UNIVERSITY OF JOHANNESBURG

FACULTY	: Science
DEPARTMENT	: Geology
CAMPUS	: APK
MODULE	: APG02B2 APPLIED ENGINEERING AND ENVIRONMENTAL GEOLOGY
SEMESTER	: Second
EXAM	: **Nov 2021 - MEMO**

DATE	: OCT 2021	**SESSION**	:
ASSESSOR(S)	: DR TV MAKHUBELA DR OM MOROENG		
MODERATOR	: DR C VORSTER		
DURATION	: HOURS (3 HOURS)	**MARKS**	: 180

MEMO

SECTION A: ENVIRONMENTAL GEOLOGY (90 MARKS)

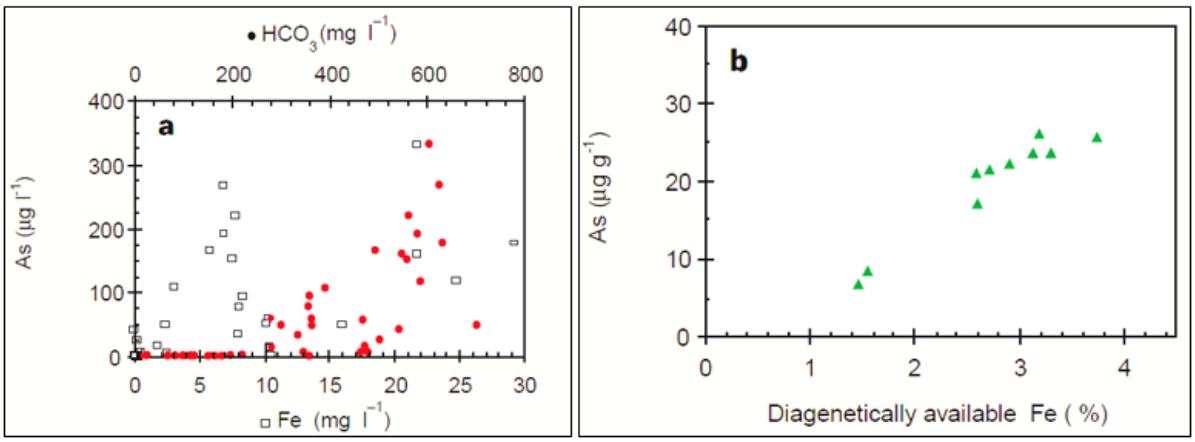
QUESTION 1 [10 marks]

Provide a brief definition or description for each of the following:

1.1 Denudation. – **combined effect of chemical weathering and physical erosion that causes mass loss.**
1.2 Saprolite. – **Weathered rock that retains recognizable bedrock structure and has not been physically mobilized.**
1.3 Bioturbation. – **disintegration caused by biological activities.**
1.4 Strip-cropping. – **Crops planted in alternating strips within the same field.**
1.5 Pediplanation. – **Back-wearing / eroding uplifted land by shedding the margins/hillslopes parallel to themselves.**
1.6 Pedocrete. – **Soils which have to a greater or lesser extent been cemented together or replaced by a particular mineral.**
1.7 Oligotrophic lake. – **Deep, clear water, low in nutrients and low fish population.**
1.8 Reservoir. – **Man-made large, reliable freshwater source created by damning a rivers.**
1.9 Potentiometric surface. – **The height of water rise as a measure of the potential energy within a confined aquifer.**
1.10 Shale gas. – **hydrocarbon gas extracted from shale.**

QUESTION 2 [10 marks]

Study the two (2) figures below from Nickson et al. (1998, *Nature* 395, 338) and answer the following questions regarding the arsenic contamination of groundwater in Bangladesh.



2.1 What does Figure (a) tell us about the arsenic (As) content in the groundwater? [2]
The As content in the groundwater is positively correlated (i.e., increases) with the HCO3 and Fe content from 250 mg/L.

2.2 What does Figure (b) tell us about the As content in the aquifer sediments? [2]

There is a positive correlation (i.e., increase in both) between the As content and the diagenetically available Fe content.

2.3 Which hypothesis is supported by the evidence presented in the two (2) figures? [2]

The reduction hypothesis.

2.4 Explain how the As was released into the groundwater based on the above hypothesis. [4]

Arsenic is brought into sediments together with Fe hydroxide coatings on sand grains. Sediments contain organic matter which is being oxidised in biological processes. As a result, all oxygen and nitrate are used up. Then, reduction of Fe3+ to Fe2+ within young sediments destroys Fe hydroxide coatings on grains where As is adsorbed, so that As is released into groundwater.

QUESTION 3 [10 marks]

3.1 Give three (3) common chemical additives for the hydraulic fracturing fluid. [3]

Table 1. Common chemical additives for hydraulic fracturing. Vidic et al., 2013, *Science*

Additive type	Example compounds	Purpose
Acid	Hydrochloric acid	Clean out the wellbore, dissolve minerals, and initiate cracks in rock
Friction reducer	Polyacrylamide, petroleum distillate	Minimize friction between the fluid and the pipe
Corrosion inhibitor	Isopropanol, acetaldehyde	Prevent corrosion of pipe by diluted acid
Iron control	Citric acid, thioglycolic acid	Prevent precipitation of metal oxides
Biocide	Glutaraldehyde, 2,2-dibromo-3-nitrilopropionamide (DBNPA)	Bacterial control
Gelling agent	Guar/xantham gum or hydroxyethyl cellulose	Thicken water to suspend the sand
Crosslinker	Borate salts	Maximize fluid viscosity at high temperatures
Breaker	Ammonium persulfate, magnesium peroxide	Promote breakdown of gel polymers
Oxygen scavenger	Ammonium bisulfite	Remove oxygen from fluid to reduce pipe corrosion
pH adjustment	Potassium or sodium hydroxide or carbonate	Maintain effectiveness of other compounds (such as crosslinker)
Proppant	Silica quartz sand	Keep fractures open
Scale inhibitor	Ethylene glycol	Reduce deposition on pipes
Surfactant	Ethanol, isopropyl alcohol, 2-butoxyethanol	Decrease surface tension to allow water recovery

3.2 What are the two (2) factors that make the best shales for shale gas extraction?
[2]

- **Shale that is rich in organic matter (more than 4% total organic content, %toc)**
- **High proportion of quartz and/or calcite grains relative to clay**
- **Have been exposed to the right depth/temperature conditions for gas generation.**

3.3 Name two (2) types of contaminants that pollute groundwater.
[2]

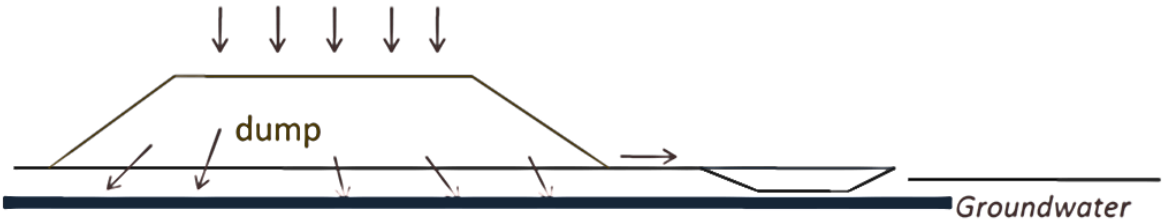
- **Miscible**
- **Immiscible**

3.4 Give three (3) categories of groundwater clean-up and aquifer restoration.
[3]

- **Containment: uses physical barriers**
- **Contaminant withdrawal: water pumped out and then treated.**
- **In situ treatment: water treated in the aquifer (e.g., using biological activities)**

QUESTION 4 [10 marks]

The following diagram represents the Witwatersrand gold mine tailings and slimes dam. Use it to answer the following questions.



4.1 What is the most problematic mineral/group of minerals associated with the mine tailings? [1]
Sulphides (pyrite)

4.2 Give three (3) contaminants/contamination challenges related to these tailings in their neighbouring communities?
[3]

As per lecture and the research assignment you have completed or will complete.

4.3 What effects do each of the three (3) contaminants cause on humans or biodiversity? [3]

As per lecture and the research assignment you have completed or will complete.

4.4 Why do mine tailings pose a more serious threat than the underground mine void? [3]

The oxygen supply on surface is abundant and replenished, thus, acid generating reactions proceed until pyrite and other sulphides are used up. Heavy metals, including uranium, are continuously dissolved and leak into groundwater, dams and river systems.

QUESTION 5 [10 marks]

Write a short essay about how the African surface, Post-African 1 surface and Post-African 2 surface were formed following the break-up of Gondwana.

- **Gondwana rifting created marginal escarpment that was mainly driven back by back-wearing erosion (pediplanation) due to the humid tropical climate of the Cretaceous and high energy potential for erosion.**
- **Post-rifting erosional cycle created coeval surfaces of low-relief separated by the step of the Great Escarpment by the end of the Cretaceous Period.**
- **The two erosional surfaces above and below Great Escarpment are the African surface and they are armoured by duricrusts and pedocretes.**
- **The African surface African Surface preserves the remains of the crater facies of diatremes whereas mountain massifs (e.g. Cape Fold Mountains, Lesotho and Namaqua highlands) are preserved above it.**
- **Minor uplift occurred during the early Miocene, leading to rejuvenation in weathering and erosion which caused incision of river valleys 100-200 m below the African surface.**
- **The cut profile below the African surface due to Miocene uplift is known as the Post-African 1 surface, and is only associated with minor calcrete to the west and ferricrete to the east.**
- **A major uplift of 700-900 m occurred in the continental interior along zone stretching between Port Elizabeth and Eswatini during the Pliocene and led to rejuvenation in weathering and erosion.**
- **This uplift resulted in major gorge cutting (river incision) and dissection in the eastern coastal hinterland. The landscape was peneplaned to lower base levels and terraces formed along interior rivers forming the Post-African 2 surface.**
- **Additional 2 marks for details pertaining to each and sequence showing understanding instead of just meaningless sentences one after another.**

QUESTION 6 [10 marks]

6.1 Describe two consequences of mining below the water table. [4]

- **Creates "wet mining" conditions**
  - Provide details as per the slides.

- **Creates unstable slopes**
  - Provide details as per the slides

6.2 What is the role of a mine-dewatering hydrogeologist? [2]

- **Promote 'Dry mining' conditions**
- **Investigate geological setting**
- **Design groundwater control programs**

6.3 What is aquifer-pumping test? [2]

As details as per the slides and practical 3.

6.4 What is a hydrograph and what is its use? [2]

As details as per the slides and practical 3.

QUESTION 7 [10 marks]

Your friend wants to buy a piece of land for residential purposes, and she has asked you to use your environmental geology knowledge to advise her on which land to buy. She has narrowed it down to two options:

Property A: sloping area underlain by granite with a wet climate.

Property B: flat area with a moist climate and underlain by limestone.

7.1 Which property would you choose with respect to mass movement avoidance and why? (hint: focus on what causes mass movements and soil forming factors)
[4]

Property B because it is in a flat area. Even though this area will have karst landscape issues such as sinkholes, it won't have sloping related mass movements. Property A on the other hand, will have conditions that drive mass movements.

7.2 Name two practical ways/methods you would implement to minimise/prohibit the dangers of mass movements in the property prone to have mass movements
[4]

- **Makes slopes gentle**
- **Stabilize slopes with rock bolts and retaining walls**
- **Drain water**
- **Plants vegetation**
- **Do not undercut slopes with down-dipping strata**

7.3 What would be the dangers of property B with regards to land stability?
[2]

The karstic features such as sinkholes, dolines, caves etc. will make the area unstable and susceptible to collapses.

QUESTION 8 [10 marks]

8.1 In which group of rocks in the Karoo Supergroup do we find the numerous coal seams mined in the eastern parts of South Africa?
[1]

Ecca Group

8.2 What is the mining method commonly used for underground coal mining in SA?
[1]

Bord and pillar

8.3 Give three (3) challenges associated with abandoned coal mines.
[3]

- **Collapsed roof leading to land degradation.**
- **Continuous fire.**
- **Barren, sulphate-encrusted soil surfaces.**

8.4 Give three (3) AMD neutralizing agents.
[3]

- **Limestone $CaCO_3$**
- **Hydrated lime pebble $Ca(OH)_2$**
- **Quicklime CaO**
- **Soda ash Na_2CO_3**
- **Caustic soda NaOH – solid or liquid**
- **Ammonia NH_3**

8.5 Name two (2) methods used for mitigating the water deterioration due to coal mining in Mpumalanga.

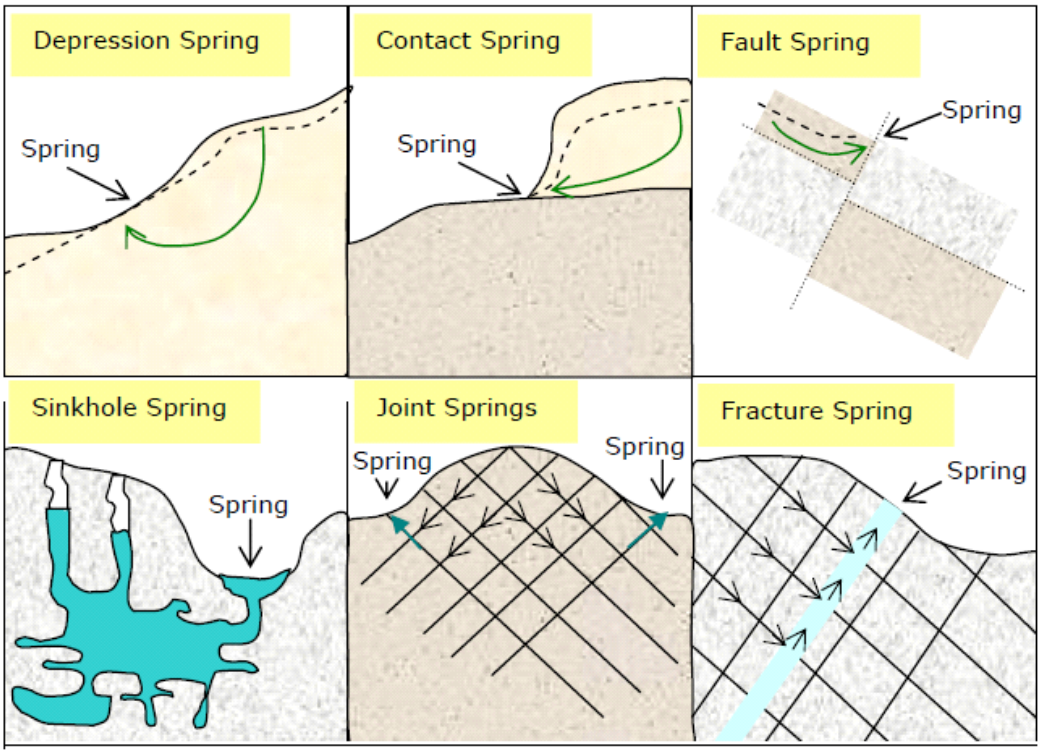
[2]

- **Evaporation dams**
- **Limiting of oxygen ingress into closed mine workings**
- **Acid neutralization**
- **Water purification**
- **Controlled release**
- **Soil protection**

QUESTION 9 [10 marks]

9.1 Give three (3) types of spring.

[3]



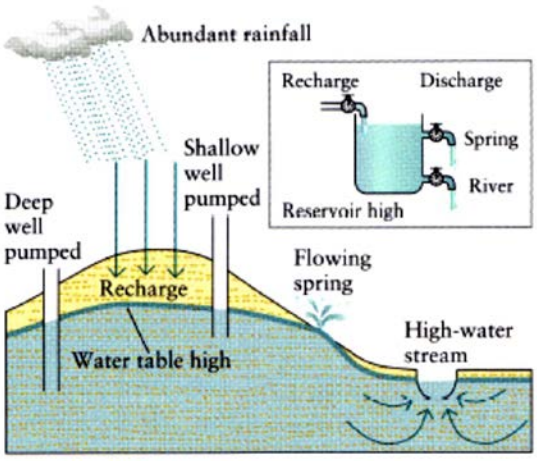
9.2 What would be the effect of a heavily pumped well on nearby shallow wells and what phenomenon causes that?

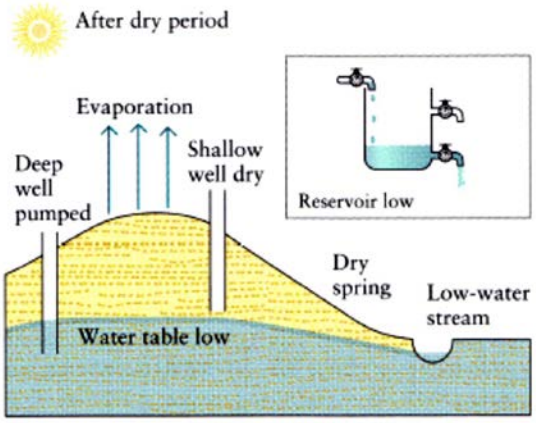
[2]

Formation of a cone of depression that leads to nearby shallow wells drying up due to rate of pumping far exceeding rate of aquifer recharge.

9.3 How would continual groundwater withdrawal in a shallow well of an area with a humid climate differ from an area with a dry climate?

[2]





9.4 What are the dangers of excessive pumping of groundwater in coastal areas and why does it happen? What type of cone results from this phenomenon?

[3]

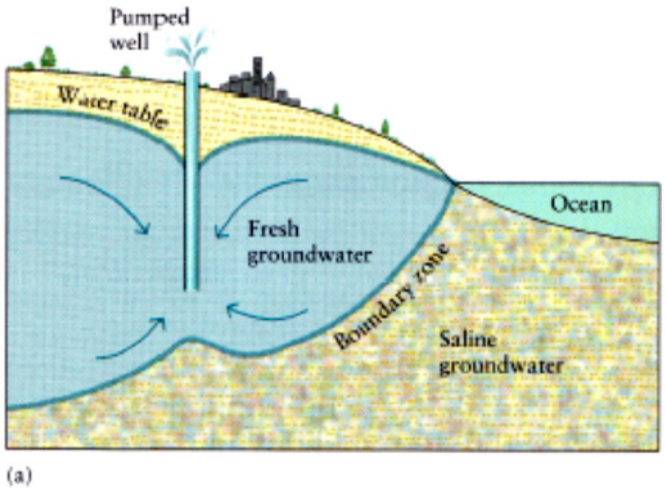
Salt water intrusion

•Excessive pumping of groundwater in coastal areas has resulted in ***saltwater intrusion***.

•Along coastlines where permeable rocks are in contact with the ocean, **fresh groundwater** (which is less dense that saltwater) forms a **lens-shaped body above the underlying saltwater.**

•The weight of the freshwater exerts pressure on the underlying seawater.

•When the rate of recharge equals the rate of withdrawal, the contact between the fresh groundwater and seawater remains the same.



(a)

END OF SECTION A

SECTION B: ENGINEERING GEOLOGY (90 MARKS)

Question 1 (20 marks)

1.1. Discuss collapsible soils and the various factors that control their distribution in South Africa. (10 marks)

Lecture 2: Soils comprising of sand- and silt-sized particles, resulting in an open texture. Expand on structure and the factors that control their distribution (e.g., climate, lithology, etc.) Can they be both residual and transported?

1.2. Differentiate between tors and corestones, including a discussion on their development (you may use illustrations). Give examples of South African lithological units associated with these. (10 marks)

Lecture 7: Jointing within rocks (including columnar jointing) provides preferred pathways for water seepage, weathering pronounced along these discontinuities leaving fresh rock further away. In one case the boulders are surrounded by a soil matrix; in the other, the soil eroded away.

Question 2 (20 marks)

2.1. Intact rock and rock mass structure both influence the strength of a rock mass, such that: intact rock strength + strength of rock mass structure = rock mass. Explain each parameter in the above simplified mathematical equation. (10 marks)

Lecture 3: Intact rock strength determined using the UCS. The rock mass structure refers to the discontinuities that bound individual blocks of intact rock; its strength depends on spacing (if systematic), persistent, roughness, etc. The rock mass strength reflects the strength of the intact rock and the rock mass structure, taken together as a whole.

2.2. The Barton-Choubey criterion is expressed as: $T = \sigma \tan[JRC\log(\frac{JCS}{\sigma}) + \phi]$

Where $\boldsymbol{\tau}$ is the shear strength, $\boldsymbol{\sigma}$ is the normal stress, and $\boldsymbol{\phi}$ is the residual friction angles. **JRC** is the joint roughness coefficient of the discontinuity, **JCS** is the joint wall compression strength of the discontinuity.

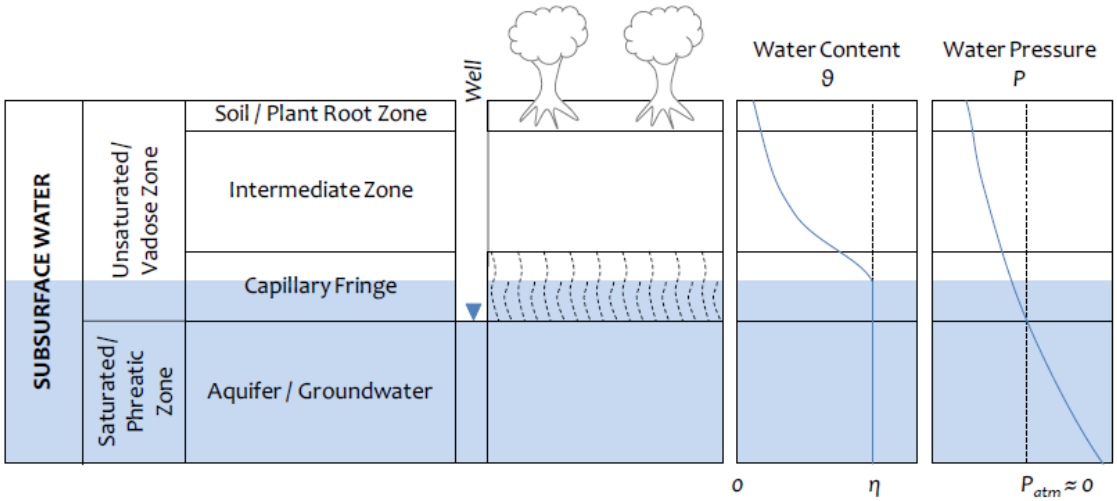
Discuss both the JRC and the JCS and the impact thereof the on the shear strength ($\boldsymbol{\tau}$). (10 marks)

Lecture 3: JRC – how rough is the plane of the discontinuity? The smoother it is, the lower the shear strength of the discontinuity. JCS – how weathered is the rock along the discontinuity. The least weathered it is, the higher the shear strength of the discontinuity.

Question 3 (20 marks)

3.1. Schematically depict the distribution of subsurface water and explain the different zones. (10 marks)

Lecture 4:



3.2. Discuss the three porosity types found in rocks. Give examples of South African lithostratigraphic associated with each porosity type. (10 marks)

Lecture 4: Intergranular aquifer – primary porosity – Karoo Supergroup, Pretoria, etc. Fractured aquifer – secondary porosity – Bushveld, etc. Karst aquifer – tertiary porosity – Malmani Subgroup. For the lithostratigraphic unit, it is important to provide units with required rock type. For example, a sedimentary rock may also be an example of a fractured aquifer.

Question 4 (30 marks)

4.1. You are appointed as the consulting engineering geologist on a project. However, before you are able to perform a site investigation, you are asked to provide your expert opinion on the engineering geology characteristics of the stratigraphic unit listed below using only the limited information given:

Witwatersrand Supergroup (comprising of a combination of conglomerates, quartzites, shales, andesites, etc). The site identified is a historic mining area and the Weinert number (N) is greater than 5.

Discuss the engineering geological properties associated with the different rock types.

How do the variations in rock properties influence the geological engineering properties of the site, and the soils produced?

What solutions would you propose to the problems identified?

Lecture 8: Undermining – subsidence, earthquakes, etc. Differential weathering, differences in foundation conditions, etc. Environmental issues – acid mining drainage. Give the necessary context and background.

END OF SECTION B