UNIVERSITY OF THE PUNJAB

NOTIFICATION

It is hereby notified that the Syndicate at its meeting held on 27-07-2023 has approved the recommendations of the Academic Council made at its meeting dated 24-05-2023 regarding approval of the Revised Syllabi and Courses of Reading for Ph.D. in Applied Hydrology under Semester System at the College of Earth and Environmental Sciences w.e.f. the Academic Session, 2021 and onward.

The Revised Syllabi and Courses of Reading for Ph.D. in Applied Hydrology under Semester System is attached herewith as Annexure 'A'.

Sd/-
REGISTRAR

Admin. Block,
Quaid-i-Azam Campus,
Lahore.

No. D/ 7669 /Acad. **Dated: 11 - 10 /2023.**

Copy of the above is forwarded to the following for information and further necessary action: -

1. Dean, Faculty of Geo Sciences.
2. Principal, College of Earth and Environmental Sciences.
3. Controller of Examinations
4. Director, IT for placement at the website
5. Admin Officer (Statutes)
6. Secretary to the Vice-Chancellor.
7. PS to the Registrar.
8. Assistant Syllabus.

Assistant Registrar (Academic)
for Registrar

Revised Curricula/Syllabi of PhD Applied Hydrology Degree Program

Program Title: **PhD Applied Hydrology**

Department: **College of Earth and Environmental Sciences**

Faculty: **Faculty of Geosciences**

1. Department Mission

The mission of the College is to groom the students into responsible and honest citizens and skilled professionals trained in their respective fields to serve the nation. Character building and moral training is an integral component of student-teacher relationship. student life in the College provides the students with all possible opportunities to acquire the most dynamic personalities with leadership qualities. Academically excellent and experienced faculty members are involved in teaching and research in the CEES. Classes are regularly held, well supplemented with laboratory work and observations in the field.

2. Introduction

The College of Earth and Environmental Sciences, University of the Punjab, Lahore is presently offering multidisciplinary degree program i.e. BS, M.Sc., MS, M.Phil. and Ph.D. degree programs in the disciplines of Environmental Sciences, Applied Hydrology, Tourism & Hospitality Management, Geomatics and Occupational Health and Safety Management. The purpose of these courses is to produce graduates in these emerging disciplines with the insight and knowledge to serve the nation for attaining environmentally sustainable development in the country

Environmental changes, like desertification, silting of dam reservoirs, water logging, salinity and contamination of land as well as surface and groundwater, have created problems related to tourism. Over exploitation of resources has adversely impacted the tourism destinations and we are facing the danger of degradation and destruction of ecological infrastructure that is essential for sustainable tourism. In Pakistan, as elsewhere in developing countries, environmental degradation is occurring due to heavy industrialization concentrated in narrow zones, specially hospitality industry.

Keeping in view the importance and the growing demands for training manpower in the emerging discipline, the College of Earth and Environmental Sciences has been established in the University of the Punjab in 2005. The new building of the College was completed in November 2008, featuring spacious rooms, moderately equipped laboratories, a library and large grounds.

3. Program Introduction

The program of ***PhD in Applied Hydrology*** is designed to impart quality education based on knowledge, research, and skill to produce PhD graduates of international caliber who contribute to science and technology, of the country with global perspectives with deeper understanding of latest problems in the field of hydrology and water resources. Training of students through soft skills, advanced technology knowledge, work ethics, advancements in hydrology though research on latest problems is part of the PhD Applied Hydrology Program.

Water has vital significance globally and without it, thus life seems impossible on our planet. As the time passed human development has casted disastrous impacts on water resources arability in quantitative and qualitative context as well. Global warming, climate change, hydrological cycle changes, land, air and Sea level rising are the important issues of this century and these issues have significant effects on economy, society and environment. Therefore, it is of vital important to have a deep and advance understanding of hydrological cycle and its multidimensional complexities. CEES provide a learning educational environment to students with the opportunities to acquire advance knowledge and skill in the field of Applied Hydrology to build a successful career and become an integral part of the community.

4. Program Objectives

In order for our program to remain preeminent and in line with the international standards, the main objectives of the program are as follows:

- To impart advanced knowledge about major areas of hydrology and water sciences.
- To enable the students to learn data collection, organization and analyses of hydrological data.
- To enhance the capabilities of the students to use various practical techniques of planning and management of water resources.
- To train students to plan and execute studies on local hydrological issues as an individual researcher as well as a part of team.
- To equip students with professional skills to be demonstrated in teaching & research in hydrology and water resources.
- To enable the students to review published literature critically and publish their own research.

5. Market Need /Rationale of the Program

Hydrology is an ancient profession which has also referenced in old testimony and ancient Chinese history. This field has been evolving with the passage of time and now it has grown to an independent field. In 15^{th} century the aim was to build basic knowledge of water resources, with the start of 19^{th}

century water resources sustainable problems become dominant field of research. Now the major areas of hydrology are climate changes, global warming and water resources sustainability issues.

Pakistan has a youth bulge whereby about 60% youth of its total population is between the age bracket of 15 and 30 years, which indicates immense human resource potential of Pakistan. The Pakistan has numerous departments in which numbers of professional already working and with the development of new projects further consumptions of hydrology professional will be prior task to these organizations. The WAPDA, Irrigation, PCRWR, Ministry of water resources, WASA, Academia and large numbers of private consultancies firms including NESPAK, NDC, MMP, ECSP, ACE, etc. will also hire our professionally trained students.

6. Admission Eligibility Criteria

Before entry into a Ph.D. program, it is the rule of the CEES that students have completed his or her BS/MS/MPhil or equivalent degrees. So far, the different Ph.D. programs are ongoing at the College of Earth and Environmental Sciences, university of the Punjab, Pakistan. In the beginning, the students from the different disciplines were adjusted in the Ph.D. program. However, after 2014 owing to several ongoing disciplines, a barrier was maintained and the students with the related fields were allowed to join the Ph.D. program. The eligibility criteria for the ongoing programs are given in Table 1.

Table 1. The eligibility criteria for the ongoing Ph.D. Applied Hydrology program at CEES

Program	**Eligibility criteria**
Ph.D. Applied Hydrology 7 seats (Open Merit)	Eligibility M.Phil Applied Hydrology (2-Yrs) or Allied Sciences with 18 Yrs of education or equivalent and Clause 24(b), Admission regulations 2018-19, Page (8).

The GPA requirement of the ongoing Ph.D. program is consistent with the policy guidelines. Overall, for admission in Ph.D. programs, a minimum CGPA of 3.0 (out of 4.0 in the semester system) or First Division (in the annual system) in the most recent degree obtained is required, whether such was degree obtained from Pakistani or foreign universities.

All applicants to Ph.D. programs are required to take a specific admissions test. When the admissions are announced an advertisement is made in the newspaper and the university portal. Test date is decided, and an official test is conducted. The test is organized with the permission of the HEC and an equivalent test is developed by the university, for admissions to graduate programs. The percentage of test is 40 %. The students who qualify for the test and are fulfilling the basic merit criteria (Shown in

Table 2) are called to appear for an interview in the panel of the College of Earth and Environmental Sciences. Based on the eligibility criteria a merit list is established and students are enrolled in the Ph.D. program. Applicants to Ph.D. programs shall be required to fulfill the following testing requirements:

Table 2. The basic merit criteria for admission in the PhD program at CEES

Program	**Merit Criteria**
Ph.D. Applied Hydrology	Basic criteria (40 marks for Academic Qualifications, 40 marks for Entry Test, 10 marks for Interview, 05 marks for Professional Experience and 05 marks for research publication in HEC recognized journals

Sr. No.	**Description**	**Marks**
1	Academic qualifications*	**40**
2	Publications in HEC approved journals/ Exhibitions/ Design Projects (One mark for each publication)	**05**
3	Professional experience in relevant field (one mark for each year for job in the relevant field/as per Departmental preference)	**05**
4	Subject written Entry Test*	**40**
5	Interview*	**10**
	TOTAL	**100**

Note: 50% marks required to be obtained in academic merit i.e. a candidate must obtain at least 20 marks in the academic qualification greater and equal to 19.1 (will be rounded to 20), written test & interview separately for M.Phil/equivalent program. However, for the Ph.D program 50% marks are required to be obtained in academic merit, 70% marks in written test & 50 % marks in the interview separately. (The candidate must obtain greater or equal to 19.1 out of 40 marks in academic merit to be eligible for taking the written departmental test).

As part of the application for admission to Ph.D. programs, applicants are informed to submit a statement of purpose at the time of application. Those who qualify for the admission test are also required to bring a statement of purpose and a brief research proposal at the time of the interview. The admissions committee/interview panel uses the information provided to ascertain the preparedness and interest of the candidate in pursuing doctoral studies, and whether the department has the requisite resources to train and supervise the doctoral candidate in the subspecialty he or she is interested in.

7. Duration of the Program

The CEES is following the HEC guidelines and PhD degree is awarded by the university after a minimum of three (3) years period. The general timeline followed by the CEES is three to five years. Number of courses taught in PhD applied Hydrology degree program will be 6 with each course having 3 credit ours. A total of 9 credit hours of course are taught in each semester (3 credit hours of

core course and 6 credit hours of elective courses). After successful completion of course work, the students haves to appear in the comprehensive exam before the start of their PhD research work.

The college designated competent authority (DDPC) to determine whether the delay is caused by circumstances beyond the student's control and if so, grant an extension for two in such exceptional circumstances. The date of notification of the award of the Ph.D. degree after the Ph.D. defence is considered to be the date of the completion of Ph.D. studies.

8. Categorization of Courses as per HEC Recommendation and Difference

Table 3: Categorization of courses as per HEC requirement

Semester	Courses	Category (Credit Hours)					
		Core Courses	Basic Courses	Major Electives	Minor Electives	Any Other	Semester Load
1	3	3		6			**9**
2	3	3		6			**9**
PU	**6**	**6**		**12**			**18**
HEC Guidelines	**6**	**6**		**12**			**18**
Difference (HEC &) PU	**0**	**0**		**0**			**0**

9. Scheme of Studies / Semester –Wise Workload

Presently College of Earth and Environmental Sciences revised the courses & syllabi keeping in view the advancements in the field of Applied Hydrology and new courses recommended by the Higher Education Commission (HEC). Most of the courses have been designed according to the latest trends of the subject that can provide an interest to the students and later help them for competing in the job market. The students can select the courses according to their interests and research directions to fulfil the requirement.

Table 4. Courses and syllabi for PhD Applied Hydrology

Sr. #	Code	Course Title	Course Type	Prerequisite	Credit hours
Semester I					
1.	HYD 701	Research Methods in Hydrology (Core-Course)	Core Course	MS / M.Phil. Applied Hydrology/Equivalent	03
2.	HYD 702	Water Resources Sustainability and Modeling (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
3.	HYD 703	Urban Hydrology (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
4.	HYD 704	Field Applications of Water Resources Management (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
5.	HYD 705	Advances in Hydrological Sciences (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
				Total Credit Hours	**09**
Semester II					
1.	HYD 706	Climate Change and its Impact on Water Resources (Core-Course)	Core Course	MS / M.Phil. Applied Hydrology/Equivalent	03
2.	HYD 707	Snow and Ice Hydrology (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
3.	HYD 708	Hydrometry (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
4.	HYD 709	Advanced GIS and Remote Sensing in Hydrology (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
5.	HYD 710	Case Studies of Ground Water (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
6.	HYD 111	New Developments in Wastewater Treatment	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
				Total Credit Hours	**09**
				Total Semester-I & II	**18**

1. Type of course may be core (compulsory), basic (foundation), major elective (professional), minor elective (specialization) etc.

10. Research Thesis / Project /Internship

The College of Earth and Environmental Sciences is following the HEC guidelines. Besides course work, each Ph.D. researcher is required to write a doctoral dissertation that meets the HEC defined criteria. The Ph.D. dissertation is supervised by a faculty member who holds a Ph.D. (or equivalent) degree and is an HEC approved supervisor. Furthermore, at the time of appointment as supervisor, the faculty member is a full-time faculty member of the University of Punjab in which the student is enrolled. The Ph.D. thesis is evaluated by the committee member and by at least two external experts. The external reviewers are Ph.D. experts from academically advanced countries. A plagiarism test following the HEC's Plagiarism Policy is conducted on the dissertation before its submission to the external experts. Further an open defence is organized by the review committee to evaluate and approve the dissertation.

10. Award of Degree

Degree awarding criteria stating:

- As a requirement, the 18 credit hours are offered in the first year of the doctoral degree. Each student is required to achieve 3 CGPA in the course work.
- According to university policy and HEC guidelines following the completion of coursework, every Ph.D. student is required to pass a comprehensive examination to be granted candidacy as Ph.D. researcher; provided that if the student fails to pass the comprehensive test, he or she shall be allowed one more attempt to take the test.
- After qualifying for the comprehensive examination, the student is officially allowed to start the research and DPCC evaluates the projects and refers to the advanced research board.
- Each Ph.D. researcher is required to write a doctoral dissertation that meets the HEC defined criteria. The Ph.D. dissertation is supervised by a full-time faculty member who holds a Ph.D. (or equivalent) degree and is an HEC approved supervisor. The Ph.D. thesis is evaluated by the committee member and by at least two external experts. Further, a plagiarism test following the HEC's Plagiarism Policy is conducted on the dissertation before its submission to the external experts. An open defence of the dissertation is required after a positive evaluation of the dissertation by the committee members.
- According to university and HEC guidelines, each Ph.D. researcher is required to publish at least one research paper as the first author during his or her doctoral studies in an HEC approved Y category (or above) journal for the award of Ph.D. degree.

11. NOC from Professional Councils (if applicable)

As a general matter, university of the Punjab established Ph.D. programs in running disciplines i.e., Applied Hydrology. The regular Ph.D. in Applied Hydrology program is ongoing since 2014 and the NOC is required for the launch the program for which the case for issuance of NOC is lying pending with HEC.

The ongoing Ph.D. program in Applied Hydrology at the College of Earth and Environmental Sciences is consistent with the university regulations and HEC guidelines. Since the program is launched in 2014, and NOC is required for this ongoing Ph.D. program in Applied Hydrology. For this purpose, A case has already been initiated to HEC for no-objection certificate (NOC) with Letter No. PhD /1954 /CEES dated 12-12-2017 to which HEC responded with some deficiencies with Letter No. 1-68/2019/QAD-NOC/HEC/UOP dated 19-3-2019, These deficiencies were adequately addressed, and the case was resubmitted with Letter No. PhD/1315/CESS dated 27-05-2021. Currently, the case is lying pending with HEC for Issuance of NOC

12 Faculty Strength

Degree	Area / Specialization	Total
PhD	1. Prof. Dr. Sajid Rashid Ahmad 2. Prof. Dr. Irfan Ahmad Shaikh 3. Prof. Dr. Nadia Jamil 4. Dr. Abdul Qadir 5. Dr. Yumna Sadef 6. Dr. Muhammad Kamran 7. Dr. Muzaffar Majid Ch. 8. Dr. Azhar Ali 9. Dr. Sana Ashraf 10. Dr. Muhammad Bilal Shakoor 11. Dr. Naeem Akhtar Abbasi 12. Dr. Mehwish Mumtaz 13. Dr. Muhammad Awais 14. Dr. Rizwan Aziz 15. Dr. Muhammad Asif Javed	**15**
MS / M.Phil.	16. Mr. Muhammad Waqar 17. Mr. Muhammad Dastgeer 18. Ms. Zahra Majid 19. Ms. Anum Tariq	**04**

13 Present Student Teacher Ration in the Department

05: 15 1:1

14. Course Outlines separately for each course.

FIRST SEMESTER

Sr. #	Code	Course Title	Course Type	Prerequisite	Credit hours
1.	HYD 701	Research Methods in Hydrology (Core-Course)	Core Course	MS / M.Phil. Applied Hydrology/Equivalent	03
2. ‘	HYD 702	Water Resources Sustainability and Modeling (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
3.	HYD 703	Urban Hydrology (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
4.	HYD 704	Field Applications of Water Resources Management (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
5.	HYD 705	Advances in Hydrological Sciences (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
				Total Credit Hours	**09**

HYD 701 RESEARCH METHODS IN HYDROLOGY (THEORY) (03 Credit Hrs.)

PRE-REQUISITE: MS / M.Phil. Applied Hydrology

LEARNING OUTCOMES

The students will be able to

- Understand research terminologies and fundamental research methods
- Be aware of the ethical principles of research, ethical challenges and approval processes
- Describe quantitative, qualitative and mixed methods approaches to research and the data collection techniques
- Identify the components of a literature review process and critically analyze published research to help formulate research question
- Learn about research reporting, documentation and publication.

CONTENTS

This course aims at providing students with the necessary knowledge and understanding to the following:

Unit-1 Foundations

1.1 Introduction to Research and the Research Processes and ethics
1.2 Research methods and approaches
1.3 Critical thinking
1.4 Innovations and novelty

Unit-II Identification of research problem and documentation of research proposal

2.1 Identification of Research Area and Problem
2.2 Developing a hypothesis, a research problem and related questions
2.3 Framing the problem with the correct research methodology
2.4 Research proposal write up (problem statement, objectives, description of study area)

Unit-III Data Sources and Data Collection

3.1 Identification of data sources
3.2 Quantitative & qualitative data
3.3 Primary and secondary data collection, and reliability of data
3.4 Sampling techniques
3.5 Survey plans and questionnaire design
3.6 Data transformation techniques
3.7 Examples of Hydrological data, management, handling and interpretation of primary and secondary hydrological data

Unit-IV Development of Conceptual Research Framework

4.1 Development of research methodology, available method
4.2 Conceptual flow charts of processes and methodology
4.3 Justification and validity of research methodology

Unit-V Data Analysis Techniques

5.1 Statistical Analyses (descriptive statistics, inferential statistics
5.2 Hypothesis testing, goodness of fit test, correlation, regression, model efficiencies tests
5.3 Time series analysis

Unit-VI Research Drafting and Publication

6.1 Write up of research publication drafting
6.2 Posters, seminars and conference presentations
6.3 Scientific Report writing
6.4 Publication ethics

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS

It is continuous assessment. The weightage of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- attitude and behavior,
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
2.	Formative Assessment	25%	It is continuous assessment during the semester covering: classroom participation, attendance, assignments and presentation, homework, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	At the end of the semester, it is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Mukherjee, S. P. (2019). *A guide to research methodology: An overview of research problems, tasks and methods.* CRC Press.
2. Adams K. A., & Lawrence E. K. (2018). *Research Methods, Statistics, and Applications* (2nd Ed.). SAGE Publications.
3. Tjora, A. (2018). *Qualitative Research as Stepwise-Deductive Induction*. Routledge Publisher.

4. Creswell, J. W. (2018). *Research design: Qualitative, quantitative and mixed methods approaches* (5th Ed). Sage Publications.
5. Bartels, K. P. R., & Wittmayer, J. M. (2018). *Action Research in Policy Analysis: Critical and Relational Approaches to Sustainability Transitions*. Routledge Publisher.
6. Alley, M. (2018). *The Craft of Scientific Writing*. Springer-Verlag. New York.
7. Smith, R.L., Nychka, D., Waller, L.A., & Schmidt, A. (2018). *Applied Environmental Statistics*. Taylor & Francis Group
8. Yin, R. K. (2017). *Case study research and applications: Design and methods (*6th Ed.) SAGE Publications.
9. Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook* (3rd Ed.). SAGE Publications.
10. Fowler Jr, F. J. (2013). *Survey research methods*. SAGE publications
11. Bryman, A. (2012): *Social Research Methods*, (4th Ed). Oxford: Oxford University Press

HYD 702 WATER RESOURCES SUSTAINABILITY AND MODELING (THEORY)

(03 Credit Hrs.)

PRE-REQUISITE: MS / M.Phil. Applied Hydrology

LEARNING OUTCOMES

- This course will provide the basic concepts of sustainable water resources, background and importance
- The students will learn about the ecological and economic perspectives of sustainable water resources management
- The students will learn the modelling and optimization methods in water resources sustainability
- The students will be able the learn about the uncertainties, challenges, threats, and climate change impacts on water resources sustainability

CONTENTS

Understating Water Resource Sustainability its applications in context to the ecological economic viewpoint. Sustainable Water resources management in context to conjunctive use, uncertainness and risks.

Unit-1 Water Sustainability

1.1 Introduction to the water occurrences and sustainability
1.2 Importance and applicability
1.3 Water quantity and water budget
1.4 Background with past civilizations and the present
1.5 Current global water challenges
1.6 Linking water supplies and growth
1.7 Global and local view of climatic conditions and trends
1.8 Water supply security

Unit-II An Ecological-Economics Perspective of Water Resources Sustainability

2.1 An ecological-economics view of sustainability
2.2 Measuring the ecological-economic value of water
2.3 A human right to water
2.4 Integrated water resources management

Unit-III Optimization and Modeling for Water Resources Sustainability

3.1 Introduction to modelling and optimization
3.2 Sustainable Groundwater and Conjunctive use policy development
3.3 Simulation/Optimization Models,
3.4 Methods of Simulating and optimization within S/O Models,
3.5 Optimization Problem Formulations

Unit-IV Multi-objective Analysis/ Conjunctive Use Planning of Groundwater and Surface Water

4.1. Introduction to surface Water and Groundwater interactions
4.2. Governing Equations
4.3. Management Objectives in Conjunctive use Projects
4.4. Supply Objectives, Quality Objectives, Economic Objectives, Environmental Objectives
4.5. Multi-objective Optimization, Multicriteria Decision Making

Unit-V Uncertainties and Risks in Water resources projects,

5.1. Risk Considerations in Hydrosystems,
5.2. Data Requirements in Risk-Based Approach
5.3. Uncertainty Analysis, future scenarios, population and other trends

Unit-VI Climate change Effects and Water Management Options

6.1 The Climate System
6.2 Definition of Climate Change, Climate Change Prediction
6.3 Droughts
6.4 Climate Change Effects
6.5 Water Management Options and climate change

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS – TYPE AND NUMBER WITH CALENDAR

It is continuous assessment. The weightage of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- attitude and behavior,
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
2.	Formative Assessment	25%	It is continuous assessment. It includes: classroom participation, attendance, assignments and presentation, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	It takes place at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Malcangio, D. (2018). *Applications in water systems management and modeling*. BoD – Books on Demand.
2. Ojha, C. S., & Kao, C. (2017). *Sustainable water resources management*.
3. Shrestha, S., 2016. *Groundwater Environment in Asian Cities: concepts, methods & ease study. Amsterdam*, Elsevior.
4. Shammas, N. K., & Wang, L. K. (2015). *Water engineering: Hydraulics, distribution and treatment*. John Wiley & Sons.
5. Jones, A. A., (2014). Water Sustainability: A Global Perspective. Routledge, New York. Setegn, Shimelis.
6. Rooney, A. (2009). *Sustainable Water Resources (How can we save our world?).* Arcturus Publishing, New Delhi
7. Larry, M., 2006. *Water Resources Sustainability*, McGraw Hill.

Assorted research papers

HYD 703 URBAN HYDROLOGY (THEORY) (3 Credit Hrs.)

PRE-REQUISITE: MS / M.Phil Applied Hydrology

LEARNING OUTCOMES

- This course will provide and introduction to urban hydrology and the difference from natural hydrology
- Students will learn about the design considerations for urban drainage structures.
- The student will learn about the estimation of access rainfall and design storm for urban watershed
- They will have the knowledge about application of modelling for urban storm simulations

CONTENTS

Understating Urban hydrology its applications in hydrology. Modeling for urban development.

Unit-1 Introduction

1.1. Urbanization and Stormwater Runoff
1.2. Urban Hydrology, Hydraulics, and Stormwater Quality.
1.3. The Origin and background of Urban Hydrology
1.4. Difference between natural and urban watersheds

Unit-II Design Rainfall for Urban Drainage Systems

2.1. Hydrologic description of rainfall
2.2. Probabilistic description of rainfall
2.3. Frequency analyses and return period and hydrologic risk
2.4. Intensity-duration-return period curves
2.5. Design rainfall and design return period
2.6. Spatial and temporal distribution of design rainfall
2.7. Construction of design-storm hyetographs

Unit-III Rainfall Excess Calculations and Open-Channel Flow in Urban Watersheds

3.1 Estimation of losses (rainfall abstractions, interception storage, infiltration, depression storage, combined loss models)
3.2 Soil conservation service method
3.3 Basic definitions and states of flow
3.4 Open-channel flow equations
3.5 Steady gradually varied flow
3.6 Open-channel rating curve
3.7 Overland flow
3.8 Channel flow routing methods

Unit-IV Calculation of Runoff Rates from Urban Watersheds

4.1 Elements of urban runoff hydrographs
4.2 Definition and estimation methods for time of concentration
4.3 Development and applications of unit hydrographs
4.4 Soil conservation service methods for runoff rate calculations
4.5 Peak discharge estimation methods for urban watersheds

Unit-V Stormwater Drainage Structures

5.1 General design considerations
5.2 Storm sewer systems
5.3 Storm sewer hydraulics
5.4 Design discharge for storm sewers

5.5 Culverts, grassed and lined channels
5.6 Stage-storage relationship and design of detention basins

Unit-VI Urban Stormwater Computer Modeling using HEC-HMS

6.1. Hydrologic modeling overview and watershed delineation
6.2. Model structure and features of HEC-HMS
6.3. HEC-HMS example problem
6.4. Model calibration and validation

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS – TYPE AND NUMBER WITH CALENDAR

It is continuous assessment. The weightage of Assignments will be 25% before and after mid term assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- attitude and behavior,
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
2.	Formative Assessment	25%	It is continuous assessment. It includes: classroom participation, attendance, assignments and presentation, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	It takes place at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Bedient P. B., Huber W. C., & Vieux B. E. (2018). *Hydrology and Floodplain Analysis* (6th Ed).). Pearson.
2. Griffin, R. D. (2018). *Principles of stormwater management*. CRC Press.
3. Riedel J. T. (2017). *Comparison of Generalized Estimates of Probable Maximum Precipitation with Greatest Observed Rainfalls*. Forgotten Books.
4. Akan A. O. & Houghtalen, R. J. (2003). *Urban Hydrology, Hydraulics, and Stormwater Quality: Engineering Applications and Computer Modeling* (1st Ed.). Wiley.
5. Sarma, A. K., Singh, V. P., Kartha, S. A., & Bhattacharjya, R. K. (2016). *Urban hydrology, watershed management and socio-economic aspects*. Springer
6. Pazwash, H. (2011). *Urban storm water management*. CRC Press.
7. World Meteorological Organization (2009). *Manual on estimation of probable maximum precipitation*. World Meteorological Organization

8. Akan A. O., & Houghtalen, R. J. (2003). *Urban Hydrology, Hydraulics, and Stormwater Quality: Engineering Applications and Computer Modeling*. John Wiley & Sons. Assorted research papers

HYD 704 FIELD APPLICATIONS OF WATER RESOURCES MANAGEMENT (THEORY)
(03 Credit Hrs)

PRE-REQUISITE: MS / M.Phil. Applied Hydrology

COURSE LEARNING OUTCOMES:

- This course will provide an introduction to the Water resource systems analysis in field.
- The students will learn about the Classification of Mathematical Programming Models.
- They will have the knowledge about the categories of Numerical Programming Models.
- The Water Supply Problems and their possible solutions will be illustrated to them.
- The students will be equipped with the various regional water supply planning processes.

CONTENTS

Introduction, importance of water resources management, numerical program models, dynamic programming, water supply programs and regional water supply models.

Unit-1 Introduction

1.1. Water resource systems analysis as a discipline
1.2. Linear Programming with reference to hydrology and water resources constraints
1.3. Problem statement, Problem formulation
1.4. Graphical representation of decision space
1.5. Finding the problem solution, Beyond optimality

Unit-II Importance of Water Resource Management

2.1 Water management options
2.2 Investigations for water resource management
2.3 Flow nets

Unit-III Category of Numerical Programming Models

3.1 Overview of the methodology by steps
3.2 Determination of shadow prices from final tableau
3.3 Dealing with equality constraints
3.4 Recognizing and unbounded objective function.
3.5 Recognizing a decision variable that is nonunique
3.6 Practice LP Problem Formulation

Unit-IV Water Supply Problem

4.1 Problem statement,
4.2 Solution formulation,
4.3 Application of LP to Groundwater simulation-optimization,
4.4 Water resources Network Models,
4.5 Integer Programming Nonlinear Programming,
4.6 Wastewater treatment problem revisited with nonlinear costs,
4.7 Piecewise approximations of nonlinear functions,
4.8 Lagrange multipliers, Gradient search techniques.

Unit-V Dynamic Programming:

5.1 Mathematical Description and its Effect on Solution of Discounting Future Returns
5.2 Fuzzy Optimization,
5.3 Data-Based Optimization,
5.4 Artificial Neural Networks,
5.5 Genetic Algorithms,
5.6 Optimal Control Uncertainty and Reliability Analysis.

Unit-VI Regional Water Supply Planning:

6.1 River-reservoir system operation,
6.2 Water distribution system operation,
6.3 Irrigation water delivery,
6.4 Groundwater remediation,
6.5 Reservoir simulations and Multicriteria decision analysis.

ASSIGNMENTS – TYPE AND NUMBER WITH CALENDAR

It is continuous assessment. The weightage of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- attitude and behavior,
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
2.	Formative Assessment	25%	It is continuous assessment. It includes: classroom participation, attendance, assignments and presentation, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	It takes place at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Loucks, D. P., & Van Beek, E. (2017). *Water resource systems planning and management: An introduction to methods, models, and applications*. Springer.
2. Thompson, S. A. (2017). *Hydrology for water management*. CRC Press.
3. McCuen, R. H. (2016). *Modeling hydrologic change: statistical methods*. CRC press.
4. Johnson, L. E. (2016). *Geographic information systems in water resources engineering*. CRC Press.
5. Eslamian, S. (2014). *Handbook of engineering hydrology (three-volume set)*. CRC Press.

Assorted research papers

HYD 705 ADVANCES IN HYDROLOGICAL SCIENCES (THEORY) (03 Credit Hrs)

PRE-REQUISITE: MS /M.Phil. Applied Hydrology

LEARNING OUTCOMES

- This course will provide an advancement in hydrological sciences and measurements and basic concepts of climate change and its impacts on water resources
- They will have the knowledge about sustainable development of water resources
- The students will get used with advance hydrological modeling and hydro-informatics
- The student will learn advancement in ground water hydrology

CONTENTS

Classification and measurement of snow, glaciers, runoff estimation from snow and snow modeling.

Unit-1 Advances in Hydrological Measurements

1.1. Advance aspects of hydrology such as environmental river flow,
1.2. Dam break study and Dam failures
1.3. Sedimentation Methods
1.4. Satellite measurements of weather
1.5. Numerical weather modeling
1.6. Global climate modeling
1.7. Advance methods in weather prediction
1.8. Climate change and water resources

Unit -2 Climate impacts on Water Resources

2.1 Hydrology of wetlands
2.2 New management topics including water scarcity
2.3 Security and governance
2.4 Water resource management

Unit-III Sustainable Development of Water Resources

3.1 Sustainability in urban water
3.2 Wastewater reuse
3.3 Storm water modeling
3.4 Water resource management
3.5 Anthropogenic aquifer and artificial recharging

Unit-IV Hydrological Modeling

4.1 Advance hydrological models
4.2 Advances in Stochastic modeling
4.3 Climate modeling
4.4 Couple Models and their applications to hydrology
4.5 Advance numerical modeling

Unit-V Artificial Intelligence

5.1 Data assimilation
5.2 ANN Techniques and their application in hydrology
5.3 Fuzzy Logics and Applications to water resources system
5.4 Hydro-informatics

Unit-VI Advances in Ground Water Sciences

6.1 Fracture rock hydrology
6.2 Hydraulics, trace tomography and data fusion
6.3 Hydro-biogeochemistry
6.4 Hydro-geophysics
6.5 Advancement in isotopic hydrology
6.6 Advance computational methods

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS – TYPE AND NUMBER WITH CALENDAR

It is continuous assessment. The weightage of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- attitude and behavior,
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
2.	Formative Assessment	25%	It is continuous assessment. It includes: classroom participation, attendance, assignments and presentation, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	It takes place at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Linge, S., & Langtangen, H. P. (2020). *Programming for Computations-Python: A Gentle Introduction to Numerical Simulations with Python 3.6*. Springer Nature.
2. Cohen, J. B. A., & Cherry, A. J. (2020). *Conceptual and Visual Understanding of Hydraulic Head and Groundwater Flow - The Groundwater Project*. The Groundwater project.

3. Cushman, J. H., & Tartakovsky, D. M. (Eds.). (2016). *The handbook of groundwater engineering*. CRC Press.

4. Singh V. P. (2016). *Chow's Handbook of Applied Hydrology*, (2nd Ed.). McGraw-Hill Education

5. Eslamian, S. (2014). *Handbook of Engineering Hydrology: Environmental Hydrology and Water Managemen*t, CRC Press.

6. Shrestha, S., Babel, M. S., & Pandey, V. P. (Eds.). (2014). *Climate Change and Water Resources*, CRC Press,

7. Satake, K., & Lin, G. F. (Eds.). (2012). *Advances in Geosciences: Hydrological science (HS)* (Vol. 29). World Scientific.

8. Beniston, M. (Ed.). (2006). *Climatic change: implications for the hydrological cycle and for water management* (Vol. 10). Springer Science & Business Media.

Assorted Research Papers

SECOND SEMESTER

Sr. #	Code	Course Title	Course Type	Prerequisite	Credit Hours
1.	HYD 706	Climate Change and its Impact on Water Resources (Core-Course)	Core Course	MS / M.Phil. Applied Hydrology/Equivalent	03
2. ‘	HYD 707	Snow and Ice Hydrology (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
3.	HYD 708	Hydrometry (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
4.	HYD 709	Advanced GIS and Remote Sensing in Hydrology (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
5.	HYD 710	Case Studies of Ground Water (Elective Course)	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
6.	HYD 111	New Developments in Wastewater Treatment	Major Elective	MS / M.Phil. Applied Hydrology/Equivalent	03
				Total Credit Hours	**09**

HYD 706 CLIMATE CHANGE AND ITS IMPACTS ON WATER RESOURCES (THEORY) (03 Credit Hrs)

PRE-REQUISITE: MS / M.Phil. Applied Hydrology

LEARNING OUTCOMES

The students will be able to

- Understand about basic theories and processes of atmosphere and climate
- Understand the relationship between climate change and water bodies
- Learn about Global Circulation Models (GCMs) and Regional Climate Models (RCMs)
- Perform performance evaluation of GCMs/RCMs and its applications in water resources

CONTENTS

This course aims at providing students with the necessary knowledge and understanding to the following

Unit-1 Introduction and Basic Concepts

1.1 Introduction to weather and climate
1.2 Impact of climate on environment, earth, its atmospheric cycle and its relationship with climate
1.3 Basic concepts of atmospheric dynamics, ocean dynamics, cloud physics
1.4 Radiative heat transfer and climate, Greenhouse gas and climate change

Unit-II Global Atmospheric Processes

2.1 Monsoon circulation, Paleo-climatic approaches to the reconstruction of monsoon circulation, emphasis on Indian monsoon,
2.2 El-Nino, La-Lina, IOD (Indian Ocean Dipole), NAO (North Atlantic Oscillation), Arctic Oscillation, Indian Summer Monsoon.
2.3 Past, Present and future climate changes
2.4 Precipitation and temperature change due to climate variations

Unit-III Hydrological Impacts of Climate Change

3.1 Water bodies on the earth and their variations due to change of climate, Relations among climate, vegetation and water.
3.2 Ecological effect on freshwater systems- surface water, ground water and glaciers; Agriculture; Marine environment
3.3 Human dimension/ impact of human settlement and infrastructure.

Unit-IV Global Circulation Models/Regional Climate Models

4.1 General Circulation processes and Theory
4.2 Climate modeling and climate change feedbacks: linking atmosphere, oceans, biosphere, and cryosphere
4.3 Downscaling and Regional Climate Models (RCMs)
4.4 Introduction to widely used GCMs/ RCMs

Unit-V Performance Assessment of Global Circulation Models/Regional Climate Models

5.1. Introduction to GCMs/RCMs data portals and frameworks
5.2. Management and Handing of GCM/RCM data sets
5.3. Graphical and Statistical Methods for climate model assessments

Unit-VI Hydrological Applications of Global Circulation Models/Regional Climate Models

6.1 Applications of GCMs/RCMs in surface water assessments (Case Studies/Examples)
6.2 Applications of GCMs/RCMs in ground water assessments (Case Studies/Examples)

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS

It is continuous assessment. The weightage of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- attitude and behavior,
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
2.	Formative Assessment	25%	It is continuous assessment during the semester covering: classroom participation, attendance, assignments and presentation, homework, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	At the end of the semester, it is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Manabe, S., & Broccoli, A. J. (2020). *Beyond global warming: How numerical models revealed the secrets of climate change.* Princeton University Press.
2. Winsberg, E. (2018). *Philosophy and climate science*. Cambridge University Press.
3. Ahrens, C. D., & Henson, R. (2016). *Essentials of meteorology: An invitation to the atmosphere*. Cengage Learning.
4. Gettelman, A., & Rood, R. B. (2016). *Demystifying climate models: A users guide to earth system models*. Springer.
5. Beniston M. (2011). *Climatic Change: Implications for the Hydrological Cycle and for Water Management* (Advances in Global Change Research) Springer.
6. Wilks, D. S. (2011). *Statistical methods in the atmospheric sciences*. Academic Press.
7. Eagleson, P. S. (2011). *Land surface processes in atmospheric general circulation models*. Cambridge University Press.
8. Randall, D. A. (2000). *General circulation model development: Past, present, and future*. Elsevier.

HYD 707 SNOW AND ICE HYDROLOGY (THEORY) (03 Credit Hrs)

PRE-REQUISITE: MS / M.Phil. Applied Hydrology

LEARNING OUTCOMES:

- This course will provide an introduction to Snow measurements
- The students will learn about the concepts of glaciers
- They will have the knowledge about runoff estimation form snow
- The students will get used to the concepts earthquake snow modeling

CONTENTS

Classification and measurement of snow, glaciers, runoff estimation from snow and snow modeling.

Unit-1 Snow Classification

1.1 Snow and its classification
1.2 Distribution of snow
1.3 Ripening of snow

Unit-II Snow Melting

2.1 Snowmelt process
2.2 Measurement of snow at time of fall
2.3 Snow surveying

Unit-III Factors Affecting Runoff

3.1 Factors affecting runoff from snowmelt
3.2 Techniques of analysis of snowmelt
3.3 Forecasting snow melt runoff

Unit-IV Properties of Snow

4.1 Snow compaction
4.2 Properties and structure of ice
4.3 Types avalanches

Unit-V Glaciers

5.1 Avalanches
5.2 Glaciers
5.3 Movement of glaciers
5.4 Impacts of glaciers
5.5 Glaciers in Pakistan

Unit-VI Snowmelt Modeling

6.1 Snow modeling for runoff
6.2 Types of snowmelt models
6.3 Properties of Snowmelt models

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS – TYPE AND NUMBER WITH CALENDAR

It is continuous assessment. The weightage of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- attitude and behavior,
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
2.	Formative Assessment	25%	It is continuous assessment. It includes: classroom participation, attendance, assignments and presentation, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	It takes place at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Singh, V. P., & Jain, S. K. (2019). *Engineering hydrology: An introduction to processes, analysis, and modeling*. McGraw-Hill Education.
2. Carry, J. (2016). *Handbook of Snow, Ice and Glaciers*. Syrawood Publishing House.
3. Singh, V. P., Singh, P., & Haritashya, U. K. (Eds.). (2011). *Encyclopedia of Snow, Ice and Glaciers*. Springer.
4. Cuffey, K. M., & Paterson, W. S. B. (2010). *The Physics of Glaciers* (*4th Ed.).* Academic Press.
5. DeWalle, D. R., & Rango, A. (2008). *Principles of snow hydrology*. Cambridge University Press.
6. Singh, P. (2001). *Snow and glacier hydrology.* Springer Netherlands

HYD 708 HYDROMETRY (THEORY) (03 Credit Hrs)

PRE-REQUISITE: MS / M.Phil. Applied Hydrology

LEARNING OUTCOMES

The students will learn how to:

- Developed a clear understanding of river and stream field measurement techniques.
- Used water quantity data collected in the field in advanced modeling tools to solve problems.
- Analyzed experimental data with a variety of universal data analysis techniques.
- Become familiar with software packages commonly used in industry and research.

CONTENTS

The goal of this course is to teach a variety of experimental measurement and data analysis techniques in the context of water measurements. This course will cover the principles, methods, instruments, and equipment for measuring water quantity and water quality variables in nature.

Unit-1 Introduction

1.1. An introduction to the hydrometry
1.2. Requirement and objectives of hydrometry

Unit-II Flow Measurements

2.1 Measurement of stage
2.2 State-discharge relationships
2.3 Models estimating evapotranspiration
2.4 Sediments measurements
2.5 Ground water measurements

Unit-III Flow velocity measurement and discharge computation

3.1 Flow Velocity
3.2 Flow distribution
3.3 Discharge computation
3.4 Slope-area Method

Unit-IV Hydro meteorological fluxes Gauges

4.1 Preliminaries and reminders
4.2 Current meter velocity gauging
4.3 Electromagnetic current meter
4.4 Acoustic doppler current profiler (ADCP)
4.5 Float gauging
4.6 Dilution (chemical) gauging

Unit-V Rating Curve

5.1. Acquisition of the physical data
5.2. Construction of the rating curve
5.3. Management of the rating curves

Unit-VI Data Processing by Different Softwares

6.1. DEM acquisition and Processing
6.2. HEC-RAS
6.3. GIS and LiDAR

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS – TYPE AND NUMBER WITH CALENDAR

It is continuous assessment. The weightage of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- attitude and behavior,
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
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3.	Final Assessment	40%	It takes place at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Muste, M. V. I., Aberle, J., Admiraal, D., Ettema, R., Garcia, M. H., Lyn, D., Nikora, V., & Rennie, C. (Ed.). (2020). *Experimental Hydraulics: Methods Instrumentation Data Processing and Management Two Volume Set*. Taylor & Francis Group.
2. Jain, S. K., & Singh, V. P. (2019). *Engineering Hydrology: An Introduction to Processes, Analysis, and Modeling.* McGraw-Hill Education.
3. Eslamian, S. (2018). *Handbook of Engineering Hydrology*. CRC Press.
4. Shaw, E. M., Beven, K. J., Chappell, N. A., & Lamb, R. (2017). *Hydrology in Practice*. CRC Press.
5. Jones, J. A. A. (2014). *Global hydrology: processes, resources and environmental management.* Routledge.
6. Boiten, W. (2008). *Hydrometry: a comprehensive introduction to the measurement of flow in open channels* (3rd Ed.). CRC Press.
7. Herschy, R. W. (2008). *Streamflow measurement*. CRC press.
8. Gupta, S. V. (2002). *Practical density measurement and hydrometry*. CRC Press.

HYD 709 ADVANCED GIS AND REMOTE SENSING IN HYDROLOGY (THEORY)

(03 Credit Hrs)

PRE-REQUISITE: MS / M.Phil. Applied Hydrology

LEARNING OUTCOMES

- This course will provide knowledge about applications of Remote sensing and GIS in Hydrology.
- The students will learn about the different freely available online spatial data platforms
- Students will have the knowledge about different spatial models being used hydrological analysis and modeling
- The students will get used to the different advanced digital cartography techniques

CONTENTS

This course provides an advanced knowledge about digital cartography, spatial models for hydrological studies, Watershed analysis, suitability analysis for Dem site selection, Flood hazard assessment, 1D, 2D & 3D Hydrological modelling and freely available platforms for spatial data collection.

Unit-1 Spatial and Non-Spatial Datasets

1.1. Raster and Vector datasets
1.2. Digitization and Topological errors
1.3. Geodatabases

Unit-II Advanced Digital Cartography

2.1 Advancement in Cartography
2.2 Cartography techniques
2.3 Large- and Small-scale maps

Unit-III Spatial Data Acquisition

3.1 Online freely available platforms
3.2 Spatial data creation
3.3 Data joining and import

Unit-IV Geo-statistical Analysis

4.1 Interpolation methods
4.2 Analytical Hierarchy process
4.3 Multicriteria indexing and scoring

Unit-V Spatial Analysis

5.1 Site suitability techniques
5.2 Digital Elevation models
5.3 Image classification techniques

Unit-VI Spatial Modelling

6.1 Model Builder in Arc GIS
6.2 Various Hydrological Models
6.3 1D, 2D & 3D Hydrological Modeling

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS – TYPE AND NUMBER WITH CALENDAR

It is continuous assessment. The weightage of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- attitude and behavior,
- hands-on-activities,
- Short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS

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RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Kang-tsung, C. (2018). *Introduction to Geographic Information Systems* (9th Ed.) McGraw-Hill Education.
2. Maribeth, P. (2018). *Mastering ArcGIS, 8th Edition*, McGraw-Hill Education.
3. William, E. & Adriano, C. (2017). *Introduction to Satellite Remote Sensing: Atmosphere, Ocean, Land and Cryosphere Applications, 1st Edition*, Elsevier, ISBN: 9780128092545
4. Lavender, S., & Lavender, A. (2015). *Practical handbook of remote sensing*. CRC Press.
5. Jian, G. L., & Philippa, J. M. (2016). *Image Processing and GIS for Remote Sensing*:
6. Fox, L. (2015). *Essential Earth Imaging for GIS*, Esri Press.
7. Thomas, L., Ralph, W., & Kiefer, J. C. (2015). *Remote Sensing and Image Interpretation, 7th Edition*, Wiley
8. Mather, P. M., & Koch, M. (2011). *Computer processing of remotely-sensed images: an introduction*. John Wiley

HYD 710 CASE STUDIES OF GROUND WATER (THEORY) (03 Credit Hrs.)

PRE-REQUISITE: MS / M.Phil. Applied Hydrology

COURSE LEARNING OUTCOMES

- This course will be helpful in understating ground water resources its applications in hydrology
- The students will learn about advance case studies pertaining to groundwater resources.
- They will have the knowledge about the groundwater resources formation.
- They will become conversant with the Practices for groundwater development.

CONTENTS

This course is designed to provide advance knowledge about groundwater in different regions of Pakistan, to have comparison among aquifers of different regions, their characteristics, management & modeling scenarios and shed light on different projects pertaining to groundwater studies in the region.

Unit-1 Introduction

1.1. Global and regional water resources status
1.2. Importance of ground water resources
1.3. Management of ground water resources

Unit-II Ground Water Resources of Central Punjab

2.1 Study of aquifers of Pakistan
2.2 Study of Lahore aquifer
2.3 Characteristics of aquifer & its management with real time case studies.
2.4 Case studies

Unit-III Aquifer Studies in Pothohar Region

3.1 Ground water in Pothohar Region
3.2 Aquifers in arid regions
3.3 Karst Aquifers & their salient features
3.4 Groundwater management options in the region
3.5 Case studies

Unit-IV Characteristics and Management of Coastal Aquifers

4.1 Groundwater in coastal areas
4.2 Aquifers characteristics of coastal areas
4.3 Sea water intrusion concept
4.4 Management & modeling of coastal aquifers
4.5 Case studies

Unit-V Ground Water in Desert Areas

5.1 Groundwater in desert areas
5.2 Characteristics of desert aquifers
5.3 Groundwater exploration &development in desert areas
5.4 Water conservation techniques
5.5 Case studies

Unit-VI Sustainable Development of Ground Water resources

6.1 Mega projects in groundwater sector
6.2 Economic and sustainability analysis
6.3 Case studies

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS – TYPE AND NUMBER WITH CALENDAR

It is continuous assessment. The weightage of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- attitude and behavior,
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
2.	Formative Assessment	25%	It is continuous assessment. It includes: classroom participation, attendance, assignments and presentation, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	It takes place at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXT BOOKS / SUGGESTED READINGS

1. Guthrie, M. (2018). *Ground and Surface Water Hydrology*. Larsen and Keller Education
2. Fares, A. (2016). *Emerging Issues in Groundwater Resources.* Springer.
3. Mandel, S. (2012). *Groundwater Resources: Investigation and Development*. Elsevier,
4. Charles, F. (2012). *Groundwater Science.* Academic Press.
5. Altaf, S. (2009). *Running on empty: Pakistan's water crisis*. Woodrow Wilson International Center for Scholars, Washington, D.C.
6. Ahmad, N. (1974). *Ground water resources of Pakistan*.

Assorted research papers

HYD 711 NEW DEVELOPMENTS IN WASTEWATER TREATMENT(THEORY) (03 Credit Hrs)

PRE-REQUISITE: MS / M.Phil. Applied Hydrology

Course Learning Outcomes

- The aim of this course is to teach the most significant advances and usage of innovative methods for wastewater treatment
- Students will develop a sound understanding of the latest developments and technologies being employed presently in the wastewater treatment sector
- At the end of the course, students should be able to design a most modern wastewater treatment system for municipal and industrial sectors, like petroleum, refinery, fertilizers, chemicals, pharmaceuticals, textiles, leather, paper, etc.

Contents

This course is meant to give a complete theoretical and practical understanding of the latest developments in various nit processes used in water and wastewater treatments. Focus of the course is mainly on the learning of emerging technologies, essential to develop a rapid, effective, and efficient treatment. An emphasis will also be made on various case studies relevant to future research in the field of wastewater treatment.

Unit-1 Advanced Oxidation Processes (AOPs)

1.1.1 Ozonation, peroxone, its combination, advantages, and disadvantages
1.1.2 Fenton & photo-fenton
1.1.3 Ultraviolet and its combinations
1.1.4 Photocatalysis and its modern applications

Unit-II Biological Treatments

1.1.5 Bio-cleaner treatment method for industrial effluents
1.1.6 Developments in suspended growth treatment systems
1.1.7 Sequencing batch reactors (SBR) and Rotating biological contactors (RBC)
1.1.8 Advancements in trickling filters and biologically active filters
1.1.9 New extended aeration Vs. Conventional activated sludge process

Unit-III Applications of Membrane Technology (MT)

1.1.10 Ultra-filtration (UF) and its application
1.1.11 Technological innovations in modern Reverse Osmosis (RO) treatment plant
1.1.12 Currents trends of using Micro-filtration (MF) for water treatment
1.1.13 Low-pressure membrane system Vs. high-pressure membrane systems

Unit-IV Nanotechnology in WWT

1.1.14 Nanofiltration (NF) and its application
1.1.15 Silver, Copper, and Zero-Valent iron (ZVI) nanoparticles
1.1.16 Nano-membranes, and Nano-adsorbents
1.1.17 Nano catalysts, Magnetic Nanoparticles, and Nano sensors

Unit-V Zero Liquid Discharge

1.1.18 Thermal evaporation and crystallization systems
1.1.19 Microbial fuel cells for electricity production from wastewater
1.1.20 Heat recovery systems for wastewater
1.1.21 Electro-dialysis (ED) and electro-dialysis reversal (EDR)

Unit-VI Applied approaches in WWT

1.1.22 Removal of micropollutants, nanoparticles, and microplastics from wastewater
1.1.23 New disinfection technologies including UV & Ozone
1.1.24 Cost-effective & energy efficient treatment methods
1.1.25 Technological innovations in modern constructed wetlands
1.1.26 Water treatment system in Singapore: An exemplary case study

TEACHING – LEARNING STRATEGIES

- Lecture based examination
- Presentation/seminars
- Class discussion
- Quizzes

ASSIGNMENTS – TYPE AND NUMBER WITH CALENDAR

It is continuous assessment. The weight age of Assignments will be 25% before and after midterm assessment. It includes:

- classroom participation,
- attendance, assignments and presentation,
- homework
- hands-on-activities,
- short tests, quizzes etc.

ASSESSMENT AND EXAMINATIONS:

Sr. No.	Elements	Weightage	Details
1.	Mid Term Assessment	35%	It takes place at the mid-point of the semester
2.	Formative Assessment	25%	It is continuous assessment. It includes: classroom participation, attendance, assignments and presentation, homework, hands-on-activities, short tests, quizzes etc.
3.	Final Assessment	40%	It takes place at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

RECOMMENDED TEXTBOOKS / SUGGESTED READINGS

1. Rene, E. R., Shu, L., & Jegatheesan, V. (2020). *Sustainable eco-technologies for water and wastewater treatment.* IWA Publishing.
2. Ahamed, M. I., Lichtfouse, E., & Asiri, A. M. (2020). *Methods for bioremediation of water and wastewater pollution*. Springer.
3. Chen, J., Luo, J., Luo, Q., Pang, Z., & Group, C. E. P. (2018). *Wastewater treatment: Application of new functional materials. China Environment Publishing Group.* Walter de Gruyter.
4. Barrett, L. M. (2014). *Wastewater treatment: Processes, management strategies and environmental/health impacts.* Nova Science Publishers, Inc.
5. Gernaey, K. V. (2014). *Benchmarking of control strategies for wastewater treatment plants*. IWA Publishing.
6. Metcalf & Eddy, Inc. (2003). *Wastewater engineering: treatment and reuse.* Boston: McGraw-Hill

Checklist for a New Academic Program

Parameters	
1. Department Mission and Introduction	✔
2. Program Introduction	✔
3. Program Alignment with University Mission	✔
4. Program Objectives	✔
5. Market Need/ Rationale	✔
6. Admission Eligibility Criteria	✔
7. Duration of the Program	✔
8. Assessment Criteria	✔
9. Courses Categorization as per HEC Recommendation	✔
10. Curriculum Difference	✔
11. Study Scheme / Semester-wise Workload	✔
12. Award of Degree	✔
13. Faculty Strength	✔
14. NOC from Professional Councils (if applicable)	✔

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Program Coordinator **Chairperson**