	-1	-5	-8	-11	-13	-11	18	13	8	4	0	-3
7	-9	-16	-21	-25	-28	-30	-5			18	18	12	5	-1	-6	-10	-14	-17	-20	-18	10	9	4	-1	-5	-9
8	-11	-20	-27	-32	-36	-39	-15			14	14	8	1	-6	-12	-17	-21	-25	-28	-27	1	-1	-2	-7	-12	-16

Figure 3.2.2.4 (+ 1 copy) 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	j = 6	7	8	9	10	11
-1	-1			-1	-1	i = 1	-1	-1			-1	-1
-3	-3			-3	-3	2	-3	-3			-3	-3
-6	-6			-6	-6	3	-6	-6			-6	-6
-10	-10			-7	12	4	-10	-10			-7	12
-15	-15			16	15	5	-15	-15			16	15
-22	4			20	20	6	-22	4			20	20
-30	-5			18	18	7	-30	-5			18	18
-39	-15			14	14	i = 8	-39	-15			14	14

Print your Number/Name Here ______________________

3.2.3 Neatly show the LG pit outline on your Figure 3.2.2.1. Do not forget to place your name/number on the Figure 3.2.2.4 and hand both in with your answer booklet. You may use an unused copy of 3.2.2.4 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 3.2.2.3 matrix, (you may indicate this on your Figure 3.2.2.1, .2 or .3 (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 fully describe how any commercial software you are familiar with accomplishes this. (3 marks)

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

Question 4 ***Syllabus "Slope Design"*** **(20 marks total)**

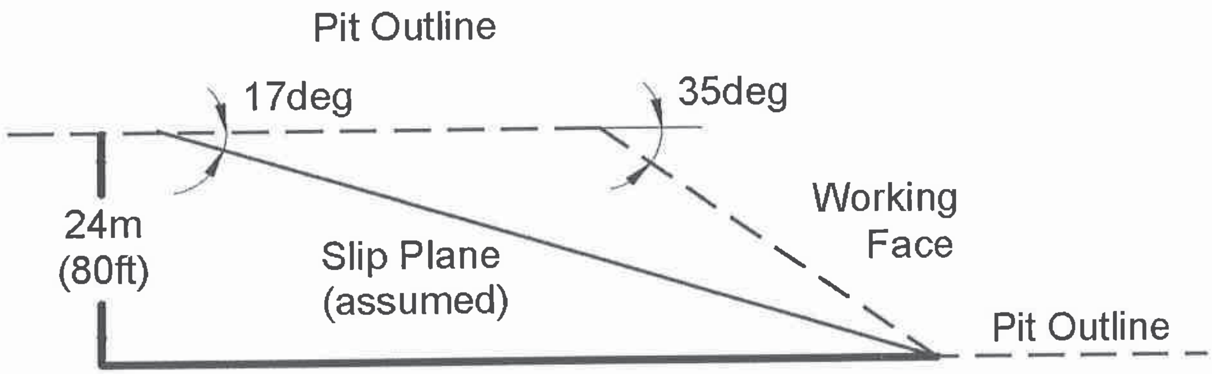
A mining engineering consultant has decided to use the "factor of safety" method to investigate and recommend a suitable wall slope angle.

4.1 What is the "factor of safety" method and is it appropriate. What other alternative methods are available to describe the stability/instability of a pit wall as a guide to indicate whether an open pit wall will be stable. What is the "accepted" non-permanent slope minimum factor of safety. (3 marks)

4.2 A first look by a mining consultant at a potential wall failure assumes a simple two dimensional (2D) planar failure exiting at the bench toe as shown in Fig 4.2 (not to scale)

4.2.1 What is the safety factor of the dry slope (Fig 4.2.1 Top) and the saturated slope (Fig 4.2.1 Bottom). (4 marks)

4.3 What conclusions can you draw regarding the method of analysis used and the effect of water on the stability of the slope. Comment on the triangular shape of the water uplift force. (3 marks)



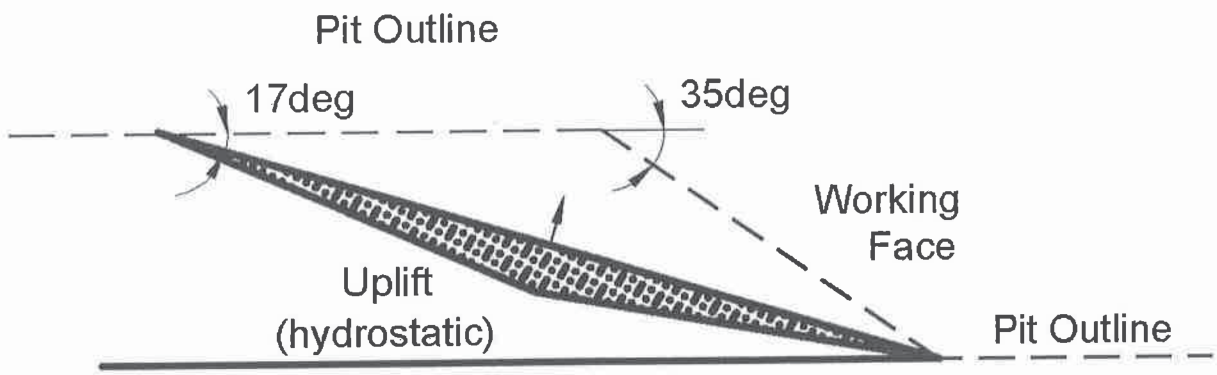
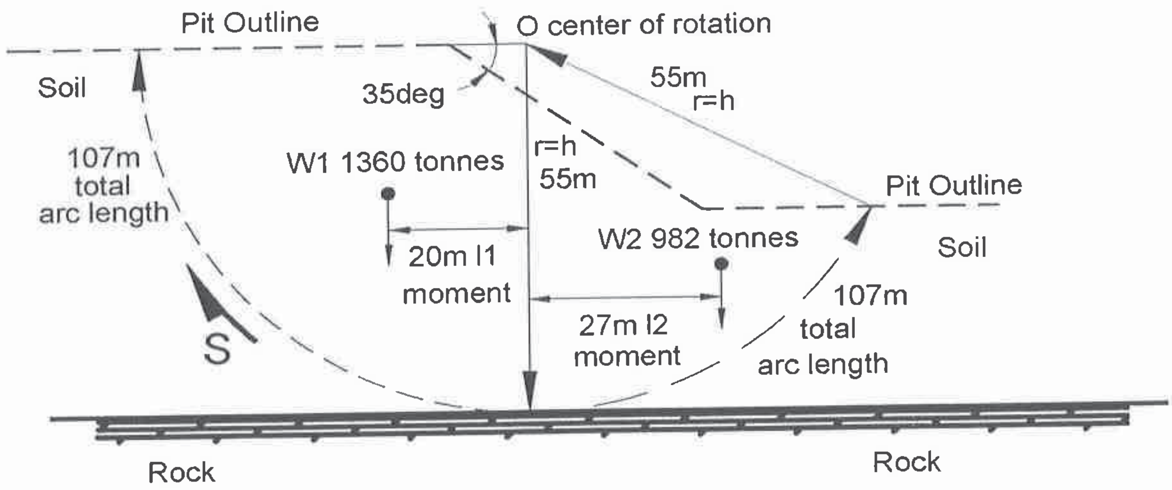


Fig 4.2 **Top (4.2.1) Dry** **Bottom (4.2.2) Saturated**

A second look (after the work described in 4.2 and 4.3) by the mining engineering consultant has decided to again use the "factor of safety" method to investigate and recommend a suitable wall slope angle but with a different approach.

4.4) Describe the "method of slices ", and what "bank failure" and "base failure" are.
(2 marks part 1, 1 mark each parts 2 and 3, total 4 marks)

A second look by the consultant again using a two dimensional (2D) analysis concluded differently than 4.2. It is recommended that the simplified base failure "Swedish" slip circle method be used with opposing bank weights on a single arc with only one slice cut. The drawing Fig 4.4 is not to scale and represents the worst case scenario minimum strength of the bank. Any slope failure will "daylight" into the face or floor of the working bench as indicated.



NTS ***based on worst case scenario*** **Fig 4.4**

The design parameters assumed are

1. The arc circle radius is 55m (180ft) about the center of rotation O
2. Density 1922 kg/m^3 (120 lbs/ft^3)
3. Cohesion *C* 5.51 kPa (115 lbs/ft^2)
4. Angle of friction ϕ 30 degrees
5. Bench height approximately 24 m (80 ft) double bench
6. Slope angle 35 degrees
7. The "worst case" center of rotation is just immediately below the "O" in Fig 4.2
8. The total failure arc (from toe of bench above to toe of working bench) is 107m (350ft)
9. The left hand driving weight is 1360 tonnes (1500 tons)
10. The left hand driving weight moment is 20m (65ft) from the line separating driving and opposing weights
11. The right hand opposing weight is 982 tonnes (1083 tons)
12. The right hand opposing moment is 27m (90ft) from the line separating driving and opposing weights

(Note, because the depth of soil varies from zero to "h" the radius of failure, an average height of $\bar{h}$ (h bar) or h/2 is used for the depth of the plane of weakness when calculating the shear strength **S.** This is the only calculation requiring the h bar or h/2 assumption)

4.5 If the slope is saturated (0.5 marks each, 3 total)

- 4.5.1 what value would you use for the angle of internal friction
- 4.5.2 what value would you use for cohesion
- 4.5.3 what are the driving and opposing moments
- 4.5.4 what is the shear strength S (Note 'h' bar)
- 4.5.5 What is the factor of safety of the saturated slope
- 4.5.6 Is the working slope acceptable if water saturates the soil from such as tension cracks

4.6 If the slope is unsaturated/dry (0.5 marks each, 3 total)

- 4.6.1 what value would you use for the angle of internal friction
- 4.6.2 what value would you use for cohesion
- 4.6.3 what are the driving and opposing moments
- 4.6.4 what is the shear strength S (Note 'h' bar)
- 4.6.5 What is the factor of safety of the unsaturated/dry slope
- 4.6.6 Is the working slope acceptable if water saturates the soil from such as tension cracks

Question 5 ***Syllabus "Pit Dewatering"*** **(20 marks total)**

A mine has chosen to use in-pit pumps in a sinking cut sump to remove water. There are two of the same type of pump available with the characteristic curves shown in Figure 5.1. below. The pumps can be used in high volume (MT) or high head (HT) configuration. The pumps can also be used submersible (with a screen adaptor around the intake) or in series (tandem) with a pipe adaptor at the inlet such that the pump inlet may have a pressure.

The mine has to move water from the sinking cut sump at 1650 meters to the pit crest discharge at 1440 meters, a 90 meter lift. The 15 meter benches from 1695 meters and up are accessible for the laying of high density polyethylene pipe, but are not suitable for pump infrastructure such as power lines, generators or for pump etc. maintenance.

The cost of a pipe line buried in the 10% ramp (900+ meters) is regarded as far too expensive and not easily repaired and therefore ignored

5.0 One pump will be placed in the sump (1650m) and run as a submersible unit and the other placed on the ramp at the 1695 meter elevation. At this upper pump, a tandem fitting will be coupled directly to the pipeline coming up from the sump. The upper tandem pump must deliver sufficient pressure to discharge water at the pit crest and has no leaks. You may assume that the friction loss in the large diameter polyethylene pipe used is small over a 125 meter length on a 45^0 pit wall.

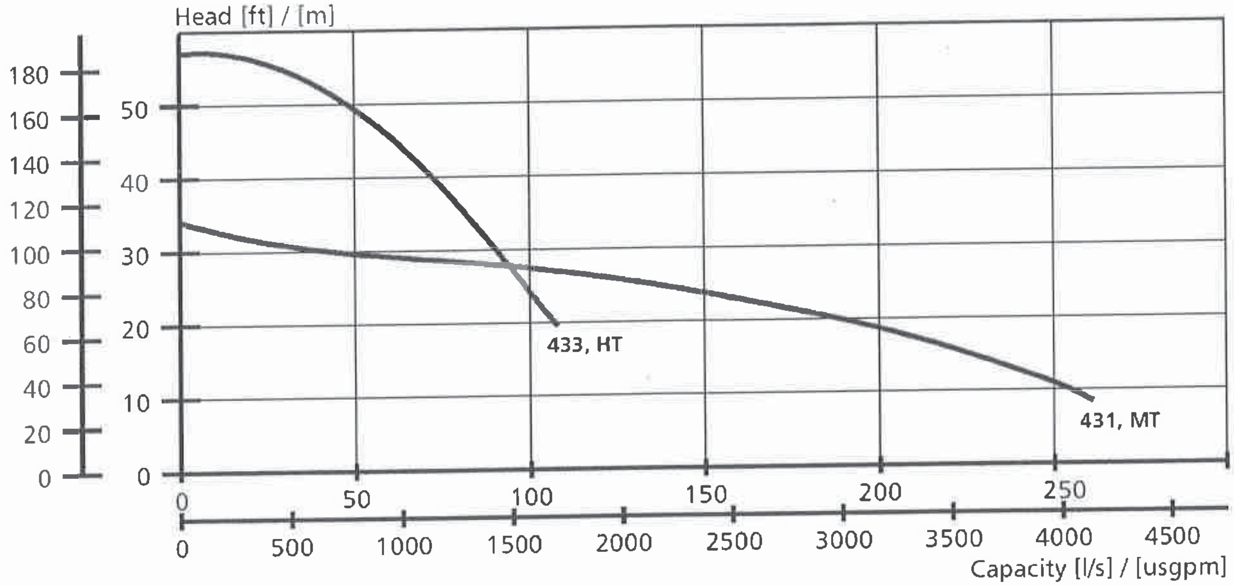


Figure 5.2 Pump characteristics (head and flow rate) for high head (433, HT) and high volume (431, MT) versions.

5.1 Describe the high volume and high head pumps in typical use in mines for the purpose of this application. (4 marks)

5.2 From the graph, Fig. 5.2, will the high volume pump configuration (431, MT) be used for both pumps. (3 marks)

5.3 What will be the maximum volume of water (liters per second) discharged at the pit crest based on the best pump configurations (HT and/or MT). (4 marks)

5.4 What will be the inlet and outlet pressures at each of the pumps in meters of water. (3 marks)

5.5 What schedule of pipe will be required at the outlets of the two pumps (3 marks)

5.6 If a check (gate) valve is fitted at the outlet of the top pump to stop water returning to the sump, what modifications will be required. (3 marks)

5. Assume the water is "clean" and temperature/pressure has no effect on density.
Some conversion factors that may or may not be of use,

1 m water at 8^{0}C is 1.41 psi 1 ft water at 62^{0}F is 0.43 psi

1 psi = 6.9 kPa 1 ft water = 3 kPa

Question 6 *Syllabus "Mine design and scheduling"* **(20 marks total)**

6.1 In Fig 6.1, the grade distribution within the pit described is shown. How is such a figure used to find, (total 2 marks)

6.1.1 the tonnage above a given cut-off grade (1 mark)

6.1.2 the grade of the material above a given cut-off grade (1 mark)

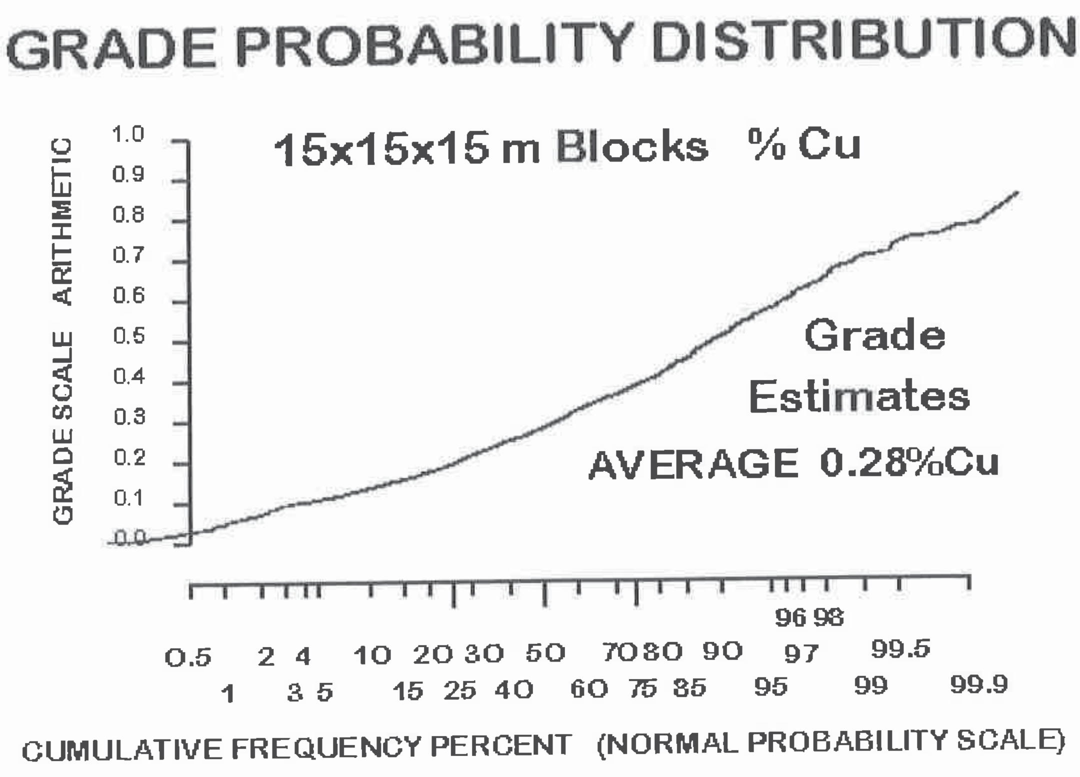


Figure 6.1 **Grade distribution of material within "ultimate" pit**

It is not expected that the many questions now asked will be answered in detail, and a summary sentence or two is all that is expected for 6.2 to 6.7 inclusive. Consider that the marks allocated to the various questions should guide the detail of your answers.

6.2 The values from a series of cut-off grades are shown in Fig 6.2. Explain the two curves shown, their shape, and why the grade rises rapidly as the cut-off grade increases. (total 2 marks)

6.3 Some assumed costs and metal prices are given below, (total 1.5 marks)

Mining Cost (ore or waste)	$1.75/tonne
Milling Cost	$5.00/tonne
General & Administration (mining)	$0.35/tonne
General & Administration (milling)	$0.80/tonne
Smelting, Refining and Sales	$0.50/lb Cu
Overall Metal Recovery	78%
Metal Price/lb Cu	$2.50

6.3.1 What is the break-even grade for the pit (1 marks)

6.3.2 Discuss the use of $2.50 as the long term price of copper (0.5 marks)

6.4 Using the break-even (e.g. cut-off) grade of 0.25 and referring to Fig 6.2 (total 3 marks)

6.4.1 What are the total tonnes (ore+waste) mined (0.5 marks)

6.4.2 What are the tonnes of ore (0.5 marks)

6.4.3 What is the average grade mined (0.5 marks)

6.4.4 What are the tonnes of waste (0.5 marks)

6.4.5 What is the stripping ratio (1 mark)

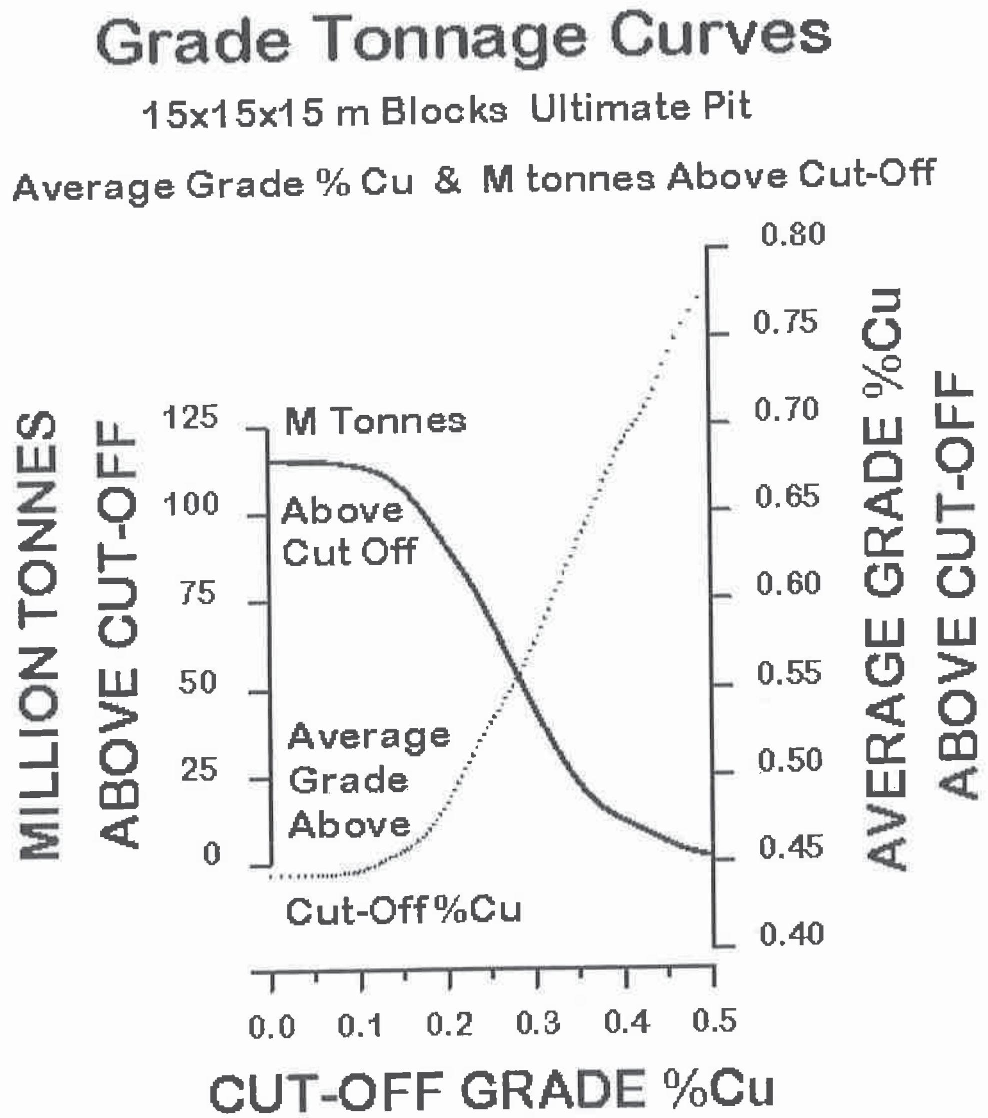


Fig 6.2 The tonnage above cut-off (left hand scale, thick curved line) and the grade of that particular sub-set of the total tonnage (right hand scale, dotted curved line)

6.5 It is now possible to estimate the life of the mine using Taylor's Rule

(total 3.5 marks)

6.5.1 What is Taylor's Rule (Taylor, H.K., 1986. Rates of working mines. Trans. Instn. Min. Metall. (Sect A: Min, Industry) 95: A203-204) (0.5 marks)

(Hint 0.2 x $\sqrt[4]{T}$ or 0.2 $T^{0.25}$)

6.5.2 What is the mine life (years) (1 marks)

6.5.3 How many tonnes are milled annually and daily (0.5 marks)

6.5.4 How much copper metal is produced annually and in total (0.5 marks)

6.5.5 From the assumed pit, estimate equipment purchases and costs, and operating costs for the mine prior to "final" pit design. (1 mark)

6.6 Costs, revenues and profits can now be estimated and later, improved upon (total 2 marks)

6.6.1 What is the total operating cost of the mine (1 mark)

6.6.2 What is the revenue from the operation (0.5 marks)

6.6.3 What is the profit (often described as cash flow), total and annual (0.5 marks)

6.7 The above describes a simplified mine design based on assumptions which will be improved upon. Some issues are as follows and you are expected to briefly describe the issues and how you will address each one in a sentence of say 10 words. (total 6 marks)

6.7.1 The Lerchs-Grossman technique used to outline the assumed maximum pit did not include the time-value of money. What effect will NPV and DCF-ROR have on the size of this assumed ultimate pit, and how can such a "time value of money" pit be designed given that the first outline (called the "assumed pit") is based on a series of assumptions which may or may not be valid. (1 mark)

6.7.2 The assumed pit will not necessarily generate early high revenues. Such early revenues can be used to retire debts. How can the mine engineer design a pit sequence which will achieve this (0.5 marks)

6.7.3 Will early stockpiling of lower grade "ore" be a suitable method of ensuring early high cash flows. What advantages will this scheme provide the mine operators. (0.5 marks)

6.7.4 Mill and processing plant facilities must be built as well as mining equipment. What can the mine planner do to operate equipment while essential mill facilities are in construction. (0.5 marks)

6.7.5 Cut off grades for all mining periods can be optimized. How would you accomplish this. (1 mark)

6.7.6 Some jurisdictions have a short early tax-free period. How will you optimize (minimize) tax payments in such a scenario. (0.5 marks)

6.7.7 The technique of "incremental analysis" can be used to ensure the "best" mine plan that improves substantially on the early assumed pit. How is such an analysis formulated. Include some information from 6.7.2 and 6.7.5 in your answer. (1 mark)

6.7.8 How will the mining sequence allow wall slope parameters to be tested. (0.5 marks)

6.7.9 The mining sequence may include mine operations under and over the mining bench. How will you avoid or mitigate any safety issues (0.5 marks)

Make sure you have included Page 3

Fig 1.3 in your answer booklet.

If you answered Question 3, make sure you have included

Pages 8 and 9 Figs 3.2.2.1 ....2 ....3 ....4 in your answer booklet.

Remember to write your name/number on each of your Figures

End of Exam **End of Exam**