

**SCHOOL OF MINES**  
**POSTGRADUATE FINAL EXAMINATIONS**  
**2010-2013 - ACADEMIC YEAR.**

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**2010 ACADEMIC YEAR FIRST SEMESTER UNIVERSITY FINAL EXAMINATIONS**  
**POSTGRADUATE DIPLOMA IN INTEGRATED WATER RESOURCES MANAGEMENT**

**IWRM 6012 (MODULE 2): Answer three (3) questions only. Possible marks / points for each question are indicated in brackets.**

1. (a) Managing water based on river catchments or basins is encouraged in IWRM as a way to manage water resources. In Zambia, the principle has been adopted in the Water Resources Action Programme (WRAP). Draw a neatly labeled map of Zambia showing these proposed catchments (12 marks)
- (b) Describe briefly how you would monitor the quantity and quality of these water resources - (8 marks)
2. You are the new Remote Sensing Coordinator working for the National Heritage Commission, to make digital maps in a GIS environment as a promotional tool in a forthcoming trade fair. You need to give some technical instructions to your research assistants on the assignment before they go hiking off to waterfalls and remote towns. Using your knowledge of the basic concepts of Remote Sensing and GIS:
  - a) Describe the components of a RS system? (8 marks)
  - b) List the eight (8) image recognition elements that will be implemented in the project? (8 Marks)
  - c) What is the difference between a supervised and unsupervised classification? (2 Marks)
  - d) What are the four possible misconceptions of a GIS that your researchers have? (2 marks)
3. Differentiate between the following:
  - a) Spatial resolution and Spectral resolution (4 Marks)
  - b) Radiometric resolution and Temporal resolution (4 Marks)
  - c) Georeference and ArcGIS (4 Marks)
  - d) NDVI and UTM (4 Marks)
  - e) TIFF and JPEG (4 Marks)
4. Hazardous chemical wastes were accidentally spilled at an industrial site. The groundwater in the area where the spillage took place is known to have an electrical conductivity (EC) of 500  $\mu\text{S}/\text{cm}$ . In order to determine whether there was a risk of contamination to the groundwater, geoelectrical measurements were taken close to the site since the contaminants were known to increase the electrical conductivity of water. Figure 1 shows the curve of apparent resistivity versus half electrode spacing for the Schlumberger array, whereas Table 1 shows the corresponding layered earth model parameters based on the electrical resistivity measurements. It is also known that the general geology of the area is Basement Complex with formation factor of about 4.

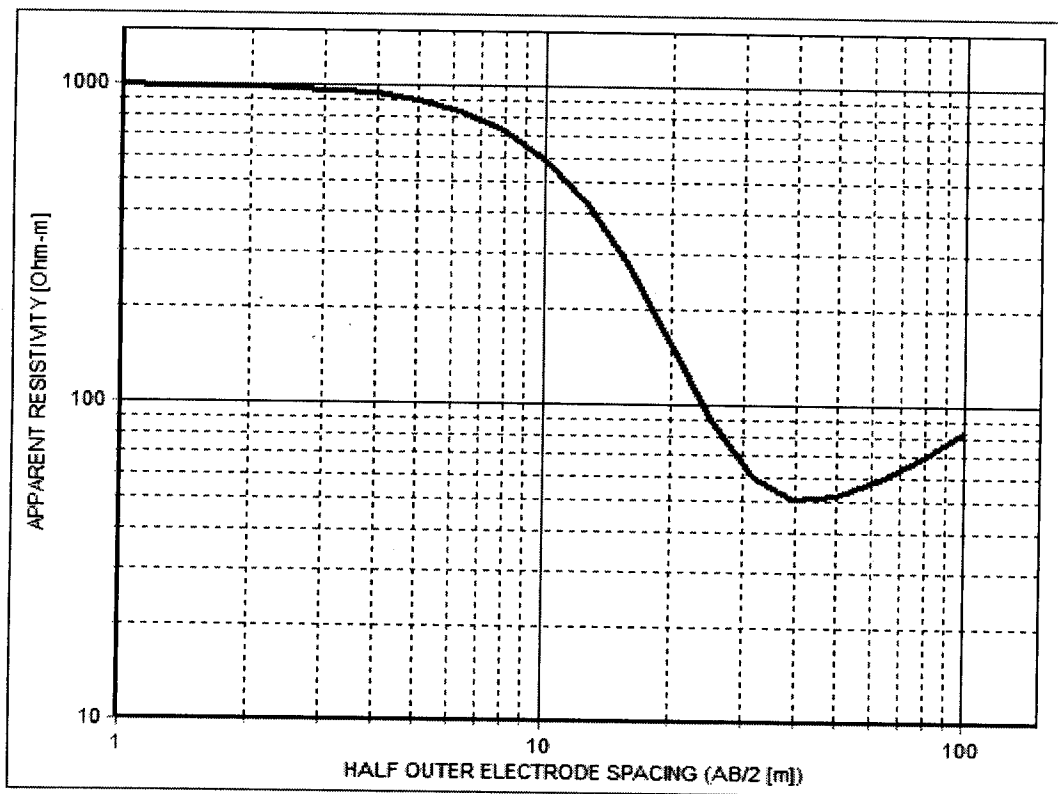


Figure 1: Apparent Resistivity Curve

Table 1: Layered Earth Model Parameters

LAYER	RESISTIVITY [Ωm]	THICKNESS [m]	DEPTH [m]
1	1,000	6	6
2	40	45	51
3	10,000	-	-

Using the available data:

- Describe the occurrence of groundwater at the site, **(10 Marks)**
- Is there any risk of contamination to groundwater at the site? Explain based on the resistivity data. **(10 Marks)**

5. (a) What geophysical techniques are recommended for the following areas of interest?
- Mineral Exploration; and
  - Environmental Surveys **(4 Marks)**

(b) Define the following terms:

- Salinity
- Hydraulic Head **(4 Marks)**

- (c) Briefly describe the occurrence of groundwater in the different groundwater provinces of Sub Saharan Africa **(12 Marks)**

**END OF EXAM**

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

**2010 ACADEMIC YEAR FIRST SEMESTER UNIVERSITY FINAL  
EXAMINATIONS**

POSTGRADUATE DIPLOMA IN INTEGRATED WATER RESOURCES MANAGEMENT

**IWRM 6013 (MODULE 3) - WATER RESOURCES MODELLING**

AND

**IWRM 6017 (MODULE 7) – SCENARIO ANALYSIS AND IMPACT ASSESSMENT**

**INSTRUCTIONS:**

**TIME: THREE (3) HOURS**

**IWRM 6013 (Module 3): ANSWER ANY THREE (3) QUESTIONS: Possible marks /  
Points for each Question are indicated in Brackets.**

**IWRM 6017 (Module 7): ANSWER THREE (3) QUESTIONS ONLY. Possible  
marks /**

**Points for each Question are indicated in Brackets.**

**NOTE: EACH MODULE SHOULD BE ANSWERED IN A  
SEPARATE ANSWER BOOKLET**

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**IWRM 6013 (MODULE 3) - WATER RESOURCES MODELLING**

**QUESTION ONE**

(a) List and explain the three main objectives of IWRM (8 marks)

(b) Lake Kariba in Zambia has the following characteristics:

- Volume: 180.6 km<sup>3</sup>
- Surface area: 4958.5 km<sup>2</sup>
- Average inflow: 1486 m<sup>3</sup>/s
- Height of the dam: 128 m

(i) What is the mean residence time of the water in the lake? (4 marks)

- \* (c) The total average river inflow into the Barotse wetlands in the western province of Zambia is about  $800 \text{ m}^3/\text{s}$ . The flooded area of the Barotse wetlands is approximately  $8000 \text{ km}^2$ . Annual average precipitation in the area is around  $2 \text{ mm/day}$  and annual average evapotranspiration is around  $4.1 \text{ mm/day}$ . Assume that no groundwater infiltration occurs in the Barotse wetlands. What is the average outflow from the Barotse wetlands? **(8 marks)**

## QUESTION TWO ✓

- a) Name the three major users of water **(3 marks)**
- b) Give the expression of the general water balance equation and show how the different components of the hydrological cycle can be fitted to the general equation **(7 marks)**
- \* c) For typical conditions in Zambia, the copper load to the river is about  $0.6 \text{ g}$  copper per  $\text{kg}$  of copper produced. The Lumwana copper mine, which recently was established in the Kabompo subbasin of the Zambezi River basin, is scheduled to produce about  $122\,000$  tons of copper per year over the next 37 years. The Kabompo River at Watopa Pantoon has an average discharge of  $341 \text{ m}^3/\text{s}$ . Natural copper concentrations in the river are around  $3 \mu\text{g l}^{-1}$ .
- (i) What is the expected copper concentration in the river in the future? **(10 marks)**

## QUESTION THREE

- (a) What is run-off coefficient? **(5 marks)**
- (b) What are the advantages and disadvantages of Smakhtin's method of estimating environmental flows **(8 marks)**
- (c) You are analyzing the Kafue basin of  $69000 \text{ km}^2$ . You model the groundwater aquifer in the catchment as a linear reservoir, i.e.

$$\frac{DV}{Dt} = r - \frac{1}{K}V$$

The groundwater recharge rate ( $r$ ) in the catchment is  $40 \text{ mm/yr}$ . The time constant of the groundwater reservoir ( $K$ ) is 200 years. In year 0, the total groundwater volume per unit surface area ( $V$ ) is  $5000 \text{ mm}$ . What will be the groundwater volume one year later (year 1)? **(7 marks)**

#### **QUESTION FOUR** ✓

- (a) What is the fundamental Management unit in water resources management? (4 marks)
- (b) Briefly describe three tools that are used in water resources management (8 marks)
- (c) The average annual precipitation for the Barotse basin (118,000 km<sup>2</sup>) is about 2.5 mm/day. The average annual observed discharge is at the catchment outlet at Katima Mulilo is about 341 m<sup>3</sup>/s. What is the runoff coefficient for this catchment?(8 marks)

#### **QUESTION FIVE**

- a) What is a flow duration curve? (4 marks)
- b) Draw the flow duration curve for a river from the following data in Table 5.1

**Table 5.1. Daily discharge and frequency of occurrence.**

Mean daily discharge	Frequency of occurrence
> 315	21
210-315	61
120-210	153
95-120	94
75-95	108
50-75	188
42-50	147
26-42	260
16-26	280
< 16	149

- i) What flow is exceeded 2% of the time? (8 marks)
- ii) What is the average flow of the river during the time period? (8 marks)

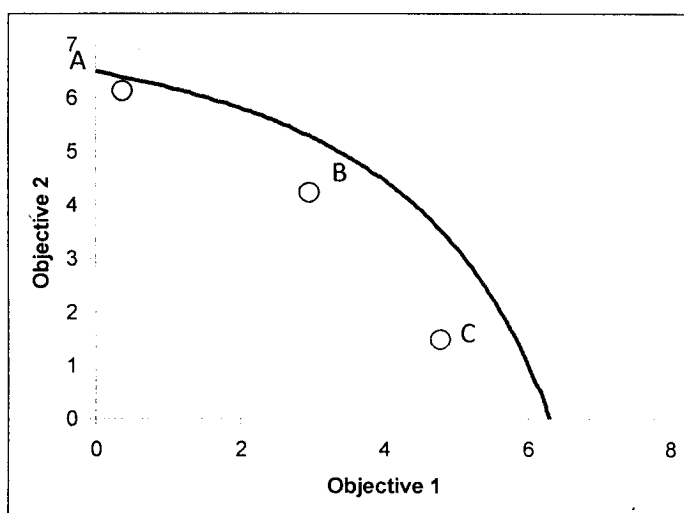
## IWRM 6017 (MODULE 7) – SCENARIO ANALYSIS AND IMPACT ASSESSMENT

### ANSWER ANY THREE

#### QUESTION ONE

- (a) List the four single objective constrained optimization methods(5 marks)
- (b) What are the pros and cons Linear Programming? (5 marks)
- (c) Figure 1.1 shows the Pareto front in a 2-objective optimization problem and the performance of 3 selected policies, A, B and C

**Figure 1.1 Pareto front diagram.**



The decision makers put equal weight on the two objectives. Which policy should they choose? Explain your answer (10 marks)

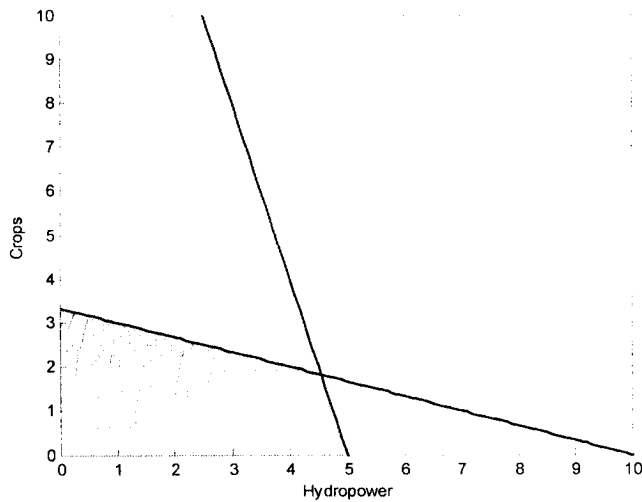
#### QUESTION TWO

- (a) Define the term crop coefficient (4 marks)
- (b) What do you understand by the term environmental flows and describe one method that is used to calculate the environmental flow (6 marks)
- (c) The average natural flow into the Luangwa Valley is about  $1500 \text{ m}^3 \text{ s}^{-1}$  in July. How many square kilometers of cotton culture can be irrigated with this amount of water, assuming a crop coefficient of 1.2 and an overall efficiency of the irrigation of 0.5? The reference ET in the Luangwa Valley in July is about  $5 \text{ mm day}^{-1}$  and precipitation is 1 mm per day. (10 marks)



### QUESTION THREE

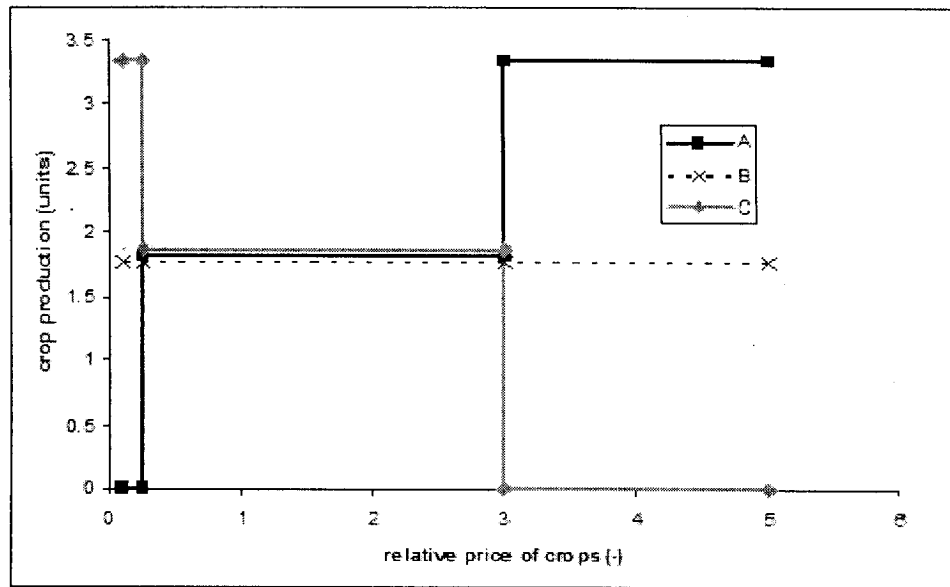
- (a) Describe any of the three application of dynamic programming in resources optimization **(10 marks)**
- (b) A basin manager faces the following problem: Crops and hydropower can be produced with inputs of land and water. Land and water are finite resources and the constraints are graphically displayed in Figure 3.1 below:



**Figure 3.1. Graph of constraints.**

- iii) The following graph shows the production of crops as a function of the relative price (price crops / price hydropower) of crops. Which is the correct graph? Justify your answer? **(10 marks)**

Figure 3.2. Crop production graph.



#### QUESTION FOUR

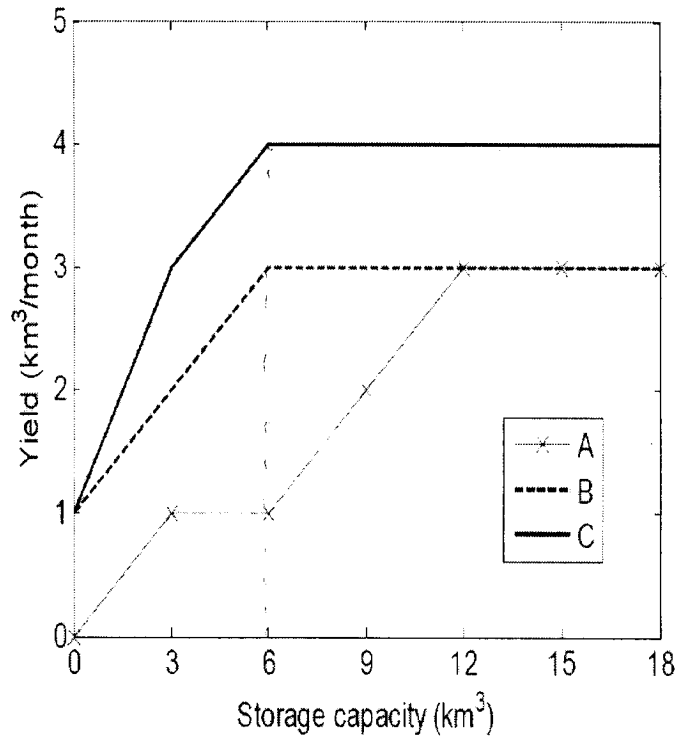
- (a) A river has the following deterministic (same every year!) hydrograph data in Table 4.1.

Table 4.1. Hydrograph data.

Season	Discharge (km <sup>3</sup> per month)
Spring (Mar-May)	2
Summer (Jun-Aug)	4
Autumn (Sep-Nov)	1
Winter (Dec-Feb)	5

Which of the three graphs show below is correct justify your answer (10 marks)

**Figure 4.1. Yield versus storage capacity diagram.**



(b) Two types of crops can be grown in particular irrigation area each year. Each unit quantity of crop A can be sold for a price  $P_A$  and requires  $W_A$  units of water,  $L_A$  units of land,  $F_A$  units of fertilizer, and  $H_A$  units of labor. Similarly, crop B can be sold at a unit price of  $P_B$  and requires  $W_B$ ,  $L_B$ ,  $F_B$  and  $H_B$  units of water, land, fertilizer, and labor, respectively, per unit of crop. Assume that the available quantities of water, land, fertilizer, and labor are known, and equal  $W$ ,  $L$ ,  $F$ , and  $H$ , respectively.

- i) Structure a linear programming model for estimating the quantities of each of the two crops that should be produced in order to maximize total income.

**(10 marks)**

### **QUESTION FIVE**

- (a) What is a decision support system? **(8 marks)**
- (b) Suppose you live in an area where the only source of water (at a reasonable cost) is from an aquifer that receives no recharge. Briefly discuss how you might develop a plan for its use over time. **(12 marks)**

***THE END OF EXAM***

**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF MINES**

**2010 ACADEMIC YEAR FIRST SEMESTER UNIVERSITY FINAL EXAMINATIONS  
POSTGRADUATE DIPLOMA IN INTEGRATED WATER RESOURCES MANAGEMENT**

**IWRM 6014 (MODULE 4) - WATER USE AND WASTE WATER  
AND  
IWRM 6016 (MODULE 6) – WATER ECONOMICS**

**INSTRUCTIONS:**

**TIME: THREE (3) HOURS**

**IWRM 6014 (Module 4): ANSWER QUESTION ONE AND ANY TWO (2) QUESTIONS:  
Possible marks / Points for each Question are indicated in Brackets.**

**IWRM 6016 (Module 6): ANSWER THREE (3) QUESTIONS ONLY. Possible marks /  
Points for each Question are indicated in Brackets.**

**NOTE: EACH MODULE SHOULD BE ANSWERED IN A SEPARATE  
ANSWER BOOKLET**

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**IWRM 6014 (MODULE 4) - WATER USE AND WASTE WATER**

**QUESTION ONE**

- a) Explain how heat can pollute a water course. **(2 marks)**
- b) Explain how organic waste discharged into a water course will affect the ecosystem of that water course. **(2 marks)**
- c) Give two types of water sampling and for each, give conditions under which it is appropriate. **(4 marks)**
- d) Faecal Coliforms are 'indicator microorganisms' for microbiological contamination of water.
  - a. Explain the meaning of 'indicator microorganism' in this context. **(2 marks)**

b. Give two reasons why faecal coliforms are preferred as indicator microorganism.

**(2 marks)**

e) Define Biochemical Oxygen Demand and explain how it relates to Chemical Oxygen Demand. **(4 marks)**

f) Explain what each of the following treatment stages is and also indicate its significance.

i) Screening **(2 marks)**

ii) Grit Removal **(2 marks)**

## **QUESTION TWO**

(a) Explain what the presence of the following gases in wastewater would signify:-

i) High content of Dissolved Oxygen. **(4 marks)**

ii) High content of Ammonia and Hydrogen sulphide. **(4 marks)**

(b) Kafue steel factory discharges toxic effluents to the activated sludge wastewater treatment plant that treats both domestic and industrial wastewater generated in Kafue town. How will this affect the treatment of the wastewater? **(6 marks)**

(c) Distinguish between volumetric organic loading rate and surface organic loading rate as they apply to wastewater treatment employing trickling filters. **(6 marks)**

## **QUESTION THREE**

(a) Explain how the colloidal and dissolved organic matter are removed from the wastewater in a conventional wastewater treatment plant. **(5 marks)**

(b) What is the purpose of secondary sedimentation tanks in a conventional wastewater treatment plant? **(5 marks)**

(c) Raw wastewater with a BOD concentration of 300mg/l is to be treated using a conventional wastewater treatment method; specifically trickling filters. The flow rate per day is 2400m<sup>3</sup>/h. With the minimum design temperature of 15°C, it is observed that the primary sedimentation tanks are able to remove 25% of the BOD. The trickling filters, under the same conditions, are able to remove 70% of the BOD.

(i) Calculate the BOD concentration in the effluent. **(5 marks)**

(ii) The wastewater is being treated by two trickling filters each with an effective height of 2m and diameter 20m, calculate the volumetric organic loading rate to the filters. **(5 marks)**

#### **QUESTION FOUR**

- (a) What do you understand by the term humus as it applies to conventional wastewater treatment? **(4 marks)**
- (b) In sludge treatment, feeding of sludge into the digester needs to be properly controlled. Explain why this is important. **(4 marks)**
- (c) Give two major distinctions between standard and high rate sludge digestion. **(4 marks)**
- (e) A high rate digester with a permissible loading rate of 3.0kg of volatile suspended solids per cubic meter per day is to treat sludge from an activated wastewater treatment plant. If the sludge characteristics are such that in a 100ml of sludge sample, there is 12g of solids out of which 75% are volatile solids, calculate how much of this sludge should be feed into the digester per day if the digester has a radius of 5 meters and a depth of 5 meters. **(8 marks)**

#### **QUESTION FIVE**

- (a) Sewage collection from residential households is normally under atmospheric pressure (open channel flow conditions). Explain why this is important? **(4 marks)**
- (b) Explain how nitrogen is removed from wastewater in an activated sludge plant. **(6 marks)**
- (c) A wastewater treatment plant is designed to handle 25 liters of domestic wastewater per second. The BOD concentration in the influent is 300mg/l and the faecal coliform count is  $1 \times 10^8$  FC/100ml. There is a faecal coliform reduction of 1 log unit in the anaerobic ponds and another log unit in the facultative ponds. Given that the reduction of bacteria in maturation ponds follows the first order equation given below

$$\frac{N_e}{N_i} = \frac{1}{\left[1 + K_b \frac{\tau}{n}\right]^n}$$

Where

$N_e$  and  $N_i$  = number of faecal coliforms in the effluent and influent respectively

$\tau$  = hydraulic retention time

$K_b$  = the die off rate coefficient (in  $\text{day}^{-1}$ ) which is temperature dependent and is given by

$$K_b = 2.6(1.19)^{(T-20)}$$

Where T is temperature in  $^{\circ}\text{C}$ .

**Design the maturation pond(s)** if the faecal coliform count in the final effluent is not to exceed 2500FC/100ml and if the lowest average ambient temperature for the coldest month for the area where the system is to be constructed is 15°C. Take the pond depth to be 1m and the width to length ratio to be 1:3. **(10 marks)**

**IWRM 6016 – WATER ECONOMICS**  
**ANSWER ANY THREE QUESTIONS FROM THIS MODULE**

**QUESTION ONE**

- (a) Define the following terms
  - i. Net Present Value(2 marks)
  - ii. Internal Rate of Return (2 marks)
- (b) What is benefit-cost analysis? (4 marks)
- (c) List four disadvantages of benefit-cost analysis (6 marks)
- (d) Explain what do you understand by discounting? (6 marks)

**QUESTION TWO**

- (a) What effect will each of the following have upon the demand for product B?
  - (i) The price of product C, a good substitute for B goes down (3 marks)
  - (ii) Consumer anticipate declining prices and falling prices (3 marks)
  - (iii) There is a rapid upsurge in population growth (4 marks)
- (b) What effect will each of the following have upon the supply for product B?
  - (i) A technological advance in the methods of producing B (3 marks)
  - (ii) An increase in the prices of resources required in the production of BN (3 marks)
  - (iii) A decline in the number of firms in industry B (4 marks)

**QUESTION THREE**

- (a) Briefly describe the four cornerstones of environmental economics (8 marks)
- (b) A dam was to be constructed in Kalabo district and the following are the cost Materials K500,000,000; Labour K 600,000,000 and the benefits were as follows: Recreation = K400,000, 000 ;Flood control = K300,000,000; Electricity = K500,000,000
  - (i) What is the net benefit of the project? (6 marks)
  - (ii) At a discounted rate of 10% should the Dam be constructed after one year? (6 marks)



#### **QUESTION FOUR**

- (a) What is a market? **(4 marks)**
- (b) How do economists define cost distinguish between explicit and implicit cost giving examples of each case **(8 marks)**
- (c) Economics is the study of the principles governing the allocation of scarce among competing ends when the objective of allocation is to maximize the attainment of the ends. Explain why the market concept fails when it comes to water resources **(8 marks)**

#### **QUESTION FIVE**

- (a) Prices are the automatic regulator that tends to keep production and consumption in line with each other. Explain? **(6 marks)**
- (b) Discuss the factors which can affect the demand and supply graph and show in each case how the graph will behave **(14 marks)**

**END OF EXAM**



THE UNIVERSITY OF ZAMBIA  
IWRM CENTRE

2011 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS

POSTGRADUATE DIPLOMA IN INTEGRATED WATER RESOURCES MANAGEMENT

IWRM 6014 (MODULE 4): WATER USE AND WASTE WATER  
AND  
IWRM: 6016 (MODULE 6): WATER RESOURCES ECONOMICS

TIME: THREE (3) HOURS

CLOSED BOOK

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INSTRUCTIONS TO CANDIDATES

1. THIS PAPER HAS TWO SECTIONS EACH CONTAINING FIVE QUESTIONS.
2. YOU ARE REQUIRED TO ATTEMPT ANY THREE QUESTIONS FROM EACH SECTION
3. SOLUTIONS FOR EACH SECTION ARE TO BE PRESENTED IN SEPARATE ANSWER BOOKLETS
4. FOR BOTH SECTIONS, ALL QUESTIONS CARRY EQUAL MARKS WHICH ARE INDICATED UNDER EACH RESPECTIVE QUESTION
5. YOU CAN ANSWER THE QUESTIONS IN ANY ORDER BUT YOUR SOLUTIONS NEED TO BE CLEARLY NUMBERED
6. WHERE INFORMATION IS NOT GIVEN, MAKE AND STATE YOUR ASSUMPTIONS
7. MARKS WILL BE LOST FOR UNTIDY AND UNORGANISED PRESENTATION
8. THE EXAMINATION IS STRICTLY CLOSED BOOK

## **SECTION A: IWRM 6014 (MODULE 4)**

### **QUESTION ONE**

- (a) "Water is a finite resource". Discuss the meaning of this statement from the water resources perspective.
- (b) What is point source pollution?
- (c) How can heat pollute a water body?
- (d) In determining how safe drinking water is from Vibrio Cholerae, a bacterium that causes cholera, a technician at the Lusaka Water and Sewerage Company Water Treatment Plant in Kafue decided to test for faecal coliforms. Explain the rationale for him testing for faecal coliforms instead of vibrio cholerae.
- (e) A treatment plant with a primary sedimentation and two trickling filters receives wastewater at an average rate of 30l/s. The sedimentation tank distributes the flow to the ~~sedimentation tanks~~ <sup>Filters</sup> in such a way that the two filters get equal flow from the sedimentation tank.
  - i) Compute the hydraulic surface loading rate for a primary sedimentation tank given that that tank has a volume of 233m<sup>3</sup> and a height of 2.33m.
  - ii) If the two trickling filters are circular with a radius of 15m, compute the organic surface loading rate to these filters if the concentration of the organic matter in the wastewater being fed to the filters is 225mg/l.

[ 4 + 2 + 3 + 3 + 8 ]

### **QUESTION TWO**

- (a) What is the function of the biological stage in conventional wastewater treatment systems?
- (b) What do you understand by the term "Fixed film process" as it applies to conventional wastewater treatment?
- (c) Why is the BOD test result always lower than the COD test result if the tests are done on the same sample?
- (d) Distinguish between BOD<sub>5</sub> and Ultimate BOD for a wastewater sample.
- (e) Explain the purpose a of primary sedimentation tank in a conventional wastewater treatment plant.
- (f) The characteristics of wastewater generated from Kembe Cold Storage is such that the ratio between the COD and BOD is 1.65. The wastewater is treated using high rate trickling

filters. Throughout out the treatment process, the COD/BOD ratio remains constant. Given that the Zambia Management Agency (ZEMA) effluent discharge standard for COD is 90mg/l, discuss whether the effluent quality in terms of COD will conform to the standard if the BOD concentration in the effluent is 65mg/l.

[ 3 + 3 + 3 + 3 + 5 ]

### **QUESTION THREE**

- (a) What is meant by the term “Hydraulic Surface Loading Rate” and what is its significance in wastewater treatment?
- (b) What is the significance Sludge Volume Index in wastewater treatment?
- (c) List one function of each of the following in a conventional wastewater treatment plant:
  - i) Screen
  - ii) Grit Chamber
- (d) Nitrogen is a nutrient which can contribute to eutrophication. Explain how it is removed from wastewater in an activated sludge treatment plant.
- (e) 240ml of sludge was dried over a water bath. The dry solids were then put in an oven and dried until a constant weight for the solids was obtained. The dried solids were then burnt in a muffle furnace at 550°C until a constant weight of the ash remained. If the mass of the solids from the oven was 37.5g,
  - i) Calculate the concentration of the solids in the sludge giving you answer in milligrams per liter (mg/l).
  - ii) Given that the percentage of the Volatile Solids in the sludge is 70%, compute the mass of ash that remains after the solids are burnt in the muffle furnace.

[ 4 + 2 + 2 + 4 + 8 ]

### **QUESTION FOUR**

- (a) Distinguish between an organic and inorganic compound.
- (b) Explain one way in which an inert compound can result in pollution of a surface water body.
- (c) A technician wanted to characterise water from the Luangwa river. He decided to collect water samples from the river and transport them to the Environmental Engineering Laboratory at UNZA since he did not have field test kits. List and explain two precautions he needs to observe when transporting the samples.

- (d) At Manchinchí Wastewater Treatment Plant, most of the humus from the secondary sedimentation tanks is recycled back to the inlet works. What is the rationale behind this recirculation?
- (e) Chunga Wastewater Treatment Plant treats a combination of domestic and industrial wastewater. The average organic matter concentration in the raw sewage is 460mgBOD/l. The effluent has an organic matter concentration of 40mg/l which is within the Zambia Environmental Management Agency discharge standard of 50mgBOD/l. Given that 25% of the organic matter is removed by the primary sedimentation tanks,
- Compute the BOD removal efficiency of the trickling filters.
  - It is observed that after a leather processing company whose effluent contains high concentration of sodium chloride starts discharging into the line leading to the plant, the organic matter concentration in the effluent from the plant increases to 250mg/l. What could be the reason for this observed increase?

[ 3 + 2 + 4 + 3 + 7 ]

#### **QUESTION FIVE**

- (a) List two advantages of non-conventional wastewater treatment systems over conventional wastewater treatment systems.
- (b) Mufumbwe districts employs stabilisation ponds to treat its wastewater which is mostly from domestic dwellings and commercial institutions. The layout of the ponds includes an anaerobic pond, a facultative pond and three maturation ponds all arranged in series. It is observed that the influent to the anaerobic pond has a COD concentration of 500mg/l but the influent to the facultative pond only has a COD concentration of 250mg/l. Explain this observation.
- (c) The normal COD removal efficiency in the facultative pond which has been observed over the past 10 years is 80%. Recently, the algae in the pond was strained out (removed). It was immediately observed that the COD removal efficiency declined to 25%. Explain the possible cause of this reduction.
- (d) Explain the term retention time as it applies to wastewater treatment and give its significance.
- (e) A maturation pond is 150m long, 70m wide and 1.2m deep. Given that the hydraulic loading rate is 0.03 cubic meters per second, calculate the hydraulic retention time of the wastewater in the pond.

[ 3 + 3 + 4 + 4 + 6 ]

## **SECTION B: IWRM 6016 (MODULE 6)**

### **QUESTION ONE**

- (a) What do you understand by the term water resources economics
- (b) Define the term opportunity cost
- (c) What are the four cornerstone of water resources economics
- (d) Explain the indifference curve

**[ 4 + 4 + 6 +6 ]**

### **QUESTION TWO**

- (a) Define the following terms
  - i. Net Present Value
  - ii. Internal Rate of Return
- (b) What is benefit-cost analysis?
- (c) List four disadvantages of benefit-cost analysis
- (d) Explain what do you understand by discounting?

**[ 4 + 4 + 6 +6 ]**

### **QUESTION THREE**

- (a) What are the four basic laws of demand
- (b) Explain what you understand by the term utility
- (c) A dam was to be constructed in Kaoma district and the following are the cost Materials K500,000,000; Labour K 600,000,000 and the benefits were as follows: Recreation = K400,000, 000 ;Flood control = K300,000,000; Electricity = K500,000,000
  - (i) What is the net benefit of the project?
  - (ii) At a discounted rate of 10% should the Dam be constructed after one year?

**[ 8 + 6 +6 ]**

### **QUESTION FOUR**

- (a) What is a market?
- (b) How do economist define cost distinguish between explicit and implicit cost giving examples of each case
- (c) What is the difference between static and dynamic efficiency give one example in each case

**[ 4 + 8 +8 ]**

### **QUESTION FIVE**

- (a) Economics is the study of the principles governing the allocation of scarce resources among competing ends when the objective of allocation is to maximize the attainment of the ends. Explain why the market concept fails when it comes to water resources
- (b) Prices are the automatic regulator that tends to keep production and consumption in line with each other. Explain?
- (c) Discuss the factors which can affect the demand and supply graph.

**[ 8 + 6 +6 ]**

**END OF EXAM  
GOOD LUCK!**

**JMT/JK /IWRM 6014-6016/EXAM/2012**



THE UNIVERSITY OF ZAMBIA  
IWRM CENTRE  
2012 ACADEMIC YEAR

MASTERS IN ENVIRONMENTAL MANAGEMENT

IWRM 6014 – WATER USE AND WASTEWATER  
FIRST SEMESTER UNIVERSITY POSTGRADUATE EXAMINATION

*November 21, 2012*

TIME: THREE (3) HOURS

CLOSED BOOK

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INSTRUCTIONS TO CANDIDATES

1. THE PAPER CONTAINS SIX QUESTIONS. YOU ARE REQUIRED TO ATTEMPT ANY FIVE
2. ALL QUESTIONS CARRY EQUAL MARKS WHICH ARE INDICATED UNDER EACH RESPECTIVE QUESTION
3. YOU CAN ANSWER THE QUESTIONS IN ANY ORDER BUT YOUR SOLUTIONS NEED TO BE CLEARLY NUMBERED
4. WHERE INFORMATION IS NOT GIVEN, MAKE AND STATE YOUR ASSUMPTIONS
5. MARKS WILL BE LOST FOR UNTIDY AND UNORGANISED PRESENTATION
6. THE EXAMINATION IS STRICTLY CLOSED BOOK



### QUESTION ONE

- (a) "Water is a finite resource". Discuss the meaning of this statement from the water resources perspective.
- (b) What is point source pollution?
- (c) How can heat pollute a water body?
- (d) In determining how safe drinking water is from *Vibrio Cholerae*, a bacterium that causes cholera, a technician at the Lusaka Water and Sewerage Company Water Treatment Plant in Kafue decided to test for faecal coliforms. Explain the rationale for him testing for faecal coliforms instead of *vibrio cholerae*.
- (e) A treatment plant with a primary sedimentation and two trickling filters receives wastewater at an average rate of 30l/s. The sedimentation tank distributes the flow to the ~~sedimentation tanks~~ <sup>Filters</sup> in such a way that the two filters get equal flow from the sedimentation tank.
- Compute the hydraulic surface loading rate for a primary sedimentation tank given that that tank has a volume of  $233\text{m}^3$  and a height of 2.33m.
  - If the two trickling filters are circular with a radius of 15m, compute the organic surface loading rate to these filters if the concentration of the organic matter in the wastewater being fed to the filters is 225mg/l.

[ 4 + 2 + 3 + 3 + 8 ]

### QUESTION TWO

- (a) What is the function of the biological stage in conventional wastewater treatment systems?
- (b) What do you understand by the term "Fixed film process" as it applies to conventional wastewater treatment?
- (c) Why is the BOD test result always lower than the COD test result if the tests are done on the same sample?
- (d) Distinguish between  $\text{BOD}_5$  and Ultimate BOD for a wastewater sample.
- (e) Explain the purpose a of primary sedimentation tank in a conventional wastewater treatment plant.
- (f) The characteristics of wastewater generated from Kembe Cold Storage is such that the ratio between the COD and BOD is 1.65. The wastewater is treated using high rate trickling filters. Throughout out the treatment process, the COD/BOD ratio remains constant. Given that the Zambia Management Agency (ZEMA) effluent discharge standard for COD is 90mg/l, discuss whether the effluent quality in terms of COD will conform to the standard if the BOD concentration in the effluent is 65mg/l.

[ 3 + 3 + 3 + 3 + 5 ]

### **QUESTION THREE**

- (a) What is meant by the term “Hydraulic Surface Loading Rate” and what is its significance in wastewater treatment?
- (b) What is the significance Sludge Volume Index in wastewater treatment?
- (c) List one function of each of the following in a conventional wastewater treatment plant:
  - i) Screen
  - ii) Grit Chamber
- (d) Nitrogen is a nutrient which can contribute to eutrophication. Explain how it is removed from wastewater in an activated sludge treatment plant.
- (e) 240ml of sludge was dried over a water bath. The dry solids were then put in an oven and dried until a constant weight for the solids was obtained. The dried solids were then burnt in a muffle furnace at  $550^{\circ}\text{C}$  until a constant weight of the ash remained. If the mass of the solids from the oven was 37.5g,
  - i) Calculate the concentration of the solids in the sludge giving you answer in milligrams per liter (mg/l).
  - ii) Given that the percentage of the Volatile Solids in the sludge is 70%, compute the mass of ash that remains after the solids are burnt in the muffle furnace.

**[ 4 + 2 + 2 + 4 + 8 ]**

### **QUESTION FOUR**

- (a) List two functions of aerators in activated sludge systems.
- (b) What is the meaning of the term “Indicator Microorganism”?
- (c) What is Mixed Liquor Suspended Solids (MLSS) and why is it important to maintain it within a certain concentration in the aeration tank of an activated sludge system?
- (d) An engineer for Mulonga Water and Sewerage Company Limited has designed a conventional wastewater treatment plant to treat domestic sewage for Mufulira District. The plant has a hydraulic loading capacity of  $200\text{m}^3$  per day. He has provided three maturation ponds in a series arrangement. Each pond is 100m long, 45m wide and 1.2m deep. Discuss the need of these ponds in this treatment system.
- (e) A cylindrical anaerobic sludge digester with an internal diameter of 12m and effective depth of 6m is designed with a sludge loading rate of  $2.0\text{Kg VS/m}^3/\text{day}$ . The sludge being feed into the digester is such that 100ml of sample contains 6.0g solids of which 80% are Volatile Solids. Calculate the maximum permissible rate at which the sludge should be fed into the digester.

**[ 3 + 2 + 4 + 3 + 7 ]**

### **QUESTION FIVE**

- (a) Distinguish between an organic and inorganic compound.
- (b) Explain one way in which an inert compound can result in pollution of a surface water body.
- (c) A technician wanted to characterise water from the Luangwa river. He decided to collect water samples from the river and transport them to the Environmental Engineering Laboratory at UNZA since he did not have field test kits. List and explain two precautions he needs to observe when transporting the samples.
- (d) At Manchinchi Wastewater Treatment Plant, most of the humus from the secondary sedimentation tanks is recycled back to the inlet works. What is the rationale behind this recirculation?
- (e) Chunga Wastewater Treatment Plant treats a combination of domestic and industrial wastewater. The average organic matter concentration in the raw sewage is 460mgBOD/l. The effluent has an organic matter concentration of 40mg/l which is within the Zambia Environmental Management Agency discharge standard of 50mgBOD/l. Given that 25% of the organic matter is removed by the primary sedimentation tanks,
  - i) Compute the BOD removal efficiency of the trickling filters.
  - ii) It is observed that after a leather processing company whose effluent contains high concentration of sodium chloride starts discharging into the line leading to the plant, the organic matter concentration in the effluent from the plant increases to 250mg/l. What could be the reason for this observed increase?

**[ 3 + 2 + 4 + 3 + 7 ]**

### **QUESTION SIX**

- (a) List two advantages of non-conventional wastewater treatment systems over conventional wastewater treatment systems.
- (b) Mufumbwe districts employs stabilisation ponds to treat its wastewater which is mostly from domestic dwellings and commercial institutions. The layout of the ponds includes an anaerobic pond, a facultative pond and three maturation ponds all arranged in series. It is observed that the influent to the anaerobic pond has a COD concentration of 500mg/l but the influent to the facultative pond only has a COD concentration of 250mg/l. Explain this observation.
- (c) The normal COD removal efficiency in the facultative pond which has been observed over the past 10 years is 80%. Recently, the algae in the pond was strained out (removed). It was immediately observed that the COD removal efficiency declined to 25%. Explain the possible cause of this reduction.
- (d) Explain the term retention time as it applies to wastewater treatment and give its significance.
- (e) A maturation pond is 150m long, 70m wide and 1.2m deep. Given that the hydraulic loading rate is 0.03 cubic meters per second, calculate the hydraulic retention time of the wastewater in the pond.

**[ 3 + 3 + 4 + 4 + 6 ]**

**END OF EXAM  
GOOD LUCK!**

**JMT /IWRM 6014/EXAM/2012**

THE UNIVERSITY OF ZAMBIA  
SCHOOL OF MINES

**2012/13 ACADEMIC YEAR SUPPLEMENTARY EXAMINATIONS**

**POSTGRADUATE DIPLOMA IN INTEGRATED WATER RESOURCES  
MANAGEMENT**

**IWRM 6012 (MODULE 2) - WATER RESOURCES MONITORING**

**EACH QUESTION SHOULD BE ANSWERED ON A SEPARATE PAGE**

**TIME: 1½ HOURS**

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**IWRM 6012 (MODULE 2) - WATER RESOURCES MONITORING**

(Answer any 3 questions only) Possible marks / points for each question are indicated in brackets.

1. (a) List the six river catchments in Zambia through which the country's water will be managed in the new Water Resources Management Act of 2011.  
.....(6 marks)
- (b) The Water Resources Master Plan (JICA-MEWD, 1995) divides land use in Zambia into eight categories. Briefly outline the Categories  
..... (16 marks)
- (c) Realising that service provision, water protection, conservation, development and management were inadequate, List the Seven guiding principles for the 1994 Water Policy.  
.....(7 marks)
2. With neatly labeled sketches or diagrams if needed, in answering the questions below:
  - (i) Large parts of Zambia regularly suffer from deforestation which has an impact on the hydrological cycle. Give 4 reasons why Quickbird data is not the best choice to observe the areas where such activities occur or monitor those that are in progress  
.....(4 marks)
  - (ii) Imagine you've downloaded an SRTM-DEM of a new study area where you will start working. Mention two graphical approaches that can be applied to evaluate the relative accuracy (plausibility) of this Digital Elevation Model. For each of these, briefly explain how it is applied.  
.....(4 marks)
  - (iii) Different hazards require different remote sensing approaches for effective monitoring. Correlate the ideal monitoring strategy with corresponding hazard in the Table given below  
.....(4 marks)

Harzards	Monitoring Strategies
(i) Hurricane / Taifun (ii) Coal Fire (iii) Flood (iv) Urban subsidence due to groundwater extraction. (v) Famine	a. Advanced Synthetic Aperture Radar ASAR; on ENVISAT) b. Geostationary weather satellite (1-4km spatial resolution) c. Tropical Rainfall Measurement Mission d. MODIS (Moderate Resolution Imaging Spectroradiometer), twince a day at 250 – 1000m spatial resolution. e. Landsat - TM

Consider this Black & White image of an area in the humid tropics in answering parts iv and v below.



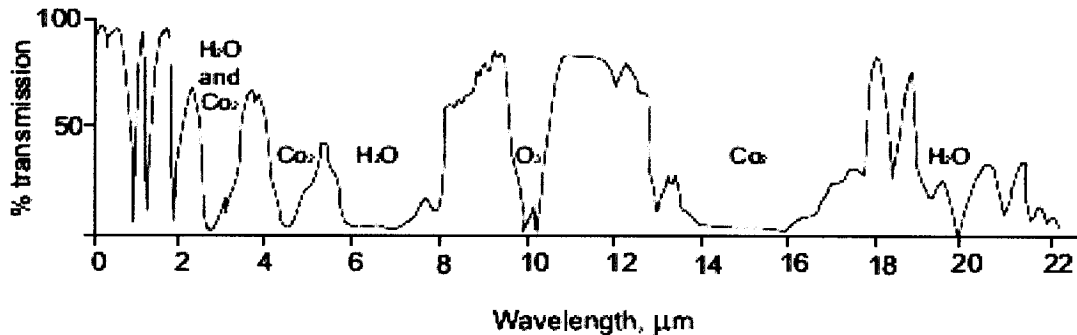
- (iv) Describe the processes and potential impacts visible on the image .....(4 marks)  
 (v) Give the image characteristics you used when you interpreted the image.....(4 marks)

3. a) Find below the descriptions of commonly used sensor / platform characteristics. Write down the correct term whose definition or decription is given below.....(8 Marks)

- (i) Range between minimum and maximum energy level that can be measured by a sensor,

- (ii) Size of the smallest unit-area that can be measured by a sensor,
- (iii) Smallest difference in energy level that can be measured by a sensor,
- (iv) Minimum time between successive image acquisitions over the same location on the Earth.

b) The Figure below shows the percentage transmission of the Earth's atmosphere against wavelength.



- (i) What is the name of the wavelength regions of the electromagnetic spectrum where transmission is almost zero? .....(4 Marks)
  - (ii) Why is transmission so low in these regions? Explain briefly.....(4 Marks)
- c) What is the difference between georeferencing and geocoding of an image? Explain very briefly.....(4 Marks)
- (d) List 10 recognition elements, which are visual clues you can use in a systematic way to identify objects in an air photo or satellite image.....(10 marks)
4. With neatly labeled sketches or diagrams if needed, **EXPLAIN** difference between the following:
- (i) Vector and Raster data models..... (4 marks)
  - (ii) Rational and Irrational databases..... (4 marks)
  - (iii) Spectral Signature and Spectral Response..... (4 marks)
  - (iv) Ellipsoid and Geoid ..... (4 marks)
  - (v) Real-time and Post-processing differential corrections applicable to GPS.....(4 marks)
5. (a) What geophysical techniques are recommended for the following areas of interest?
- i. Mineral Exploration.....(2 marks)
  - ii. Environmental Surveys.....(2 marks)
- (b) Define the following terms:
- i. pH.....(2 marks)
  - ii. Hydraulic Conductivity.....(2 marks)
- (c) Briefly describe the occurrence of groundwater in the different groundwater provinces of Sub Saharan Africa .....(8 marks)
- (d) Answer the following:
- i. Names of ministries in Zambia involved in the Water Sector.....(2 marks)
  - ii. Give years when the New National Water Policy and the Water Resources Management Act became effective.....(2 marks)

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

**2013 ACADEMIC FIRST HALF UNIVERSITY FINAL EXAMINATIONS**

POSTGRADUATE DIPLOMA IN INTEGRATED WATER RESOURCES MANAGEMENT

**IWRM 6013 (MODULE 3): WATER RESOURCES MODELLING  
AND**

**IWRM: 6017 (MODULE 7): SCENARIO ANALYSIS AND IMPACT ASSESSMENT**

**TIME: Three (3) hours**

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**IWRM 6013 (Module 3):** Answer ANY THREE (3) questions. Candidates are advised to make use of illustrations and examples wherever appropriate. Possible marks / Points for each Question are indicated in Brackets.

**IWRM 6017 (Module 7):** Answer ANY THREE (3) questions. Candidates are advised to make use of illustrations and examples wherever appropriate. Possible marks / Points for each Question are indicated in Brackets.

**EACH MODULE SHOULD BE ANSWERED IN A SEPARATE ANSWER BOOKLET**

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**IWRM 6013 (MODULE 3) - WATER RESOURCES MODELLING**

**QUESTION ONE**

- a) What is hydrology (3 marks)
- b) Describe a hydrological cycle and list the four components of the hydrological cycle (4 marks)
- c) Describe briefly three examples where the application of hydrology is important. (3 marks)
- d) Define the following terms
  - (i) Storativity
  - (ii) Hydraulic conductivity
  - (iii) Transmissivity
  - (iv) Effective porosity

**(2+2+2+2 marks)**



- e) What percentage does groundwater constitute of the world's fresh water resources  
(2 marks)

## **QUESTION TWO**

- a) What is a decision support system? (4 marks)
- b) Why develop and use models? (4 marks)
- c) List and explain briefly the four types of aquifers(4 marks)
- d) Describe briefly the four factors that affect evaporation(4 marks)
- e) What is Transpiration and explain one method used to measure it (4 marks)

## **QUESTION THREE**

- a) Name four form of precipitation (4 marks)
- b) The flow of water in the ground is defined by Darcy's theory explain what you understand by Darcy's theory(4 marks)
- c) Describe briefly how you would estimate the missing rainfall data at Unza Meteorological station for a particular day(4 marks)
- d) Annual precipitation at rain gauge A is given plus the average of 12 stations in the surrounding area Table 3 (c ). Has there been any significant changes in the data at A. if so when (8 marks)

**Table 3 ( c)**

<b>Year</b>	<b>GAUGE A (mm)</b>	<b>12 Stations (mm)</b>
1974	604	560
1975	640	624
1976	874	604
1977	640	564
1978	592	502
1979	346	468
1980	482	462
1981	590	664
1982	448	564

**QUESTION FOUR**

- (a) Discuss the difference between a conceptual model and a numerical model(12 marks)
- (b) Briefly describe three tools that are used in water resources management (8 marks)

## **QUESTION FIVE**

- (a) What is the fundamental Management unit in water resources management? (4 marks)
- (b) Define the term recharge and explain briefly it's important in groundwater resources management. (6 marks)
- (c) List four factors, which influence surface runoff. (4marks)
- (d) A village in Sesheke District has 137 households, with an average of 8 people per household and if each person needs 40 liters of water per day, how many hours of pumping are necessary if the yield of the borehole is 0.4l/s? (6 marks)

## **IWRM 6017 (MODULE 7) – SCENARIO ANALYSIS AND IMPACT ASSESSMENT**

### **ANSWER ANY THREE**

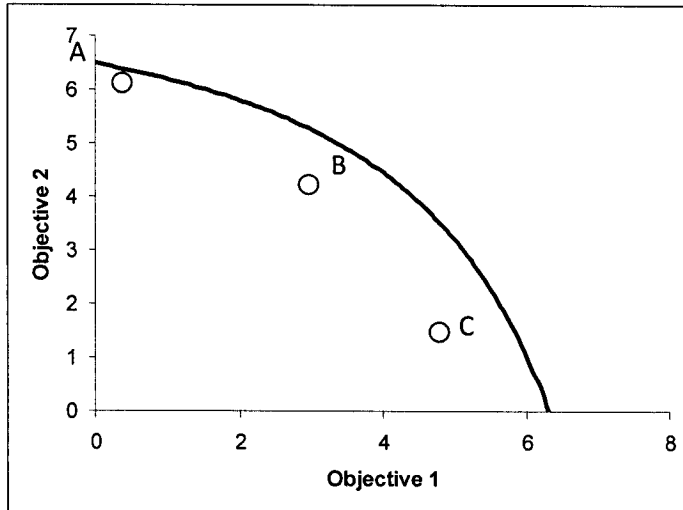
## **QUESTION ONE**

- (a) Briefly explain give an example what you understand by the term optimization (8 marks)
- (b) The average natural flow into the Luapula River is about  $1200 \text{ m}^3 \text{ s}^{-1}$  in December. How many square kilometres of Maize Field can be irrigated with this amount of water, assuming a crop coefficient of 0.9 and an overall efficiency of the irrigation of 0.7? The reference ET in the Luapula Catchment in December is about  $4.5 \text{ mm day}^{-1}$  and precipitation is 2.5 mm per day. (12 marks)

## **QUESTION TWO**

- (a) List the four single objective constrained optimization methods(5 marks)
- (b) What are the pros and cons Linear Programming? (5 marks)
- (c) Figure 2.1 shows the Pareto front in a 2-objective optimization problem and the performance of 3 selected policies, A, B and C

**Figure 2.1 Pareto front diagram.**



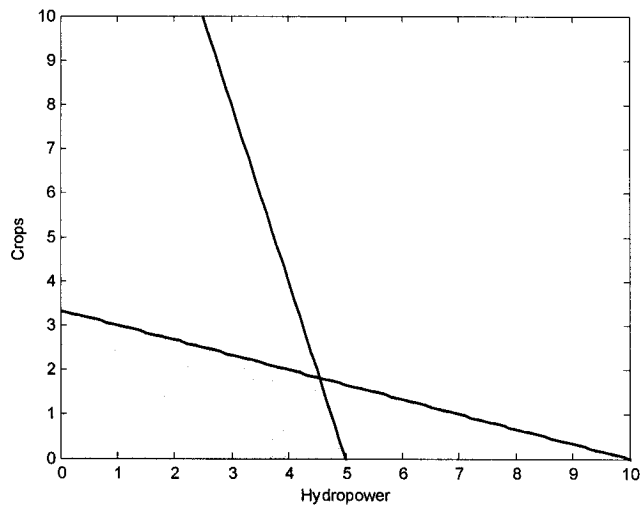
The decision makers put equal weight on the two objectives. Which policy should they choose? Explain your answer **(10 marks)**

### **QUESTION THREE**

- (a) With the help of sketches write the water balance equation and explain each term **(8 marks)**
- (b) Consider a rainfed maize crop. Precipitation is 700 mm, of which 100 mm is intercepted and evaporates, 100 mm runs off into stream. Of the remaining 500 mm that infiltrates into the soil, 100 mm percolates to the subsoil and recharges aquifers. The maize crop yields 4000 kg/ha. What is the water utilisation efficiency of this rainfed crop? **(12 marks)**

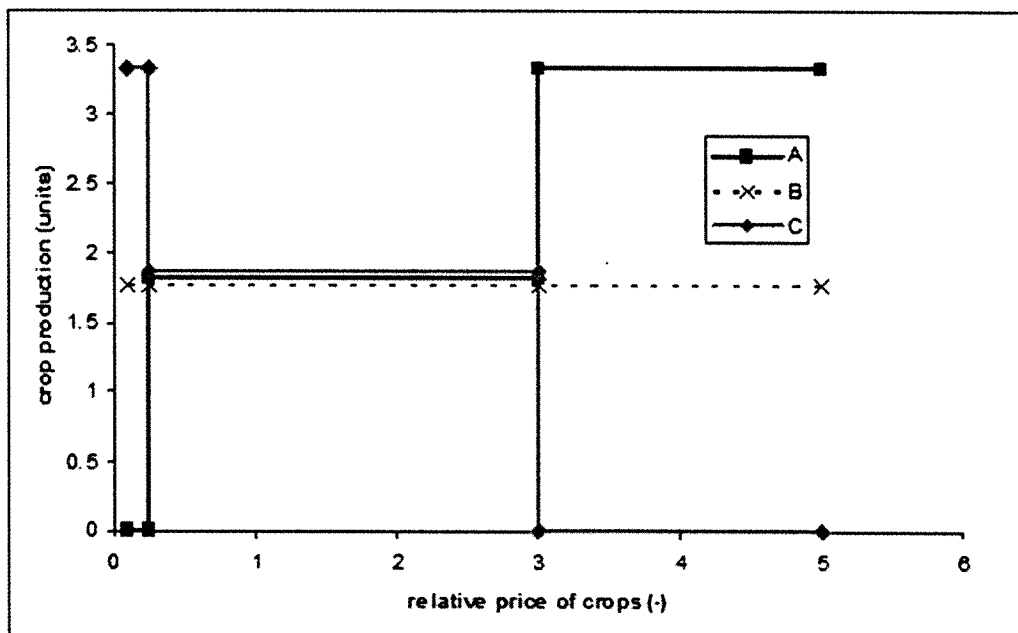
### **QUESTION FOUR**

- (a) Describe any of the three applications of dynamic programming in resources optimization **(10 marks)**
- (b) A basin manager faces the following problem: Crops and hydropower can be produced with inputs of land and water. Land and water are finite resources and the constraints are graphically displayed in Figure 4.1 below:



**Figure 4.1. Graph of constraints.**

- i) The figure 4.2 shows the production of crops as a function of the relative price (price crops / price hydropower) of crops. Which is the correct graph? Justify your answer? (10 marks)



**Figure 4.2. Crop production graph.**

### **QUESTION FIVE**

- (a) Lower Kafue Sub-basin, large parts of which are located in Zambia, no observed discharge is available. You estimate the discharge from this sub-basin assuming a runoff coefficient of 0.3. The Lower Kafue Sub-basin has a total size of  $103,000 \text{ km}^2$  and the average precipitation in this basin is about 2.5 mm/day. What is the estimated discharge at the outlet of the Lower Kafue Sub-basin? **(10 marks)**
- (b) Suppose you live in an area where the only source of water (at a reasonable cost) is from an aquifer that receives no recharge. Briefly discuss how you might develop a plan for its use over time. **(10 marks)**

***THE END OF EXAM***

***GOOD LUCK***



**THE UNIVERSITY OF ZAMBIA  
SCHOOL OF MINES**

**2014 ACADEMIC YEAR FIRST SEMESTER FINAL EXAMINATIONS**

**POSTGRADUATE DIPLOMA IN INTEGRATED WATER RESOURCES MANAGEMENT**

**IWRM 6014 (MODULE 4): WATER USE AND WASTE WATER  
AND  
IWRM: 6016 (MODULE 6): WATER RESOURCES ECONOMICS**

**TIME:** **Three (3) hours** **Closed Book Exam**

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**IWRM 6014 (Module 4):** Answer ANY THREE (3) questions from section A. Candidates are advised to make use of illustrations and examples wherever appropriate.

**IWRM 6016 (Module 6):** Answer ANY THREE (3) questions from section B. Candidates are advised to make use of illustrations and examples wherever appropriate.

**EACH MODULE SHOULD BE ANSWERED IN A SEPARATE ANSWER BOOKLET**

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**IWRM 6014 (MODULE 4)**

**SECTION A (Answer ANY THREE Questions)**

**IWRM 6014 (MODULE 4)**

**ANSWER ANY THREE**

**QUESTION ONE**

- (a) Give two reasons why it is important to control pH of wastewater in a treatment plant.
- (b) Discuss two ways in which “laboratory wastewater analysis” would differ from “field wastewater analysis”.
- (c) Read the following sentence carefully: *“Polluting a water body by addition of nutrients will lead to increased water treatment costs for water treatment plants located downstream of the point of pollution”*. State whether this statement is True or False and give two reasons for your answer.
- (d) Microbiological quality of water can be better assessed through the use of Faecal Coliforms as opposed to Total Ccoliforms? Discuss why.

- (e) For each of the problems listed below which are associated with conventional wastewater treatment plant utilizing trickling filters, list one possible cause of the problem and give one solution to the problem:
- Unpleasant odours from the filters
  - Increased prevalence of the Psychoda
  - Increased BOD in the effluent from the secondary sedimentation tanks

***[4 + 3 + 4 + 3 + 6 marks]***

## **QUESTION TWO**

- (a) Determination of the microbiological quality of the wastewater is done by using indicator microorganisms. Give two reasons why we use indicator microorganisms instead of the full range of microorganisms in the wastewater.
- (b) Mr. Kalibe is requested to analyse a wastewater sample for organic matter content. He decides to analyse for COD and BOD and got the following results:  
BOD = 258mg O<sub>2</sub>/l  
COD = 195mg O<sub>2</sub>/l  
Discuss these results.
- (c) Domestic wastewater is being treated in a conventional wastewater treatment plant. Explain what parameter you expect to change after the primary stage and give a reason for this change.
- (d) Wastewater contains high numbers of microorganisms. Faecal coliforms alone are in the range of  $1 \times 10^6 - 1 \times 10^8$ . How are these microorganisms reduced to within the required standards of  $\geq 2500$  in a conventional wastewater treatment plant?
- (e) Chawama Wastewater Treatment Plant in Kafue receives wastewater at an average rate of 20m<sup>3</sup>/h. The wastewater has a BOD concentration of 280mg/l and a pH of 7.2.
- How much organic matter is received at the treatment plant on a daily basis?
  - If the wastewater is treated by a conventional wastewater treatment plant employing four trickling filters each with a diameter of 20m and a depth of 2.0m, calculate the Volumetric Organic Loading rate to each filter given that there is no primary treatment in the plant and that the wastewater is distributed equally to each of the four filters.

***[3 + 4 + 4 + 3 + 6 marks]***



### **QUESTION THREE**

- (a) When collecting water samples, why is it important to take note of the date and time of sampling?
- (b) What is the major difference between conventional and non-conventional methods of wastewater treatment?
- (c) List and discuss two major functions of aerators in a suspended film process like in the Activated Sludge System.
- (d) Design of trickling filters is mostly based on empirical formulae like the National Research Council Formula given below:

$$E = \frac{100}{1 + a \sqrt{\left\{ \frac{L}{A_f * D * F} \right\}}}$$

If wastewater with an organic matter content of 280mg/l is to be treated by a trickling filter with a diameter of 30m and effective depth of 2m so that the effluent has an organic matter concentration of not more than 40mg/l, compute the required removal efficiency of the trickling filter.

- (e) Discuss the significance of the following in the control of activated sludge systems:
  - i) Mixed Liquor Suspended Solids (MLSS).
  - ii) Sludge Volume Index (SVI).

***[4 + 4 + 4 + 4 + 4 marks]***

### **QUESTION FOUR**

- (a) Give and discuss two reasons why non-conventional methods of wastewater treatment would be a preferred option for wastewater treatment in rural towns of Zambia.
- (b) The anaerobic pond is comparable to a primary sedimentation tank. Give one reason why both organic matter and suspended matter removal efficiency is higher in anaerobic ponds as compared to primary sedimentation tanks.
- (c) A facultative pond is comparable to a biological stage in a conventional wastewater treatment plant whose main aim is to remove colloidal and dissolved organic matter. Explain the processes responsible for organic matter removal in the facultative pond.
- (d) Discuss any two mechanisms in the maturation ponds that are responsible for the reduction of microorganisms in the wastewater.

- (e) Chelstone Stabilisation Ponds treat domestic wastewater from Chelstone and Avondale. The average wastewater flow to the facultative pond is 34.72l/s and the organic matter concentration is 260mgBOD/l. Given that the required retention time of the wastewater in the facultative pond is 10 days,
- Compute the required volume of the pond;
  - If the depth of the pond is 1.0m and the length to width ratio is 1:3, compute the width, and length of the pond?

**[4 + 3 + 4 + 3 + 6 marks]**

## **IWRM 6016 (MODULE 6)**

### **SECTION B (Answer ANY THREE Questions)**

#### **QUESTION ONE**

- Define the following terms
  - Opportunity cost
  - Marginal cost
  - Discounting
- Economics is the study of the principles governing the allocation of scarce resources among competing ends when the objective of allocation is to maximize the attainment of the ends. Explain why the market concept fails when it comes to water resources
- Explain and illustrate graphically the production function

**[6 +10+4 marks]**

#### **QUESTION TWO**

- What effect will each of the following have upon the demand for product B?
  - The price of product C, a good substitute for B goes down
  - Consumers anticipate declining prices and falling prices
  - There is a rapid upsurge in population growth
- What effect will each of the following have upon the supply for product B?
  - A technological advance in the methods of producing B
  - An increase in the prices of resources required in the production of B
  - A decline in the number of firms in industry B

**[10+10 marks]**

#### **QUESTION THREE**

- Define the following terms
  - Net Present Value
  - Internal Rate of Return
- What is benefit-cost analysis?
- List four disadvantages of benefit-cost analysis
- What is the common characteristic of pure public goods like water?

**[4+2+4+6+4 marks]**

#### **QUESTION FOUR**

- (a) What is a market?
- (b) How do economists define cost distinguish between explicit and implicit cost giving examples of each case
- (c) What is the difference between static and dynamic efficiency give one example in each case

***[4+8 +8 marks]***

#### **QUESTION FIVE**

- (a) Prices are the automatic regulator that tends to keep production and consumption in line with each other. Explain?
- (b) Discuss the factors which can affect the demand and supply graph

***[10+10 marks]***

**END OF EXAM**

**GOOD LUCK!**

**JMT/IWRM 6014/EXAM/2014**

**JK/IWRM 6016/EXAM/2014**

THE UNIVERSITY OF ZAMBIA.  
SCHOOL OF HUMANITIES AND SOCIAL SCIENCES.

FINAL EXAMINATIONS

**IWRM 6015: PUBLIC POLICY AND THE ENVIRONMENT.**

**Time:** Three Hours.

**Instructions:** Answer any THREE questions from the list below. Take account of good grammar and relevant illustrations.

1. What strengths and weaknesses for the Elitist Approach to policy making would you identify in Zambia's policy environment?
2. Explain the Rational Approach to policy making, and identify the limitations that policy analysts have to grapple with from time to time.
3. If inputs are equated to effort, then outputs are equated to effects. Analyze this assertion in relation to the policy cycle and give illustrations of what has happened in your country.
4. If the water in the Zambezi river was polluted by industrial effluents, who would be: (a) the principal, policy, stake holders?  
(b) the other policy stake holders?

What policy issues would make consensus building difficult, and which ones would easily be agreed upon?

5. What would you do to build policy capacity in your country's legislature?

**END OF EXAMINATION.**

THE UNIVERSITY OF ZAMBIA.  
SCHOOL OF HUMANITIES AND SOCIAL SCIENCES.

FINAL EXAMINATIONS

**IWRM 6015: PUBLIC POLICY AND THE ENVIRONMENT.**

**Time:** Three Hours.

**Instructions:** Answer any THREE questions from the list below. Take account of good grammar and relevant illustrations.

1. What strengths and weaknesses for the Elitist Approach to policy making would you identify in Zambia's policy environment?
2. Explain the Rational Approach to policy making, and identify the limitations that policy analysts have to grapple with from time to time.
3. If inputs are equated to effort, then outputs are equated to effects. Analyze this assertion in relation to the policy cycle and give illustrations of what has happened in your country.
4. If the water in the Zambezi river was polluted by industrial effluents, who would be: (a) the principal, policy, stake holders?  
(b) the other policy stake holders?

What policy issues would make consensus building difficult, and which ones would easily be agreed upon?

5. What would you do to build policy capacity in your country's legislature?

**END OF EXAMINATION.**