National Exams **May 2016**

09-MMP-A4, Mine Valuation and Mineral Resource Estimation

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 a closed 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 7.

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.

6. Use large (½ page or larger) neat sketches and drawings to illustrate your answers when possible.

Compulsory Question 1 (40 marks)

You must answer <u>all</u> of this question, parts 1.1 to 1.6 inclusive

1.1 What are the prices of the following products as given by say "Metals Week", BNN or "Globe and Mail", and similar media ***on the day before this examination***. Answers are expected in US$, the customary currency of such products, and per pound, troy ounce or barrel are commonly used. You may use metric units if you prefer. Answers +/- 20% of actual will receive half marks, and +/- 10% full marks.

1.1.a) copper 1.1.b) gold 1.1.c) silver 1.1.d) zinc 1.1.e) oil

(1 mark each, total 5)

1.2 Describe the decision making process that determines whether a mining deposit will be mined and if so, by underground or open pit methods. (6 marks)

1.3 With regard to the semi-variogram (commonly termed "variogram") and with the aid of a sketch describe the following;

1.3.a) Random Component
1.3.b) Regional Component
1.3.c) Nugget
1.3.d) Sill
1.3.e) Range
1.3.f) Indicate on your sketch variogram the units of the X and Y axes.

(1 mark each, total 6)

1.4 A low grade open pit porphyry copper deposit located in central British Columbia is at the advanced stage of a feasibility study.

1.4.a) As an investment analyst, what typical values would you expect for the average head grade of copper milled.

(Question 1.4 continued)

1.4.b) Payable by-products are molybdenum, gold and silver. What typical head grade values would you expect for these metals.

1.4.c) If the deposit has not been oxidized, and the milling process consists of flotation of crushed and rod and ball milled ore, what, typically, would be the percentage of copper in the concentrate.

1.4.d) Would a separate molybdenum concentrate be produced.

1.4.e) Where would the "payable" gold and silver be found and accounted for after the milling process.

(2 marks each, total 10 marks)

1.5 Calculate the "Net Present Value" (NPV) for the mineral project with expenditures and revenues shown in the table below. Assume a discount rate of 10% and use the common "end of year" convention.

Year	Revenue ($ millions)	Expenditure ($ millions)
0	0	5
1	0	10
2	0	20
3	10	5
4	20	10
5	40	20
6	40	20

(5 marks)

1.6 Describe the "ordinary kriging matrix" for block grade estimation, and how the input values are determined. After the "matrix" has been solved, what output values are typically produced.

(8 marks)

Question 2 (20 marks)

The Alberta oil-sands are a huge resource, and this question starts discussing geological conditions and controls of this mineral assemblage. Fluvial, estuarine, and marginal marine deposits of the Lower Cretaceous Wabiskaw-McMurray succession make up these deposits.

2.1 Describe the simplified geology and formation of a typical oil sand deposit in the Fort McMurray – Fort Mackay area of the Wood Buffalo region.

- 2.1.1 Draw an east-west section to aid your description.
- 2.1.2 Include the predominant economic oil-sand bands in your description.
- 2.1.3 Indicate the typical grades of bitumen found in the bands.
- 2.1.4 Discuss the geological era's in which the oil-sands deposits lie.
- 2.1.5 Show on your section the saline and "fresh"water in the fluvio-estuarine zones.

(1.5 marks each 2.1.2 to 2.1.5, 2 marks 2.1.1, total 8)

2.2) Discuss and differentiate between the following, giving examples of which mine expenditures are applicable, relevant methods of calculation, and effect on cash flows.

- 2.2.1) Depreciation
- 2.2.2) Depletion
- 2.2.3) Amortization

(1.5 marks each, total 4.5)

2.3) In Canada, mining resources are owned by Provinces/Territories/First Nations Groups. Discuss the role of Federal and Provincial Corporate Taxation, Provincial Mining Taxes and Royalties in providing a satisfactory return to Canada, the provinces and First Nations groups when such oil sands resources are mined.

(1.5 marks)

2.4) A mining company has negotiated to mine part of an oil sand lease to feed a major producer during their intermittent periods of low production. A 5 year test operation following a 1 year development period has been planned. This feasibility study has generated the following anticipated cash flows in millions of dollars shown in the following table. The Government has agreed to a 50% limit on taxation to encourage such projects.

(Question 2 continued)

Note that "year" is the year end, and year 3 (for example) shows the production etc. for year 3. Year "0" refers to the year before start-up, and all interest calculations, etc., are based on the "year end".

Year	0	1	2	3	4	5
Production (recovered million tons)	0	0.052	0.036	0.026	0.018	0.016
Revenue at $40/bbl or $250/ton	0	13.0	9.0	6.5	4.5	4.0
Royalties (10%)	0	1.3	0.9	0.65	0.45	0.4
Net Revenue	0	11.7	8.1	5.85	4.05	3.6
Operating Costs	0	-2.0	-1.5	-1.0	-0.7	-0.5
Mine Acquisition & Construction	-5.0	-2.0	0	0	0	0
Depreciation	0	-1.5	-2.0	-1.5	-0.5	-1.5
Amortization	-0.5	-0.6	-0.6	-0.6	-0.6	-0.1
Taxable Income before Depletion	-5.5	5.6	4.0	2.75	2.25	1.5
50% Limit	0	2.8	2.0	1.375	1.125	0.75
Percentage Depletion (15% of Net Revenue)	0	-1.76	-1.21	-0.88	-0.61	-0.54
Cost Depletion	0	0.4	0	0	0	0
Loss Forward	0	-5.5	-0.35	0	0	0
Taxable Income	-5.5	-1.66	2.44	1.87	1.64	0.96
Tax (40%)	0	0	-0.98	-0.75	-0.66	-0.38
Net Income	-5.5	-1.66	1.46	1.12	0.98	0.58
Depreciation	0	0.9	1.6	1.1	0.8	0.6
Amortization	0.5	0.6	0.6	0.6	0.6	0.6
Depletion Taken	0	1.8	1.2	0.9	0.6	0.5
Loss Forward	0	5.5	0.4			
Mine Equipment	0	-6.7				
30% Development	-2.15	-0.85				
Mineral Property Acquisition	-1.0					

(Question 2 continued)

After Tax Cash Flow (ATCF)	**-8.15**	**-0.41**	**5.26**	**3.72**	**2.98**	**2.28**

2.4.1) Calculate the After Tax Net Present Value (NPV) at a discount rate of 15%.
If the corporate required rate is 15%, is the project acceptable to management.

2.4.2) Calculate the Present Value Ratio for (2.4.1) above, and explain if this is not/is acceptable.

2.4.3) Estimate the After Tax Discounted Cash Flow Rate of Return (DCF-ROR) for the project.

(2 marks each, 2.4.1 to 2.4.3, total 6 marks)

Question 3 (20 marks)

3.1 Provide a sketch section and describe a typical "porphyry" deposit of the type found in the Canadian Cordillera. (2 marks)

Your description should include;

3.1.1 Tectonic Setting
3.1.2 Host (and associated) rock types
3.1.3 Alteration Mineralogy
3.1.4 Associated economic minerals

(1.5 marks each, except 3.1 is 2 marks, total 8 marks)

3.2 Such deposits (3.1) usually have good descriptive variograms which you have already discussed in some detail in 1.3. and are best described by a "nested spherical" model

A nested spherical semi-variogram (the more usual term "variogram" is used interchangeably in this exam) consists of a nugget and two structures.

3.2.1 Make a sketch graph showing the following "nested" structure and the sum of values;

Nugget		0.1		
Structure (1)	Sill	0.5	Range	100m
Structure (2)	Sill	0.4	Range	500m

(2 marks)

What is the gamma (γ) variogram value at distances of;

3.2.1.a)	0 meters	3.2.1.b)	50 meters
3.2.1.c)	250 meters	3.2.1.d)	1000 meters

(1.5 marks each, total 6)

3.2.2 Practitioners often use the same variogram to estimate block grades in "high grade" areas and "lower grade" areas. Detail any pitfalls in such an approach.

(2 marks)

Question 4 (20 marks)

The porphyry copper ore-body (Question 1.4 and 3) contains amounts of lead slightly less than the grade of molybdenum. As the potential mine is located in central British Columbia, the copper concentrate could be sent to smelters in eastern Canada or to ports on the eastern Pacific coast.

4.1) As an analyst, describe a typical smelter contract for the copper concentrate. Include items such as;

4.1.a) Charges and deductions
4.1.b) How refining of the copper will be accounted for
4.1.c) What effect the lead will have on revenue
4.1.d) How gold and silver will be accounted for

(1 mark each, total 4 marks)

4.2) Transporting concentrates from the mine to the smelter incurs substantial costs. Use a diagram to help describe the various modes of transportation employed in getting concentrate from mine site to smelter destinations in both eastern Canada and the Pacific rim. Include some estimates of costs and justify a choice of either destination.

(1.5 marks)

4.3) Why does molybdenum provide almost as much revenue as copper, despite the molybdenum grade being typically less than a quarter that of the copper in the ore.

(1.5 marks)

4.4 to 4.7 Net smelter return model -- simplified model for Copper only
(Note some questions are duplicated to maintain the flow of calculations)

4.4 :- A small copper mine produces 275,000 tonnes (mt) of ore annually. The mined ore grade is expected to be 2.32 % Cu. One metric ton (mt) is referred to throughout as 2205 lbs. Mill recovery is 85%. The grade of concentrate is 21%. The copper price is $1.5/lb ($3307.5/mt).

4.4.1 What are the mt of the metal contained in ore

4.4.2 What are the mt of metal in ore after recovery

4.4.3 What are the mt of concentrate if the grade of concentrate is 21%

(Question 4 continued)

4.4.4 What is the mt of contained metal in concentrate.

4.4.5 What are the lbs of contained copper in concentrate (0.5 marks each total 2.5)

4.5 :- Find the payable metal

A fixed deduction of 1.1 units (22.05 lbs *1.1) is charged.
The treatment charge is equal to $75 per tonne of concentrate.
Transport, with loading and representation, costs $39 per tonne.
The refining charges are equal to $0.075 per pound of payable copper
Assume no penalties or price participation.

4.5.1 Find the contained metal in concentrate

4.5.2 Find the metal per mt concentrate

4.5.3 Find the metal per lb concentrate

4.5.4 Find the metal deduction (lbs Cu)

4.5.5 What is the payable metal. (0.5 marks each total 2.5)

4.6 :- Deductions and charges have to be accounted for :-

4.6,1 What is the total value of charges per mt concentrate

4.6.2 What is the refining charge per mt of concentrate

4.6.3 What is the total value of deductions in $ per mt concentrate

4.6.4 What is the value after deductions and refining per mt concentrate

4.6.5 Find the value per mt of ore after deductions. (0.5 marks each total 2.5)

(Question 4 continued)

4.7 :- Estimate the NSR (Net Smelter Return)

4.7.1 What is the NSR factor (0.5 mark)

4.7.2 Find the value per mt ore (0.5 mark)

4.7.3 What is the NSR in $ revenue per mt ore (2.5 marks)

4.8 :- Discuss the smelter contract for metals such as copper, zinc, and molybdenum. Be sure to include such as stoppages (mine and smelter), rules for assaying, date/time/location of metal price fixes, applicable courts, modes of transportation and shipping containers, and mixing of concentrates from several mines to avoid demurrage. (2 marks)

Question 5 (20 marks)

5.1.a) Given simple 10% straight line depreciation, sketch a graph showing DCF Yield (Y) against General Rate of Inflation (X) with a tax rate of 45%. Does the DCF Yield increase or decrease with inflation. (2 marks)

5.1.b) Sketch a further graph using the same axes showing how a project financed with 60/40 loan/equity ratio capital will behave in an inflationary environment. Ignore any taxes paid by the lender and investor. Assume again 10% straight line depreciation and a 45% tax rate. Does the DCF Yield increase or decrease with inflation. (2 marks)

5.1.c) Will the Inflationary effects of (taxes and depreciation versus capital at 60/40) cancel in some cases, and is this a reason to ignore inflation when assessing mining projects.

(1 mark)

For the following sections of Question 5, use examples relating to Canadian mined products and to Canadian mining corporations working internationally where applicable.

5.2) Recent capital cost estimates for mine and plant construction have often been half of the eventual cost. How would you analyze and apportion the causes of such a huge increase that is obviously not due to inflation alone. Include your recommendations to avoid such problems in future capital cost estimates.

(1 mark)

5.3) For almost all mined products, selling prices can go down as well as up, sometimes double or half in a year. Compare and contrast the five approaches to price inflation/deflation listed below which can be used in estimating future selling prices.

5.3.a) Extrapolation of historical data
5.3.b) Long term econometric modeling
5.3.c) The 'inferred price' or historical relationship between production cost and average selling price
5.3.d) Estimation of the "breakeven price"
5.3.e) "Monte Carlo" simulation

(0.5 marks each, total 2.5)

(Question 5 continued)

5.4) In international project evaluation, the currency used is up to the evaluator. Discuss which currency is most appropriate for the following costs;

5.4.a) Engineering

5.4.b) Construction

5.4.c) Operating

5.4.d) Product sales revenues

(1 mark each, total 4)

5.5) Discuss the appropriateness of the following three methods of accounting for inflation in mining project feasibility over the life of a project;

5.5.a) Work in constant present day money

5.5.b) Work in current money

5.5.c) Work in current money for a number of years (say to start of production) and thereafter work in constant money terms

(1 mark each, total 3)

5.6) Discuss and differentiate between the following, giving examples of which mine expenditures are applicable, relevant methods of calculation, and effect on cash flows.

5.6.a) Depreciation

5.6.b) Depletion

5.6.c) Amortization

(1.5 marks each, total 4.5)

Question 6 (20 marks)

6.1 Open pit "epithermal "gold deposits are becoming the major source of gold as opposed to vein and concentrated type underground deposits.

6.1.1 Provide a sketch section and describe a typical "epithermal" deposit of the type found on the Pacific Rim and the Rocky Mountain area. (2 marks)

Your description should include;

6.1.1.a Tectonic Setting (including Caldera's)
6.1.1.b Action of water (as fluid or steam)
6.1.1.c Alteration Mineralogy
6.1.1.d Associated economic minerals

(1.5 marks each, 6.1.1.a to 6.1.1.d. total 6 marks)

6.1.2) In "simple" kriging, the sum of weights is seldom 1 (100%). How is the problem of systematically under/over estimating block grades resolved.

(2 marks)

6.1.3) Describe and compare the "ordinary" and "simple" kriging methods of obtaining block grade gold estimates from dispersed assay data.

(2 marks)

6.2 In recent years "indicator" kriging has become a more mainstream method of estimating block grades in "epithermal" type gold deposits.

6.2.1 What characteristics of simple kriging make it ineffective in estimating "epithermal" gold.

6.2.2 Describe typical "indicator" variograms.

6.2.3 Discuss the basic results of "indicator" kriging

6.2.4 Show how the method can be used to estimate the volume and average grade of both the ore and the waste contained in a block at any given a cut-off grade.

(2 marks each, total 8)

Question 7 (20 marks)

Describe, with the aid of sketches/sections, the geologic settings and ore deposit models of the following types of deposit. Specify the constituent economic minerals/products, typical mining methods and operating costs as applicable to resource estimation in the Canadian mining industry.

7.1) Volcanogenic massive sulphide (VMS)
7.2) Besshi type
7.3) Evaporites such as those from the Permian basins
7.4) Sedimentary exhalative deposits (SEDEX)
7.5) Sudbury igneous complex (SIC)

(4 marks each, total 20)

End of Exam