CURRICULUM

CONSULTANCY SERVICES IN CURRICULUM DEVELOPMENT FOR IWRM ACADEMIC EDUCATION IN SOMALIA

SUBMITTED TO THEMINISTRY OF ENERGY AND WATER RESOURCES, FEDERAL GOVERNMENT OF SOMALIA

Submission Date: December 2021

Implemented by:

1. PURPOSE OF THE REPORT

This report presents the proposed curriculum for the IWRM Masters Programme in Somalia which the Ministry of Energy and Water Resources of the Federal Government of Somalia commissioned Waternet to develop. The Terms of Reference for this assignment are the following:

i) Engage, guide and discuss with the advisory panel committee for the implementation of IWRM MSc program in Somalia
ii) Develop curriculum and syllabus for the implementation of IWRM MSc program in Somalia
iii) Share the regional experience in establishing academic IWRM programmes and feed that into all activities undertaken;
iv) Link the selected university in Mogadishu with a network of universities in the region and facilitate contracted services like experienced teachers, distance learning courses/lectures, thesis supervision, and more;
v) Assess the capacity of the chosen university to deliver the program and to engage in training of trainers (teachers) that the admission of students is well managed, and that practical arrangements are undertaken.
vi) Support and enable quality control and international accreditation

Waternet needed to develop an outline of the curriculum that the Somalia Advisory Panel accepted as satisfying their needs before detailed syllabi for the modules are elaborated on. Thus this report presents the curriculum developed based on the Draft Curriculum submitted by Waternet to the Somalia Advisory Panel. The panel consisted of the following persons:

Name	**Organisation**
Mr Ahmed Kurweyne	Director Water resources Somalia
Mr Abdullahi Hassan	National Advisor for IWRM-Ministry of Energy and Water Resources
Mr Bashir Omar Isse	Director General: School of Management & Public Administration,Somali National University
Dr Klas Sandström	Senior Advisor Transboundary Water Resources Management

2. APPROACH TO CURRICULUM DEVELOPMENT

The development of the outline for the curriculum was based on a) a needs assessment, b) situation analysis, c) reflective analysis, and d) literature review.

A needs assessment was aimed at establishing the existing water resources problems in Somalia, and the available tertiary education programmes with capacities to impart knowledge and skills for managing these problems within the national framework for achieving sustainable development. The results of the needs assessment assisted in developing the content of the IWRM Masters Programme, and determining the sustainability of the programme overtime. This needs assessment was done through discussions with representatives of the Ministry of Energy and Water Resources of the Federal Government of Somalia, review of reports commissioned by the same government and international cooperating partners, and other publications.

The situation analysis was undertaken using the same approach for the needs assessment and aimed at establishing the existing human and technical capacities for delivering an IWRM Masters Programme. The results inform the content of the syllabi for modules, and recommendations for any capacity enhancement for those who will deliver the programme. Any training programme has to take into account the prior knowledge and skills of the target group as these influence the content and delivery of learning materials. Discussions with the Advisory Panel and a report[1] by Ministry of Federal Government of Somalia Ministry of Education, Culture and Higher Education were used to get an understanding of the target group. Informal discussions with persons with experience in teaching at universities in Somalia also assisted in this regard. A trend analysis of the curriculums for IWRM postgraduate training was done through internet searches. This involved examining contents of curriculums of these programmes, and changes made over time.

Waternet has been running for the last 20 year a Regional IWRM Masters Programme hosted by several universities in east and southern Africa. The curriculum for this programme has been reviewed and improved several times. In addition, Waternet has a over 70 members who are institutions involved in research and training of IWRM related matters. Each year, an annual general meeting (AGM) of the members meet during the annual Waternet/GWPSA/WARFSA Symposium, and deliberate on their activities including the Regional IWRM Masters Programme. An active Waternet Alumni Association exists and provide feedback about the Region IWRM Masters Programme through the AGM and written reports[2]. A reflective analysis of the Waternet Regional Masters Programme was therefore used in the development of the curriculum for Somalia.

3. HOSTING OF THE IWRM MASTERS PROGRAMME IN SOMALIA

Waternet was advised by the Advisory Panel that the IWRM Masters Programme will be run by the Somalia National University in Mogadishu which is a state university established in 1954. This university has the following 11 faculties:

1) Agriculture and Environmental Science
2) Education and Social Sciences
3) Economic and Management Sciences
4) Engineering

[1]Federal Government of Somalia Ministry of Education, Culture and Higher Education. Education Sector Analysis, 2012-2016

[2]Fatch, J and Katambara, Z. (2015) The impact of the WaterNet Masters Programmes on the water sector in East and southern Africa. Waternet Alumni Association.

5) Islamic Studies
6) Social Sciences
7) Medicine and Surgery
8) Veterinary Medicine and Animal Husbandry
9) Science
10) Law
11) Health Sciences and Tropical Medicine

The number of students in 2017 was estimated at over 4000 students with about 104 teaching staff. About 10% of the teaching staff had PhD degrees[3]. The Somalia National University offers 4 year undergraduate degree programmes. The academic year is divided into two semesters each with 20 weeks.

4. PROPOSED IWRM PROGRAMME IN SOMALIA

4.1 Objectives of the programme

The following are the recommended general objectives of the IWRM Masters Programme in Somalia:

i) To develop an understanding of factors and processes accounting for the occurrences and movement of water in the atmosphere, on and below the land surface, and how humans affect both the quantity and quality of water resources.
ii) To impart skills for collecting and analysing relevant data for assessing spatial and temporal variability of both the quantity and quality of surface water and groundwater resources.
iii) To develop the capacity for identifying and analysing water resources management problems, formulate appropriate and feasible solutions for the conditions in Somalia, and in line with IWRM principles and the national sustainable development goals.

4.2 Duration

The IWRM Masters Degree Programme will have a duration of two years in line with all masters degree programmes at the Somalia National University. Each year is divided into two semesters, with each semester being 20 weeks.

4.3 Programme Structure

During the development of the programme structure, Waternet submitted to the Advisory Panel a Discussion Paper. The Advisory Panel met with water experts in Somalia and other stakeholders, and submitted list of modules they recommended for consideration. The

[3]Arnaldo et al. (2020) : Research in Somalia: Opportunities for cooperation, ODI Report, Overseas Development Institute (ODI), London

Advisory Panel also suggested additional materials for consideration. Based on these submissions and further discussions with the Advisory Panel, Waternet identified modules for the programme which address the needs in Somalia. These modules are outlined below.

The programme has a taught component and a research component. There shall be 16 taught modules out of which 12 are Core Modules and 4 are Elective Modules.

The research component will require a student to develop and present a research proposal, and when approved, the student will collect, analyse data, and write a dissertation for examination. The research component will be done during the second semester of the second year of study.

4.4 Outline of Modules

Table 1 below presents the modules comprising the IWRM Masters Degree Programme.

Table 1: Core and elective modules for the Masters Degree Programme in IWRM in Somalia

CORE Modules

1. Principles of Integrated Water Resources Management
2. Principles of Hydrology
3. Fundamentals of Water Quality Management
4. Water and Ecosystems
5. Water Governance
6. GIS and Remote Sensing Applications for Water Resources Management
7. Groundwater Assessment and Development
8. Water Resources Economics and Financing
9. Water Resources Planning
10. Climate Change and Adaptation for Integrated Water Resources Management

ELECTIVE MODULES

1. Water Treatment and Supply Systems
2. Wastewater and Fecal Sludge Management
3. Water Resources Information Systems
4. Gender Mainstreaming in Integrated Water Resources Management

RESEARCH

1. Research Methods
2. Group Work Project
3. Dissertation

Semester 1 : Modules 1 to 5 are foundational modules and will be taught in Semester 1.

Semester 2: Modules 6 to 10 develop an understanding and skills for analysing water resources, identifying water resources management problems and developing appropriate solutions.

Semester 3: Students will be required to select FOUR elective modules in Semester 3. Elective modules develop an advanced understanding and skills for investigating and managing specific aspects of water resources management. It is anticipated that overtime the number of elective modules will be expanded to provide opportunities for specialisation in different aspects of IWRM, e.g. Water and Society, Technical/Engineering, Data and Information Management. During the initial years students will

Both the Research Methods and Group Work Project modules are compulsory and will be done in Semester 3. The Group Work Project Module will involve students working in group to investigate a selected water resources management problem, writing a report, and giving an oral presentation.

Semester 4: The Dissertation will require a student to develop and present a research proposal for a specific water resources management issue. After approval of the research proposal, the student will collect and analyse data, and submit a written thesis for examination.

4.5 Descriptions of the modules

A brief description of each of the modules in Table 1 is presented below. A detailed syllabus for each module is being developed by the respective expert. The template being used to write the syllabus for each module is given Table 2. The brief description below is therefore not an exhaustive listing of the module contents.

4.5.1 Principles of IWRM

This module introduces the existing water management challenges and their drivers, the weakness of the past approaches to water resources management, and the rationale for the adoption of new paradigm in water management, the IWRM. The module will cover Dublin Principles also known as IWRM Principles, the IWRM objectives (social equity, economic efficiency, environmental sustainability), gender equality, stakeholders participation, catchment management. IWRM management tools and instruments will also be introduced. Global debates about the relevancy of water resources management to achieving sustainable development goals(SDGs) and African Union (AU) Agenda 2063, will be covered. A critical analysis of selected case studies dealing with IWRM implementation will be included.

4.5.2 Principles of Hydrology

This module introduces students to atmospheric, surface and subsurface (soil water and groundwater) elements of the terrestrial water cycle. Processes affecting the movement and storage of terrestrial water will be covered. The module will introduce students to methods for measuring and quantifying fluxes and storage of water. Spatial and temporal variability of the movement of water (precipitation, evapotranspiration, river flows, groundwater, etc) within Somalia, Africa and the world will be covered.

4.5.3 Fundamental of Water Quality Management

The module introduces physical, chemical and biological characteristics of surface water and groundwater, and effects of water quality on water uses. The module will cover types of water pollution, and their effects on humans and river systems, types of monitoring including bio-monitoring (active and passive monitoring).The design of water quality monitoring systems, methods for collection and analysis of water quality data will be included. Methods for categorising groundwater based on quality will be taught. Water pollution control measures will also be covered.

4.5.4 Water and Ecosystems

The module introduces basic concepts in ecology, biodiversity, physical disturbance, basic limnology, active and passive bio monitoring with a special emphasis on water-related ecosystems. The module will develop an understanding of services and goods provided by water-related ecosystems, and how these contribute to livelihoods. The module will cover how changes of rivers through impoundments, water abstraction and diversion affect ecosystems. The same will be done for groundwater-dependent ecosystems. Livelihoods derived from water-related ecosystems by different communities in Somalia will be given special emphasis.

4.5.5 Water Governance

This module covers policies, laws, and institutional arrangement for IWRM from local, national, regional and transboundary levels. Approaches for social inclusion in IWRM at local, national and regional levels that have or are being implemented and relevant case studies will be presented. Cultural dimensions and faith in IWRM will be examined. Stakeholders analysis and participation and inclusive decision making mechanisms will be also introduced. Socio-cultural dimensions and faith in IWRM will be examined.

4.5.6 GIS and Remote Sensing Applications for Water Resources Management

The module develops an understanding of spatial data and skills for acquiring, storing and analysing these data for water resources planning and management. The module also covers basic principles of remote sensing, acquisition, and analysis of remote sensing data for water resources planning and management.

4.5.7 Groundwater Assessment and Development

The module builds on the material covered in the Principles of Hydrology modules and develops an advanced understanding of the occurrences and movement of groundwater in different hydrogeological settings. Quantitative methods for representing and predicting flow and storage of groundwater will be covered. The module will cover various methods for investigating the occurrences and development of groundwater including the suitability of these methods in different hydrogeological and socioeconomic settings. A special emphasis will be given to hydrogeological and socioeconomic conditions in Somalia. Typical problems encountered in groundwater utilisation (both quantity and quality) will be examined.

4.5.8 Water Resources Economics and Financing

The module covers valuation and pricing of water resources, water allocation systems, supply-demand management, political economy of water, application of economic tools in IWRM. Techniques such as costs and benefits analysis of water investments, financing water projects, will be covered.

4.5.9 Water Resources Planning

The module will focus on planning cycle for IWRM including planning steps and processes, initiation, identification and situation analysis of water resources management problems, development of water resources planning objectives and strategies, stakeholder participation, development and implementation of IWRM plans, river basin/watershed planning, use of models for water resources planning, etc.

4.5.10 Climate Change and Adaptation for Water Resources Management

The module will introduce factors and processes determining the climate system, causes of climate change, how climate change projections are derived, projected climate changes for different emission scenarios. Effects of climate change on availability of water resources in Somalia, Africa and the world will be covered. Climate change adaptation options relevant for the water sector especially in Somalia and Africa will be examined.

4.5.11 Water Treatment and Supply Systems

The module will cover the characteristics of surface and groundwater, and the appropriate treatment units like sedimentation and settling systems, filtering system, precipitation and complexation, ion exchange, reverse osmosis, desalination plant, disinfection. The module will examine decentralized water treatment including the household water treatment systems. The main transmission and distribution systems including pumping will be covered. Sustainability of water supply projects and schemes will be examined. Water utility management will also be introduced.

4.5.12 Wastewater and Sludge Management

The module will introduce wastewater and fecal sludge physical, chemical and biological characteristics with particular focus on impacts on public and environmental health. It will also cover on-site and offsite sanitation systems, wet and dry sanitation. The module will provide an understanding of the sanitation value/service chain including the capture, containment, emptying and transport, treatment and disposal and re-use. A great deal of attention will be paid on sanitation technologies appropriate to the Somalia context including decentralized wastewater treatment (DEWATS).

4.5.13 Water Resources Information Systems

The module develops an understanding of the need for effective water resources information systems for IWRM implementation. The module will cover local, national, and global

challenges for developing and managing effective water resources information systems. Some of the issues to be covered will include development and maintenance of water resources information systems appropriate for IWRM, data sources, integration of different data sets within a water resources information system, development of products relevant for different users, e.g. community, planners, decision-makers. The module will also cover information dissemination and knowledge sharing, options for participation of citizens in data collection. Big data, internet of things, machine learning and artificial intelligence will also be introduced

4.5.14Gender Mainstreaming in Integrated Water Resources Management

The module develops an understanding of the need for integrating gender in IWRM. Tools for including gender in various IWRM activities will be examined. Case studies demonstrating local, national and global challenges and opportunities for integrated gender in IWRM will be included. Gender analysis, gender impact assessment, location and design of water management and development projects and empowerment and decision-making will be examined.

4.5.15 Research Methods

The module will introduce different research paradigms, the range of qualitative and quantitative research methods. The module will cover how to formulate a feasible research project, and select appropriate research methods. The role of literature review in research will be considered. Different experimental designs, sampling strategies and data analysis methods will also be examined.. The module will also deal with communicating research findings through different methods and prepare research reports

4.5.16 Group Project

The Group Project module aims to develop skills for a student to participate effectively as a team member in investigating, analysing and reporting on an aspect of water resources management. Students will be assigned to groups, with each group investigating a specific water resources management issue. Each group will write a report and give an oral presentation.

4.6 Dissertation

The dissertation aims at developing skills for a student to independently undertake an in-depth investigation of a research problem. This will require a student to demonstrate the capacity to review literature and formulate a research project, followed by collection and analysis of data, deriving conclusions that are logically consistent with results obtained. The students will develop skills for presenting orally and in written form research results using accepted conventions for scientific writing.

5. Syllabi for Modules

Waternet wrote syllabi for the following 12 modules as per the contract with the Ministry of Energy and Water Resources of Somalia.

Core Modules

1. Principles of Integrated Water Resources Management
2. Principles of Hydrology
3. Fundamentals of Water Quality Management
4. Water and Ecosystems
5. Water Governance
6. GIS and Remote Sensing Applications for Water Resources Management
7. Groundwater Assessment and Development
8. Water Resources Economics and Financing
9. Water Resources Planning
10. Climate Change and Adaptation for Integrated Water Resources Management

Elective Modules

1. Water Treatment and Supply Systems
2. Gender Mainstreaming in Integrated Water Resources Management

The syllabi were written by the following experts:

MODULE	Module Writer	Affiliation
1. Water Governance	Prof Emmanuel. Manzungu	University of Zimbabwe
2. Principles of Surface Water	Dr Kawawa Banda & Prof D. Mazvimavi	University of Zambai
3. Fundamentals of Water Quality	Prof Innocent Nhapi	Chinhoyi University of Technology, Zimbabwe
4. Water and Ecosystems	Prof Tamuka Nhiwatiwa	University of Zimbabwe
5. GIS and Earth Observation	Prof Timothy Dube	University of the Western Cape, South Africa
6. Water Resources Economics and Financing	Prof Stefano Faroli	CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement), France
7. Climate Change and Adaptation for Water Resources Management	Dr Mulungu	University of Dar es Salaam
8. Water Resources Planning	Prof Dominic Mazvimavi	University of the Western Cape, South Africa
9. Principles of IWRM	Dr Richard Kimwaga	University of Dar es Salaam
10. Groundwater Assessment and Management	Prof Modreck Gomo	University of the Free State, South Africa
11. Water Supply Systems	Dr Richard Kimwaga	University of Dar es Salaam
12. Gender and Integrated Water Resources Management	Prof Svunurai Chingarande-Mutanga	Ezekiel Guti University, Zimbabwe

The syllabi written are presented in the tables below.

5.1 PRINCIPLES OF INTERGRATED WATER RESOURCES MANAGEMENT

Module Title	Principles of Integrated Water Resources Management
Module Aim	The module develops an understanding of IWRM principles and the rationale for the global adoption of this approach
Expected learning outcome(s)	At the end of the module a student should be able to; 1. Describe different water resources and water users 2. Explain water management challenges 3. Describe the global, regional and Somalia development agenda 4. Describe IWRM and associated key concepts. 5. Understand the key principles of IWRM. 6. Understand the IWRM management tools and constituents for water management 7. Explain the IWRM approach and demonstrate understanding of IWRM in practice through analysis of case studies.
Module Status	Core
Credit Rating	15
Total Hours Spent	150
Module Content	List of topics to be covered. **1. Introduction** 1.1. Earth's water abundance and distribution - (seawater vs freshwater - surface and groundwater, precipitation, runoff, evapo-transpiration) 1.2. Water users and uses - (Food production (agriculture and livestock), water supply and wastewater/sanitation, mining, industry, environmental protection (sustaining ecosystems), fisheries, tourism, energy and transport 1.3. Approaches and methods for determining the water demand for different water users 1.4. Global and Regional Development agenda 1.5. SDGs (background, 17 goals, SDG 6, target 6.5) 1.6. 4th Industrial Revolution (circular economy, digitalization, SMART systems, robotic, artificial intelligence, big data) 1.7. Africa Union (AU) Agenda 2063: The Africa We Want **2. Water Resources Management Challenges** 2.1. Limited access to fresh water 2.2. The water scarcity and insecurity 2.3. Population growth, urbanization and economic development 2.4. Climate change and variability 2.5. Trans-boundary water issues 2.6. Competition for scarce water resources 2.7. Water conflicts among various water use sectors and societies 2.8. Waste discharge and water pollution. 2.9. Water related disasters (floods and droughts) **3. The Urgency for Water Security** 3.1. Water-energy-food nexus 3.2. Water for growing urban areas, cities and towns (urbanization) 3.3. Depleted water resources 3.4. Working together across sectors 3.5. Need for social change 3.6. Water is key to development 4. **Water Management Approaches Prior to IWMR Adoption**

	4.1. Fragmented and uncoordinated development and management of water resources. 4.2. Water management considering administrative boundaries 4.3. Top-down approaches for the decision making processes in water issues 4.4. Supply management is dominating the past and current water management. 4.5. The current water governance crisis 4.6. Need for new paradigm shift - (IWRM) **5. Integrated Water Resources Management** 5.1. Evolution of IWRM 5.2. Describe the objectives of IWRM 5.3. Describe the principles of IWRM The Dublin Principles 5.4. Define Key IWRM concepts **(**multiple uses, holistic management, multiple perspectives, participatory approach, women involvement) **6. Elements of Integration/What are We Integrating** 6.1. Natural system integration (Freshwater and Coastal zone, Land and Water, "Green water" and "Blue water", Surface water and Groundwater, Quantity and Quality, Upstream and Downstream) 6.2. Human system integration - Mainstreaming of water resources in national policies (economic policy, food policy, environment policy, health policy, energy policy), Cross-sectoral integration (all major water use sectors and Involving all stakeholders) **7. Describe benefits of IWRM to different sectors** 7.1. Benefits to water supply and sanitation 7.2. Benefits to food production 7.3. Benefits to the environment **8. Tools for the Implementation of IWRM approach** 8.1. Enabling environment (policies and legal frameworks) 8.2. Institutions 8.3. Management Instruments/tools - (water resources assessment, Plans for IWRM, Water Allocation tools, Water Demand Management, Social change instruments, Conflict resolution, Stakeholder participation methods,Pollution control measure, Regulatory instruments, Monitoring activities, Economic and financial instruments, Information management systems and exchange **9. IWRM case studies** Guiding Questions • What indicators of success can be used to assess the effectiveness of IWRM? • What factors limit the success of IWRM projects? • What considerations should be made in implementing an IWRM project?
Teaching and Learning Activities	Lectures, tutorials, assignments and exercises
Assessment	This course is assessed by coursework – CA(40%) and University examination – UE (60%) Suggested assignments/tasks/exercises. E.g. Assessment 1: Discuss the water resources management challenges in Somalia Assessment 2: To what extent has Somalia domesticated the SDGs and AU Agenda 2063 Assessment 3: Explain the development of an IWRM approach, and the rationale for global adoption of this approach Assessment 4: How can IWRM approach be used to improve the water situation in Somalia Assessment 5: What are the gaps and weakness for the implementation of IWRM approach in Somalia Assessment 6: Explain the IWRM approach and demonstrate understanding of IWRM in practice through analysis of case studies
Reading materials/reference list	1. Mei Xie (2006):Integrated Water Resources Management (IWRM) – Introduction to Principles and Practices**,** *World Bank Institute (WBI)*

2. Cap-Net: Integrated Water Resources Management (IWRM) Tutorial. 2003. http://www.capnet.org/iwrm_tutorial/mainmenu.htm

3. Global Water Partnership (GWP). 2000. Integrated Water Resources Management. (TAC background paper; no. 4). Stockholm, Sweden. online at http://www.gwpforum.org/gwp/library/Tacno4.pdf

4. GWP. 2003a. "Rationale for IWRM and the Toolbox." Found online at http://www.gwpforum.org/gwp/Media/Toolbox/IWRM_and_the_toolbox.pdf

5. GWP. 2003b. "Main Features of the Toolbox." Found online athttp://www.gwpforum.org/gwp/Media/Toolbox/main_features.pdf

6. GWP. 2003c. "Toolbox: List of Tools." Found online at http://www.waterland.net/index.cfm/site/Toolbox%20-%20en/pageid/4663B313-A25C-8A9B 5C1C99D060C92B62/page/1/index.cfm

7. Water Resources of Somalia, 2007

8. SIWI, 2020: Principles and Practices of Integrated Water Resources Management Workplace-based Professional Training

9. United Nations. (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. UN Doc. A/RES/70/.1. https://sustainabledevelopment. un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development %20 web.pdf

10. AU agenda 2063

11. Cap-Net. (2008). Integrated Water Resources Management for River Basin Organisations. International Network for Capacity Building in Integrated Water Resources Management, Cape Town, https://www. gwp.org/globalassets/global/toolbox/references/iwrm-for-river-basin-organisations-capnet-2008.pdf

12. Global Water Partnership. (2000). Integrated Water Resources Management. Global Water Partnership Technical Advisory Committee Background Papers, No. 4, 2000, https://www.gwp.org/globalassets/global/toolbox/publications/background-papers/04-integrated-water-resources-management-2000-english.pdf

13. Gumbo, B. and Van der Zaag, P. (2001). Principles of integrated water resources management (IWRM). Global Water Partnership Southern Africa. Southern Africa Youth Forum 24-25 September 2001, Harare, Zimbabwe

14. United Nations. (1992a). Sustainable Development, United Nations Conference on Environment and Development, Agenda 21, https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf United Nations. (1992b). The Dublin Statement. International Conference on Water and Environment, http://www.wmo.int/pages/prog/hwrp/documents/ english/icwedece.html

15. UNEP. (2012). *Status Report on the Application of Integrated Approaches to Water Resources Management*. United Nations Environment Programme, Nairobi, Kenya

16. Woyessa, Y.E., Hensley, M. and van Rensburg, L.D. (2006). Catchment management in semi-arid area of Central South Africa: strategy for improving water productivity. *Water SA* 32: 648–654.

SUGGESTED TIME ALLOCATION

ACTIVITY	**HOURS**
Lectures	60
Tutorials & Seminars	15
Practical	0
Assignments	45
Independent Study	30
TOTAL	150

5.2 PRINCIPLES OF HYDROLOGY

Module Title	Principles of Hydrology
Module Aim	To provide students with principles, theoretical and applied physical aspects of surface and subsurface water and the application of these principles to solve hydrologic and hydrogeologic problems
Expected learning outcome(s)	At the end of the module a student should be able to; 1. Demonstrate knowledge of the hydrological cycle and how its individual components including subsurface water can be quantified. 2. Explain how hydrological changes impact upon the quantity of surface and subsurface water. 3. Predict the hydrological and hydrogeological impacts of diverse climate change scenarios given a particular range of climatic regimes. 4. Provide solutions to hydrological and hydrogeological problems in different environments.
Module Status	Core
Credit Rating	xxx
Total Hours Spent	160
Module Content	**1. Introduction to the Hydrological Cycle** 1.1. Definition of hydrology 1.2. Hydrological cycle 1.3. Drainage basin and its characteristics 1.4. Water balance equation 1.5. Global water balance **2. Precipitation** 2.1. General atmospheric circulation system 2.2. Classification of liquid and solid precipitation 2.3. Processes responsible for precipitation formation and the growth of rain drops in the atmosphere 2.4. Types of precipitation; orographic, cyclonic and convectional precipitation 2.5. Measurement of point rainfall, and factors affecting accuracy of rainfall measurement 2.6. Methods for estimating areal rainfall 2.7. Diurnal, seasonal and intra-annual variations of precipitation in Somalia, Africa and the world 2.8. Influence of El Nino, La Nina, Southern Oscillation, Indian Ocean Dipole on rainfall variability 2.9. Spatial variations of precipitation in Somalia, Africa and the world **3. Evapotranspiration** 3.1. Evaporation and transpiration processes 3.2. Factors influencing evaporation from water bodies, soils, and plants 3.3. Reference evapotranspiration 3.4. Temperature based methods for estimating reference evapotranspiration 3.5. Estimation of reference evapotranspiration 3.6. Measurement of solar radiation, relative humidity, atmospheric temperature, wind direction and speed 3.7. Measurement of evapotranspiration using evaporation pans, lysimeters, eddy flux tower, scintillometer, heat pulse velocity 3.8. Use of satellite data for estimation of evapotranspiration **4. Soil water** 4.1. Saturated and unsaturated zones 4.2. Infiltration process 4.3. Infiltration capacity, field capacity, wilting point 4.4. Soil water movement during and after infiltration

	4.5. Soil water balance **5. Runoff** 5.1. Components of runoff 5.2. Mechanisms for runoff formation 5.3. Temporal and spatial variations of runoff 5.4. Objectives of river flow measurement 5.5. Methods for stage and river discharge measurements 5.6. Analysis of river flows data, hydrograph analysis, flow duration curves, mean monthly flows, conversion of river discharges to different measurement units (millimetres, cubic metres, etc) **6. Floods** 6.1. Definition and causes of floods 6.2. Flood frequency analysis, flood return period and design flood 6.3. Introduction to flow routing 6.4. Flood management; structural and non-structural flood management measures **7. Droughts** 7.1. Definition and causes of droughts 7.2. Analysis of droughts 7.3. Drought preparedness and management 7.4. Review of causes and impacts of selected droughts in Somalia **8. Hydrological modelling** 8.1. Introduction to hydrological models 8.2. Purposes of hydrological modelling 8.3. Types of hydrological models 8.4. Development of a simply catchment model (bucket model) **9. Hydrological impact of land cover/land use change [3 lectures]** 9.1. Impacts of afforestation, deforestation, cultivation, urbanization 10. **Groundwater** 10.1. Rocks and groundwater; aquifer systems; groundwater recharge and discharge 10.2. Groundwater flow and transport theory 10.3. Relations between groundwater and surface water
Teaching and Learning Activities	Lectures, exercises, case studies and field work to a river basin
Assessment	1. Estimation of areal rainfall for a catchment or region in Somalia using rain gauge data. 2. Analysis of rainfall data to establish monthly, seasonal and interannual variations of rainfall. 3. Estimation of reference evapotranspiration rates using the Penman-Monteith Equation 4. Analysis of river flow data to establish monthly and interannual variations. 5. Field report based on river flow measurement 6. Flood frequency analysis and estimation of design floods with 5, 10, 25, 50 and 100 years return periods. 7. Analysis of rainfall, river flow and water table data to determine severity or past droughts in Somalia. 8. Development of drought management plan for a given region in Somalia. 9. Report based on literature review of hydrological effects of land use and land cover change in Somalia.
Reading Materials/Reference List	1. Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. 1998. Crop evapotranspiration (guidelines for computing crop water requirements). FAO Irrigation and Drainage Paper No. 56, FAO, Water Resources, Development and Management Service Rome, Italy. 2. Barry, R.G. and Chorley, R. J, 2004. Atmosphere, weather, and climate. Routledge, Publishers, New York. 3. Brutsaert, W. 2005. Hydrology. An Introduction. Cambridge University Press. 4. Dingman, S.L. 2002. Physical hydrology. Prentice Hall, 645 p. 5. Helsel, D.R. and Hirsch, R.M. Statistical Methods in Water Resources. Techniques of Water-Resources Investigations of the United States Geological Survey Book 4, Hydrologic Analysis and Interpretation. 523 p

	6. Herschy, R.W. 2009. Streamflow measurement. Routledge Taylor & Francis, 507 p. 7. Karamouz, M., Nazif, S. and Falahi, M. 2013. Hydrology and Hydroclimatology: Principles and Applications. CRC Press. Taylor & Francis Group, 731 p. 8. Maidment, D.R. (Ed) 1993. Handbook of hydrology. McGraw-Hill. 9. Todd, David Keith, and Larry W. Mays. Groundwater Hydrology . 3rd ed. Hoboken, N.J: Wiley, 2005. Print 10. Ward, R.C. and Robinson, M. 2000. Principles of hydrology. McGraw-Hill. 11. World Meteorological Organization. 1994. Guide to Hydrological Practices. Data cquisition and processing,analysis, forecasting and other applications. WMO-No. 168., 739 p. 12. World Meteorological Organization. 2009. Guide to Hydrological Practices. Volume I: Hydrology – From Measurement to Hydrological Information. WMO-No. 168., 296 p. 13. World Meteorological Organization. 2009. Guide to Hydrological Practices. Volume II: Management of Water Resources and Application of Hydrological Practices. WMO-No. 168., 302 p. 14. World Meteorological Organization. 2009. Integrated flood management concept paper. WMO Report WMO-No-1047. Associated Programme on Flood Management, World Meteorological Organization,. 15. World Meteorological Organization, 2010, Manual on Stream Gauging Volume I – Fieldwork WMO-No. 1044.

SUGGESTED TIME ALLOCATION

ACTIVITY	**HOURS per semester**
Lectures	60
Tutorials & Seminars	10
Practical	30
Assignments	30
Independent Study	30
TOTAL	160

5.3 FUNDAMENTALS OF WATER QUALITY MANAGEMENT

Course Title	Fundamentals of Water Quality Management
Course Aim	The aim of the course is to introduce students to a range of water quality management concepts and tools, which include monitoring physical, chemical and biological components, assessment of the impact of pollution on aquatic ecosystems and water quality modelling.
Expected learning Outcome(s)	At the end of the course students should be able to: 1. Understand the chemistry, biological, ecological, and physical concepts necessary to analyze basic water quality problems. 2. Understand the processes of pollutant transport and ability to apply mass balance to determine pollutant concentrations in space and time 3. Understand local, regional, and global water quality management problems 4. Understand the process of environmental management, including pertinent laws and regulations 5. Communicate effectively on issues in water quality management
Course status	Core
Credit rating	12 credits
Total hours spent	120
Course content	**1. Introduction to Water Quality** 1.1. Chemical, physical, and biological characteristics of aquatic systems 1.2. Sources of water pollution 1.3. Consequences of poor water quality 1.4. Ecological principles impacting water quality 1.5. Hydrologic and hydraulic principles relating to water-quality monitoring and modelling 1.6. Quantitative characterization of assimilative capacity of aquatic systems 1.7. Assessment, remediation, planning and management, and post-audit/monitoring strategies 1.8. Water and wastewater treatment technologies **2. Water Quality Measurement and Monitoring** 2.1. The purpose of monitoring (e.g. compliance v. continuous improvement) 2.2. Flow measurement and estimation 2.3. Physico-chemical and biological parameters 2.4. Sampling techniques and procedures 2.5. Design of monitoring programmes and quality control 2.6. Legislative and other requirements and incorporating monitoring into the EIA//EIS/EMP 2.7. Water quality standards 2.8. Water quality assessment and use of indices 2.9. Practical water sampling exercise: sampling plan, sample collection and handling procedures **3Aquatic Ecosystems and Biomonitoring** 3.1. What is ecotoxicology? 3.2. How were the trigger values derived 3.3. High reliability versus low reliability guidelines 3.4. Deriving site specific trigger values 3.5. Whole effluent testing 3.6. River health 3.7. Objectives of biological sampling programs 3.8. Biomonitoring tools and indices 3.9. Active and passive biomonitoring 3.10. Potential impacts (from mining) on aquatic ecosystems and biota 3.11. Example approaches to selecting monitoring tools

	4. Water Quality Management Tools 4.1. Standards and criteria 4.2. Regulations and guidelines 4.3. Water quality indices 4.4. Institutional strategies and legal framework 4.5. Statistical applications and risk analysis 4.6. GIS and Remote Sensing applications **5. Data Handling** 5.1. Management and Interpretation 5.2. Recording of field observations and trends 5.3. Quality control 5.4. Reporting to different stakeholders (e.g. industry, regulators, community) **6. Groundwater quality** 6.1. Groundwater geochemistry – Summary and significance for water resources management 6.2. Groundwater monitoring systems 6.3. Design of monitoring plans and networks (including wells, bores and piezometers), underground mines and groundwater contamination 6.4. Sampling protocols/procedure 6.5. Laboratory analysis 6.6. Evaluation of quality of data 6.7. Estimations for pollutant loads **7. Water Quality Modelling** 7.1. Basic modelling approaches 7.2. Selected models in water quality management (groundwater, river and lake water quality modelling) **8. Practical Water Sampling Exercise** 8.1. Sampling plan 8.2. Sample collection and handling procedures **9. Laboratory and fieldwork** 9.1. Labwork: temperature, pH, DO, turbidity, EC, BOD_5, COD, TN, TP, Faecal Coliforms 9.2. Fieldwork: Polluted river, polluted dam
Teaching and Learning Activities	The following teaching strategies will be used in the delivery of this course: Lectures, Groupwork, Fieldtrips, Laboratory work
Assessment	Student assessment will be based on formative assessment (continuous assessment) and summative assessment (examination). Depending on the degree regulations, coursework contributes about 30% while the examination contributes 70% of the final mark. **Formative Assessment (continuous)** a. Fieldwork: 2 fieldwork reports covering a description of the visited areas, a critical review of the situation, and suggestions for improving the situation b. Laboratory exercise: 2 lab report on experiments done in the lab. c. Groupwork: Group assignment on managing water pollution around the university campus or local town and 15-minute classroom PowerPoint presentations + max 5-page written report. The assignment should demonstrate understanding of scientific principles and a combination of national governance and regulatory framework. **Summative Assessment (examination)** At the end of the module students will sit for a 3 hour closed book examination paper that will contribute 70% of the final course mark. The examination will comprise of six questions, of which the student will choose any five.

Reading materials/reference list	The following texts are recommended for this module: 1. Howard, G. (2002). Water quality surveillance: a practical guide. Loughborough University. 2. Helmer, R., &Hespanhol, I. (1997). Water pollution control: a guide to the use of water quality management principles. CRC Press. 3. Alley, E. R. (2007). Water quality control handbook. McGraw-Hill Education. 4. Chapman, D. V. (Ed.). (1996). Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring. CRC Press. 5. Tebbutt, T. H. Y. (2013). Principles of water quality control. Elsevier. 6. Konieczka, P., &Namieśnik, J. (2018). Quality assurance and quality control in the analytical chemical laboratory: a practical approach. CRC Press. 7. Bartram, J., &Ballance, R. (Eds.). (1996). Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programmes. CRC Press. 8. APHA/AWWA/WEF (2005) Standard Methods for the Examination of Water and Wastewater, APHA, Washington DC, USA 9. Pilz, D. (2006). Broadening participation in biological monitoring: handbook for scientists and managers (Vol. 680). US Department of Agriculture, Forest Service, Pacific Northwest Research Station. **10.** Gerhardt, A. (2002). Bioindicator species and their use in biomonitoring. Environmental monitoring, 1, 77-123. **Key websites and on-line resources** 1. http://www.waternetonline.org 2. https://www.un-ihe.org/ 3. www.wrc.org.za ~~4.~~ https://www.iwapublishing.com

SUGGESTED TIME ALLOCATION

	Hours
Lectures	46
Seminars/workshops	4
Practical classes/laboratory	16
Structured exercises	8
Set reading etc.	10
Self-directed study	10
Assignments – preparation and writing	10
Examination – revision and attendance	16
Total	120

5.4 WATER AND ECOSYSTEMS

Course Title	Water and Ecosystems
Course Aim	The module aims to develop an understanding of the structure and functioning of water-related ecosystems, and ecosystem services they provide
Expected Learning Outcome(s)	At the end of the module a student should be able to; 1. Understand what constitute an ecosystem and energy cycling in these systems 2. Describe biogeochemical cycle, water interfaces with many different elements of the biosphere (e.g. vegetation, soils, animals) and various anthropogenic activities. 3. Describe different types of waterbodies which include lentic systems (e.g. lakes & reservoirs); lotic systems (rivers) and wetlands especially understand that these systems are linked and dependend on each other. 4. Develop an understanding of the structure and functioning of lentic aquatic systems (e.g. light energy & productivity, stratification, nutrient cycling, foodwebs). 5. Develop an understanding of the structure and functioning of lotic aquatic systems (define & classify river-system, sources of water (e.g. groundwater baseflow, linkages with the catchment, habitat structure of flowing waters; nutrient cycling; flora & fauna and resulting foodwebs; biological monitoring etc.) 6. Develop an understanding of the structure and functioning of wetland systems (e.g. definitions and types of wetlands; role & functions of wetland; characteristic of wetlands; threats to wetlands etc.) 7. Identify and understand threats to availability of water (quality & quantity) and how the interconnectivity of lentic, lotic and wetland systems is central to this. 8. Identify ecosystem services provided by water-related ecosystems
Course status	Core
Credit rating	xxxxxx
Total hours spent	160 hours
Course content	List of topics to be covered. **1. Ecosystem** 1.1 Ecosystems as energy machines 1.2 Matter and Energy. 1.3 Individual – Population – Community – Ecosystem – Biomes. **2 Biogeochemical cycles** 2.1 Key building blocks of ecosystem function. 2.2 Solar energy as driver of ecosystem motion 2.3 Cycling of matter (and consequently energy), in this case water. **3 Hydrological cycle** 3.1 Biosphere 3.2 Terrestrial ecosystems (e.g. with soil, vegetation etc.) 3.3 Waterbodies such as lakes, rivers and groundwater. **4. Lentic systems** 4.1 Types of systems 4.2 Structure and function 4.3 Nutrient cycling and productivity 4.4 Flora & fauna; food webs; **5 Lotic systems** 5.1 Types of systems 5.2 Structure and function 5.3 Nutrient cycling and productivity 5.4 Flora & fauna; food webs 5.5 Standing/Lacustrine water systems. **6 Wetlands** 6.1 Definition of wetland systems and their diversity

	6.2 Characteristics of wetlands that identifies them as systems of global importance 6.3 Impacts and threats to wetlands ecosystems 6.4 Microorganisms and invertebrates 6.5 Wetland plants and animals 6.6 Spatial and temporal patterns 6.7 Wetland functions; Invasive species; Restoration and creation; 6.8 Global climate change; The value and future of wetlands. **7. Ecosystems Services** 7.1. Definition of ecosystem services 7.2. Fundamentals of ecosystem approach 7.3. Assessment of ecosystem services 7.4. Ecosystems services and sustainable development **8. Environmental flows** 8.1. Definition of environmental flows 8.2. Rationale for the provision of environmental flows 8.3. Outline of methods for environmental flow assessment. 8.4. Environmental flows and water allocation
Teaching and Learning Activities	Lectures, Written Assignments, Tutorials and seminars, Fieldwork and Laboratory Practicals
Assessment	This course is assessed by coursework – CA(50%) and University examination – UE (50%) Suggested Assignments **ASSIGNMENTS** **Assessment 1:** Describe various morphometric characteristics of lentic waterbodies and discuss their importance in understand lentic system structure and function. **Assessment 2:** Discuss why an IWRM manager should have an understanding of aquatic ecosystem structure and function. **Assessment 3:** Discuss the role and importance of wetlands to human society. **PRACTICALS** **Assessment 4: Practical 1:** Visit a lake /reservoir system and take various measurements of the water physical & chemical characteristics. Also sample the biota and do a write-up of the findings. In your write up include all information that is known about that waterbody. **Assessment 5: Practical 2:** Visit a lotic/river system. Assess its the water physical and chemical characteristics including the flora & fauna (fish, macroinvertebrates). In your write up, compare and contrast what flora & fauna you observed in lentic and lotic systems. **Assessment 6: Practical 3:** Visit a lotic/river system. Carry out a biological monitoring exercise based on SASS 5 method. Prior to the practical, the lecturer shall show a demonstration video to the students. This is group work so the lecturer might choose a written submission or a tutorial session to go over the results with the class. **Assessment 7: Practical 4**: If there are nearby wetlands, a field visit shall be arranged. Students to describe and characterize the wetland first. Students to observe activities taking place within and around the wetland. If there are communities nearby, they can also carry out some interviews on the importance of the wetland to communities. Students should also query if there have been major changes e.g. like the hydrology of the wetland and what impact that has had on ecosystem services.
Reading materials/reference list	1. Gerber and M.J.M. Gabriel. 2002. Aquatic Invertebrates of South African Rivers. Institute for Water Quality Studies Department of Water Affairs and Forestry First edition. 2. Walter Dodds, Matt Whiles. **Freshwater Ecology**: Concepts and Environmental Applications of Limnology. 3rd Edition - 2019. eBook ISBN: 978012813256 3. Arnold G van der Valk.The Biology of Freshwater Wetlands. Oxford University Press. 4. Lotic systems ecology. https://www.bionity.com/en/encyclopedia/Lotic_system_ecology.html 5. Annelise Gerber, Carina J Cilliers, Carin van Ginkel and Rene Glen. 2004. Easy identification of aquatic plants. Department of Water Affairs. ISBN: 0-621 -35113-X. 6. John Peter Obubu, SeyoumMengistou, TadesseFetahi, Wolfram Graf & Robinson Odong (2021) A critical review of macroinvertebrate-based bioassessment approaches in

	Africa's lotic systems: developments, challenges, and legal requirements, African Journal of Aquatic Science, 46:4, 377-389, DOI: 10.2989/16085914.2021.1924609. 7. SudhirBhandarkar. 2017. Species Diversity & Richness of Benthos in Freshwater Lotic Ecosystems. LAP LAMBERT Academic Publishing. **ISBN-13:** 978-6202061995. 8. Dickens, C. WS, and P. M. Graham. "The South African Scoring System (SASS) version 5 rapid bioassessment method for rivers." *African Journal of Aquatic Science* 27.1 (2002): 1-10. 9. Abdi, Mohamed Hassan Sheikh, ArzuMorkoyunluYüce, BerilÖmeroğluTapan, and FüsunÖncü. "Aquatic Ecosystem Management: The Case of Somalia." *City Health Journal* 2, no. 2 (2021): 43-46.

SUGGESTED TIME ALLOCATION

ACTIVITY	**HOURS**
Lectures	60
Tutorials & Seminars	30
Practicals	24
Assignments	16
Independent Study	30
TOTAL	160

5.4 WATER GOVERNANCE

Course Title	Water Governance
Course Aim	The module aims to make students aware of the importance of water governance to sustainable water resource management and development.
Expected learning Outcome(s)	At the end of the course students should be to; 1. Aware of the importance and definition of water governance and how it is related to politico-administrative governance. 2. Understand the common approaches and principles of water governance. 3. Appreciate the importance of policy, law and institutions in water governance and how they are interlinked. 4. Understand the multi-level and scalar dimensions of water governance and their significance in good water governance. 5. Appreciate the elements of a practical water governance operational framework 6. Understand the importance and components of a monitoring and evaluation water governance framework and how it can be applied across the water sub-sectors.
Course status	Core
Credit rating	12
Total hours spent	120 hours
Course Content	Topics to be covered **1. Rationale, Evolution and Definition of Water Governance** 1.1. Rationale and evolution of water governance 1.2. Definition of water governance 1.3. Relationship between water governance and political governance **2. Principles of Water Governance** a. Foundations of water governance principles b. OECD water governance principles i. Principle 1. Clearly allocate and distinguish roles and responsibilities ii. Principle 2. Manage water at appropriate scale(s*)* iii. Principle 3. Encourage policy coherence iv. Principle 4. Adapt the level of *capacity* of responsible authorities to the complexity of water challenges v. Principle 5. Produce, update, and share timely, consistent data vi. Principle 6. Ensure that governance arrangements help mobilise water finance and allocate financial resources vii. Principle 7. Ensure that sound water management regulatory frameworks are effectively implemented viii. Principle 8. Promote adoption and implementation of innovative water governance practices ix. Principle 9. Mainstream integrity and transparency practices x. Principle 10. Promote stakeholder engagement xi. Principle 11. Encourage appropriate water governance frameworks xii. Principle 12. Promote regular monitoring and evaluation 2. 3 Principles of good water governance 2.3.1. Participation 2.3.2. Transparency 2.3.3. Equity 2.3.4. Accountability 2.3.5. Coherence 2.3.6. Responsiveness 2.3.7. Integration 2.3.8. Ethics 2.4 Principles of local water governance **3. Dimensions and Components of Water Governance** 3.1 Link between dimensions and components of water governance 3.2 Four dimensions of water governance 3.2.1 Social dimension 3.2.2 Economic dimension 3.2.3 Political dimension 3.2.4 Environmental dimension

	3.3 Components of water governance 3.3.1 Water policy 3.3.2 Water law 3.3.3 Water institutions **4 Scales and Levels in Water Governance** 4.1 Need for understanding scale and level of water governance 4.2 Multi-layered governance 4.3 Multi-level governance 4.3.1 Definition 4.3.2 Guidelines for effective management of multi-level governance **5. Towards a Practical Water Governance Operational Framework** 5.1 Values and traditions 5.2 Functions 5.3 Attributes 5.4 Outcomes 5.5 Application of the framework **6. Monitoring and Evaluating Water Governance** 6.1 Need for monitoring and evaluating water governance 6.2 Water governance indicators 6.3 OECD water governance indicator framework 6.3.1 Objectives 6.3.2 Components 6.3.3 Assessment conditions 6.3.4 Methodology 6.3.5 Self-assessment toolkit
Teaching and Learning Activities	Lectures, seminars and tutorials, field trips, assignments and tests and independent study (10 hours).
Assessment	Assessment will be assessed as follows a final examination (40%) and CA (60 **See Appendix 1**
Reading materials	• Bakker, K. and Morinville, C. (2013) The governance dimensions of water security: a review, *Philosophical Transactions of the Royal Society*, http://dx.doi.org/10.1098/rsta.2013.0116. • Benson, D.; Gain, A.K. and Rouillard, J.J. 2015. Water governance in a comparative perspective: From IWRM to a 'nexus' approach? Water Alternatives 8(1): 756-773. • De Stefano, L.; Svendsen, M.; Giordano, M.; Steel, B.S.; Brown, B.;Wolf, A.T (2014) .Water governance benchmarking: Concepts and approach framework as applied to Middle East and North Africa countries. *Water Policy*, 16, 1121–1139. • effective transboundary water resources management**,** *Int. J. Sustainable Society, 1(3) 207-223* • Graham, J.; Amos, B.; Plumptre, T. (2003). *Principles for Good Governance in the 21st Century*; Institute on Governance (IOG): Ontario, Canada. • Hukka, J.J., Castro, J.E. and Pietilä,P.E. (2010) Water, policy and governance, *Environment and History*, 16(2). 235-251. • Hukka,J.J. Castro, J.E. and Pietilä, P.E. (2010) Water, Policy and Governance, *Environment and History* 16 (2) 235-251. • Jacobson, M.; Meyer, F.; Tropp, H.; Oia, I.; Reddy, P. (2013), User's Guide on Assessing Water Governance; United Nations Development Programme: Stockholm, Sweden. • Johns, C and VanNijnatten, D. (2021) Using indicators to assess transboundary water governance in the Great Lakes and Rio Grande-Bravo regions, *Environmental and Sustainability Indicators*, 10, https://doi.org/10.1016/j.indic.2021.100102. • Kuzdas, C. Wiek, A. Warner, B., Vignola, R. and Morataya, R. (20214) Sustainability *Appraisal of Water Governance Regimes: The Case of Guanacaste, Costa Rica, Environmental Management*, 54:205–222. • Lautze, J.; de Silva, S.; Giordano, M.; Sanford, L. (2011) Putting the cart before the horse: Water governance and IWRM. *Natural Resource Forum*, 35, 1–8. • Marks, G. (1993). Structural Policy and Multi-level Governance in the EC. In: Cafruny, A. & Rosenthal, G. (eds) *State of European Community*. Vol. 2. Lynne Rienner, Boulder,

	Colorado, and Longman, London, pp. 391–410. • Medinilla, A. (2018) African river basin organisations from best practice to best of it, Political Economy Dynamics of Regional Organisations in Africa,Discussion Paper No. 236, www.ecdpm.org/236. • Merrey, D. J. 2009. African models for transnational river basin organisations in Africa: An unexplored dimension. *Water Alternatives*, *2*(2), 183–204. • Moench, M.; Dixit, A.; Janakarajan, M.; Rathore, S.; Mudrakartha, S. (2003). *The fluid mosaic, water governance in the context of variability, uncertainty and change.* Nepal Water Conservation Foundation, Kathmandu, and the Institute for Social and Environmental Transition, Boulder, Colorado, USA. • Moriarty, P. Batchelor, C. Laban, P. Fahmy, H. (2007) The EMPOWERS Approach to Water Governance: Background and Key Concepts. • OCED (2015) OECD Principles on Water Governance**:** Adopted by the OECD Regional Development Policy Committee on 11 May 2015 and welcomed by the Ministers at the OECD Ministerial Council Meeting on 4 June 2015. http://www.oecd.org/regional/water. • OCED (xx) *Water Governance in OCED Countries: A Multi-level Approach –Highlights*. www.oecd.org/water. • OECD (2018) OECD Water Governance Indicator Framework, Website: http://oe.cd/water-gov. • Ostrom, E. (2005). *Understanding Institutional Diversity*. Princeton University Press. • Pahl-Wostl, C. (2009) A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Glob. Environ. Chang. 19, 354–365. • Rahaman, M.M. (2009) Principles of international water law: creating • Rogers, P. and Hall, A.W., (2003). *Effective Water Governance*. TEC Background Papers No. 7, Global Water Partnership, Technical Committee, Stockholm, Sweden. • Ross, A. (n.d.) Multi-level Integrated Water Governance: Examples from New South Wales and Colorado, In: K. A. DANIELL and A. KAY (eds). Multi-level Governance: Conceptual challenges and case studies from Australia, Australian National University Press, https://www.jstor.org/stable/j.ctt1zgwjv0.20. • UNDP (United Nations Development Programme). (2007). Effective Water Governance: The Key to Sustainable Water Management and Poverty Eradication. United Nations Development Programme. Available at: http://www.undp.org/water/about_us.html. • United Nations World Water Assessment Programme (2006). Water: A Shared Responsibility. The United Nations World Water Development Report 2; United Nations Educational, Scientific and Cultural Organization (UNESCO): Paris, France. • United Nations World Water Assessment Programme. UN Water, Poster for divulgation, march 2006. • Van der Valk, M.R. and Keenan, P. (eds.) (2011). *Principles of Good Governance at Different Water Governance Levels*,Papers presented at a workshop held on 22 March 2011 in Delft, the Netherlands. • Woodhouse, P. and Muller, M. (2017). Water Governance – an historical perspective on current debates. *World Development*, *92*(1), 225-241. https://doi.org/10.1016/j.worlddev.2016.11.014 • WORLD WATER ASSESSMENT PROGRAMME (WWAP). "Sistema de apoyo a la gobernabilidad del agua. Informe del proyecto". (*System for the support of water governance. Project report*) 2004. Internal report (Executive sum-mary, manual). UNESCO.

5.6 GIS AND REMOTE SENSING APPLICATIONS FOR WATER RESOURCES MANAGEMENT

Module Title	GISand Remote Sensing Applications for Water Resources Management
Module Aim	To develop fundamental knowledge, understanding, and technical proficiency in GIS and remote sensing for applications in Water Resources Management
Expected learning outcome(s)	At the end of the module a student should be able to; 1. Describe geographic information systems (GIS) and related areas such as geodesy and remote sensing 2. Explain how GIS and remote sensing are applied in Water Resources Assessment 3. Understand how GIS tools work in Water Resources Management

	4. Understand use of GIS and remote sensing software and techniques for water resources assessment 5. Understandthe core principles and components of GIS and remote sensing, 6. Apply knowledge of spatial analysis techniques and database queries to solve water related problems, 7. Capability to visualize and display spatial data effectively, and create maps using water related data, 8. Understand GIS and remote sensing are applied to explain, analyze, interpret and model water related processes and problems.
Module Status	Core
Credit Rating	xxxxx
Total Hours Spent	120
Module Content	Topics to be covered. **1. Introduction and principles of Geographic Information System(GIS)** 1.1 Introduction to GIS 1.2 Historical development of GIS as a science; 1.4 Definitions and core elements of GIS 1.5 GIS Functionalities in Water Resources Management 1.6 Core GIS components 1.6 Models of spatial data (raster vs. vector) 1.7 Geographic data & representing spatial complexity (Topology) 1.8 Geospatial data sources (Primary & secondary data) 1.9 Geospatial data creation (digitizing, Google Earth) 1.10 Digital Elevation models (DEM) **2. Spatial reference systems in GIS and database management systems** 2.1 Introduction to spatial reference systems 2.2 Maps projections and datums 2.3 Co-ordinate systems 2.4 Geoid and reference ellipsoids 2.5 Datums 2.6 East African projections and co-ordinate systems 2.7 Database and database management systems **3. Overlay operations and spatial analysis in GIS** 3.1 Boolean operators in GIS 3.2 Spatial overlay analysis & neighbourhood analysis 3.3 Data integration and reclassification 3.4 Spatial data query in a GIS 3.5 Geospatial modelling of water resources 3.6 Digital Terrain Analyses- Digital Elevation Model based watershed and stream network delineation 3.7 Spatial data visualization and mapping 3.9 Principles of cartography and map composition. **4. Introduction and Principles of Remote Sensing** 4.1 Concept and elements of remote sensing 4.2 The electromagnetic spectrum and spectral signatures 4.3 Sensor Types – passive and active sensors 4.4 Image processing and transformation 4.5 Image enhancement and visualization 5. **Remote Sensing Applications in Water Resource Assessment** 5.1. Digital Image Classification 5.2. Types of digital image classification 5.3. Image classification accuracy assessment techniques 5.4. Remote sensing of water resources (quality & quantity) 5.5. Satellite system -global positioning system (GPS) 5.6. GPS use and applications in water resources assessment

	5.7. Land cover and land use assessment for water resources management 5.8. Estimation of rainfall using satellite data 5.9. Estimation of evapotranspiration using satellite data 5.10. Monitoring and management of floods and droughts using GIS and remote sensing data
Teaching and Learning Activities	Lectures, seminars, practicals
Assessment	**Individual Computer-based Practical** • **Practical 1: Software Induction & GIS Project Management;** -Introduction to GIS softwares, functionalities, environmental & water resources data capturing in a GIS using examples from environmental and water resources (rivers, dams, soils, land use, basin and sub-basin boundaries, etc.) -Displaying & visualising water resources & environmental spatial layers (data) in a GIS environment • **Practical 2: Sources of spatial data; Query Operations, & GPS Database management systems.** -Acquiring water resources data & use of GPS in field data collection & development of geodatabase - Georeferencing and digitizing water resources features from aerial photographs e.g. rivers, dams etc. -extracting catchments, river reaches and water bodies of interest using spatial query language from a database • **Practical 3: Overlay analysis in a GIS –** -Delimitation of hydrological response units using slope, geology, soil types, land cover and land use. -Construction of thiessen polygons and use in estimating catchment rainfall. -Use of GIS & remote sensing to assess groundwater potential and vulnerability to pollution modelling, - Flood modelling using the DEM and rivers, dams, soils, land use, basin and sub-basin boundaries, vegetation, settlements, Population, etc • **Practical 5 : Remote sensing data acquisition and preprocessing –** -Use of Landsat images to determine NDVI, land cover and land use classification • **Practical 6: Remotely-sensed Evapotranspiration estimation (Group Practical)**
Reading materials/reference list	1. Campbell, James B. 2011. Introduction to Remote Sensing (Fifth Edition) . New York, The Guilford Press 2. Burrough, P. A., McDonnell, R. A., & Lloyd, C. D. (2015). *Principles of geographical information systems*. Oxford university press. 3. Bonham-Carter, G. F., & Bonham-Carter, G. (1994). *Geographic information systems for geoscientists: modelling with GIS* (No. 13). Elsevier. 4. Burrogh, P. A. (1986). Principles of GIS for land resources assessment. Clarendon: Oxford. 5. Chuvieco, E. (2020). Fundamentals of satellite remote sensing: An environmental approach. CRC press. 6. Curran, P. J. (1985). Principles of remote sensing. Longman Inc.. 7. Darkwah, O., Scoville, M. D., & Wang, L. K. (2021). Geographic Information Systems and Remote Sensing Applications in Environmental and Water Resources. Integrated Natural Resources Management, 197-236. 8. Engman, E. T., & Gurney, R. J. (1991). Remote sensing in hydrology. Chapman and Hall Ltd. 9. Finch, J. (2000). Remote Sensing in Water Resources Management. The State of the Art. By WGM Bastiaanssen. Colombo, Sri Lanka: International Water Management Institute (1998), pp. 118, US12. 50). ISBN 92-9090-363-5. *Experimental Agriculture*, *36*(3), 415-418. 10. Gaulton, R. (2013). Remote sensing and global environmental change, by S. Purkis and V. Klemas: Chichester, Wiley-Blackwell, ISBN 978-1-4443-4025-9. 11. Jha, M. K., Chowdhury, A., Chowdary, V. M., & Peiffer, S. (2007). Groundwater management and development by integrated remote sensing and geographic

	information systems: prospects and constraints. *Water resources management*, *21*(2), 427-467. 12. Lloyd, C. (2010). Spatial data analysis: an introduction for GIS users. Oxford university press. 13. Jha, M. K., & Peiffer, S. (2006). Applications of remote sensing and GIS technologies in groundwater hydrology: past, present and future. Bayreuth: BayCEER. 14. Johnson, L. E. (2016). Geographic information systems in water resources engineering. CRC Press. 15. Longley, P., & Batty, M. (2003). *Advanced spatial analysis: the CASA book of GIS*. ESRI, Inc.. 16. Rees, W. G. (2013). Physical principles of remote sensing. Cambridge university press. 17. Schultz, G. A., & Engman, E. T. (Eds.). (2012). Remote sensing in hydrology and water management. Springer Science & Business Media. 18. Tempfli, K., Huurneman, G., Bakker, W., Janssen, L. L., Feringa, W. F., Gieske, A. S. M., ... & Woldai, T. (2009). Principles of remote sensing: an introductory textbook. International Institute for Geo-Information Science and Earth Observation. 19. Zaikanov, V. G., T. B. Minakova, and E. V. Buldakova. "Principles of GIS support of geoenvironmental mapping at a regional level." *Water Resources* 42.7 (2015): 970-974.

SUGGESTED TIME ALLOCATION

ACTIVITY	**HOURS per day (per semester)**
Lectures	60
Tutorials & Seminars	
Practical	40
Assignments	30
Independent Study	10
TOTAL	120

5.7 GROUNDWATER ASSESSMENT AND DEVELOPMENT

Module Title	Groundwater Assessment and Development
Module aim	To develop an understanding and skills for assessing, developing and managing the groundwater resources
Expected Learning Outcome(s)	At the end of the module a student should be able to; 1. Assess the occurrence and potential for developing groundwater for utilization 2. Supervise the installation of production and monitoring boreholes and welles 3. Conduct aquifer pumping test for various purposes 4. Estimate aquifer parameters 5. Evaluate borehole (well) efficiency 6. Estimate sustainable/safe/reliable borehole yield 7. Understand groundwater recharge processes and estimate groundwater recharge 8. Understand the basics of groundwater numerical models, **9.** Understand basic aspects of groundwater management
Module status	Core
Credit rating	xxxxxx
Total hours spent	140
Module content	List of topics to be covered. **1. Assessment of groundwater potential** 1.1. Factors that control the groundwater occurrence/potential 1.2. Steps for assessing groundwater potential 1.3. Desktop studies 1.4. GIS and remote sensing (Covered under GIS and remote sensing) 1.5. Geophysical surveys basic approaches: Theory and applications • *Electrical resistivity* • *Electromagnetics* • *Magnetotellurics* 1.6. Groundwater potential reporting **2. Boreholes and Hand-dug wells** 2.1. Borehole drilling methods • Principles of borehole drilling supervision • On-site supervision activities: Planning • On-site supervision activities: Drilling • Borehole drilling reporting 2.2. Hand-dug wells • Excavation • Construction **3. Hydraulic Aquifer Tests** 3.1. Different types of aquifer pumping tests 3.2. Principles of aquifer pumping tests • Step Drawdown Test • Constant Discharge Test • Borehole Yield Test 3.3. Planning for aquifer pumping tests 3.4. Principles and methods for analysing aquifer pumping test data

	3.5. Application of flow diagnostic tools • Estimation of aquifer parameters • Estimation of sustainable/safe/reliable borehole yield • Evaluation of borehole efficiency • Estimation of yield and parameters in hand-dug wells 3.6. Operations and maintenance of boreholes and hand-dug wells **4. Groundwater Recharge** 4.1. Different forms and processes of groundwater recharge 4.2. Natural recharge 4.3. Managed Aquifer recharge 4.4. Groundwater recharge assessments 4.5. Isotopes 4.6. Chemical methods 4.7. Quantitative methods 4.8. Natural recharge 4.9. Managed Aquifer Recharge **5. Groundwater Management** 5.1. Principles of groundwater resource management 5.2. Groundwater policy and governance 5.3. Groundwater Legal and Institutional frameworks 5.4. Groundwater monitoring 5.5. Introduction to groundwater modelling 5.6. Understanding the impacts of climate change on groundwater
Teaching and Learning Activities	Lectures,Seminars, tutorials, Individual autonomous study, Group study, Assignments, Written tests, Practical, Written Exam
Assessment	**Suggested Assignments** **Assessment 1:** Such as the construction of groundwater flow nets to determine the groundwater flow direction, estimate hydraulic gradient and groundwater discharge **Assessment 2:** Data is provided by the lecturer to characterize the groundwater flow regimes, estimation of aquifer properties, estimation of borehole safe/sustainable/reliable yield, and evaluation of borehole efficiency **Assessment 3**: Assessing groundwater potential to determine the feasibility of drilling boreholes, Using Darcy experiment to estimate aquifer parameters for different soil materials, Estimation of the aquifer hydraulic conductivity using slug test, Estimation of aquifer parameters using constant discharge test and recovery test, Estimation of borehole yield using constant discharge test and recovery test, Evaluation of the borehole efficiency using step discharge test
General reading materials	1. Fetter, C.W., 1994, Applied Hydrogeology, 3rd ed. Macmillan College Publishing, Inc., New York 2. Freeze, R.A., and J.A. Cherry. "Groundwater". Prentice-Hall. 1979 3. Bear, J. "Hydraulics of Groundwater". McGraw-Hill. 1979 4. Driscoll, F.G., (1986).Groundwater and Wells. 2nd Edition. U.S. Filter/Johnson Screens 5. SADC-GMI, IGRAC, IGS. 2019. SADC Framework for Groundwater Data Collection and Data Management, SADC GMI, IGRAC, IGS. Bloemfontein, Delft

SUGGESTED TIME ALLOCATION

ACTIVITY	HOURS / Day	HOURS
Lectures		45
Tutorials & Seminars		12
Practicals		7
Assignments		6
Independent Study		70
TOTAL		150

5.8 WATER RESOURCES ECONOMICS AND FINANCING

Module Title	Water Resources Economics and Financing
Module Aim	The module will develop an understanding of economics concepts and methods applied to water governance, management and valuation. The module covers pricing of water resources, water allocation systems, supply-demand management, political economy of water, application of economic tools in IWRM. Techniques such as costs and benefits analysis of water investments, financing water projects, will be covered.
Expected Learning Outcome(s)	At the end of the module a student should be able to; 1. Define main economic concepts and terms relevant to the water sector, and about the legal, institutional and social context of water resource management. 2. Describe Cost Benefit Analysis, valuation techniques, economic instruments for water policy and financing water projects, conflict resolution methods and processes for water management. 3.Appraise field water situations about water resources, and apply to real case studies the economic methods learned to analyse the problems and to propose management and policy actions.
Module Status	Core
Credit Rating	xxxxxx
Total Hours Spent	124
Module Content	Topics to be covered. **1. Water and development: why economics and governance are important in water management?** 1.1. Water and development issues in Africa 1.2. Principles of IWRM 1.3. Water and poverty, concepts and indexes **2. Water and Economics** 2.1 Water as an economic good 2.2 Public/private goods 2.3 Characteristics of water as an economic good: 2.4 Social attitudes towards water 2.5 Legal/Political considerations 2.6 Costs and benefits 2.7 Economic criteria for water allocation 2.8 Concepts and definitions: Opportunity Cost Efficiency Pareto Optimality Deadweight Loss Shadow pricing **3. Water valuation for different uses and application to African contexts** 3.1 Elements of welfare economics 3.2 Concepts for water economic valuation 3.3 Methods; Stated preferences, Revealed preferences 3.4 Case studies in African contexts 3.5 Field operational research for water economics studies **4. Cost-Benefit Analysis and financing of water projects** 4.1 Concepts 4.2 Procedure and methods 4.3 Examples and case studies **5. Externalities** 5.1 Definition 5.2 Market failures and institutional failures

	5.3 Positive and negative externalities 5.4 Formalization 5.5 Internalization of externalities, elements of water policies **6 Policies for pollution control and water quality improvement** 6.1. Formalization of a simple economic system with pollution 6.2. Externality control policy instruments (taxes, subsidies, standards, penalties, etc.) 6.3. Examples 6.4. AnaWag (or other practical) session on pollution control policies **7.Water pricing, tariffs, coverage of water services and water provision costs** 7.1. Water pricing for various water uses 7.2. Water tariffs 7.3. International comparisons of water tariffs 7.4. Water affordability and social aspects of water pricing 7.5. Case studies **8. Water allocation methods** 8.1. Intersectoral competition for water 8.2. Models for water allocation (partial equilibrium, linear programming, etc.) 8.3. Case studies 8.4. AnaWag (or other practical) session on water allocation
Teaching and Learning Activities	Lectures, practical exercises using a simple classroom experimental game (AnaWag), and interactive sections discussing topics chosen and presented by the students. A proposed allocation of hours among the topics and activities (cf. suggested time allocation table below) is as follows: 1. Water and development: why economics and governance are important in water management? (4h) 2. Water and Economics (4h) 3. Water valuation for different uses and application to African contexts (8h) 4. Cost-Benefit Analysis and financing of water projects (6h) 5. Externalities (2h) 6. Policies for pollution control and water quality improvement (4h Lectures + 2h Game) 7. Water governance and institutions (6h lecture + 2h Game) 8. Water pricing, tariffs, coverage of water services and water provision costs (2h) 9. Water allocation methods (4h lecture + 2h Game) 10. Seminars proposed by the students (4h)
Assessment	1. Give a definition, an example and a graphic illustration of an externality 2. What is a Pareto irrelevant externality? Give a formal answer (graphic or mathematical) 3. What are the main elements characterising the "Efficiency Without Optimality" approach? 4. Describe the Circular Economy model (if you prefer, even graphically) and discuss its material and immaterial flows using the thermodynamics laws. 5. What does the Coase theorem say? 6. What are the main criticisms concerning the Coase theorem? 7. What is an optimal Pigouvian tax? 8. Externalities are external costs not compensated: how can we derive these costs from private costs graphically? 9. What are the main economic tools for environmental policy? 10. Why economic tools are considered more efficient than command and control instruments? 11. What are the main causes of standard/penalties non efficiency? 12. Give an example of an economic tool used to reach a standard and discuss its better efficiency with respect to the couple standard/penalty.
Reading materials/reference list	1. Farolfi, S. 2011. An introduction to water economics and governance in Southern Africa, Notes for the course "Water Economics and Governance", IWEGA, UEM, 112p. This text is freely downloadable at: https://agritrop.cirad.fr/561748/1/document_561748.pdf 2. The classroom experimental game is described and fully tutored in the paper: 3. Farolfi S., Erdlenbruch K. 2020. A classroom experimental game to improve the understanding of asymmetric common-pool resource dilemmas in irrigation water management. *International Review of Economics Education*, 35, 100199 : 17 p. The paper

	can be made available free of charge by the authors for teaching purposes. In order to update the information included in the mentioned notes, two excellent and more recent texts a 4. Burnett, K, Howitt, R., Roumasset, J.A., and Wada, Ch.A. 2017. Routledge Handbook of Water Economics and Institutions, Taylor & Francis, Routledge, 410p. 5. Griffin, R.C. 2016 Water Resource Economics, The Analysis of Scarcity, Policies, and Projects, MIT University Press, 496p

SUGGESTED TIME ALLOCATION

ACTIVITY	**HOURS**
Lectures	40
Seminars (papers chosen, presented and discussed by students)	4
Practical	6
Assignments (preparation) and Exams writing	20+4
Independent Study	50
TOTAL	124

5.9 WATER RESOURCES PLANNING

Course title	Water Resources Planning
Course aim	To develop the capacity to analyse water resources management problems in a given situation, and formulate an appropriate and IWRM aligned plan for overcoming the identified problems
Expected learning outcome(s)	1. To have capacity to identify water resources management problems, their causes and effects within a given setting. 2. To be able to explain and justify the steps to be followed when developing a water resources management plan. 3. An understanding to the tools used for analysing water resources problems and development of appropriate water resources management plan. 4. To be able to identify, collect and analyse data required for water resources planning. 5. To be able to explain the reasons for stakeholder participation during water resources planning, and formulate a plan for this participation 6. To have the capacity to formulate a water resources plan which is aligned with the IWRM principles (economic, social and environmental sustainability)
Course status	Core
Credit rating	xxxxxx
Total hours spent	120
Course content	List of topics to be covered. 1. Objectives for water resources planning 2. Frameworks for water resources planning 3. Integrated water resources planning 4. Spatial and temporal scales for water resources planning 5. Stakeholder participation in water resources planning. 5.1. Stakeholder analysis for IWRM 5.2. Effective approaches for stakeholder participation during water resources planning 5.3. Barriers to stakeholder participation in water resources planning 6. Planning Cycle 6.1. Initiation 6.2. Situation analysis 6.3. Development of a plan for stakeholder participation 6.4. Problem identification and analysis 6.5. Development of water resources planning objectives relevant for specific problems 6.6. Formulation of alternative water resources plans 6.7. Monitoring and Evaluation 7. Resilience and water resources planning 8. Case Study: Development of a water resources management plan (e.g. village, urban, agricultural water supply, wastewater management) 9.

Teaching and Learning Activities	Face-to-face lecture, Group work
Assessment	1. Undertake an analysis of causes and effects of water resources management problems for a given location in Somalia. 2. Do a stakeholder analysis for the location referred in Question 1 above, and propose a plan for stakeholder participation during the formulation of a water resources management plant. 3. Group Work: Development of a water resources management plan for a given location in Somalia. 4. For a given location in Somalia, identify and quantify the current water demands. Estimate the water demand for this location in 5, 10 and 20 years time. 5. Evaluate water supply options for a given location in Somalia. Giving justifications, recommend the option that is most appropriate and aligned with IWRM principles. 6. Present a monitoring and evaluation plan for the water resources management plan developed during Group Work
Reading materials/reference list	1. Loucks, D.P. and Van Beek, E., 2017. *Water resource systems planning and management: An introduction to methods, models, and applications*. Studies and Reports in Hydrology, United Nations Educational,Scientific and Cultural Organization, Paris. 2. Hare, M.P., Barreteau, O., Beck, M.B., Letcher, R.A., Mostert, E., Tàbara, J.D., Ridder, D., Cogan, V. and Pahl-Wostl, C., 2006. Methods for stakeholder participation in water management. In *Sustainable management of water resources: an integrated approach* (pp. 177-231). 3. Lee, K.E., Abdullah, R., Hanafiah, M.M., Halim, A.A., Mokhtar, M., Goh, C.T. and Alam, L., 2018. An integrated approach for stakeholder participation in watershed management. In *Environmental risk analysis for asian-oriented, risk-based watershed management* (pp. 135-143). Springer, Singapore. 4. Dungumaro, E.W. and Madulu, N.F., 2003. Public participation in integrated water resources management: the case of Tanzania. *Physics and Chemistry of the Earth, Parts A/B/C*, *28*(20-27), pp.1009-1014. 5. Agarwal, A., delos Angeles, M.S., Bhatia, R., Chéret, I., Davila-Poblete, S., Falkenmark, M., Villarreal, F.G., Jønch-Clausen, T., Kadi, M.A., Kindler, J. and Rees, J., 2000. *Integrated water resources management*. Stockholm: Global water partnership. 6. Wathern, P. (Ed.). (1995). *Environmental impact assessment*. Routledge

SUGGESTED TIME ALLOCATION

ACTIVITY	**HOURS**
Lectures	50
Tutorials & Seminars	10
Practicals	24
Assignments	24
Independent Study	12

TOTAL	120

5.10 CLIMATE CHANGE AND ADAPTATION FOR INTEGRATED WATER RESOURCES MANAGEMENT

Course Title	Climate Change and Adaptation for Integrated Water Resources Management
Course Aim	To impart knowledge and skills for analyzing and evaluating climate change impacts on water resources, identifying appropriate tools (models & frameworks) and solutions, and formulate/assess adaptation strategies.
Expected Learning Outcome(s)	At the end of the module a student should be able to; 1. Explain factors and processes determining the climate system; 2. Explain causes of climate change; 3. Explain projected climate changes for different emission scenarios; 4. Evaluate climate change on climatic variables such as rainfall and temperature using GCM projection data; 5. Analyse effects of climate change on availability of water resources in Somalia, Africa and the world 6. Evaluate climate change adaptation options relevant for the water sector especially in Somalia and Africa in integrated manner.
Course status	Core
Credit rating	
Total hours spent	160
Course content	List of topics to be covered. **1. Climate change** 1.1 Climate system 1.1.1 Elements of the climate system (Atmosphere; Ocean; Biosphere – has major role on carbon cycle including Co_2 in the atmosphere; Cryosphere – ice & snow; Geosphere – rock & soil) 1.1.2 Physical units of the biosphere • The lithosphere (the land) • The hydrosphere (water) • The atmosphere (the air) 1.1.3 Hydrological cycle as the connecting link of the physical units in any landscape 1.1.4 Linkages of water cycle with carbon cycle and nitrogen cycle 1.1.4.1 Carbon cycle (e.g. in plants & animals: inorganic carbon-organic carbon-mineral carbon-inorganic carbon; fossil fuels; change in land cover - agriculture, deforestation, and reforestation) 1.1.4.2 Nitrogen cycle (inorganic and organic nitrogen) 1.2 Drivers of climate change 1.2.1 The Sun (Solar radiation) powers the climate system 1.2.2 Various gases in the atmosphere (composition) 1.2.2.1 Gases 1.2.2.2 Internal and external factors that affect climate 1.2.3 Greenhouse gases and changes in composition 1.2.3.1 Changes in composition due to natural forcings such as natural phenomena (volcanic eruptions and solar variations) 1.2.3.2 Changes in composition due to external forcings such as human-induced changes in atmospheric composition (persistent anthropogenic changes in the composition of the atmosphere or in land use) 1.2.4 Greenhouse effect and changes in terrestrial radiation 1.2.5 Global cooling (decrease in temperature) – cooling of the climate system 1.2.6 World climate zones (e.g. an arid climate in Somalia) 1.3 Climate change scenarios 1.3.1 The IPCC Special Report on Emissions Scenarios (SRES) 1.3.2 The IPCC Representative Concentration Pathways (RCPs) 1.3.3 The IPCC Shared Socioeconomic Pathways (SSPs) (e.g. SSP5-8.5: worst case scenario, SSP3-7.0: medium range scenario) 1.3.4 RCPs-SSPs

	1.4 Climate modelling 1.4.1 General Climate Models (GCMs) 1.4.2 Regional Climate Models (RCMs) 1.4.3 Statistical Downscaling 1.4.3.1 Change factors 1.4.3.2 LARS WG modelling • More information on the LARS-WG software: https://sites.google.com/view/lars-wg 1.4.3.3 SDSM modelling • More information on the SDSM software: o https://co-public.lboro.ac.uk/cocwd/SDSM/ o htpps://sdsm.org.uk/sdsmmain.html o https://sdsm.org.uk/software.html 1.4.4 Some criteria for selecting climate models (e.g. Vintage, Resolution, Validity and Ensembles) 1.4.5 Climate change global data sources from Coupled Model Intercomparison Project (CMIP) • The Coordinated Regional Modeling Experiment (CORDEX): o https://esgf-node.llnl.gov/search/esgf-llnl/ o CMIP 6: https://esgf-node.llnl.gov/search/cmip6 o CMIP 5: https://esgf-node.llnl.gov/search/cmip5 **2. Impacts on water resources** 2.1 Hydrological cycle & Impact analysis concepts 2.2 Rainfall 2.3 Temperature 2.4 Evapotranspiration 2.5 Surface water 2.6 Groundwater 3. Adaptation strategies 3.1 Concept of Adaptive Planning Process 3.2 Identification of sensitive sectors and communities in Somalia 3.3 Development of adaptation measures (e.g. Local, Regional & Global) 3.3.1 Adaptive measures on water resources/availability (e.g. extreme events) 3.3.2 Prioritization of adaptation measures and integration (integrated adaptive management) 3.3.3 Implementation of measures
Teaching and Learning Activities	Lectures, tutorials, assignments and exercises
Assessment	**Assessment 1** Description as a group assignment: A common confusion between weather and climate arises when scientists are asked how they can predict climate 50 or 100 years from now when they cannot predict correctly the weather a few weeks from now! Discuss! Alternatively,is lots of rain in an area a sign of climate change? Discuss! **Assessment 2** Description as a group assignment: Discuss the sources/sinks of organic and inorganic carbon in the atmosphere or rivers; Explain why climate change scenarios are used? Which ones to use in an area? Alternatively,calculation of a site-specific comparison between raw GCM output and historical observations of climate variables (rainfall & mean temperature) for one selected GCM (e.g. MRI-CGCM3 or MRI-ESM2-0), one selected climate scenario and for the future period seasonal (Jan – Dec) metrics. Given monthly time series of rainfall and temperature values averaged for the present (day) conditions (e.g. 1980 – 2010) and future (e.g. 2040 – 2070). Project climate change in rainfall or temperature in the future using a simple approach? **Assessment 3** Description as a group assignment 3: Adaptation to the impacts of climate change on groundwater resources in an arid area such as Somalia. What can be done about climate change impacts of reduced rainfall and groundwater recharge in Somalia?
Reading materials/reference list	1. Abdelfattah, M.A. (2021). Chapter 10: Climate Change Impact on Water Resources and Food Security in Egypt and Possible Adaptive Measures. In: Emerging Challenges to Food Production and Security in Asia, Middle East, and Africa (eds: Mohamed Behnassi, Mirza BarjeesBaig, Mahjoub El Haiba& Michael R. Reed), Springer Nature Switzerland AG 2021, 330p.

2. Bats, B.C., Kundzewicz, Z.W., Wu, S. and Palutikof, J.P. (2008). Climate change and water. Technical paper of the IPCC, IPCC Secretariat, Geneva.
3. Bierkens M., Dolman H., and Troch P. (2008). Climate and the Hydrological Cycle. IAHS Special Publication 8, 344p, ISBN 978-1-901502-54-1.
4. Burroughs, W. J. (2007). Climate Change: A Multidisciplinary Approach (2nd edition), Cambridge University Press. ISBN: 9780521690331
5. Döll, P. (2002). Impact of climate change and variability on irrigation requirements: a global perspective. Climatic change, 54(3), 269-293.
6. Dismas, J., Mulungu, D.M.M. and Mtalo, F.W. (2018). Advancing rainwater harvesting as strategy to improve water access in Kinondoni Municipality Tanzania. Water Science and Technology: Water Supply Journal 18(3): 745-753. DOI: 10.2166/ws.2018.007
7. Gulacha, M.M. and Mulungu, D.M.M. (2017). Generation of climate change scenarios for precipitation and temperature at local scales using SDSM in Wami-Ruvu River basin Tanzania. Journal of Physics and Chemistry of the Earth (JPCE) 100: 62-72. DOI:10.1016/j.pce.2016.10.003

8. Houghton J. (2009). Global Warming: The Complete Briefing 4th edition 456pp, Cambridge University Press, ISBN 978-0-521-88256-9.
9. IPCC (2022). Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). Climate change 2022 Impacts, adaptation & vulnerability: https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/
10. IPCC (2022). Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). Climate change 2022 Synthesis report: https://www.ipcc.ch/ar6-syr/
11. IPCC (2020). IPCC special report on climate change and land. Geneva, IPCC. https://www.ipcc.ch/srccl/
12. IPCC (2019). IPCC special report on the ocean and cryosphere in a changing climate. Geneva, IPCC. https://www.ipcc.ch/srocc/
13. IPCC (2018). IPCC special report on global warming of 1.5oC. Geneva, IPCC. https://www.ipcc.ch/sr15/
14. Intergovernmental Panel on Climate Change. (2014). Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects. Cambridge University Press.
15. IPCC (2007). Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, 976 pp.
16. IPCC-TGICA (2007). General guidelines on the use of scenario data for climate impact and adaptation assessment. Version 2. Prepared by T.R. Carter on behalf of the Intergovernmental Panel on Climate Change, Task Group on Data and Scenario Support for Impact and Climate Assessment. 66 pp.
17. John Houghton (2009). Global Warming, The Complete Briefing. Cambridge University Press, ISBN: 978-0-521-70916-3.
18. Levejoy, T.E. and Hannah, L. (2005). Climate Change and Biodiversity. Yale University Press, New Haven, 418p. ISBN 0-300-11980-1.
19. Metz B. (2009). Controlling Climate Change. Cambridge University Press, 376pp ISBN 978-0-521-76403-2.
20. Nakićenović, N. et al. 2000 Emissions scenarios. A special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA. 599 pp.
21. Neelin J.D. (2011). Climate Change and Climate Modeling.Cambridge University Press, 304p.ISBN 0521602432, 97805216024332011.
22. Pielke, R. A. (2005). Land use and climate change. Science, 310(5754), 1625-1626.
23. Rotich, S.C. and Mulungu, D.M.M. (2017). Adaptation to climate change impacts on crop water requirements in Kikafu catchment Tanzania. Journal of Water and Climate Change 8 (2): 274-292. DOI: 10.2166/wcc.2017.058
24. Smit, B., Burton, I., Klein, R. J., and Wandel, J. (2000). An anatomy of adaptation to climate change and variability. Climatic change, 45(1), 223-251.

SUGGESTED TIME ALLOCATION

ACTIVITY	HOURS / Day	HOURS
Lectures	3	60
Tutorials & Seminars	1	20
Practicals	0	0

Assignments	2	40
Independent Study	2	40
TOTAL	8	160

5.11 GENDER AND INTEGRATED WATER RESOURCES MANAGEMENT

Course title	Gender and Integrated Water Resources Management
Course aim	The aim of the course is to introduce students to key gender concepts to foster an understanding of the concepts and to equip students with knowledge and tools to effectively mainstream gender in IWRM
Expected learning outcome(s)	1. At the end of the course students should be able to: 2. Explain the key gender concepts and the relevance and importance of gender equality in water resources management. 3. Explain the legal and policy framework around gender equality and women empowerment 4. Explain how and when to use gender analysis so that they can take account of gender in IWRM. 5. Conduct gender analysis using various gender analysis frameworks and tools 6. Explain gender mainstreaming steps and processes in IWRM 7. Develop a gender mainstreaming strategy and action plan for IWRM 8. Conduct monitoring, evaluation and reporting on gender in IWRM
Course status	Core
Credit rating	12 credits
Total hours spent	120
Course content	**1. Defining Key Gender Concepts** 1.1. Gender and sex 1.2. Culture, Religion, Socialisation and Gender 1.3. Gender and sex roles 1.4. Gender roles and Gender Based Violence 1.5. Gender Equality and Gender equity 1.6. Gender and IWRM **2. The Legal and Policy Framework Governing Gender Equality and Women Empowerment** 2.1 International legal and policy framework 2.2 Regional legal and policy framework 2.3 National legal and policy framework 2.4 Progress and Challenges towards the implementation of laws and policies 2.5 Gender and water governance 2.6 Barriers to inclusion of gender in IWRM **3. Gender mainstreaming in theory** 3.1 What is gender mainstreaming? 3.2 Gender analysis frameworks • Moser's Gender Planning Framework; • Harvard Analytical Framework, • Gender Analysis Matrix, • Social Relations Approach • The Women Empowerment Approach • The Capacity and Vulnerability Assessment 3.3 Mainstreaming gender in IWRM

	3.4 Benefits of mainstream gender in IWRM 3.5 Gender and environmental sustainability **4. Practical Exercise: Gender Mainstreaming in Practice** 4.1 Internal Gender Mainstreaming: key areas to consider 4.2 External gender mainstreaming • Gender Mainstreaming cycle • Gender analysis in IWRM: • Gender roles and Responsibilities • Access and control of resources • Access to services including information and knowledge • Participation in decision making • Patterns of power at household level • Gender Based Violence • Factors influencing the way the society is organised **5. Practical Gender Mainstreaming Exercise: Developing a Gender Mainstreaming Strategy and Action Plan in IWRM** 5.1 Key elements of a gender mainstreaming strategy • Rationale and objectives of a Gender Mainstreaming Strategy • Strategic Analysis of Gender Mainstreaming Challenges and Opportunities • Platform for Action 5.2 Gender sensitive approach to water supply 5.3 Gender sensitive approach to sanitation 5.4 Gender sensitive approach to agriculture **6. Monitoring, Evaluation and Reporting on Gender in IWRM** 6.1. Defining Monitoring, Evaluation and Reporting 6.2 Evaluation criteria 6.3 Use and types of indicators in monitoring and evaluation of gender 6.4 Gender sensitive indicators 6.5 How to develop gender sensitive indicators
Teaching and Learning Activities	The following teaching strategies will be used in the delivery of this course: 1. Lectures: This will involve face-to-face or online teaching. 2. Individual exercises 3. Group work: Some teaching will involve groupwork discussions and presentations on selected topics. This will be done to enhance sharing of experiences on gender issues in water resources management 4. Fieldtrips: these field trips will be for practical sessions on gender analysis and gender mainstreaming in water resources management
Assessment	Student assessment will be based on continuous assessment and an examination. Depending on the degree regulations, coursework contributes about 30% while the examination contributes 70% of the final mark. ***Continuous assessment***

	a. Fieldwork: A gender analysis report indicating the key findings of gender issues in water resources management in a particular community and recommendations for improving the situation. b. Group work: Group assignment followed by a Powerpoint presentation and a brief report ***Eexamination*** At the end of the module students will sit for a 3 hour examination paper that will contribute 70% of the final course mark. The examination will comprise of six questions, of which the student will choose any three.
Reading materials/reference list	The following reference materials are recommended for this module: 1. World Bank. (2012). World Development Report 2012: Gender Equality and Development. Washington, DC: World Bank.Helmer, R., & Hespanhol, I. (1997). Water pollution control: a guide to the use of water quality management principles. CRC Press. 2. CAP-NET, GWA 2014. Why Gender Matters in IWRM: a tutorial for water managers. https://cap-net.org/wp-content/uploads/2020/03/gender-tutorial-mid-res.pdf 3. Alston, M., & Kent, J. (2008). The big dry: The link between rural masculinities and poor health outcomes for farming men. The Australian Sociological Association, 44, 133–147. 4. Ambaw, G., Tadesse, M., Mungai, C., Kuma, S., Tamene, L., & Solomon, D. (2019). Gender assessment for women ' s economic empowerment in Doyogena climate-smart landscape in Southern Ethiopia. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).Chapman, D. V. (Ed.). (1996). Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring. CRC Press. 5. Brown, S., A.S. Kebede, and R.J. Nicholls. 2009. Sea-Level Rise and Impacts in Africa, 2000 to 2100. School of Civil Engineering and the Environment, University of Southampton, Southampton. https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/africa/regional---africa/Brown-et-al.--2009.--SLR--Impact-in-Africa.pdf 6. Chanana-Nag, N. and P.K. Aggarwal. (2020). Women in agriculture and climate risks: hotspots for development. Climatic Change, 158(1): 13-27. DOI: 10.1007/s10584-018-2233-z 7. Chopra, K., Leemans, R., Kumar, P., & Simons, H. (2005). Ecosystems and human well-being: policy responses. Island Press. 8. Drake, E. 2018. Water Stress and Conflict Severity: A Study On How Environmental Changes Affect Conflicts In Africa. https://doi.org/10.17615/fnxa-9w69.Bartram, J., & Ballance, R. (Eds.). (1996). Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programmes. CRC Press. 9. APHA/AWWA/WEF (2005) Standard Methods for the Examination of Water and Wastewater, APHA, Washington DC, USA **10.** Huyer, S. (2016). Closing the Gender Gap in Agriculture. Gender, Technology and Development, 20(2). https://doi.org/10.1177/0971852416643872Gerhardt, A. (2002). Bioindicator species and their use in biomonitoring. Environmental monitoring, 1, 77-123.

	11. UNDP 2006 Mainstreaming Gender in Water Management: Resource Guide

SUGGESTED TIME ALLOCATION

Total student hours 120	*Student Hours*
Lectures	46
Seminars/workshops	4
Practical classes	16
Structured exercises	8
Set reading etc.	10
Self-directed study	10
Assignments – preparation and writing	10
Examination – revision and attendance	16
Other:	0
Total	120

5.12 WATER TREATMENT AND SUPPLY SYSTEMS

Module Title	Water Treatment and Supply Systems
Module Aim	The module is intended to give knowledge and skills on all components of water treatment and supply systems including, the water sources, intakes, transmission and distribution mains, pumping systems, treatment units, sludge management and sustainability of water schemes.
Expected learning outcome(s)	At the end of the module a student should be able to; 1. Explain different components of water treatment and supply systems (water sources, intakes, transmission and distribution mains, pumping systems, treatment units, sludge management and sustainability of water schemes 2. Select the appropriate water treatment units in Somalia context 3. Design different components of water treatment and supply systems 4. Explain the sustainability requirements for water supply systems
Module status	Core
Credit rating	15
Total hours spent	150
Module content	List of topics to be covered. **1 Water Demand Assessment** 1.1 Different water uses (domestic, institutions, commercial etc) 1.2 Factors which affect water demand 1.3 Water consumption patterns for different water use 1.4 Population Projection 1.5 Water demand for different water users **2. Water Sources Analysis** 2.1 Types of Water sources (surface - rivers, streams, ponds, reservoirs, dams, groundwater, rainwater) 2.2 Hydrological analysis - (frequency analysis) 2.3 Groundwater (hydro-geological) investigation 2.4 Water quality analysis **3. Water Intakes and Hydraulic Analysis** 3.1 Types of intakes 3.2 Transmission mains (pressurized and gravity) 3.3 Distributions mains (types of distribution and design) 3.4 Pumps and pumping systems (types and selection criteria) 3.5 Energy for pumps (solar, wind, diesel etc) 3.6 Hydraulic analysis (Hardy cross methods, Hazen Williams, EpaNet software) **4. Rainwater Harvesting** 4.1 Types of rainwater harvesting 4.2 Roof catchments 4.3 Land catchments (sand dams etc) 4.4 Considerations for selection of rainwater harvesting methods **5 Water Treatments** 5.1 Types of water treatment units 5.2 Screens 5.3 Grit chambers 5.4 Sedimentation tanks 5.5 Coagulation and flocculation 5.6 Filters (roughing filters, rapid sand filter, rapid sand filters) 5.7 Disinfection (chlorination, ozonation etc) 5.8 Precipitation and complexation 5.9 Desalination plants (reverse osmosis etc) 5.10 Decentralized water treatment system (household water treatment systems **6. Water Treatment Sludge Management**

	6.1 Characterization of sludge 6.2 Thickening 6.3 Dewatering 6.4 Re-use of treated sludge **7. Sustainability of Water Supply Systems** 7.1 Willingness and affordability to pay 7.2 Cost recovery mechanisms 7.3 Operation and maintenance requirements for water supply systems 7.4 Water supply scheme management committees/models 7.5 Innovative funding mechanisms to sustain water supply schemes
Teaching and Learning Activities	Lectures, tutorials, assignments and exercises, field trips, group works, excursions
Assessment	This course is assessed by coursework – CA(50%) and University examination – UE (50%) Suggested assignments/tasks/exercises. E.g. Assessment 1: Perform water demand assessment in a given geographical setting Assessment 2: Analyze the water sources available in a particular setting Assessment 3: Select the appropriate water source in a given village Assessment 4: Select and design appropriate water treatment plants Assessment 5: Analyze and recommend the sustainability of given water supply scheme
Reading materials/reference list	1. AWWA, Lyonnaise des Eaux and Water Research Commission of South Africa (1996). *Water Treatment Membrane Processes*. New York, McGraw-Hill, Inc. 2. Au K-K et al. (2002). The role of oxidants on particle removal. Proceedings of the American Water Works Association Annual Conference. 3. Au K-K, LeChevallier MW (2000). Effects of oxidation on particle removal: the role of natural organic matter. Proceedings of the American Water Works Association Water Quality Technology Conference. 4. Becker WC, O'Melia CR, Croker RA (1998). *Oxidation, Filter Media Configuration and Filter Ripening. Volume D: Water Quality*. 1998 Annual Conference Proceedings. Denver, CO, American Water Works Association. 5. Bellamy WD, Hendricks DW, Logsdon GS (1985). Slow sand filtration: influences of selected process variables. *Journal of the American Water Works Association*, 77(12):62–66. 6. Drikas M et al. (2001). Using coagulation, flocculation and settling to remove toxic cyanobacteria. *Journal of the American Water Works Association*, 39(2):100–111. 7. Jeschke R (1998). Microsand enhanced flocculation and settling technology improves water quality: a pilot plant study. *1998 Annual Conference Proceedings: Volume D, Water Quality*. Denver, CO, American Water Works Association. 8. Rajagopalan R, Tien C (1976). Trajectory analysis of deep-bed filtration with the sphere-in-cell porous media model. *American Institute of Chemical Engineers Journal*, 52:523–533. 9. WHO (2004). *Guidelines for drinking-water quality*, 3rd ed., World Health Organization, Geneva.

SUGGESTED TIME ALLOCATION

ACTIVITY	HOURS p
Lectures	60
Tutorials & Seminars	15
Practical	0
Assignments	45
Independent Study	30
TOTAL	150