Addis Ababa University

Ethiopian Institute of Water Resources

Revised PhD Curriculum

in

Water Resources Engineering and Management (WREM)

Final

August 2024

Table of Contents

1. Background

Addis Ababa University (AAU), in its strategic plan (Strategic Plan for AAU 2020), envisages the creation of a multidisciplinary center of excellence for development-oriented research and training programs in by using its long years of services in the academic front that produces hundreds of thousands of professional and contributed for the country's human resources development. One of the key areas for a center of excellence in AAU is in the areas of water resources. Water resources, in its multi-disciplinarity is the major focus of the Ethiopian Institute of Water Resources (EiWR). Sustainable water resources management is at the core of water resources engineering and management interventions which can be addressed by training and research programs in Water Resources Engineering and Management (WREM), among others. As it is well documented, Ethiopia is endowed with reasonably large surface and groundwater resources. However, the water resources of Ethiopia are not abundant, as evidenced by the per capita water availability, which is closely approaching 1,000 m^3, which is the threshold value for water scarcity. On the other hand, despite the potential, the high variability of the resources both in space and time exposed Ethiopia to be vulnerable to the multiple dimensions of climatic shocks and water stress conditions. The water resources of the nation have been so far little developed and utilized; while the reasons may include limitation in technical capacity, financial capacity, institutional capacity, and skilled human capacity. To address the needs of the fast-growing population, tackle the impacts of climate change, and enable the water resources sector to contribute more to the national economy, the need for highly trained researchers and water resources engineering and management professionals is decisive.

The government of Ethiopia has already concluded in its long-term vision to transform the wellbeing of citizens and economic situation of the country that soicio-economic development shall take sustainable water resources development and management at a focal point. This led the government to endorse Integrated Water Resources Management (IWRM) and accept it as a guiding principle in the Ethiopian Water Resources Policy and Strategy. Moreover, it has passed a proclamation for the establishment of River Basin development offices and other water sector organizations and commissions for the development, management, and regulation of water resources. The government's budget for the water sector has also significantly increased over the last couple of years, indicating the importance of the water sector for the overall socio-economic development and wellbeing of the people. Based on the recent needs of the country and dynamic changes in the subject matter, the Ethiopian Institute of Water Resources (EIWR) has come up with a PhD programme in Water Resources Engineering and Management. The graduate program would thus offer advanced instruction in water engineering and management towards solving the country's outstanding problems in the water sector and aligned with envisioned sustainable social and economic development of Ethiopia through training and research.

The PhD program in Water Resources Engineering and Management is designed to encapsulate major water resources engineering and management concerns; in a 4-year study program comprising of courses and PhD dissertation.

2. Rationale

Water resources play a critical role in meeting various competing needs, including domestic use, agriculture, industry, and ecosystem well-being. However, the extensive use and misuse of surface and groundwater, coupled with pollution from residential, agricultural, and industrial sources, pose significant threats to the water resources at global scale. Additionally, climate change exacerbates these challenges, affecting water availability and quality. One of the pressing global issues is water scarcity. Managing this scarce resource under changing environmental conditions such as catchment modifications and climate variability is imperative. Quantifying water resources in terms of both quality and quantity, as well as predicting extremes e.g., floods and droughts, becomes essential for the present and future generations. As well noted by the international scientific community, sustainable water resources management will be one of the most important challenges in the 21st century. Water management is faced by increasing and emerging challenges; both natural and anthropogenic, which need state-of-the art knowledge, techniques and technologies to address them. Water resources-related problems, such as water pollution, water scarcity, drought, flooding, conflicts on water between users, transboundary water management, etc. are already affecting Ethiopia, which need immediate actions based on informed decision making. On the other hand, Ethiopia's future development endeavors heavily reply on its capacity to develop and manage its water resources on sustainable basis. This in turn requires cutting edge researches and trainings at PhD levels to shape the development and management of water resources in conjunction with ecosystems sustainability in a multidisciplinary manner.

Addis Ababa University recognizes the need for an integrated curriculum that addresses these multifaceted water issues. Thus, the curriculum will empower professionals to solve real-world problems at global, regional, and local scales. Ethiopia, with its abundant rivers and water potential, is witnessing rapid water resources development. However, challenges persist, including water security, extreme events, and water quality. The knowledge acquired from this program will enable water engineers and managers to plan, develop, operate and manage the country's water resources sustainably. The rationale for this PhD program in Water Resources Engineering and Management is, therefore, the need for highly trained water resources engineering and management professionals capable of shaping management of water resources of Ethiopia on sustainable manner for the socio-economic development on the nation in face of increasing and emerging local, regional and global water related challenges. Hence, the programme will produce high-level professionals capable of addressing water-related challenges across sectors, from infrastructure development to water management. By bridging

academia, research, and practical applications, this program aims to ensure Ethiopia's water resources are harnessed effectively to meet the social, economic and environmental sustainability.

3. Mission

The program aims to train professionals capable of addressing critical water challenges at national, regional, and international levels. Through high-quality education and research, it equips students and mid-career professionals with technical competence in water resource, engineering, and management. By empowering them to apply their knowledge to real-world water problems, the program contributes to informed decision-making processes.

4. Objectives

The main objective of the programme in water resources Engineering and Management is to educate students that expected to understand the multiple interactions and dynamics of water cycle in the landscape and quantifying changes associated with human, landscape and water at various spatio-temporal scales. Moreover, the graduates in the programme will be proficient in water engineering techniques, water management approaches, hydrologic design, planning and operation of water resources systems. Consequently, the PhD program is expected to satisfy the national demand for highly trained Water Professionals capable of solving complex water related challenges through application of state-of-the-art methods and conducting cutting edge research. The specific objectives of the PhD program are:

- To provide highly qualified water professionals for the country, especially in higher education and research institutions;
- To train high-level professionals capable of solving practical water engineering problems independently and within a team.
- To train water engineers and professionals who are capable of handling the planning, design, management, and construction of complex water related Civil Engineering Projects;
- To strengthen the link with the water industry so that candidates would work on the country's water engineering and management problems;
- To initiate, promote and foster research in different fields of water engineering and management in line with the national needs;
- To promote interdisciplinary scientific knowledge and technological development based on water resources internationally.
- To evaluate and analyses hydrological systems and processes at a wide range of scales in both space and time for the purpose of water resources assessment, natural hazard assessment, mitigation and management (e.g. droughts and floods).

- To provide an in depth understanding about the concept of surface and sub-surface hydrological system.
- To enhance knowledge and skill on the major hydrological methodologies and applications with regard to water quantity and quality, including techniques for data collection, processing and analysis, and the application of catchment hydrological modelling and aquifer modelling techniques.

5. Graduate profile/competencies

The graduates of this program will play a key role in solving real water problems at various levels related to water and environment to meet the societal needs in the following areas:

Participants in this programme will have the following competencies.

- Proficiency in developing and applying hydrological models to understand water flow, distribution, and availability.
- Understanding hydrological processes, water quality, and ecosystem interactions.
- Efficiently organizing tasks and prioritizing critical activities context specific to water resources planning, development, and management.
- Acquire knowledge in sustainable water allocation, reservoir management, and infrastructure design.
- Ability to collaborate with diverse stakeholders (government agencies, communities, industry) to address water-related challenges.
- Competence in designing and conducting experiments or field studies related to water resources.
- Skills to plan, execute, and monitor water projects effectively.
- Ability to guide teams and make informed decisions.
- Collaborating effectively with diverse stakeholders.
- Clear and concise communication, both written and verbal.
- Analyzing complex water challenges and proposing solutions.
- Capacity in research and analytical skill, mastery of statistical analysis, optimization techniques, and data interpretation.
- Teach, carry out cutting edge research and lead water resources related research projects in higher learning and other research institutions;
- Hold senior/leadership positions in government, non-governmental and other international organizations on water resources development and management related tasks;
- Demonstrating leadership in research projects, mentoring, and collaboration.
- Leading role and participation in shaping the sustainable development and management of water resources.

6. Admission Requirements

To be admitted to the PhD-WREM program, prospective students should fulfil the following:

a. General

- M.Sc. Degree or equivalent in Water Resource Engineering, Hydraulic Engineering, Irrigation Engineering, Hydrology and Water Resources, Water Resources Management, or closely related fields from a recognized institution. Applicants with M.Sc. degrees in other related subjects than stated above may have to attend additional courses. Because of this, they may require more time to complete the PhD program;
- MSc degree CGPA of 3.25 and above;
- Prospective PhD students should sit for and pass a Graduate Admission Test (GAT) administered by the Addis Ababa University;
- Candidates must also meet the general application and admission policy of the Addis Ababa University

b. Specific Requirements

- The institute shall administer a written qualifying examination or an oral presentation or an interview to determine the candidate's suitability;
- Candidates may be expected to write a proposal/concept note for their PhD dissertation. The proposal/concept note has to be approved by at least one professor from the Department;
- The decision for admission needs to be approved by the Academic Council (AC) of the Institute;

7. Duration of the Study

The duration of the PhD program will be four years. However, if justifiable reasons are presented for not being able to complete the study in four years, the duration shall be extended by a maximum of two years (total 6 years) as per the AAU Senate Legislation. The extension, however, needs to assessed, determined and endorsed by the EIWR AC, and approved by the ASPRC of the AAU. While the normal duration of the study is four years, the minimum duration the PhD study can be completed is three years.

8.0 Graduation Requirements

The requirements to obtain the PhD degree are:

- Successful completion of at least 4 courses (one elective) and 2 graduate seminars or 19 Credit Hours or 38 ECTS, and cumulative average grade of "B" required in the course work;
- Successful completion and approval by the PhD supervision committee of a PhD dissertation of 60 Credit Hours or 120 ECTS and its successful public defence;

- Two published articles in reportable journals or proof of acceptance of the same as per the AAU Senate Legislation, Article 121.4.3. The published articles should be based on and related to the PhD student's research work; the data used also needs to be collected as part of the PhD study.
- A minimum evaluation grade of "satisfactory" for the PhD dissertation;
- While the program is normally for four years, it is mandatory that a student should actively undertake the study for a minimum of three years; and continuous registration is required at the beginning of each semester to keep the program active. A candidate who fails to maintain a continuous registration without officially withdrawing from the program will be considered to have dropped out and shall not be eligible for graduation.

9.0 Degree Nomenclature

Degree of Doctor of Philosophy (PhD) in Water Resources Engineering and Management

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10.0 Teaching and Learning Methodology

The teaching and learning methodology designed to achieve the outcomes and graduate profile are described as follows. Techniques and approaches below are described in a more detail under specific courses template, which is found in appendix.

Core compulsory course delivery: Core courses are designed to be offered to the students in face-to-face class room delivery. Each course in their syllabus should comprises a teaching and learning strategies, mode of delivery and evaluation.

Seminars: Preparation of seminars by students in each core courses are mandatory. The seminars will create an interactive session where students discuss research papers, case studies, and emerging trends. Students should link their research questions to what the industries in the country are really wanted to be resolved and given high priority. Furthermore, seminars within the department will be one mode of knowledge exchange expected to be delivered by the staff members, when new articles are published, disseminate and share findings in their field of study.

Group work/peer learning: group work is designed in a such a way that different cases on subject matter will be provided to the students. Students will assign chairman and secretary to lead the group. Each student will participate on the raised issues. Students within the group will learn through the peer learning. Moreover, student centered learning is one of the approaches that will be implemented in the programme, that enable active learning, problem-solving, and self-directed exploration, fosters curiosity, creativity, and independent thinking.

Communication and networking skill: Students are obliged to engage in communication skills through day-to-day class activities and short recapitulate about what they have learned. Such reiteration

process should be practiced by the course instructors. Essay writing and presentation about key what they have learned on a daily basis is one of the mechanisms that will enhance their communication and writing skills of the students. Preparing students to become leaders in water related fields are essential through linking them with known organizations, institutions, and experienced researchers in their field of study.

Laboratory Sessions: Theoretical concepts and theories should be tested on laboratories. Hands on practical work in hydrological laboratories is essential to solve real water challenges in the field.

Field trip/observations: application of theories and concept in core and elective courses should be supported by field observations. Students should learn the realities in the field. Particularly, experimental field site demonstrations, equipped with instrumentations are imperative to test hypotheses and realities. Moreover, it will help to enhance science-based decision making in their field.

Acquaint students to exploit web-based resources: due to advances in science and technology conventional method of data acquisition is now enhanced by remotely sensed data. Utilization of online materials, including multimedia resources and hydrological databases are vital to solve data limitation and to-update the current techniques in the field of study. Hence, exposure to modeling software and global datasets will be one of our approaches in this programme.

Research Projects: Students engage in original research, exploring specific hydrological questions primarily addressing to solve the country's water challenges. They develop models, analyze data, and contribute to scientific advancements.

11.0 Assessment policies and techniques

PhD students are encouraged to largely learn by themselves. However, for the delivery of the courses, the teaching methods shall be through lectures, individual literature study and group and individual project works. The assessment and evaluation of the PhD students shall vary from course to course based on the nature of the course. The general evaluation and assessment methods may consist of individual assignments, group assignments, group project works and seminar presentations, field work reports, examinations, PhD progress reports, etc. Course instructors have the right to adopt appropriate means of assessment from the combination of the above methods. Assessment grades will be given to students as per the Senate Legislation of Addis Ababa University.

Mechanisms to evaluate and improve quality and standards

The PhD program will be assessed for quality and standards on a continuous basis through the existing units of the institute. Ensuring the quality of the program relies on the way we do things related to the program including student recruitment, teaching and assessment and research supervision. Maximum efforts will be made by the Institute to ensure the quality of the program. Some of the mechanisms include, among others:

- *Student recruitment:* prospective students of the program will be selected based on the admission criteria stated in this document. Efforts will be made to recruit best students in terms

of both academic backgrounds and performance. This will be decided through multiple evaluation phases at Education coordination office, Graduate programs council and finally at the AC of the Institute. Passing GAT test is must to be admitted to the program.

- *Assignment of instructors:* Instructors teaching courses of the program will be carefully assigned based on their expertise. It will be finally decided by the AC of EIWR.
- *Class attendance:* Regular attendance of classes by students is a must. A minimum attendance of 80% is considered for students to be eligible to sit for the final examination.
- *Students feedback on evaluation of instructors:* At the end of each semester, students will evaluate their instructors of their knowledge in the subject area and the overall course delivery strategy, which will be used as inputs as a basis of improvement in the next semesters.
- *Assignment of thesis supervisors:* Supervisors of thesis work need to be assigned based on proven knowledge and expertise in one's area of research. Assignment of supervisions shall be proposed by students or EIWR units and the final assignment shall be approved by the AC of EIWR.

Progress and performance of students on thesis work: Thesis supervisors shall report on regular basis on the performance of students on their research work. Based on the reports, appropriate remedial corrective measures will be taken by the units or/and AC of the EIWR.

12.0 Grading

The requirements to obtain the PhD degree are:

- Successful completion of at least 4 courses (one elective) and 2 graduate seminars or 19 Credit Hours or 38 ECTS, and cumulative average grade of "B" required in the course work;
- Successful completion and approval by the PhD supervision committee of a PhD dissertation of 60 Credit Hours or 120 ECTS and its successful public defense;
- Two published articles in reportable journals or proof of acceptance of the same as per the AAU Senate Legislation, Article 121.4.3. The published articles should be based on and related to the PhD student's research work; the data used also needs to be collected as part of the PhD study.
- A minimum evaluation grade of "satisfactory" for the PhD dissertation;
- While the program is normally for four years, it is mandatory that a student should actively undertake the study for a minimum of three years; and continuous registration is required at the beginning of each semester to keep the program active. A candidate who fails to maintain a continuous registration without officially withdrawing from the program will be considered to have dropped out and shall not be eligible for graduation.

Doctoral Dissertation

General

- Candidates are expected to initiate and carry out original research in their field of specialization with the assistance of his/her supervisor. The research projects should focus on addressing and solving national and regional water related problems, in addition to contributing to the pool of scientific knowledge. The result of the PhD research will be presented as a doctoral dissertation subject to careful scrutiny by internal and external examiners as per the University regulation;
- A doctoral dissertation will constitute a partial fulfillment for the requirements of the PhD Program;
- The doctoral dissertation shall constitute individual effort in academic pursuits to design and conduct high standard scientific research for solving problems or generating knowledge. The conclusions arrived at and/or the methodology employed shall be of such standard as to have been judged original. In as much as possible, the areas of study shall be relevant to Ethiopia or the region.

Publication

Before a candidate defends his/her PhD dissertation, he/she should have a minimum of two articles published or accepted for publication in a reputable journal that will be judged and decided by the AC of the Institute. Any other provision regarding publications as indicated in the AAU Senate legislation shall apply.

Assignment and approval of PhD supervisors

A PhD candidate shall have minimum of two and a maximum of three supervisors with excellent expertise in the research area of the PhD student. At least one of the supervisors should be from EIWR for proper follow-up and supervision of the PhD work. The candidate will have a Supervisor (Promoter) with an Academic rank of Associate professor and above; and Co-supervisor(s) with academic rank of Assistant professor and above all with a PhD. The supervisor and co-supervisors shall be assigned by the academic and research units of the Institute, or can be through mutual agreement of the student and supervisor/s; however, the supervisors need to be approved by the Academic Commission (AC) of EIWR.

Selection and Approval of title of Doctoral Dissertation

- The subject for doctoral dissertation work shall be selected by the student in consultation with the research primary advisor/supervisor and must be approved by the Advisory Committee;
- The selection of the doctoral dissertation title shall be on the basis of the broad needs of the country and/or in line with the development plans of the nation and/or addressing national and regional water related problems. The PhD research shall fall in at least one of the Thematic research areas of the Institute.
- The title of the doctoral dissertation of each student shall be approved by the Academic Council (AC) of the EIWR before the student makes significant progress in the proposal.

  Format of Doctoral Dissertation

The format of the PhD dissertation shall be monograph or article-based; and will be in accordance with the guidelines set by Addis Ababa University for the same.

Examination Committee

- When a candidate, after conferring with the supervisor and through him, with the advisory committee, gives notice of readiness to submit his dissertation, the Graduate Council/ EIWR units propose an Examining committee and presents to the AC for approval.
- The Examining committee shall consist of a minimum of 3 members; two internal and one external examiner (three renowned professors in the research area). The external examiner shall be with a rank Associate professor or above.
- The examination committee decides on the acceptance, modification or rejection of the dissertation, organizes the disputation and grades the written thesis and oral examination (disputation). It decides on the necessary modifications to their satisfaction prior to the publication of the dissertation.

Procedures of Examination

- The doctoral dissertation oral examination shall be scheduled within three months and minimum of one month after the submission of the doctoral dissertation to the Academic unit in question.
- The dissertation will be evaluated by the Graduate Council of the Institute for fulfillment PhD dissertation quality.
- If acceptable by the Council, the dissertation is then presented to the AC for further evaluation and acceptance. If acceptable. The AC selects (approves) examination committee members, and sets the date of defense.
- The dissertation is then sent to the external examiner by academic unit and requests feedback on the quality and defendability of the dissertation. The external examiner gives back his/her feedback within two week's time.
- If feedback is positive, on the date set by the AC, the candidate gives a public presentation on the content or partial content of his dissertation. The duration of the presentation shall not exceed 30 minutes, and the whole examination session shall be 2 hours maximum.
- In the disputation, the candidate has to defend the content of his dissertation. The disputation covers the content of the dissertation but it can also include basics of the subject matter. The active disputation occurs among the examination committee and the PhD candidate. The disputation shall not exceed one hour and half hours.

Decision on the Acceptance or Rejection of Doctoral Dissertation

(i) Accepted Doctoral Dissertation:

A doctoral dissertation is:

- accepted with no change or with some minor changes;

- accepted with modification in which the doctoral dissertation requires substantial changes in substance, which are to be made to the satisfaction of members of the Examining Board or it's designate. The examining committee report must include a brief outline of the nature of the changes required and must indicate the time by which the changes are to be completed.

(ii) Rejected Doctoral Dissertation:

A doctoral dissertation shall be rejected if:

- the work does not meet the required PhD standard;
- the work is plagiarized as judged by the examining committee;
- it has been already used to confer a degree from this or another University. However, this shall not prelude the candidate submitting such dissertation provided enough work has been done to expand the scope and depth of the subject.

  Copies of the Doctoral Dissertation Required

  Three copies of the PhD dissertation are required to be submitted, of which one copy is kept at the EIWR and one copy is deposited at the library. Moreover, the soft copy of the dissertation will be submitted to the library to be stored in the repository.

  Grading of the dissertation

- If a candidate passes in the oral examination at the public defense of the dissertation, he/she obtains a grade of "Pass" with the granted grade, and a grade of "Fail' if he/she fails to pass;
- Immediately after the end of the oral examination, the examination committee decides on the final grade in a non-public session based on the oral examination reports;
- The final grade shall be "passed with excellent results", "passed with very good results", "passed with good results" and "passed with satisfactory results";
- The examination committee decides whether modifications of the dissertation are required prior to publication of the desecration;
- After the grade has been decided, the head of examination committee informs the candidate about the final result.

Award

A candidate who fulfills the requirements laid down in this curriculum, and whose research study and examination results are judged to be of sufficient merit, shall be recommended by the Director of EIWR, on behalf of the EIWR AC, to the University Senate, through the Office of Registrar, for approval of the award of the degree of Doctor of Philosophy (PhD) in Water Resources Engineering and Management with respective specializations.

13.0 Resources required and available

13.1 Human Resource (Teaching Staff)

Table 1. Active academic staff profile of the Ethiopian Institute of Water Resources

Specialization	Academic Degree			Academic Rank			
	PhD	MSc	Total	Prof.	Assoc. Prof	Asst. Prof.	Lecturer
Hydrology and Water Resources	3	0	3	0	2	1	0
Hydro-climatology and Climate Change	1	1	2	0	1	0	1
Hydraulic Engineering /River Basin	2	0	2	0	0	2	0
Irrigation engineering and Management	2	0	2	0	0	2	0
Groundwater management/Hydrogeology	2	0	2	0	0	2	0
Forest Hydrology and water Management	1	0	1	0	0	1	0
Environmental and Hydro-economics	1	0	1	0	0	1	0
Water and Health	1	2	3	0	1	0	2
Water Quality Management	1	0	1	0	1	0	0
Environmental Public Health	1	0	1	1	0	0	0
Health and Environmental Risk	1	0	1	0	1	0	0
Water and Wastewater Treatment	1	0	1	0	0	1	0
Environmental Engineering	1	1	2	0	0	2	0
Sewerage and Urban Drainage	1	0	1	0	0	1	0
Total	**18**	**4**	**22**	**1**	**3**	**15**	**3**

13.2 Material & Infrastructure Resources (Teaching Facilities)

The Ethiopian Institute of Water Resources was based for about 4 years at the AAU Akaki campus which originally belong to the National Bank of Ethiopia. However, since 2019, it has moved to the Addis Ababa Institute of Technology (AAiT) campus. Currently, the EIWR is based on Library building of the AAiT. The space occupied is currently not adequate and suitable to create a conducive working environment. Moreover, there are limitations in terms of working spaces for graduate students. However, as there are no under-graduate students at EIWR, most of the graduate students work from home, their own offices, and other premises, and as a result the current space shortages have little impacts on the actual performance of the Institute.

However, for the Institute to excel in teaching and research and to enable it contribute more visibly to the university and to the national development agenda, better space and facilities are required. For this, the request was forwarded to the AAU higher management and positive feedback was obtained to provide better facilities for the institute in the buildings nearing completion in the AAU main campus. If this is realized, the institute will be well positioned to capitalize on its current excellent work in graduate education and research in water and related disciplines. Currently, the EIWR has the following facilities.

Table 2. Current available facilities of EIWR

S. No	Name	Remarks
1	A working office space of area 290 m^2 (academic and admin staff)	The Institute has recently prepared and submitted a space requirement to the AAU management and hopes that more facilities and working spaces will be availed soon.
2	Four large size classrooms with adequate chairs	
3	One large size computer room	
4	Water quality laboratory equipment, although they are not adequate and currently no laboratory is available.	
5	Field research equipment (augurs, core samplers, soil moisture meters, current meters, etc.)	
6	Eddy Covariance Atmospheric Flux equipment	
7	Installed compact weather equipment installed at about 50 sites over the Blue Nile Basin	
8	Two Experimental learning watersheds for hydrological, climatic and bio-physical data monitoring (under establishment)	The plan is to start establishment in 2022/23 Ac. Year.

14.0 Quality Assurance

The PhD program will be assessed for quality and standards on a continuous basis through the existing units of the institute. Ensuring the quality of the program relies on the way we do things related to the program including student recruitment, teaching and assessment and research supervision. Maximum efforts will be made by the Institute to ensure the quality of the program. Some of the mechanisms include, among others:

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and finally at the AC of the Institute. Passing GAT test is must to be admitted to the program.

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- Class attendance: Regular attendance of classes by students is a must. A minimum attendance of 80% is considered for students to be eligible to sit for the final examination.
- Students feedback on evaluation of instructors: At the end of each semester, students will evaluate their instructors of their knowledge in the subject area and the overall course delivery strategy, which will be used as inputs as a basis of improvement in the next semesters.
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- Progress and performance of students on thesis work: Thesis supervisors shall report on regular basis on the performance of students on their research work. Based on the reports, appropriate remedial corrective measures will be taken by the units or/and AC of the EIWR.

15.0 Module

15.1 Module and Course Coding

The course codes for all the courses are preceded by "WREM" which stands for Water Resources Engineering and Management followed by four-digit numbers, explained as follows:

WREM: Stands for Water Resources Engineering and Management

First digit: Year where the course is given starting from undergraduate studies (8 or 9)

Second digit: Specialization (1: Hydrology and Climate, 2: Engineering and Programming, 3: Research and Seminar) (1, 2, 3)

Third digit: Semester where the course is offered (1 or 2)

Fourth digit: Course listing number within a semester (1 to 5)

15.2 Module list

Module 1: Hydrology and climate (Hydro-climatology, Advanced Geostatistics, Hydrological Measurement, Advanced Water Resources Systems Analysis, Advanced Stochastic Hydrology)

Module 2: Engineering and Programming (Advanced Hydraulic Structures, Advanced Numerical analysis and programming tools for water resources management, Irrigation Systems Planning, Design and Analysis).

Module 3: Research and Seminar (Graduate Seminar, PhD Research Proposal, PhD dissertation)

15.3 Modular structure

Table 1. The summary table shows the modular structure

Module Category	Course List	Module Objectives
Module 1 Hydrology and Climate	Hydro-climatology	Aim to create experience that trains the candidates with the necessary skills and knowledge to address contemporary hydrology and climatology and effectively.
	Advanced Geostatistics	
	Hydrological Measurement	
	Advanced Water Resources Systems Analysis	
	Advanced Stochastic Hydrology	
Module 2 Engineering and Programming	Advanced Hydraulic Structures	Aim to equip students with the necessary skills, knowledge, and experience to excel in specialized areas of water resources engineering and management and programming
	Advanced Numerical analysis and programming tools for water resources management	
	Irrigation Systems Planning, Design and Analysis	
Module 3 Research and Seminar	Graduate Seminar	Aim to enrich students' specific interests and prepare them to carryout water resources engineering and management research.
	PhD Research Proposal	
	PhD dissertation	

15. Courses within Modules

Table 2. List of courses PhD-Water Resources Engineering & Management (WREM)

S.N	Module	Courses Code	title	ECTS	Mode of Delivery	**Lecture (hrs)**	**Exercise/Group Work (hrs)**	**Fieldwork (hrs)**	**Lab Work (hrs)**	**Self-study (hrs)**	**Notional Learning time (hrs)**
1	Module 1 Hydrology and climate	WREM 8111	Hydro-climatology	7	Parallel	48	24	16	16	85	189
		WERM 8112	Advanced Geostatistics	7	Parallel	48	24	0	32	85	189
		WREM 8125	Hydrological Measurement	7	Parallel	48	24	16	16	85	189
		WREM 8121	Advanced Water Resources Systems Analysis	7	Parallel	48	24	0	32	85	189
		WREM 8122	Advanced Stochastic Hydrology	7							
2	Engineering and programming	WREM 8223	Advanced Hydraulic Structures	7	Parallel	48	24	16	16	85	189
		WREM 8213	Advanced Numerical analysis and programming tools for water resources management	7	Parallel	48	24	0	32	85	189

		WREM 8214	Irrigation Systems Planning, Design and Analysis	7	Parallel	48	24	16	16	85	189
3	Research and Seminar	WREM 8324	Graduate Seminar	5	Parallel	32	24	0	0	79	135
		WREM 9311	PhD Research Proposal	-	Sequential (After all courses)						
		WREM 9321	PhD dissertation	30	Sequential (After all courses and proposal defense)						

16. Semester course breakdown

Table 3. Semester course distribution for PhD-WREM

Year	Semester	Course code	Course name	ECTS
I	I	WREM 8111	Hydro-climatology	7
	I	WREM 8112	Advanced Geostatistics	7
	I	WREM 8213	Advanced Numerical analysis and programming tools for water resources management	7
	I	WREM 8214	Irrigation Systems Planning, Design and Analysis	7
		Semester total		**28**
	II	WREM 8121	Advanced Water Resources Systems Analysis	7
	II	WREM 8122/ WREM 8223/ WREM 8125	PhD course I (Elective-mandatory)	7
	II	WREM 8122/ WREM 8223/ WREM 8125/	PhD course II (Elective-non mandatory) only one to be taken	7
	II	WREM 8324	Graduate Seminar I	5
		Semester total		**26**

II	I	WREM 9311	PhD Research Proposal	P/F
	I	WREM 9321	PhD dissertation	30
	II	WREM 9321	PhD dissertation	30
III	I	WREM 9321	PhD dissertation	30
	II	WREM 9321	PhD dissertation	30
IV	I	WREM 9321	PhD dissertation	30
	II	WREM 9321	PhD dissertation	30
		Total		234

Addis Ababa University

Course Development Template

College: TBD

Department: TBD

Program: PhD in Water Resources Engineering and Management (PhD in WREM)

Course Title: Hydroclimatology

Year ____First_____ Semester _____I_____

Instructor:

- Name:
- Contact information:
- Office hours:

No	Section	Contents	Remarks
1.	Module to which the course belongs:		
	1.1. Module Title	Hydroclimatology	
	1.2. Type of Module	Hydrology and climate	
2.	Competencies	The course help students to acquire climate data from the most recent climate change scenario archives, implement various bias-correction techniques, and calculate various	

		extreme climate indicators. In addition, it helps student to assess the impact of climate change on water resources.	
3.	Course Type	Face-to-face, synchronous	
4.	Course Identifiers		
	4.1. Course Code	WREM 8111	
5.	4.2. Credit Point in ECTS	7	
6.	Prerequisite	None	-
7.	Course Description	Earth's energy balance, Earth's water balance, Hydroclimatic spatio-temporal variations, the global climate system, general circulation, global water cycle, natural climate variability, climate change, natural and anthropogenic effects to climate change, feedbacks in climate, modeling of climate system: GCMs and RCMs, evaluation of the performance of RCMs/RCMs, bias correction of GCMs/RCMs, hydrologic modeling with emphasis on effects of climate change, spatial and temporal variations in hydro-climatic variables, Extreme events: droughts and floods (moisture deficit and excess), large-scale oscillations (ENSO, La Nina Events, Indian Ocean Dipole, Pacific Decadal Oscillation, and other important oscillations) and the effects of these oscillations on the hydro-climatic variables, hydroclimatic trend analysis, hydro-climatic characteristics of major Ethiopian river basins, climate change impacts on water resources.	
8.	Learning Outcomes	Upon completion of the course students are expected to: ✓ Identify the best representative GCMs/RCMs for a particular catchment using performance indicators for the historical climate records	

		✓ Select the most recent climate change scenario data ✓ Apply bias-correction techniques and calculate extreme climate indicators ✓ Use pre-processed and bias-corrected climate data for hydrological modelling as well as water resources availability estimations. Questions to be answered after completion of the course ✓ How a global water and carbon cycle vary spatially and temporally ✓ How the global climate system is designated into the major climate components ✓ What is general circulation, large-scale oscillations (ENSO, La Nina Events, Indian Ocean Dipole, Pacific Decadal Oscillation ✓ How Global or Regional Climate was modelled ✓ How is the best representative Global Climate Model (GCM) can be selected for a specific study region ✓ How are the biases in GCM-simulated data can be corrected ✓ How trend, drought, and extreme climate indicators can be calculated ✓ What is the impact of climate change on water resources availability	
9.	Course Contents	Part I: Global Climate System (15%)	

		1. Global Climate System 1.1. Earth's energy balance 1.2. Earth's water balance 1.3. Hydroclimatic spatio-temporal variations 1.4. The global climate system and general circulation 2. Climate change 2.1. Natural climate variability 2.2. Greenhouse gas effects 2.3. Natural and anthropogenic effects to climate change 2.4. Feedbacks in climate system Part II: Modelling of the climate system (10%) 1. Modeling of climate system: GCMs and RCMs 2. Climate change emission scenarios Part III: Large scale oscillations and Ethiopia climate (15%) 1. Major large-scale oscillations 2. The influence or coincidence of large-scale climate oscillations to Ethiopian seasonal rainfall	

		Part IV: Climate change model selection (25%) 1. Performance evaluation climate models 2. Sub-setting best performing climate models 3. Bias-correction of climate model simulated data Part V: Extreme climate (25%) 1. Hydro-climatic characteristics of major Ethiopian river basins 2. Extreme climate indicators 2.1. Rainfall related climate extremes 2.2. Temperature related climate extremes 3. Drought analysis 3.1. Drought analysis using open-source climate data and drought indicators Part VI: Climate change impact on water resources (10%) 1. Hydroclimatic trend analysis 2. Climate change impacts on water resources at catchment scale	
10.	Teaching and learning techniques	Generally active/cooperative learning approaches will be adopted. The teaching methods include lectures (virtual or face to face), group works, project works, case studies,	

		field works and visits, individual studies, and researches. More time will be given for students to work individually and in a group on case studies, project works, as well as field work.	
11.	Assessments	Continuous assessment will be implemented adopting various forms of instruments that help assess the expected learning outcomes. Thus, four individual tasks based on the core content of the hydroclimatology and one group work on literature review will be assessed. Assignments and projects will be announced on first class with guides	
12.	Course Policy	- Assignments need to be strictly submitted before the due date and time. - Students need to be cautious of the use of AI in individual and group assignments. Contents generated from use of AI will be carefully assessed. - At least 80% attendance is mandatory for the face-to-face and virtual lecture classes - Students should not copy from each other on individual assignments and project works.	
13.	Learning Resources	- Chakilu GG, Sándor S, Zoltán T, Phinzi K (2024). The patterns of potential evapotranspiration and seasonal aridity under the change in climate in the upper Blue Nile basin, Ethiopia. Journal of Hydrology, 131841. - Omid Bozorg-Haddad O (2021). Water Resources: Future Perspectives, Challenges, Concepts and Necessities. Publisher: IWA Publishing. - Costas G, Helmis l, Panagiotis T, Nastos T (2012). Advances-in-Meteorology-Climatology-and-	

		Atmospheric-Physics. Springer-Verlag Berlin, Heidelberg - Amanda H, John L, Cassano J (2006). Applied Atmospheric Dynamics. John Wiley & Sons Ltd. - Barry RG, Hall-McKim EA (2014). Essentials of the Earth's Climate System. Cambridge University Press. - Shelton ML (2009). Hydroclimatology. Perspectives and Applications. Cambridge University Press. - Karamouz M, Nazif IS, Falahi IM (2013). Hydrology and Hydroclimatology Principles and Applications. CRC Press Taylor & Francis Group. - Shrestha S, Babel MS, Pandey VP. Eds., (2014). Climate Change and Water Resources. CRC Press, Taylor & Francis Group.	
14.	Assessment rubrics (optional)[1]	- Both skill based and standards-based rubrics shall be adopted in assessing students. - Top achievers and bottom achievers will be assessed in each case and others accordingly marked for each assignment.	

Addis Ababa University

Course Development Template

College TBD

Department TBD

Program PhD in Water Resources Engineering and Management (PhD in WREM)

Course Title: Advanced Geostatistics

Year First Semester I

Instructor:

- Name:
- Contact information
- Office hours: _

No	Section	Contents	Remarks
1.	Module to which the course belongs:		
	1.1. Module Title	Advanced Geostatistics	
	1.2. Type of Module	Hydrology and climate	
2.	Competencies		
3.	Course Type	Face-to-face, synchronous, home assignment Seminar, exercise and project paper	
4.			
	4.1. Course Code	WREM 8112	
5.	4.2. Credit Point in ECTS	7	

6.	Prerequisite	None	
7.	Course Description	The concept of regionalized variables; spatial correlation and geologic structure; auto-correlation and cross-correlation in space-time; variogram and cross-variogram; kriging and co-kriging; geostatistical simulation; applications of geostatistics to real world case studies related to groundwater, surface, and watershed hydrology The general technique of prediction is known as kriging. It requires a mathematical model to describe the spatial covariance, usually expressed as a variogram, which in its parameterized form has become the central tool of geostatistics. Successful kriging and estimation of the variogram depend on sampling adequately without bias and with suitable spatial configurations and supports. These differ somewhat from design-based estimation with its emphasis on random sampling. The aim of the course is to capacitate students how to characterize data those varies in space and/or time.	
8.	Learning Outcomes	Upon completion of the course students are expected to: ▶ Select and apply appropriate methods and tools to analyze geostatistical data	

		▶ Select and apply suitable visual and numerical interface to explore the spatial data set ▶ Select best model for sequence/auto-correlation data ▶ Use appropriate prediction tool and mechanism to population of the space Questions to be answered after completion of the course ▶ How a variable are spatial variables in space ▶ What are the derivers for the variability ▶ Which are the representative samples ▶ What is the characteristics of a variable at new (interpolated) location ▶ What is the uncertainty of the analysis, the interpolation, the model and the simulation	
9.	Course Contents	**Part I: Concept of Geostatistical analysis (10%)** 1. Concept of Geostatistics 1.1. The nature of earth science data 1.2. Statistical methods and temporal modeling 1.3. Deterministic nature of data 1.4. Limitations to different spatial analysis	

		2. History 2.1. 1950s and 1960s discoveries 2.2. Detection of variance as weighted moving average 2.3. The autocorrelation and variogram concepts 2.4. Geostatistical applications after 1980s 3. *Assignment (Literature review)* **Part II: Geostatistics and statistical considerations (15%)** 1. Definition of Geostatistics 2. Basic statistics consideration 2.1. Spatial vs temporal statistics 2.2. Random sampling and variables 2.3. Realization 2.4. Inferential statistics 2.5. Bias, uncertainty, stationarity 2.6. Distribution and probability functions 2.7. Bi-variate statistics 2.8. Trend and lag **Part III: Semivariogram analysis (25%)** 1. Variance, correlation and semi-variance 1.1. Variance and correlation 1.2. Semi-variance 2. Semi-variance modeling 2.1. Spherical 2.2. Guassian 2.3. Polynomial 2.4. Exponential	

		3. Lag and its determination 3.1. Negative autocorrelation 3.2. Different lad distances 4. Semi-variogram characteristics 4.1. Sill, nugget and range 4.2. Modeling with different lag, model, and characteristics 5. Direction 5.1. Isotropic and anisotropic 5.2. Transformation 6. *Exercise (Analytical based variogram and kriging analysis)* **Part IV: Kriging and Simulation (25%)** 1. Spatial geometry 1.1. Lag and angular tolerance 1.2. Bandwidth 2. Kriging 2.1. Distance algorithms 2.2. Different type of kriging (Simple, ordinary, universal, co-kriging, indicator) 3. Simulation 3.1. Methods 3.2. Sequential guassian simulation *4. Exercise with tutorial ArcGIS Geostatistics tool* **Part V: Geostatistics and Time application (10%)** 1. Spatial variables with time dimension 1. Hydrology and climate	

		2. Space-time aggregation 2. Methods 1. Time lag consideration and two dimensions 2. Modified variogram 3. Patched kriging and prediction 4. Models **Part VI: Hydrological application of Geostatistics (15%)** 1. Hydro-geostatistics concepts 1.1. Water balance components 1.2. Sampling and design 1.3. Data and randomization 1.4. Stochastic simulation 2. Methods 2.1. Intrinsic random functions 2.2. Multi-order moments 2.3. Fractal geometry 2.4. Nested metric structure	
10.	Teaching and learning techniques	1. Seminar and discussion 2. Reading assignments 3. Excel based analytical exercise to construct a variogram and kriging techniques 4. Exercise using ArcGIS Geostatistics tool	Map the interface between learning outcomes and identified teaching and learning techniques. Examine if the techniques can help students develop the learning outcomes/or competencies of the course.
11.	Assessments	Literature review: critics and power point presentation (group) = 30% Variogram and kriging prediction analysis using excel (Individual based) = 30% Project based (a topic related to student's own PhD) paper (Individual, Final exam) = 40%	Assessment requirements are clearly stated, along with due dates. Assignments and projects are announced in first class, along with guides and rubrics.

12.	Course Policy	Students will be oriented at the beginning of the module regarding attendance, classroom code of conducts, due dates of submission of assignments, cellphone use, plagiarism, discussion platforms	
13.	Learning Resources	**Course reference** 1. Webster, R. and Oliver, M.A. 2007. Geostatistics for Environmental Scientists, 2nd ed. John Wiley and Sons Inc. England **Reading resources** 1. Lyon, S.W., Seibert, J., Lembo, A.J., Walter, M.T., Steenhuis, T.S. 2006. Geostatistical investigation into the temporal evolution of spatial structure in a shallow water table. Hydrology and Earth System Sciences 10, 113-125. 2. Libertino, A., Allamano, P., Laio, F., Claps, P. 2018. Regional-scale analysis of extreme precipitation from short and fragmented records. Advances in Water Resources 112, 147-159 3. Baalousa, H. 2010. Assessment of a groundwater quality monitoring network using vulnerability mapping and geostatistics: A case stury from Heretaunga Plains, New Zealand. Agricultural Water Management 97, 240-246 4. Skoien, J.O. and Bloschl, G. 2006. Catchments as space-time filters – a joint spatio-temporal geostatistical analysis of	

		runoff and precipitation. Hydrology and Earth System Sciences 10, 645-662 5. Fisher, P. 1998. Improved modeling of elevation error with geostatistics. Geoinformatica 2:3, 215-233 6. Ly, S., Charles, C., Degre, A. 2013. Different methods for spatial interpolation of rainfall data for operational hydrology and hydrological modeling at watershed scale: a review. Biotechnol. Agron. Soc. Environ. 17 (2), 392-406.	
14.	Assessment rubrics (optional)[2]	Rubrics for the assessment of assignments	

Addis Ababa University

College/ Institute: TBD

Department: TBD

Program: PhD in Water Resources Engineering and Management (PhD in WREM)

Course Title: Advanced Numerical analysis and programming tools for water resources management

Year: One **Semester:** I

Instructor:

- Name:
- Contact information:
- Office hours:

No	Section	Contents
1.	Module to which the course belongs:	
	1.1. Module Title	Advanced Numerical analysis and programming tools for water resources management
	1.2. Type of Module	Engineering and programming
2.	Competencies	Computer programming, computational methods
3.	Course Type	The course is basically organized as a face-to-face approach in a classroom and in computer laboratories. In addition, the course has an e – learning platform to accomplish practical exercises. Communications & assignment submissions will be conducted through a course telegram groups.
4.	Course Identifiers	
	4.1. Course Code	WREM 8213

5.	4.2. Credit Point in ECTS	7
6.	Prerequisite	None
7.	Course Description	Designed to equip students with the essential programming skills needed to address various challenges in the field of water resources. Students will learn to navigate Python programming environments, using Jupyter notebooks. The curriculum covers fundamental programming concepts such as data types, variables, expressions, control flow, functions, loops, and file handling. Emphasis is placed on data manipulation using the Pandas library and data visualization with Matplotlib. Python programming language with application of water resources engineering and management where students will learn to develop own simple programs to solve equations governing flow and transport in the water environment. Students will gain understanding of both the numerical techniques needed to predict water flows and the underlying physical processes described by the mathematical equations.(Matrix, Time series data, graphs, plots and Network common data format (NetCDF) processing and handling).
8.	Learning Outcomes	After the module is completed, the participants would be able to: • Write Python code and handle errors • Explain basic concepts of object-oriented programming • Manipulate data types, variables, expressions, functions, and loops • Create Python programs that analyze and visualize hydrological data • Implement Python programs for hydrological applications and case studies • Perform data manipulation using libraries like Pandas • Create data visualizations using libraries like Matplotlib • Learn and apply common geospatial tools for NetCDF data analysis in Python • Create full-featured data visualizations for geospatial and 3D data

		• Gain experience in using relevant libraries and frameworks (e.g., NumPy, SciPy, Matplotlib in Python) to facilitate computational tasks and enhance productivity.
9.	Course Contents	Chapter 1: Introduction to Python Programming • Python syntax and fundamentals • Data types, variables, and expressions • loops • Functions and modules Chapter 2: Python Libraries for Data Analysis • Numpy for numerical and matrix computing • Pandas for data manipulation and analysis • Matplotlib for data visualization Chapter 3: Analyzing Hydrological Data with Python • Loading and preprocessing hydrological data • Performing exploratory data analysis • Visualizing hydrological data • Case studies in hydrological modeling Chapter 4: Geospatial (NetCDF) Analysis with Python • Introduction to geospatial data formats • Spatial data manipulation using libraries like Geopandas • Spatial data visualization and mapping • Integrating geospatial analysis with hydrological modeling

10.	Teaching and learning techniques	Teaching computational methods and computer programming effectively requires a blend of pedagogical strategies, practical exercises, and supportive resources. • Interactive Lectures • Hands-on Coding Exercises • Problem-Based Learning • Group Projects • Pair Programming • Online Discussion Forums • Cloud Computing and Big Data • e – learning
11.	Assessments	Assignments, programming (Lab), report and project
12.	Course Policy	Students will be oriented at the beginning of the module regarding attendance, classroom code of conducts, due dates of submission of assignments, cellphone use, and unacceptable behavior of plagiarism
13.	Learning Resources	**Core References:** Lin, J. (2022). An Introduction to Python Programming for Scientists and Engineers. Shen, C., Phanikumar, M. S., & Fang, Z. (2022). Modelling Hydrology, Hydraulics and Contaminant Transport Systems in Python. McKinney, W. (2017). Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython (2nd ed.) Kong, Q., Siauw, T., & Bayen, A. (2020). *Python Programming and Numerical Methods*. Academic Press. Shen, C., Phanikumar, M. S., & Fang, Z. (2022). Modelling Hydrology, Hydraulics and Contaminant Transport Systems in Python **Online Resources** https://www.w3schools.com/python/pandas https://www.digitalearthafrica.org/ https://pandas.pydata.org/pandas-docs/stable/
14.		

Addis Ababa University

Course Development Template

College: TBD

Department: TBD

Program: PhD in Water Resources Engineering and Management (PhD in WREM)

Course Title: Irrigation Systems Planning, Design and Analysis

Year ____First_____ Semester _____I_____

Instructor:

- Name:
- Contact information:
- Office hours:

No	Section	Contents	Remarks
1.	Module to which the course belongs:		
	1.1. Module Title	Irrigation Systems Planning, Design and Analysis	
	1.2. Type of Module	Engineering and programming	
2.	Competencies	Students will be able to: - make seamless planning of new irrigation systems considering multiple criteria - perform hydraulic design of gravity and sprinkler irrigation systems using state of the art approaches - apply various design tools and aids for irrigation systems designs	

		- evaluate the technical and financial soundness of irrigation system designs	
3.	Course Type	- This course is more of an engineering design course focused use of multi-criteria approaches for planning of technically sound irrigation systems, design as well as appraisal of irrigation system designs. Students will develop these skills through individual as well as group learning approaches. - The learning methods are mainly synchronous, but also consist of significant asynchronous elements (for self-study, individual assignments and exercises)	
4.	Course Identifiers		
	4.1. Course Code	WREM 8214	
5.	4.2. Credit Point in ECTS	7	
6.	Prerequisite	None	-
7.	Course Description	This course aims to equip students with the knowledge and skills required for technical and financial planning of new irrigation systems, and make a hydraulic design of technically sound components of all irrigation systems, and systems analysis. Students will delve into critical thinking for design and analysis of sustainable irrigation systems. The course will address deign of gravity as well as pressurized irrigation systems. The course will also focus on state of the art design and operation approaches for irrigation systems that are water efficient, thereby saving the water and reducing undesirable environmental effects. It will also address irrigation systems analysis (technical, environmental, social and financial). The course delivery will have brief lectures on selected topics. Substantial amount of time will be devoted for self	

		and group works on projects and case studies. Hands on exercises on case studies and examples will be the main part of this course. In general, both synchronous and asynchronous learning approaches will be employed in the course.	
8.	Learning Outcomes	After completion of this course, students will be able to: - Identify suitable irrigation systems for a given biophysical, environmental and socio-economic perspectives; - Plan new irrigation systems taking into consideration various factors; - Make a layout of technically sound irrigation system components (gravity and pressurized) - Analyze irrigation system layouts for technical and financial appraisal; - Perform a hydraulic design of irrigation systems using state of the art design approaches and tools; - Solve complex problems related to planning and design of irrigation systems; - Evaluate irrigation system plans and designs for technical soundness, financial viability, and environmental integrity; - Develop skills of team work to analyze and address problems in a group.	
9.	Course Contents	**1. Planning of irrigation systems** • Introduction to planning • Stages in irrigation systems planning • Selection of irrigation systems	

		• Water and land resources assessment for irrigation • Technical aspects • Socio-economic issues • Economic/financial viability of irrigation systems **2. Design and analysis of gravity irrigation systems** • Why gravity irrigation systems? • Requirements for gravity irrigation systems • Components of gravity irrigation systems • Layout of gravity irrigation systems • Technical and financial appraisal in irrigation system layout • Aids in gravity irrigation systems layout • Design criteria for various components of gravity irrigation systems • Design of irrigation headwork • Design and analysis of conveyance systems	

		• Design of flow control and regulation in irrigation **3. Surface irrigation systems design and analysis** • Why surface irrigation? • Water scarcity vs. surface irrigation • Requirements for surface irrigation • Infiltration and infiltration equations • Soil intake families • Surface irrigation hydraulics • Design of surface irrigation systems • Modelling and evaluation of surface irrigation systems **4. Design of pressurized and micro irrigation systems** • Why pressurized irrigation? • Pressurized irrigation components and layouts • Design considerations	

		• Evaluation of water sources and energy demands • Pressurized irrigation typologies and implications for design • Layout and design of sprinkler irrigation systems • Layout and design of micro irrigation systems • Household low pressure drip irrigation systems	
10.	Teaching and learning techniques	Generally active/cooperative learning approaches will be adopted. The teaching methods include lectures (virtual or face to face), group works, project works, case studies, field works and visits, individual studies, and researches. More time will be given for students to work individually and in a group on case studies, project works, as well as field work.	
11.	Assessments	The assessment techniques are: - Group projects, quick tests, individual project reports, field work reports, design appraisal reports, case study reports, research reports, and exams.	
12.	Course Policy	- Assignments need to be strictly submitted before the due date and time. - Students need to be cautious of the use of AI in individual and group assignments. Contents	

		generated from use of AI will be carefully assessed. - At least 80% attendance is mandatory for the face-to-face and virtual lecture classes - Students should not copy from each other on individual assignments and project works.	
13.	Learning Resources	- Phocaides, A. (2007). *Handbook on pressurized irrigation techniques*. Food & Agriculture Org. - Singh, V. P., & Su, Q. (2022). *Irrigation engineering: Principles, processes, procedures, design, and management*. Cambridge University Press. - Asawa, G. L. (2006). *Irrigation and water resources engineering*. New age international. - Ahmad, S., & Ajaz, A. (2019). Design and Operations Manual Pressurized Irrigation Systems Volume I. - Derrel, M. L., Gilley, J. R., & Baumer, O. W. (1993). Part 623: Irrigation. National Engineering Handbook.	References for the course
14.	Assessment rubrics (optional)[3]	- Both skill based and standards-based rubrics shall be adopted in assessing students. - Top achievers and bottom achievers will be assessed in each case and others accordingly marked for each assignment.	

Addis Ababa University

Course Development Template

College TBD

Department TBD

Program PhD in Water Resources Engineering and Management (PhD in WREM)

Course Title: __Advanced Water Resources Systems Analysis

Year _____First_____ Semester_____I

Instructor:

- Name:
- Contact information ____
- Office hours: __

No	Section	Contents	Remarks
1.	Module to which the course belongs:		
	1.1. Module Title	Advanced Water Resources Systems Analysis	
	1.2. Type of Module	Hydrology and climate	
2.	Competencies	The module helps participants to have proficiency in systems analysis and optimization techniques, understanding of economic and financial evaluation principles, and skills in water management. Students also develop competencies in decision-making under uncertainty, integrated water resources	

		management, stakeholder engagement, and the use of software tools for modeling and solving complex water resource problems	
3.	Course Type	Face-to-face, synchronous	
4.	Course Identifiers		
	4.1. Course Code	WREM 8121	
5.	4.2. Credit Point in ECTS	7	
6.	Prerequisite	None	
7.	Course Description	In summary, water resources planning, and management integrates engineering, science, economics, policy, and stakeholder engagement to ensure reliable, equitable and sustainable management of this critical resource. Graduate programs typically include coursework in hydrology, water resources systems analysis, water law and management, and project assessment. The course will use a combination of lectures, case studies, and hands-on exercises to reinforce the concepts and their practical applications. Students will work on a term project that applies the techniques learned in class to a real-world water resources problem. By the end of the course, students will have a solid understanding of the systems approach to water resources planning and management and the ability to apply various optimization and evaluation techniques to support sustainable and equitable decision making	
8.	Learning Outcomes	After the module is completed, the participants would be able to: • Understand and explain the fundamental concepts of systems and systems analysis.	

		• Apply classical optimization techniques and the Lagrangian approach to solve nonlinear programming problems relevant to water resource management. • Formulate real-world water resource issues as linear programming problems and solve them using the simplex method. • Analyze multi-stage decision processes and apply dynamic programming techniques to optimize solutions for water resource management challenges. Apply varieties of instructional methods of teaching in the courses they offer. • Familiar and effectively use software tools such as Excel Solver, MATLAB, and Python to model and solve optimization problems in water resources. • Effectively utilize water resources optimization software to develop, analyze, and implement models that address complex water management challenges.	
9.	Course Contents	Unit1. Concept of System and Systems Analysis (10%) 1.1 Concept of water system analysis Unit 2 Optimization Using Calculus (Nonlinear programming) (15%) 2.1. Classical optimization 2.2. Langrangian approach Unit 3. Linear Programming (15%) 3.1. Formulation and application 3.2. Simplex method 3.3. Duality Unit 4. Dynamic Programming (15%) 4.1. Multi-stage decision processes 4.2. Computational procedure 4.3. Application examples Unit 5. Modelling System or Water resources optimization software (20%)	

		5.1. Excel Solver 5.2. MATLAB 5.3. Python to model and solve optimization problems in water resources Unit 6. Software Seminar (25%) 6.1. participants of the course will be given different topics, and each will make a presentation	
10.	Teaching and learning techniques	The methodological approaches to be followed in this module pay particular attention to learner engagements. The approach generally models the type of teaching methods that the module promotes and there will be no negotiation on that. Under this general direction, here are a few suggestions: • Instructor(s) presentation using interactive methods (brainstorming, question and answer, mind mapping, small group discussion, buzz groups, etc.) • Independent learning methods such as reading assignments, article reviews, group project works, classroom visits in campus and presentation of reports will be submitted. • Any other methods the instructors consider important for learner engagement will be employed.	
11.	Assessments	Both Continuous and summative assessments will be employed using various forms of instruments that help assess the expected learning outcomes. Thus, final examination, projects and presentations, group works, debates and case studies, research reports, designing courses, lesson planning, and other individual tasks will be applied as appropriate to the experiences of students and departments. Furthermore, assessment requirements will be clearly stated with due date. Assignments and projects will be announced on first class with guides and rubrics. *If the general pedagogy instructor handles the module, the tasks and values of the tasks will be revised.	

		Assignments, Project, Test, and report and presentation	
12.	Course Policy	Students will be oriented at the beginning of the module regarding attendance, classroom code of conducts, due dates of submission of assignments, cellphone use, and unacceptable behavior of plagiarism *At least 80% attendance is mandatory for the face-to-face and virtual lecture classes	
13.	Learning Resources	1. S. Vedula and P.P Mujumdar (2005). Water Resources systems analysis. 2. Loucks, D. P., J. R. Stedinger, and D. A. Haith. (1981). Water Resource Systems Planning and Analysis. 3. Mimikou, M., Baltas, E., & Tsihrintzis, V. (2020). Hydrology and Water Resource Systems Analysis. 4. Karamouz, M., Szidarovszky, F., & Zahraie, B. (2003). Water Resources Systems Analysis (Water Resources Systems Analysis Using MATLAB) 5. Hatarilabs. (2024). Diploma in Python for Water Resources and Geoscience (https://hatarilabs.com/ht-en/diploma-in-python-for-water-resources-and-geoscience-asynchronous) 6. Jain and Singh (2006) Water Resources Planning and Management.	

		7. Floudas, C., Pardalos, P. (eds) Optimization in Water Resources. 8. Loucks, D.P., Stedinger, J.R., & Haith, D.A. (1982). Water Resources Systems Planning and Analysis. Prentice Hall Inc. 9. Chaturvedi, M. (2016). Water Resources Systems Planning and Management. Lecture Notes, Veer Surendra Sai University of Technology.	
14.	Assessment rubrics (optional)[4]	- Both skill based, and standards-based rubrics shall be adopted in assessing students. - Top achievers and bottom achievers will be assessed in each case and others accordingly marked for each assignment	

Addis Ababa University

Course Development Template

College: TBD

Department: TBD

Program: PhD in Water Resources Engineering and Management (PhD in WREM)

Course Title: Graduate Seminar

Year _____I_____ Semester ____II_____

Instructor:

- Name:
- Contact information
- Office hours:

No	Section	Contents	Remarks
15.	Module to which the course belongs:		
	1.1. Module Title	Graduate Seminar	
	1.2. Type of Module	Research and Seminar	
16.	Competencies	Graduate seminar course helps to deeply engage students into in the discipline of water resources engineering and management, promote critical thinking and in depth analyses about related subjects. Moreover, students will also be exposed to exploring and learning about a range of research methods that are relevant and commonly applied in the field. The students will also be able to identify researchable problems and the various disciplinary issues associated with their seminar topics, as well suggested frameworks and tools that they need to know in the field of WREM.	
17.	Course Type	Lectures, Seminar, Essays, Academic writing	

18.			
	4.1. Course Code	WREM 8324	
19.	4.2. Credit Point in ECTS	5	
20.	Prerequisite	None	
21.	Course Description	In this course students will have the opportunity to actively work on reading, exploring, inquiring and writing a review and summary of scientific papers/literature on specific areas of their preference. Students will develop skills in reviewing articles and presenting it in a summarized form, and co-learning between students will be enhanced. Through providing more attention and exercising time for reading academic literatures of various types and scrutinizing how the contents are interrelated to each other and the subject of interest, participants gain experience in critically thinking about their subjects, finding key messages of science communications, and ultimately advance their knowledge of research in the field. Moreover, student will also be guided to presenting and engaging in discussions with each other about the topics they have explored through reading. The presentations and discussions enable the students to gain more experience and confidence in communicating knowledge and information on complex scientific topics in their field. In addition, as part of the progressive learning process, the students will also prepare an academic essay and/or	
22.	Learning Outcomes	After the module is completed, the students would be able to: ▪ Identify researchable and relevant research issues related to EFL and assess what has been done in the area and defend the worth of the issue; ▪ The students will learn on commonly applied research methods, what should be the content of a research report, what should come as different elements of the report, as well as ethical considerations. ▪ The students will be able to analyze, organize, and objectively evaluate information presented in the academic writings and scientific literature.	

		▪ The students will practice and gain experience to easily understand and critically evaluating other students' work, such that they will engage more into scientific discussions with the academic community. ▪ The students will gain more experience in identifying best methods and implement them for planning, developing and communicating scientific information in their area of research interest. They will develop skill in making quality scientific presentation in a way that is appropriate and relevant to varied types of audiences.	
23.	Course Contents	**Unit 1- Introduction to Graduate Seminar** 1.1. Basic concepts 1.2. Defining purposes, interdisciplinary considerations 1.3. Types and categories of scientific papers 1.4. Techniques of articles review - Grasping the concepts 1.5. Science communication **Unit 2– written report on the summary of each paper** 2.1 Selection of topic of interest, quick scanning of contents and areas of research 2.2 An in depth reading and identification of focus of the paper 2.3 Summarization, categorization in terms of methods and type of article, analysis and key messages, limitations and critiques, and comparison and contrasting. 2.4 The use of existing science knowledge (literature) - theories, ideas, and research relevant to the subject area of the article. **Unit 3- Presentation on reviewed articles/Seminar** 3.1 Principles of good presentation and research communication 3.2 Elements of a seminar topic 3.3 Lead a discussion on the research topics reviewed 3.4 Provide a brief introduction that places the readings in context,	

		3.5 Then give detailed summary of the papers you reviewed, support them with examples, and questions to facilitate interactive discussions **Unit 4- Research methods** 4.1 Concepts and elements of a research proposal 4.2 Concepts and elements of a research article o Abstract, background and context setting, methodology, results, discussion and conclusion. 4.3 Development and application of frameworks and tools for analyzing data/information 4.4 Types of research papers 4.5 Review and publication process 4.6 Ethical considerations **Unit 5 - Research concept note development and Academic Essay writing** 5.1 Exploring research interest: what possible domains and questions you might be interested in. 5.2 Formulating a topic or a particular sets of research questions that you want to investigate according to your identified research interest 5.3 Write an introduction – a back ground and theoretical framing into context of what you would like to research on 5.4 Develop a methodology to carry out the research 5.5 Describe kinds of possible results, expected key findings 5.6 Identify multi-level target audiences 5.7 Explore multiple ways of communications o Preparing oral presentations o Preparing posters and visualizations o Conferences and press releases	
24.	Teaching and learning techniques	The methodological approaches to be followed in this module pay particular attention to learner engagements. The approach generally models the type of teaching methods that the module promotes and there will be no negotiation on that.	

		Under this general direction, here are a few suggestions: • **Team teaching** approach between student and subject area method instructors(if any) • **Instructor(s) presentation** using interactive methods (brainstorming, question and answer, mind mapping, small group discussion, buzz groups, etc.) • **Independent learning methods** such as reading assignments, article reviews, group project works, classroom visits in campus and presentation of reports will be submitted • Any other methods the instructors consider important for learner engagement will be employed.	
25.	Assessments	Both continuous and final assessments will be employed using various forms of instruments that help assess the expected learning outcomes. Continuous assessment will be based on: • Paper reviews – written summary reports • Presentations, leading and facilitating discussions • Subjective learning advancement, active participation, the energy and enthusiasm that the student puts in the leaning process, • Participation in discussions and exertion in leading discussions Final assessment will be based on: • Final paper: academic essay/proposal/article writing o The quality of the writing of the final paper • Presentation of the final paper: The depth and extent of the students' engagement with the research of the topic of their final paper.	
26.	Course Policy	Students will be oriented at the beginning of the module regarding attendance, classroom code of conducts, due dates of submission of assignments, email communications, and unacceptable behavior of plagiarism	
27.	Learning Resources	- Biggs, R., De Vos, A., Preiser, R., Clements, H., Maciejewski, K., & Schlüter, M. (2021). The Routledge handbook of research methods for social-ecological systems: Taylor & Francis.	

		- Davis, M., Davis, K. J., & Dunagan, M. (2012). Scientific papers and presentations: Academic press. - Hanganu-Bresch, C., Zerbe, M. J., Cutrufello, G., & Maci, S. (2022). The Routledge Handbook of Scientific Communication: Routledge. - Inyang, H. I. (2022). Guidebook on scientific writing with a focus on the water sector: UNESCO Publishing. - Jones, J. C. (2015b). Concepts In Scientific Writing. 1st edition © 2015 J. Cliford Jones & bookboon.com. ISBN 978-87-403-1091-7. In. - Mishra, S. B., & Alok, S. (2011). Handbook of research methodology. - Tsatsenko, Natalia (2021) Academic writing: guidelines for preparing a seminar paper with examples. OPUS Siegen. doi.org/10.25819/ubsi/9890 - Norback, J. S. (2022). Oral communication excellence for engineers and scientists. Springer Nature. - Pandey, P., & Pandey, M. M. (2021). Research methodology tools and techniques: Bridge Center. - Sayer, E. J. (2019). The essentials of effective scientific writing–A revised alternative guide for authors. In (Vol. 33, pp. 1576-1579). - (Davis, Davis, & Dunagan, 2012; Hanganu-Bresch, Zerbe, Cutrufello, & Maci, 2022; Norback, 2022; Sayer, 2019)	

28. Assessment rubrics (optional)[5]

Learning tool	**Category**	**Total mark (%)**
1. Review articles – summary reports	At least two	20
2. Oral presentation of the review articles	Two	15
3. Facilitation/session moderating	one	10
4. Final paper: essay/proposal/article writing	One - final	30
5. Poster presentation	One	15
6. Final paper presentation	One – final	10
Total		**100**

Addis Ababa University

Course Development Template

College TBD

Department TBD

Program PhD in Water Resource Engineering & Management

Course Title: PhD Dissertation

Year II-IV Semester I – II

Instructor:

- Name: _____
- Contact information _____
- Office hours: _____

No	Section	Contents	Remarks
1.	Module to which the course belongs:		
	1.1. Module Title	PhD Dissertation	
	1.2. Type of Module	Research and Seminar	
2.	Competencies	The module helps participants develop the ability to critically understand applied research from the inception up to the dissemination. Students develop and plan research, conduct data collection, analysis, and interpret data scientifically. Follow the writing techniques, present and publish findings. Finally, defend the research work in a panel of experts also to the public.	
3.	Course Type	The course will be conducted by students by themselves with close supervision. However, it will have laboratory work, field data collection, or similar	

4.	Course Identifiers		
	4.1. Course Code	WREM – 9321	
5.	4.2. Credit Point in ECTS	180	
6.	Prerequisite	PhD Proposal	
7.	Course Description	PhD student will work on their PhD dissertation by designing and developing research ideas and methods to achieve considerable contributions in the field of study. Students work individually with the guidance of their supervisors and prepare a dissertation to be defended in public. In conformity with AAU legislation, parts of dissertation work should be published in peer-reviewed and acceptable journals before public presentation.	
8.	Learning Outcomes	After the module is completed, the participants will be able to: • plan and design data collection and analysis techniques • write research findings and present them to the community • publish the findings in journals • contribute knowledge to the field of study	
9.	Course Contents	None	
10.	Teaching and learning techniques	A main supervisor will be assigned so that to assist in all aspects of the thesis work. He/she should be in the areas of the research topic and has extensive experience in the research and in advising students. One or two co-supervisors are also assigned to assist the main supervisors in different aspects of the research.	
11.	Assessments	The main supervisor and also the co-supervisors frequently evaluate the progress of the research against the research action plan. Furthermore, at least two time per year, the students should present to the public to assess his/her performance. The result of the performance assessment can be a fail/pass grade. Successive failure on the progress track will potentially be terminated to the study	

12.	Course Policy	Students will be oriented at the beginning of the module by his/her main supervisor about the research ethics, meeting schedule, frequent performance evaluation, and the deadline to finalize the study as per AAU senate regulations.	
13.	Learning Resources	It varies based on the research type	
14.	Assessment rubrics (optional)[6]		

Elective Courses for PhD in WREM

Addis Ababa University

Course Development Template

College TBD

Department TBD

Program PhD in Water Resources Engineering and Management (PhD in WREM)

Course Title: Advanced Stochastic Hydrology

Year One Semester II

Instructor:

- Name:
- Contact information
- Office hours:

No	Section	Contents	Remarks
1.	Module to which the course belongs:	Hydrology	
	1.1. Module Title	Advanced Stochastic Hydrology	
	1.2. Type of Module	Hydrology and climate	
2.	Competencies	• Competences in understanding about the occurrence and severity of floods and droughts, which are critical for water resources management. • Develop skills and knowledge on techniques for analyzing hydrological data over time, including trends, seasonality, and variability.	

		• Acquire knowledge by using probability concepts to quantify uncertainty in hydrological models. • Competence in applying techniques for estimating model parameters from observed data to fit particular probability distribution and estimation of flood quantiles.	
3.	Course Type	-Face-to-face lecture -Seminar/peer learning -Assignment (group and individual based) -Review articles relevant to the course	
4.	Course Identifiers		
	4.1. Course Code	WREM 8122	
5.	4.2. Credit Point in ECTS	7	
6.	Prerequisite	None	
7.	Course Description	The course introduces students to statistical methods used in hydrology for data analysis, risk and uncertainty assessment, and simulation. The course is designed to understand statistical description of hydrological data, flood frequency analysis and estimation methods of parameters for quantile estimation of rainfall and streamflow. Testing statistical hypothesis, analysis of extreme hydrological events and regionalization, drought and Low flow analysis, which are essential to address critical water challenges (droughts and floods). Reservoir withdrawal and capacity determination, time series analysis and modeling of selected stochastic processes, random, autoregressive and moving average processes (AR, MA and ARMA Models) are discussed in more detail in the course. These are part of the major concepts, which discussed in this course mainly to generate data and to perform forecasting and to make decisions about the water resources now and future time horizon.	

8.	Learning Outcomes	• Apply relevant statistical methods to answer hydrology-related research questions. • Demonstrate a thorough understanding and application of probability theory to stochastic random processes. • Make decisions: both design and operational decisions in water resources system. • Students to know how the methods of determining the various decisions on water resources systems. • Gain insight into random variables and their probability density and cumulative distribution function. • Understand and apply data generation and forecasting techniques for water resources decision making. • Recognize and enhanced understanding about statistical methods and their application in hydrological variables. • Apply time series analysis and modelling for the stochastic random processes in hydrological data. • Apply risk based hydrologic design, which accounts for non-stationarity and climate change in the design of resilient water resources infrastructure. • Apply stochastic streamflow simulation for management of water resources under uncertainty.	
9.	Course Contents	**Part I: Advanced Stochastic Hydrology**	

		Unit1. Introduction (5%) 1.1 Stochastic and deterministic model comparison. 1.2 Typical water resources system 1.3 Area of application of stochastic hydrology. 1.4 Random variables in hydrology. .5 Discrete and continuous random variables in hydrology .6 Probability distribution and cumulative distribution .7 Probability mass function for discrete variables and probability density function for continuous random variable. .8 Mixed distribution **Unit 2 Bivariate distributions in Hydrology (10%)** 2.1. Probability distribution of two variables 2.2. Discrete two-dimensional random variable 2.3. Joint probability density function of two random variables 2.4 Joint cumulative density function of two random variables 2.5 Marginal probability distribution 2.5.1 Marginal density function for discrete random variables 2.5.2 Marginal density function for continuous random variables 2.6 Conditional distribution **Unit 3. Moment of a distribution (5%)** 3.1 Measure of central tendency	

		3.2 Measure of spread or dispersion 3.3 Measure of symmetry 3.4 Measure of peakdness **Unit 4. Commonly used distribution in Hydrology (15%)** 4.1. Frequency distributions in hydrology 4.2 Standard Normal variate 4.2. Normal distribution 4.2 Log-Normal distribution 4.3 Gamma distribution 4.4 Exponential distribution 4.5 Extreme value distributions (type I, II, and III) 4.6 Parameter estimation of a distribution 4.6.1 Method of Moment 4.6.2 Probability weighted moment 4.6.3 Maximum likelihood **Unit 5. Covariance and correlation of random variables in hydrology (5%)** 5.1. Covariance 5.2 Correlation coefficient 5.3 Covariance and correlation of rainfall and runoff **Unit 6. Data Generation (10%)**	

		6.1. Importance of data generation and application area 6.2. Statistical regularity of flows 6.3 Trends and variabilities consideration in data generation **7. Time series Models (50%)** 7.1. Time series analysis 7.1.1 Discrete and continuous time series 7.1.2 Stochastic and deterministic component in time series 7.1.3 Time series, realization, ensemble, and ergodic process 7.1.4 Stationary and strictly stationary time series 7.1.5 Auto correlation and auto-covariance in time series 7.1.6 Data generation and forecasting 7.1.7 Data generation for serially correlated and uncorrelated data pectral analysis or frequency domain analysis in hydrology 2.1 Periodicity in time series 2.2 Spectral density 2.3 Line density and power spectrum 2.4 Power spectrum-Fourier cosine transform of auto covariance function uto Regressive Integrated Moving average model (ARIMA) 3.1 Regression and auto-regressive model 3.2 Partial auto-correlation of order 1 and 2 3.3 Differencing in ARIMA model	

		3.4 Operator 'B' in ARIMA model Box and Jenkins model 4.1 Identification of the model structure 4.2 Parameter estimation and calibration 4.3 Model testing and validation allotment: • Lecture hrs 3*16=48hrs • Lab---Not applicable • Fieldwork ----Not applicable • Self-study 5.44*16=87hrs	
10.	Teaching and learning techniques	The methodological approaches to be followed in this module pay particular attention to learner engagements. The approach generally models the type of teaching methods that the module promotes and there will be no negotiation on that. Under this general direction, here are a few suggestions: • **Face to face lecture:** Instructor are obliged to deliver the course in class room. In the process of teaching-learning, students are encouraged to ask question and interact on the topics. • **Student centered learning**: Some of the theoretical concept in the course given to the students to learn as a peer learning methodology. Instructor will follow-up their understanding through oral presentation in the class room.	

		• **Seminar:** For selected units, semester-based seminar is prepared by the instructor to be presented by the students. The seminar work can be done individual or in a form of group work. • **Individual and group assignments**: to enhance and deepen the student knowledge and skill, for each unit assignments are given to the students. Some of the assignments are organized to be presented in class room. This is anticipated to strengthen their communication skill and sharing knowledge to their colleague. • **Communication and networking:** Communication and networking is an essential component of the teaching and learning processes. In this course students and instructor are communicated via digital communication to share lecture notes, lecture materials, assignments and any relevant data e.g. telegram. Students are encouraging to exchange ideas and make debate on the subject matter through virtual media.	
11.	Assessments	Four types of assessments along with the percentage of mark distribution are set for this course. • Article review on methods of parameter estimation using frequency distributions oral presentation and written synthesized literature review (10%). **(Due date end of third weeks, since class begin).** • Group-Assignment on fitting frequency distribution of streamflow and rainfall for Ethiopian river basins (20%). **(Due date end of eight weeks, since class begin).** • Individual assignment on data generation and time series model (20%). **(Due date end of fourteen weeks, since class begin).** • Final examination (50%) **(Due date based on the academic calendar set by the AAU).**	

12.	Course Policy	Students will be oriented at the beginning of the module regarding attendance, classroom code of conducts, due dates of submission of assignments, cellphone use, and unacceptable behavior of plagiarism.	
13.	Learning Resources	**References** 1. Haan, C.T., "Statistical Methods in Hydrology", First East-West Press Edition, New Delhi, 1995. 2. Bras, R.L. and Rodriguez-Iturbe, "Random Functions and Hydrology", Dover Publications, New York, USA, 1993. 3. Clarke, R.T., "Statistical Models in Hydrology", John Wiley, Chinchester, 1994. 4. Yevjevich V. "Probability and statistics in Hydrology" , Water Resources Publications, Colorado, 1972. 5. Ang, A.H.S. and Tang, W.H., "Probabilistic concepts in Engineering Planning Design", Vol. 1, Wiley, New York, 1975.	
14.	Assessment rubrics (optional)[7]	• In all mode of assessments, the following points will be considered. • Assignments should be clearly reported to the instructor on due dates. • Plagiarism act will lead to a reduction of mark depending on plagiarism checker tool. • Students have the freedom to review and discuss their results prior to the official release of final grades. • Assignments will be assessed based on the weight provided in assessments part.	

Addis Ababa University

Course Development Template

College: TBD

Department: TBD

Program: PhD in Water Resources Engineering and Management (PhD in WREM)

Course Title: Advanced Hydraulic Structures

Year: Year I Semester: Semester II

Instructor:

- Name:)
- Contact information:
- Office hours: _____

No	Section	Contents	Remarks
1.	Module to which the course belongs:		
	1.1. Module Title	Advanced Hydraulic Structures	
	1.2. Type of Module	Engineering and programming	
2.	Competencies	To develop a better understanding of the advanced methods of design of concrete dams and assessing safety measures to protect dam appurtenant structures subjected to high velocity and high-pressure flows. The student will understand the design principles of special hydraulic structures such as bridges and culverts. They will also be able to develop competence to suggest the remedial measures for assuring the safety of the hydraulic structures subjected to cavitation and water hammer phenomenon	

3.	Course Type	The course is given in a face-to-face type of delivery, i.e., lectures. Its assessment comprises of class exercises, assignments/projects and final exam	
4.			
	4.1. Course Code	WREM 8223	
5.	4.2. Credit Point in ECTS	7	
6.	Prerequisite	None	
7.	Course Description	The course focusses on advanced methods of analysis of concrete gravity and arch dams. Cavitation is one of the phenomena that affects hydraulic structures subjected to high velocity flows such as outlets, spillways and energy dissipators. In this course, the method of analysis as well as prevention from cavitation damages and remedial measures are incorporated. Penstocks and their accessories, such as anchor blocks, slide and thrust blocks and their design are covered. In addition, penstocks are subjected to high heads which leads to water hammer pressure during power plant operation. These surges are considered and analysis and preventive measures are done by designing a surge tank of appropriate type and size. Design of Special hydraulic structures such as bridges and culverts are also dealt with in good detail.	
8.	Learning Outcomes	Upon completion of the course students are expected to: ▪ Conduct design and analysis of concrete dams applying modern and advanced analysis methods (e.g., FEM). ▪ Describe the effect of high velocity flow and occurrence of cavitation in the design of hydraulic structures, especially spillways and energy dissipators. ▪ Be able to design various cavitation protection measures, including design of aerators.	

		▪ Explain the fundamental physics of water hammer, and the application of mathematical techniques to analyze water hammer events (i.e. wave speed calculations, and pressure rise); ▪ Be able to design surge tanks for the protection of the conveyance system (tunnels and pipes/conduits) from water hammer pressure. ▪ Describe and design special hydraulic structures such as bridges and culverts, ▪ Calculate hydraulic capacity, size of waterways and conduct hydraulic design bridges and culverts.	
9.	Course Contents	**Chapter I: Advanced Methods of Concrete Dam Analysis (25%)** 1.1.Concrete Gravity Dams 1.1.1.Trial Load Analysis 1.1.2.Finite Element Analysis 1.2.Concrete Arch Dams 1.2.1.The Elastic Theory 1.2.2.Trial Load Analysis 1.2.3.Finite Element Method (FEM) **Chapter II: Cavitation and Air Entrainment in Hydraulic Structures (30%)** 2.1.Cavitation in Spillways and Energy Dissipators 2.1.1.Cavitation index 2.1.2.Cavitation damage 2.1.3.Cavitation on spillway surfaces 2.1.4.Cavitation in energy dissipators	

		2.1.5.Prevention of cavitation in spillways and energy dissipators 2.1.6.Remedial measures and repairs 2.2.Air Entrainment and Forced Aeration 2.2.1.Air entrainment on spillways 2.2.2.Location of point of inception 2.2.3.Effect of entrained air on stilling basin performance 2.2.4.Forced aeration 2.2.5.Mechanism of aeration 2.2.6.Design of an aerator system *2.3.Chapter Examples and Exercises* **Chapter III: Design of Hydropower Conveyance and Accessory Structures (25%)** 3.1.Penstock and Accessories 3.1.1.Design Criteria for Penstocks 3.1.2.Penstock Supports 3.1.3.Surges in Pipes/Penstocks 3.2.Water Hammer in Pipes and Penstocks 3.2.1.Rigid Water Column Theory of Water Hammer Analysis 3.2.2.Elastic Method of Water Hammer Analysis 3.2.3.Design of Surge Tanks *3.3.Chapter Worked Examples and Exercises* **Chapter IV: Hydraulic Design of Bridges and Culverts (20%)**	

		4.1. Hydraulic Design of Bridges 4.1.1. Design Considerations 4.1.2. Linear Waterway of a bridge 4.1.3. Scour depth computation 4.1.4. General Principles of hydraulic design *4.2.* Hydraulic Design of Culverts *4.3. Worked Examples and Exercises*	
10.	Teaching and learning techniques	The course is given in a face-to-face type of delivery, i.e., lectures. ▪ After lecture of each chapter is completed, chapter examples are done; ▪ Chapter exercises/assignments are given to students to be submitted on deadlines; ▪ Projects in the form of literature review and design assignments are given to students; ▪ Finally, the course is concluded by final examination and its assessment.	
11.	Assessments	Both Continuous and summative assessments will be employed using various forms of instruments that help assess the expected learning outcomes. Thus, three exercise-based assignment, one literature review individual assignment, and final examination covering the entire chapters comprising of both concept and computational problems. The literature review and exercise assignments are done individually. Assignments and will be given at the end of each chapter and the deadline of submission is announced at the same time.	
12.	Course Policy	Students will be oriented at the beginning of the module regarding attendance, classroom code of conducts, due dates of submission of	

		assignments, cellphone use, unacceptable behaviour of plagiarism, and punctuality	
13.	Learning Resources	1.	
14.	Assessment rubrics (optional)[8]	Rubrics for the assessment of assignments	

Addis Ababa University

Course Development Template

College: TBD

Department: TBD

Program: PhD in Water Resources Engineering and Management (PhD in WREM)

Course Title: Hydrological Measurement

Year Two Semester One

Instructor:

- Name:
- Contact information
- Office hours:

No	Section	Contents	Remarks
1.	Module to which the course belongs:		
	1.1. Module Title	Advanced Hydrological Measurement Technique	
	1.2. Type of Module	Hydrology and climate	
2.	Competencies	Critically understand hydrological measurement techniques, expertise in integrating data with hydrological models, ability to interoperate and apply model out puts for water resource management, and hands-on experience with field work and data analyses.	
3.	Course Type	This course includes in-person lectures, practical sessions, and on-site fieldwork. Students will have the opportunity to interact directly with	

		instructors and classmate in a classroom environment, participate in hands-on activity, and undertake field work research to enhance their understanding of hydrological measurement techniques.	
4.	Course Identifiers		
	4.1. Course Code	WREM 8125	
5.	4.2. Credit Point in ECTS	7	
6.	Prerequisite	None	
7.	Course Description	This course offers a comprehensive exploration of hydrological measurement techniques, which are crucial for the effective understanding, modeling, and management of water resources. It begins with a detailed study of the fundamental principles underlying hydrological measurements, including stage-discharge relationships that are essential for monitoring river flows and predicting flood events. Students will also delve into the measurement of soil hydrology, focusing on the methods used to assess soil moisture contents and infiltration rates, which are vital for understanding ground water recharges and managing agricultural water use. Evaporation measurement techniques, such as the use of pan evaporation and lysimeters, will be covered to provide insights into the processes that control the loss of water to the atmosphere, a key component in the water balance of any ecosystems. A significant portion of the course is dedicated to the integrations of hydrological measurements into hydrological modeling. Students will learn how to use measurements data to calibrate and validate models, which are essential for simulating water flow, predicating the impacts of climate change, and managing water resources under varying scenarios. The course will also cover the interpretations of model outputs, helping students develop the skill to use models for decision-making in water management, flood risk assessment, and drought mitigations	

		By combining theoretical knowledge with practical field and data analysis exercises, this course equips students with the comprehensive skill set needed to accurately assess and model hydrological parameters in diverse environmental settings. This preparation is crucial for those aspiring to careers in water resources management, environmental consulting, research, and beyond.	
8.	Learning Outcomes	Upon completion of the course students are expected to: □ Demonstrate understanding of hydrological principles including stage-discharge relations, soil hydrology, and evaporation. □ Apply appropriate instruments and methods for collecting, calibrating, and analyzing hydrological data in various environment settings. □ Utilize measurement data to calibrate, validate, and simulate hydrological models, and effectively predict water resource dynamics under different □ Analyze and interpret the outputs of hydrological models to make informed decisions in water management, flood risk assessment, and drought mitigation.	

9.	Course Contents	**Chapter One: Introduction to hydrological Measurements** 1.1. Overview of hydrological systems 1.2. Key Concepts in hydrology **Chapter Two: Instrumental and Data Collection Techniques** 2.1. Instrumentation in hydrology 2.2. Data collection and quality management 2.3.Remote Sensing and GIS application techniques in hydrology **Chapter Three: Stage-Discharge Relationships** 3.1. Understanding the principles of stage-discharge relationships. 3.2.Method for measuring and calculating discharge. 3.3.Applications in Hydrological monitoring and Management. **Chapter Four: Soil Hydrology** 4.1. Measurement of soil moisture and infiltration rates. 4.2. Assessment of soil hydrological properties 4.3.Implications for Groundwater Recharge and Agricultural **Chapter Five: Evaporation Measurement Techniques** 5.1. Methods of Measuring Evaporations. 5.2.Factors Influencing Evaporation Rates. 5.3. Role of Evaporation in Water Balance and Resource Planning **Chapter Six: Introduction to Hydrological Modelling** 6.1. Overview of hydrological models, and their applications 6.2. Types of Hydrological Models	

10.	Teaching and learning techniques	The methodological approaches to be followed in this course pay particular attention to learner engagements. The approach generally models the type of teaching methods that the course promotes and there will be no negotiation on that. Under this general direction, here are a few suggestions: • Lecturer and seminars Deliver core concepts and theoretical knowledge through lecture and interactive seminars. • Interactive Learning Tools Incorporate interactive tools, such as GIS and remote sensing software, to enhance understanding and engagement. • Simulation and Modelling exercises Use simulation tools and modeling software to provide hands-on experience in hydrological modeling and analysis.	
11.	Assessments	Both continuous and summative assessments will be utilized through various instruments that help assess the expected learning outcomes. This includes an individual assignment, a group literature review assignment including presentation, and a final examination. The literature review and presentation will be conducted both individually and groups, while other assignments will be completed individually. Details for all assignments and projects will be provided in the first class, along with guidance.	
12.	Course Policy	Students will be oriented at the beginning of the module regarding attendance, classroom code of conducts, due dates of submission of assignments, cellphone use, plagiarism, discussion platforms	
13.	Learning Resources	1. Manning, J.C., 2016. Applied principles of hydrology. Waveland Press. 2. Brooks, K. N., Ffolliott, P. F., & Magner, J. A. (2012). Hydrology and the Management of Watersheds. John Wiley & Sons. 3. Robinson, D. A., Campbell, C. S., Hopmans, J. W., Hornbuckle, B. K., Jones, S. B., Knight, R., ... & Wendroth, O. (2008). Soil moisture measurement for ecological and hydrological watershed-scale observatories: A review. Vadose zone journal, 7(1), 358-389.	

<table>
<tr><td></td><td></td><td>4. Holmes, J. W. (1984). Measuring evapotranspiration by hydrological methods. Agricultural Water Management, 8(1-3), 29-40.
5. Devia, G. K., Ganasri, B. P., & Dwarakish, G. S. (2015). A review on hydrological models. Aquatic procedia, 4, 1001-1007.
6. Skoien, J.O. and Bloschl, G. 2006. Catchments as space-time filters – a joint spatio-temporal geostatistical analysis of runoff and precipitation. Hydrology and Earth System Sciences 10, 645-662</td><td></td></tr>
<tr><td>14.</td><td>Assessment rubrics (optional)[9]</td><td>Assignment Rubric
<table>
<tr><td>Criteria</td><td>Excellent (5)</td><td>Good (4)</td><td>Fair (3)</td><td>Poor (2)</td><td>Unsatisfactory (1)</td></tr>
<tr><td>Understanding</td><td>Thorough and insightful</td><td>Good with minor Gaps</td><td>Basic with Several Gaps</td><td>Limited understanding</td><td>Minor understanding</td></tr>
<tr><td>Application</td><td>Correct and innovative</td><td>Correct with few errors</td><td>Basic with some errors</td><td>Frequent errors</td><td>Incorrect applications</td></tr>
<tr><td>Analysis</td><td>Comprehensive and accurate</td><td>GOOD with minor</td><td>Adequate but lacks depth</td><td>Superficial and incorrect</td><td>Incomplete and incorrect</td></tr>
</table></td><td></td></tr>
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[9] Including rubrics is highly encouraged, but it might not be mandatory for every single assignment.

			inaccuracies			
Presentation	Well-organized and accurate	Organized with minor issues	Some organization issues	Poorly organized	Disorganized	

Exam Rubric

Criteria	Excellent (5)	Good (4)	Fair (3)	Poor (2)	Unsatisfactory (1)
Knowledge	Comprehensive and accurate	Good with minor inaccuracies	Basic with some errors	Limited with frequent errors	Minor knowledge
Application	Effective applications	Correct with few errors	Basic with some misunderstandings	Frequent errors	Incorrect applications

		Clarity	Clear and well structure	Mostly clear with minor issues	Adequate but lacks clarity	Unclear or poorly structured	Confusing or poorly articulated	