Chapter 9: WATER RESOURCES, WATER SERVICES AND SANITATION MANAGEMENT PRINCIPLES

9.1 Introduction

This unit describes the competencies required to apply water resource management principles. It involves determination of hydrological processes, quantification of surface water, mapping of rock types and aquifers, establishment of suitable site for wells. It also involves conservation of environment and development of water harvesting structures. It also involves application of water and environmental law in water resource management and application of integrated water resources management (IWRM) principles.

9.2 Performance Standard

Determine hydrological processes, quantify surface water, map rocks and aquifers, establish well sites, conserve the environment, develop water harvesting structures, apply water and environmental law in water resource management, apply integrated water resources management principles based on WMO guidelines and OSH.

9.3 Learning Outcomes

9.3.1 List of Learning Outcomes

a) Determine hydrological processes
b) Quantify surface water
c) Map rocks and aquifers
d) Establish well sites
e) Conserve the environment
f) Develop water harvesting structures

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9.3.2 Learning Outcome No 1: Determine Hydrological Processes

9.3.2.1 Learning Activities

Learning Outcome No 1: Determine Hydrological Processes	
 **Learning Activities**	**Special Instructions**
1.1 Identify ***concepts of Hydrological cycle*** 1.2 Identify precipitation types and forms 1.3 Determine precipitation 1.4 Determine evaporation rate 1.5 Determine stream flow 1.6 Observe safety in hydrometry	• Project • Case studies • Field trips • Discussions • Demonstration by trainer • Practice by the trainee

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9.3.2.2 Information Sheet No9/LO1 Determine Hydrological Processes

Introduction to learning outcome

This learning outcome covers concepts of hydrology, hydrological cycle and hydrological processes, principles and application. The different areas of hydrology include drainage management, surface hydrology, hydrometeorology, hydro-informatics, isotope hydrology, eco-hydrology among others

Definition of key terms

Hydrology: - This is a branch of science that deals with the properties of the earth's water in relation to its movement, occurrence, and distribution near the earth's surface.

Hydrological cycle: It is the water recycling system which includes the sum of processes in which water moves around the earth. It's also called the water cycle. The elements of the cycle are evaporation, condensation, transportation, precipitation, groundwater, inflow and surface runoff.

Infiltration: It is the process of flow of water from the ground surface as it enters the subsurface layers.

Percolation: After water has entered the soil them it has to flow through it. The movement of water through the soil layers by forces of gravity, and capillarity.

Condensation: It is the transformation of a substance physical states of matter from gaseous phase into the liquid phase.

Content/procedures/methods/illustrations

1.1 Identify concepts of Hydrological cycle based on WMO guidelines Concepts of Hydrological cycle

Hydrological cycle is the water cycle that describes the movement of water from atmospheric surfaces to subsurface levels. The main benefit is the temperature regulation, soil formation, creates rainfall, mineral circulation and the presence geological features

Stages involved include:

1. **Evaporation:** The hydrological cycle starts with evaporation which occurs when water is changed from liquid to gaseous state factors that contribute to evaporation include, vapour pressure, solar radiation, atmospheric pressure and wind currents. Water absorbs energy from the turning into vapour. The transformation normally occurs larger scales in oceans, seas, lakes and storage reservoirs.
2. **Condensation:** Condensation is the process by which physical states of water vapour changes to liquid state at points which vapour in the air is at saturation point, in the form of particles in the form of clouds, fog, and dew. It's an exothermic process that releases heat which was initially utilized in forming water vapour to the environment
3. **Precipitation:** When water particles fall from the atmosphere to the ground surface. Frictional drag forces and gravitational forces influence the particle decent till it hits the ground.
4. **Runoff:** The flow from the drainage basin that appears in surface streams. It consists of flaw that is unaffected by human or natural activities of diversion.
5. **Infiltration:** Infiltration involves water transfer as it seeps across the boundary layer of soil and is normally associated with soil profile, soil permeability and soil porosity.
6. **Percolation:** The movement of water that through the soil by virtue of capillary and gravitational forces is called percolation. Water contained in the aeration zone is called vadose water. In the saturation zone the water stored here becomes groundwater.

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1.2 Identify precipitation types and forms based on WMO guidelines Precipitation types (Orographic, Convective, and Cyclonic)

The phase in which precipitation falls to the ground characterize the type of precipitation. The phase be either liquid or solid and sometimes transient which occurs in between the two. The forms of precipitation include, ice crystal, hail, snow, and graupel. Occurrences of precipitation commences when air saturated with water vapours, is no longer able to sustain the levels of water vapor in gaseous form. The process starts when dense moist air cools when an air mass rises through the atmosphere. The types of precipitation include:

1. Cyclonic

When a boundary of two air masses with different densities meet, the air which wormer and less dense rises above the colder air which is denser creating an effect of precipitation. Also called frontal precipitation which is as a result of frontal systems surrounding extra tropical cyclones. When worm air forces out an already existing cold air mass, it creates a worm front which is characterized with long periods of light rain. Cold fronts occur when denser cold air pushes worm air mass. The process occurs sharply causing intense precipitation with shorter durations.

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2. Convection

When the earth's surface surrounded by an unstable moist atmosphere, is heated more than its surrounding, significant evaporation occurs. This type of precipitation is caused by convective clouds (cumulonimbus).

3. Orographic

Is also called relief rainfall which occurs when air masses are forced up the side of land formations as a result of adiabatic cooling normally referred to as an upslope effect. Relief features like mountains are subjected to consistent winds leading to a moist climate on the windward side which is the upwind side of a mountain than on the leeward side which is the downwind side. Rain shadow occurs when orographic lift removes moisture leaving drier air.

1.3 Determine precipitation based on the WMO guidelines Precipitation

Precipitation is determined in terms of the amount that reaches the ground over a certain duration and is expressed as the depth it would cover a given horizontal projection of the earth's surface.

The form of measurement adopted is by taking representative samples of the fall over the area to which measurement is required.

Rain gauge is used to measure rainfall by taking the catch of the instrument as the representation of precipitation within an area of perfect exposure.

The rain gauges can be classified as recording and non-recording. In a non-recording gauge precipitation is measured by a graduated cylinder and a graduated dip rod.
Error correction is necessary since they arise due measuring the catch or due to uncertainty effects arising instrument exposure. Daily gauges are read to the nearest 0.2 mm, weekly readings to nearest 1mm. recording gauges include the **weighing type**, **float type**, **tipping-bucket type**, **rainfall intensity recorder**. Snow consisting of ice crystals in flaky form is measured directly with graduated dip stick or scale

1.4 Determine evaporation rate based on WMO guidelines

The methods applicable in determination of evaporation include pan evaporation, evaporation models, and the water balance equation. The penman equation is applied in data analysis.

Penman Equation

$$Eo = \frac{700Tm/((100-A)+15(T-Td))}{(80-T)}\ mmday^{-1}$$

Where:
Tm = T +0.006h, h = Elevation (meters), T = Mean temperature, A = latitude (degrees)
Td = dew point value, (T-Td) = monthly means (obtained from tables)

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1.5 Determine stream flow based on the WMO guidelines

Stream flow measurements can be either be **direct methods** or **by the use of hydraulic formulas**. Direct methods will be highlighted in this case since they present results of higher quality data.

Main methods

a) **Volumetric Method:** Discharge is calculated based on the time that has elapsed and volume of water run into graduated reservoir. This method is suitable for low discharge conditions. Water runways or flood gates can be used in case of specific measurements.

b) **Velocity Area Method:** This method is conducted by measuring the fluid flow speed at different points of a section and then the surface area of the wetted section.

c) **Hydraulic Methods:** This is determined by employing a correlation of forces which include Viscosity, Inertia, and weight of fluid

d) **Physical methods:** Physical properties of the fluid like concentration of dissolved elements and their variations during water flow are taken in to consideration

1.6 Observe safety in hydrometry based on OSH

Hydrological measurements are usually made over a wide range of conditions, some of which are hazardous. Appropriate training is necessary in order to create awareness of the hazards and the ways to avoid or minimize them. The use of Personal Protective Equipment should be encouraged at all times

Some of the hazards are shown in the following table and how they occur.

Table 16: Hazard consideration

Hazard	**Considerations**
Safety at recording station	Access (steps, ladders, footpaths) Platforms (slippery surfaces, handrails) Wells (falling)
Safety on bridges	Traffic hazard Suspended equipment
Safety while wading	Wadding techniques Safety lines and taglines Lifejackets Mishap technique
While working on boats	Lifejackets Use of tag lines Use of dinghies

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Conclusion

This learning outcome covered Concepts of hydrology, Hydrological cycle and Hydrological processes, principles and application

Further Reading

1. Meteorological data collection instruments
2. Applications of hydrology in engineering

9.3.2.3 Self-Assessment

Written assessment

1. In determining evaporation, the penman equation is used. Distinguish which of the following is not a variable in the equation?
    a) Net radiation
    b) Heat capacity
    c) Atmospheric pressure
    d) Density
2. In the water cycle the mass balance equation is used to quantify precipitation, select one variable that is not applicable in computing precipitation
    a) Evaporation
    b) Outflow
    c) Evapotranspiration
    d) Inflow
3. Hydrological services should aid in achieving sustainable development goals. Select which one is not provided under the services rendered?
    a) IWRM
    b) WRA
    c) Water quality assessment
    d) Land conflict resolution
4. While collecting hydrometric data, select which of the following will be a safety precaution to observe
    a) Measure the length and width of land below
    b) Use of tag line while reading a rain gauge
    c) Use of life jacket while processing hydrometric data
    d) Peer education on risk factors
5. Distinguish which one is not a variable in the rational formula?
    a) Discharge (Q)
    b) Area (A)
    c) Rainfall intensity
    d) Gravitational force

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Practical Assessment

Measure and predict the amount of evaporation around your local area.

Oral Assessment

Explain the cyclone formation process

Practical Assessment

Assemble a non-recording rain gauge network and use it to obtain daily precipitation for one month. Use the data to determine average annual precipitation

9.3.2.4 Tools, Equipment, Supplies and Materials

- Computers
- Stationery
- Evaporation pan (Class A)
- Rain gauge
- Current meter
- Wading suit
- Tape measure
- Staff gauge
- Hand lens
- Clinometer
- GPS receiver
- Maps
- Steel file
- Steel knife
- Rock samples
- Minerals
- PPE

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9.3.2.5 References

Barry, R. G. (2019). The world hydrological cycle. In Introduction to Physical Hydrology (pp. 8-26). Routledge.

Carrier, O., Shahidzadeh-Bonn, N., Zargar, R., Aytouna, M., Habibi, M., Eggers, J., & Bonn, D. (2016). Evaporation of water: evaporation rate and collective effects. Journal of Fluid Mechanics, 798, 774-786.

Sun, Q., Miao, C., Duan, Q., Ashouri, H., Sorooshian, S., & Hsu, K. L. (2018). A review of global precipitation data sets: Data sources, estimation, and intercomparisons. Reviews of Geophysics, 56(1), 79-107.

9.3.3Learning Outcome No 2: Quantify Surface Water

9.3.3.1 Learning Activities

Learning Outcome No 2: Quantify Surface Water	
Learning Activities	**Special Instructions**
2.1 Identify sites for installation of ***hydrological instruments*** 2.2 Identify and installed hydrological Instruments 2.3 Collect hydrological data 2.4 Analyze and quantify hydrological data	• Project • Case studies • Field trips • Discussions • Demonstration by trainer • Practice by the trainee

9.3.3.2 Information Sheet No9/LO2 Quantify Surface Water

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Introduction to learning outcome

This learning outcome covers WMO guidelines on identifying site for irrigation of hydrological instruments as well as the identification and installation of some. It also covers collection and analysis of parameters to be measured.

Definition of key terms

Precipitation: This Consists of all forms of moisture that reach the earth from the atmosphere.

Stream flow: A stream can be defined as a flow channel into which the surface runoff from a specified basin drain

Hydrometry: It is the process of monitoring the occurrence of water, its properties and distribution on, beneath the earth's surface and also in the atmosphere.

Content/procedures/methods/illustrations

2.1 Identify sites for installation of *hydrological instruments* based on WMO guidelines

Hydrological instruments

- Rain gauges

A rain gauge is a meteorological instrument used for measuring rainfall. There are two main categories of rain gauges

a. Recording rain gauge
b. Non-recording rain gauge which includes: Tipping bucket rain gauge, Float type rain gauge, Weighing type rain gauge, Automatic-radio-reporting rain gauge

Below are the criteria for selecting a suitable site;

i. A rain gauge should be placed near the stream gauge if the observations will represent the entire general area
ii. It can be placed at a distance from the stream gauge depending on the topography of the location.
iii. It should be placed in a location such that the basin precipitation can be determined easily for each stream-gauging station
iv. Open place, away from obstruction at least four times the height of the tallest obstructing object.
v. Level ground to ensure gage mouth is horizontally exposed
vi. Site should be shielded from direct strong winds

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- **Evaporation pans**

Evaporation pans are used to determine the rate of evaporation for a given catchment area. The site for placing an evaporation pan is selected according to the climatic region, size and shape of the lake/water body.

- **Current meters**

Current meters are devices used to record the velocity of water in a stream. The current meter stations should always be placed in stretches that are straight and uniform to ensure consistency in recording data. The stream channel should have smooth beds and banks and have minimal flow disturbances.

2 .2 Identify and install hydrological Instruments based on WMO guidelines

Hydrologic instruments include water level gauge, thermometer, soil penetrometer, water level gauge, thermistor, radiometer, pressure transducer, conductivity probe, encoder etc.

2 .3 Collect *hydrological data* based on parameters to be measured

Hydrological data

- **Rainfall data** is measured as the vertical depth of water (or water equivalent in case of solid forms) that would accumulate on a flat level surface if all the precipitation remained where it had fallen.

- **Evaporation data** -This is collected using Direct methods evaporation pan, atmometers or Indirect methods e.g. water budget, energy budget, aerodynamics or mass transfer, other empirical equations. Evaporation is measured in mm.

- **Evaporation Pan**: Measurement of evaporation is done by US Weather Bureau Class A pan (USWB class A pan) which may be installed as land pan, sunken or floating pan. Details of USWB class A pan installed as land pan is as sketched below.

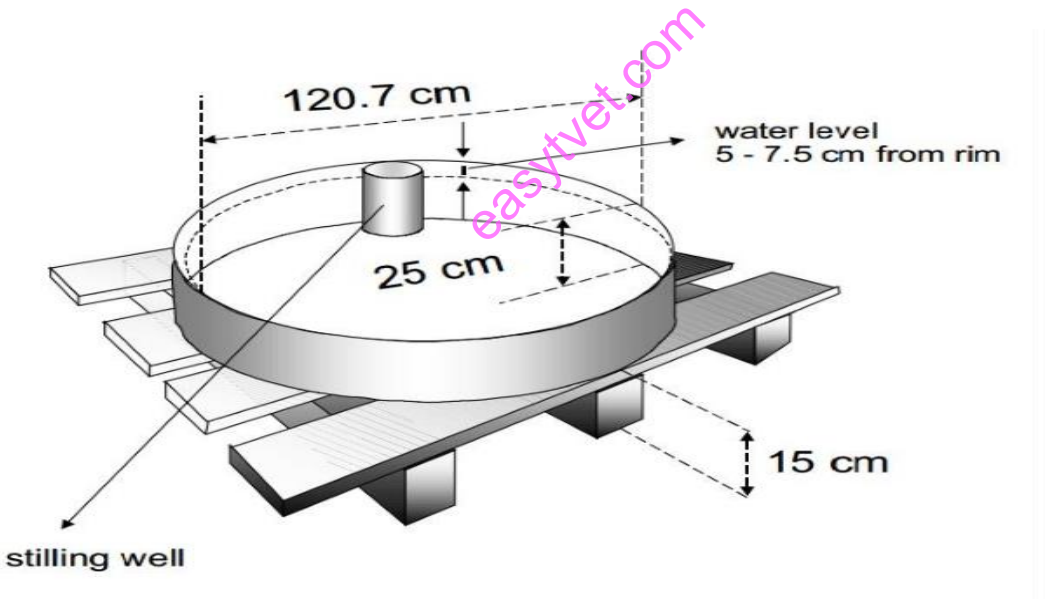

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Figure 98: Evaporation Pan
Source:https://www.researchgate.net/figure/26-US-Weather-Bureau-Class-A-Evaporation-Pan_fig24_321299610

- **Stream flow data** - Streamflow is measured as discharge measurement (m^3/s) can be measured using the following methods:

i. Direct determination of stream discharge:
   (1) Area-Velocity method
   (2) Dilution techniques
   (3) Electromagnetic method and
   (4) Ultrasonic method (Mohit Mayoor, 2018).

ii. Indirect methods:
    (1) Artificial controls e.g. weirs, flumes, slope-area formula as Manning's and Chezy's
    (2) Ffloat gauging
    (3) Indirect stage –rating

2 .4 Analyse and quantify hydrological data based on the collected parameters

Rainfall collected in the rain gauge is measured in mm and recorded

Evaporation- the amount of evaporated water is measured in millimetres. Evaporation is determined from the records of water level changes in the pan, corrected for the amount of water added to it by rainfall and artificially. When water level variation is measured by means of adding water to or removing water from the pan up to the constant water mark on its wall, the evaporation value is determined by using the following equation:

E=P±ΔH where E= evaporation in mm, P= rainfall depth in mm and ΔH= the depth of water added (+) or the amount removed (-) from the pan, the value of ΔH is computed using a standard cup equivalent to 0.5mm of rainfall.

ΔH = No. of cups added or removed x 0.5 mm. Note that if P=0, then E = ±ΔH or E=0 when there is no change of level.

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Streamflow is measured in m3/s

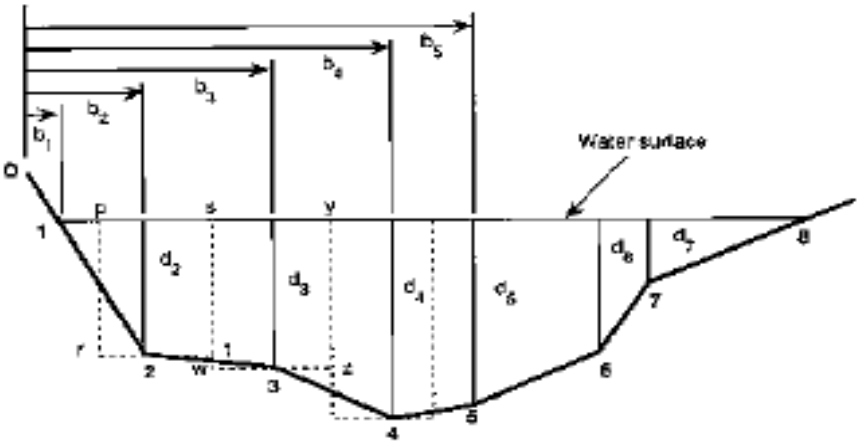

Figure 99: Streamflow
Source: Bartram,Et Al, 1996

Procedure: The horizontal distance b1 and b2 is measured from the reference point. The vertical distance d2 is measured.

Mathematical techniques like mid-section method or mean section method are used to derive area and mean velocity and the process is repeated on the other sections.

Conclusion

This learning outcome has covered Precipitation measurement- types of rain gauges, Evaporation measurement from US class A pan, Stream flow measurement- selection of a regular gauging station site, River gauging, Computation of stream discharge (mean section method, mid-section method; Stage discharge relationship and Personal safety in hydrometry.

Further Reading

Read more on mid-section and mean section methods of determining stream flow

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9.3.3.3 Self-Assessment

Written assessment

1. Select which units are used in rainfall measurement.
    a) m
    b) cm
    c) mm
    d) km
2. Explain how evaporation is measured.
3. Select which is not a hydrological instrument?
    a) Rain gauge
    b) Current meter
    c) Multimeter
    d) Thermometer
4. Distinguish which of the following statement is false?
    a) A rain gauge site should be open without obstruction
    b) Accessibility of a rain gauge is not mandatory
6. Current meters should be placed in bends and corners of a stream, justify

7. Evaluate the following terms
    a) Precipitation
    b) Evaporation
    c) Streamflow
    d) Hydrology
8. Categorize the types of rain gauges

Oral Assessment

1. Explain the meaning of hygrometry in quantifying surface area

Practical Assessment

Visit your nearest meteorological station and identify the available hydrological instruments. Prepare a report on instruments available and explain their functions.

9.3.3.4 Tools, Equipment, Supplies and Materials

- Computers
- Stationery
- Evaporation pan (Class A)
- Rain gauge
- Current meter
- Tape measure
- Staff gauge
- Hand lens
- Clinometer
- GPS receiver
- Maps
- Steel file
- Steel knife
- Rock samples
- Minerals

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9.3.3.5 References

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9.3.4 Learning Outcome No 3: Map Rocks and Aquifers

9.3.4.1 Learning Activities

Learning Outcome No 3: Map Rocks and Aquifers	
Learning Activities	**Special Instructions**
3 .1Identify ***Tools and equipment*** for mapping 3 .2Identify ***Rock types*** 3 .3Identify ***Aquifer types*** 3 .4Map rock types and aquifers 3 .5Map aquifers	• Project • Case studies • Field trips • Discussions • Demonstration by trainer • Practice by the trainee

9.3.4.2 Information Sheet No9/LO3 Map Rocks and Aquifers

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Introduction to learning outcome

This learning outcome covers Geologic time scale (Eons, Eras, Periods, Series), Earth origin theories, Internal structure of the earth (crust, mantle, core), Earth processes (weathering, volcanism, isostasy, magmatism), Rock types and their characteristics: (sedimentary, metamorphic, igneous,), Rock structures, Minerology: Physical properties of minerals, rock forming minerals, mineral groups and Aquifer types and characteristics : confined, non-confined, leaky, perched.

Definition of key terms

Rock this is a naturally occurring material which contains minerals

Minerology this is the study of the physical and chemical properties of a mineral

Aquifer a rock under the earth's surface which can hold or transfer groundwater.

Content/procedures/methods/illustrations

3 .1 Identify Tools and equipment for mapping based on physical properties and user preference

- Rock Hammer.
- Hand Lens.
- Handheld GPS.

- Mineral Hardness Kit.
- Acid Bottle

3 .2 Identify *Rock types* based on their origin

An eon is defined as the geologic time scale that relates the stratigraphy of the earth to time. An era subdivides Eons to smaller periods the table below shows the time frame of eons and eras

Table 17: Time frame of eons and eras

Eon	**Era**	**Time**
Phanerozoic	Cenozoic Mesozoic Paleozoic	66m years ago to date 252m to 66m years ago 541 to 252 years ago
Proterozoic	Neoproterozoic Mesoproterozoic Paleoproterozoic	1000 to 541 years ago 1600 to 1000m years ago 2500 to 1600m years ago
Archean	Neoarchean Mesoarchean Paleoarchean Eoarchean	2800 to 2500m years ago 3200 to 2800m years ago 3600 to 3200m years ago 4000 to 3600 m years ago
Hadean		formation of the earth to 4000m years ago

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The earth is divided into four main parts

- The outer crust which consists of the continental plate i.e. Main land and ocean surface
- The mantle (liquid form)
- The liquid outer core containing iron and nickel
- The solid inner core containing iron and nickel in liquid state

Rock types

- **Igneous rocks** are formed when magma from a volcano is rapidly cooled
- **Metamorphic**: this is either igneous, metamorphic or sedimentary rock that changes its nature due to exposure to high temperature or pressure
- **Sedimentary**-These rocks are formed by the piling up of dead animals and plants and which cement over a long period of time

3 .3 Identify Aquifer types based International Association of Hydro-geologists (IAH) guidelines

Aquifer types

- Confined -they are water bodies that accumulate in rock layers
- Unconfined- water bodies located near land surface and aren't enclosed with a layer of clay
- Perched- these are unconfined aquifers that occur when groundwater water body is separated from main groundwater. The amount of water is minimal.

3 .4 Map rock types and aquifers based on their formation

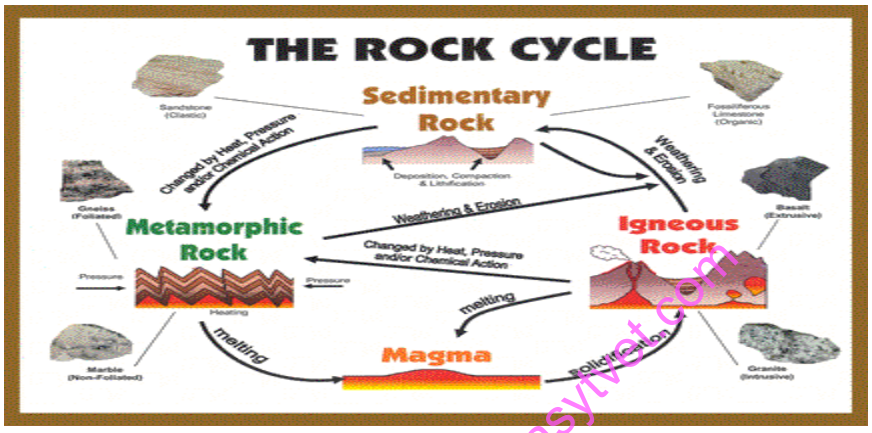

Figure 100: Map rock types and aquifers

Source: http://riovistad4.blogspot.com/2014/01/the-rock-cycle.html?m=1

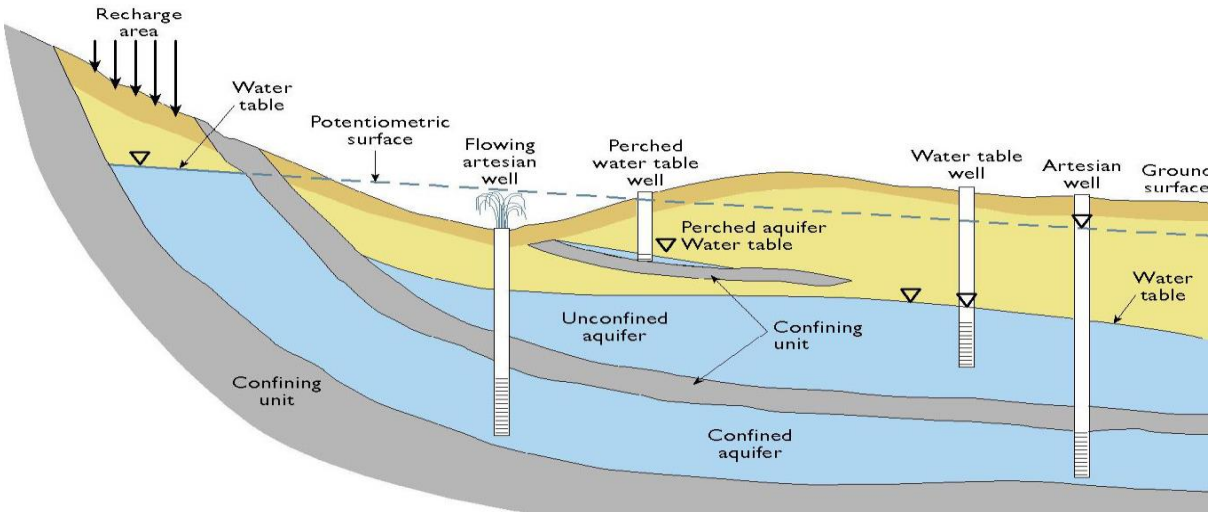

Figure 101: Map rock types

Source: The G360 Institute for Groundwater Research, 2017

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3 .5 Map aquifers based on rock units

Aquifers are able to store groundwater due to the nature of the surrounding rocks' texture. The source of the groundwater is mainly from surface runoff and infiltration which is then the primary supplier of seas and streams. Rocks with fine and compact texture are less porous (excellent aquifer) hence have a higher water retaining capability while those with high porosity (poor aquifers) supply wells and springs. Poor aquifers contain granites and schist while excellent aquifers contain fractured volcanic rocks.

Conclusion

This learning outcome has covered Geologic time scale (Eons, Eras, Periods, Series), Earth origin theories, Internal structure of the earth (crust, mantle, core), Earth processes (weathering, volcanism, isostasy, magmatism), Rock types and their characteristics: (sedimentary, metamorphic, igneous,), Rock structures, Minerology: Physical properties of minerals, rock forming minerals, mineral groups and Aquifer types and characteristics .

Further Reading

Read more on a Leakey aquifer

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9.3.4.3 Self-Assessment

Written assessment

1. Select the state of the outer core of the earth?
    a) Liquid
    b) Solid
    c) Gas
2. Distinguish and elabourate the tools and equipment used in mapping.
3. Summarize the process in which igneous rocks are formed
4. Select which rock are contained in poor aquifers and justify why they are
    a) Schist
    b) Sedimentary rocks
    c) Granite
    d) Volcanic rocks

5. Compare the categories of eons and their respective eons.
    a) Phanerozoic
    b) Hadean
    c) Archean
    d) Neoarchean
6. Briefly discuss what is contained in the inner core of the earth
    a) steel
    b) magnesium
    c) nickel
    d) iron
7. Justify the duration of the Hadean Eon and specify the exact timing.
    a) formation of the earth to 4000m years ago
    b) 2800 to 2500m years ago
    c) 3200 to 2800m years ago
    d) 3600 to 3200m years ago
8. Explain the following terms
    a) Rock
    b) Mineral
    c) Aquifer
9. Categorize the types of aquifers and explain each category
10. Distinguish and explain the three types of rock.
11. Explain how are sedimentary rocks formed?
12. State 5 hydrological tools

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Oral Assessment

What water body feeds streams and seas?

Practical Assessment

Identify 3 different types of rock in your neighbourhood

9.3.4.4 Tools, Equipment, Supplies and Materials

- Computers
- Stationery
- Evaporation pan (Class A)
- Rain gauge
- Current meter
- Wading suit
- Tape measure
- Staff gauge
- Hand lens

- Clinometer
- GPS receiver
- Maps
- Steel file
- Steel knife
- Rock samples
- Minerals
- PPE

9.3.4.5 References

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Schilling, K. E., Jacobson, P. J., Libra, R. D., Gannon, J. M., Langel, R. J., & Peate, D. W. (2017). Estimating groundwater age in the Cambrian–Ordovician aquifer in Iowa: implications for biofuel production and other water uses. Environmental Earth Sciences, 76(1), 2.

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9.3.5 Learning Outcome No 4: Establish Well Sites

9.3.5.1 Learning Activities

Learning Outcome No 4: Establish Well Sites	
 **Learning Activities**	**Special Instructions**
4 .1Identify Suitable sites for wells 4 .2Identify ***Suitable methods for well site establishment*** 4 .3Establish Suitable well sites 4 .4Prepare well site establishment report	• Project • Case studies • Field trips • Discussions • Demonstration by trainer • Practice by the trainee

9.3.5.2 Information Sheet No9/LO4: Establish Well Sites

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Introduction to learning outcome

This learning outcome covers identification of suitable sites for wells, methods of well site establishment, establishment of suitable well sites based on groundwater potential and well site establishment report writing.

Definition of key terms

Groundwater potential: Groundwater potential is the unrealized water found underground in the cracks and areas of soil, sand and rock according to www.groundwater.org.

Well siting: Well siting is the location of possible well sites to provide ample water to satisfy current and future water needs, according to geoservicesltd.com.

Content/procedures/methods/illustrations

4 .1 Identify Suitable sites for wells-based groundwater potential

Suitable sites: are those sites which have characteristics that meet the minimum requirements for the design, construction and operation of a sediment processing/ transfer facility in accordance with the standards established by the project (EPA, 2004)

Methods

Digital elevation mode (DEM) with a higher distance resolution is used to derive slope and drainage density map using the ArcGIS tool. The development of drainage density involves filling sinks, flow direction, flow accumulation and stream network (Tolche, 2020).

- Machine drilling
- Manual drilling
- Concrete lined dug well

4 .2 Identify Suitable methods for well site establishment based on user preference

Suitable methods for well site establishment

- Metallic rod pegs
- Hard wood pegs
- Concrete pegs
- Protected dug holes

4 .3 Establish Suitable well sites based on groundwater potential

Groundwater potential is the unrealized water found underground in the cracks and areas of soil, sand and rock according to www.groundwater.org

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Factors to be considered include;

- Land formations in the area
- Distance of location from the latrine
- Ground water motion direction
- Distance between the water table and the base of the pit latrine

Table 18: Minimum Safe Separation Distance in Deep Water Table

Sediment Type	Depth to Water Table	Min. Safe Separation Distance
Clay, silt,or fine sand	5 meters or more	15 meters or more
Medium sand	5 meters or more	15 meters or more
Coarse sand or gravel	10 meters or more	15 meters or more
Fractured rock	10 meters or more	15 meters or more

Table 19: Minimum Safe Separation Distance in Shallow Water Table

Sediment Type	Depth to Water Table	Min. Safe Separation Distance
Clay, silt,or fine sand	0 meters (latrine at or near water table)	15 meters
Medium sand	0 meters (latrine at or near water table)	50 meters
Coarse sand or gravel	0 meters (latrine at or near water table)	500 meters
Fractured rock	0 meters (latrine at or near water table)	500meters

Source; http://www.clean-water-for-laymen.com/well-site.html

4 .4 Prepare well site establishment report based on Water Resource Management rules (WRM) 2007*

In writing a well establishment report the following must be taken into account;

- The main reason for the construction
- Method of construction
- The cost of construction
- The specific location of the well
- The area description; topology, geology, drainage etc.
- Ground water occurrence; discharge and recharge.
- Water quality
- Policy, legal and regulatory frame work

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Conclusion

This learning outcome has prepared the student to be able to classify wells: dug, driven, drilled, identify a suitable well site, establish a suitable well site, know the factors affecting well siting, state the methods of well site establishment and Well site establishment report writing.

Further Reading

Read more on ground water potentials

9.3.5.3 Self-Assessment

Written assessment

1. Then following are classification of wells. Which one is not?
    a) Dug
    b) Borehole
    c) Drilled
    d) Dam
2. Analyze the steps one can use to identify sustainable well site
3. The following processes falls under hydrological cycle. Which one does not?
    a) Evaporation
    b) Infiltration
    c) Irrigation
    d) Surface run-off
4. Which of the following statement is false?
    a) 97% of the earth's water occurs in oceans.
    b) 2% occurs in the polar ice caps and frozen glaciers
    c) Only 3% is available as fresh water.
5. Explain the term groundwater
6. State the suitable methods for well site establishment
7. Explain the factors affecting well siting
8. Analyze the importance of establishing a well site

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Oral Assessment

1. Explain the need of establishing a well site
2. Summarize the methods of well site establishment

Case Study Assessment

The reduction in the water table is known in groundwater terms as a drawdown. Why do you think drawdown occurs?

Practical Assessment

1. Plan the steps undertaken in identifying a suitable well site
2. Given the rain gauge observations during a storm. Construct the mass curve of precipitation.
3. Estimate rainfall using the Thiessen polygon method

9.3.5.4 Tools, Equipment, Supplies and Materials

- Computers
- Stationery
- Evaporation pan (Class A)
- Rain gauge
- Current meter
- Wading suit
- Tape measure
- Staff gauge
- Hand lens
- Clinometer
- GPS receiver
- Maps
- Steel file
- Steel knife
- Rock samples
- Minerals
- PPE

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9.3.5.5 References

Facts, G. (2010). Water resources. Irrigation, Sanitation, and Supply.

Sioutas, C., Pandis, S. N., Allen, D. T., & Solomon, P. A. (2004). Special issue of Atmospheric Environment on findings from EPA's Particulate Matter Supersites Program.

Tolche, A. D. (2020). Groundwater potential mapping using geospatial techniques: a case study of Dhungeta-Ramis sub-basin, Ethiopia. Geology, Ecology, and Landscapes, 1-16.

9.3.6 Learning Outcome No 5: Conserve the Environment

9.3.6.1 Learning Activities

Learning Outcome No 5: Conserve the Environment	
Learning Activities	**Special Instructions**
5 .1 Identify Factors affecting water and soil conservation 5 .2 Identify water and soil conservation measures 5 .3 Identify types of land degradation 5 .4 Identify causes of land degradation 5 .5 Identify effects of land degradation 5 .6 Identify control measures	• Project • Case studies • Field trips • Discussions • Demonstration by trainer • Practice by the trainee

9.3.6.2 Information Sheet No9/LO5: Conserve the Environment

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Introduction to learning outcome

This learning outcome covers Water conservation, Soil conservation, Water and soil conservation measures, Types of land degradation, Causes of land degradation, Effects of land degradation and Control measures of land degradation.

Definition of key terms

Soil conservation: Soil conservation is the preservation of soil from erosion and other forms of degradation in order to maintain soil fertility and productivity

Land degradation: Land degradation is a decline or loss of the productive potential of the biophysical environment

Water conservation: Water conservation is the method of using water effectively to reduce excessive water usage.

Content/procedures/methods/illustrations

5.1 Identify Factors affecting water and soil conservation based on natural and artificial activities.

Water conservation: is the method of using water effectively to reduce excessive water usage.

Soil conservation: Soil conservation is the preservation of soil from erosion and other forms of degradation in order to maintain soil fertility and productivity.

Factors affecting water conservation

- Climate change
- Deforestation
- Pollution
- Sedimentation
- Landscape changes
- Urban growth (Sprl, 2004)

Factors affecting soil conservation

- Practices on land use in agriculture: use of some fertilizers affects microorganisms in the soil to produce nutrients naturally.
- Mining: some methods of mining cause soil loss.
- Construction and development: some soils at construction sites washes or blow away because its protective plant cover has been removed according to www.classzone .com.

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5 .2 Identify water and soil conservation measures based on the identified factors

Water conservation measures consist of measures aimed at reducing the quantity of drainage effluent and measures aimed at reducing the mass pollution of the constituents into the receiving water (Christen and Skehan, 2000).

Soil conservation measures reduces soil erosion and provides solutions on farms

Soil conservation measures

Practices on land use in agriculture: conserved through crop rotation, contour ploughing, wind breaks, conservation tillage and terracing.

Mining: by use of best methods of mining.

Construction and development: proper measures should be put in place during site clearance and all construction activities.

Water conservation measures

Sedimentation: there should be proper land use practices

Landscape changes: conserved through minimum use of conversion of natural landscape to farming and human activities.

Urban growth: proper measures should be put into place when cities grow to preserve water.

Deforestation: it is conserved through minimum clearing of forests and planting of more trees.

Figure 102: Fanya juu terraces

Source: **Fanya juu terraces** in a semi-arid area which have developed over time into benches: note well established grass strips along the bunds (Kenya). (c) Hanspeter Liniger, WOCA

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5 .3 Identify types of land degradation based on environment

Land degradation: is a temporary or irreversible decrease in the productive ability of land (UNEP, 1992b).

Types of land degradation

Water erosion: includes all aspects of soil erosion by water, including soil erosion. Human-induced intensification of landslides triggered by forest clearing, road construction.

Wind erosion: refers to the loss of soil by wind, which occurs mainly in dry regions.

Soil fertility decline: is used in the short term to refer to what is more precisely described as deterioration of soil physical, chemical and biological properties.

Waterlogging: is a decrease in land productivity due to an increase in precipitation below the soil surface.

Salinization: is used in its broad sense to refer to all forms of soil deterioration caused by the increase of salts in the soil.

Lowering the water table: occurs as a consequence of excessive groundwater pumping bellow the water table.

5 .4 Identify causes of land degradation based on degradation types identified
Deforestation- cutting of forest will affect soil adversely since forest are helpful in binding up of soil particles with the help of roots if vegetation.

Excess use of fertilizers and pesticides - excess use of fertilizers causes an imbalance in the quality of certain nutrients in the soil which affects vegetation.

Overgrazing- over exploitation of pasture by livestock makes grass and other vegetation's unable to survive and grow. This lack of vegetation cover leads to soil erosion.

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Desertification- this is the destruction of the biological potential of land due to mismanagement of forest, overgrazing, mining and quarries can lead to desert like condition.

Soil erosion- this is the loss of top fertile soil along with nutrient through run off water, strong wind may also blow the loose and coarse soil particle across long distance.

5 .5 Identify effects of land degradation based on degradation types identified
Water erosion: Once the soil enters the water supply, the concentration of phosphorous and nitrogen in the water increases, resulting in decreased water oxygen levels and reduced water quality.

Wind erosion: Wind erosion reduces the soil's ability to retain nutrients and water, rendering the atmosphere drier.

Soil fertility decline: Decrease in soil fertility causes a lack of the necessary soil nutrients for crops.

Waterlogging: Waterlogging prevents aeration and gas exchange and thus causes the soil to shut down in many habitats.

Salinization: Salinization causes plant dehydration leading to a decrease in yield

Lowering water table: Lowering the water table causes wells to be unable to access groundwater

5 .6 Identify control measures based on the identified factors

Water erosion degradation is managed by mulching which is covering the soil surface with a crop residue or growing plant cover.

Wind erosion degradation is controlled by the reduction of cultivated fallow, the maintenance of the vegetable cavity, the reduction of the tillage and the prevention of overgrazing,

Soil fertility decline is regulated by the retention of crop residues on site, the use of a reduced tillage method and the application of soil modifications or fertilizers.

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Salinization is controlled by the monitoring of the groundwater levels and the quantity of salts and water in the land and encouraging preventative measures to stop the salts moving towards the surface.

Waterlogging is controlled by removal of excess water and minimizing compaction according to www.ccmacknowledgebase.vic.gov.au. The lowering of water table is managed by controlling sub-irrigation and drainage.

Conclusion

This learning outcome has covered Water conservation, Soil conservation, Types of land degradation, Causes of land degradation, Effects of land degradation and Control measures of land degradation.

Further Reading

Read more on land degradation and its control measures

9.3.6.3 Self-Assessment

Written assessment

1. Which is of the following is not a type of land degradation?
    a) Wind erosion
    b) Waterlogging
    c) Groundwater
    d) Salinization
2. Evaluate the importance of environmental conservation
3. The following are factors affecting water conservation. Which one is not?
    a) Sedimentation
    b) Mining
    c) Deforestation
    d) Overgrazing
4. Which of the following is a factor affecting soil conservation?
    a) Water logging
    b) Mining
    c) Sedimentation
    d) Salinization
5. Explain factors affecting water conservation
6. Evaluate the effects of land degradation
7. Distinguish the types of land degradation
8. Discuss the control measures based on land degradation

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Oral Assessment

1. Explain land degradation
2. Summarize the causes of land degradation

Case Study Assessment

Investigate the causes and effects of land degradation in your area

Practical Assessment

Conduct a site visit to a mining location and come up with a strategy on how to conserve the soil.

9.3.6.4 Tools, Equipment, Supplies and Materials

- Computers
- Stationery
- Evaporation pan (Class A)

- Rain gauge
- Current meter
- Wading suit
- Tape measure
- Staff gauge
- Hand lens
- Clinometer
- GPS receiver
- Maps
- Steel file
- Steel knife
- Rock samples
- Minerals
- PPE

9.3.6.5 References

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Facts, G. (2010). Water resources. *Irrigation, Sanitation, and Supply*.

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9.3.7 Learning Outcome No 6: Develop Water Harvesting Structures Situations

9.3.7.1 Learning Activities

Learning Outcome No 6: Develop water harvesting structures	
Learning Activities	**Special Instructions**
6 .1 Identify water harvesting techniques 6 .2 Identify suitable sites for water harvesting reservoirs 6 .3 Design simple water harvesting structures 6 .4 Operate and maintain simple water harvesting structures	• Project • Case studies • Field trips • Discussions • Demonstration by trainer • Practice by the trainee

9.3.7.2 Information Sheet No9/LO6 Adapt First Aid Procedures for Remote

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Introduction to learning outcome

This learning outcome covers Water harvesting techniques Types of water harvesting reservoirs), Site selection for water harvesting structures factors considered: Hydraulic properties of rock units (porosity, Permeability, compressibility), Topography and Proximity, Design of simple water harvesting structures and Operation and maintenance of water harvesting structures.

Definition of key terms

Water pans: this is depression on the ground that collect and stores surface runoff from uncultivated grounds, road.

Water dams: Are structures constructed along a water course to store water on its upstream besides controlling its flow.

Porosity: it is a measure of the void space in a material and can be further explained as fraction of the volume of voids over the total volume.

Permeability; It is the measure of the rate of flow of a fluid through a porous medium.

Content/procedures/methods/illustrations

6 .1 Identify water harvesting techniques based on site conditions

Water harvesting techniques are ways in which water is collected either on the surface or below the ground lever to store water during wet season to be used during dry period.

They include:

1. Roof catchments: a technique used for collecting rainwater with suitable roof cover conditions over buildings.
2. Rock catchment: they collect rain water from rock outcrops to concentrate the runoff water into a storage structure.
3. Surface water catchment; water is collected on land and channeled to a single point.

6 .2 Identify suitable sites for *water harvesting reservoirs* based on geological structures

Water harvesting reservoirs: Dams (Earth, sand, concrete), Water pans, Ponds, Man-made lakes

Suitable sites of the water harvesting reservoirs should be where:

a. Hydraulic properties involving the layers beneath should have low permeability and less porous earth material.
b. Topography involves mapping and detecting shallow depths to ensure a depth equal to the proposed height of reservoir.
c. Proximity entails the site being at a location where it is close to infrastructure for accessibility purposes.

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6 .3 Design simple water harvesting structures based on the need

Designing a water dam will involve the following process

i. Description of the need and the location of dam
ii. A hydrological assessment of the dam in relation to catchment features and climatic conditions
iii. An assessment of environmental and social impacts of the dam
iv. Description and analysis of reservoir, embankment, spillway, draw-off system, scour and ancillary structures details
v. Preparation of the design drawings
vi. Description of catchment protection works
vii. Estimation of construction cost
viii. Preparation of construction works and schedule
ix. Preparation of operation rules and schedule of inspection and maintenance

6.4 Operate and maintain simple water harvesting structures based on standard operating procedures

Operation and maintenance are done by:

- Refilling erosion rills on the embankment slopes with compacted material
- Keeping and noting records of spillway flows
- Removing silt from reservoir area
- Frequent operation of valves during inspections to ensure they are working
- Regular inspections of the structure
- Addressing safety concerns by maintenance of fencing the structure and repainting of warning sign

Conclusion

This learning outcome has covered Water harvesting techniques Types of water harvesting reservoirs), Site selection for water harvesting structures factors considered: Hydraulic properties of rock units (porosity, Permeability, compressibility), Topography and Proximity, Design of simple water harvesting structures and Operation and maintenance of water harvesting structures.

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Further Reading

Learners should do further reading on Environmental Impact Assessment of water harvesting reservoirs and be able to do computations on design of reservoir structures

9.3.7.3 Self-Assessment

Written Assessment

1. Distinguish the different water harvesting techniques used to collect and store water
2. Which one of the following is not a water harvesting technique based on site conditions?
    a) Roof catchments
    b) Micro-catchment
    c) Rock catchments
    d) Surface water catchment

3. The following are hydraulic properties of rock units except one which one?
    a) Compression strength
    b) Permeability
    c) Porosity
    d) Compressibility
4. Classify the various subsurface water harvesting used in Kenya.
5. Categorize the types of water harvesting reservoir?
    a) Dams
    b) Water pans
    c) Ponds
    d) Plant pits
6. Explain the term porosity
7. Differentiate between porosity and permeability
8. Summarize the ways of maintaining water harvesting structures
9. Evaluate the reliability of rain water harvesting as a technique for water harvesting.
10. Over the years Masinga dam has been serving its purpose as a water harvesting reservoir. Discuss its purposes and uses in Kenya.

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9.3.7.4 Tools, Equipment, Supplies and Materials

- Computers
- Stationery
- Evaporation pan (Class A)
- Rain gauge
- Current meter
- Wading suit
- Tape measure
- Staff gauge
- Hand lens
- Clinometer
- GPS receiver
- Maps
- Steel file
- Steel knife
- Rock samples
- Minerals
- PPE

9.3.7.5 References

Ministry of water and irrigation. (2015) practice manual for small dams, pans and other water conservation structures in kenya. Nairobi: state department of water and irrigation

Saeid eslamian. (2020). Handbook of water harvesting and conservation. John wiley & sons

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