Proposed Syllabus for Online M. Tech Program on

Flood and Water Resources Management

offered by

Department of Civil Engineering, IIT Guwahati

CEO 501: Introduction to Numerical and Optimization Methods (3-0-0-6)
Pre-Requisite: Nil

Course Objectives

- To build a strong foundation in numerical analysis and optimization techniques relevant to engineering.
- To develop computational proficiency in solving linear/nonlinear equations, differential equations, and optimization models.
- To enhance analytical and programming skills for applications in civil, environmental, and water resources engineering.

Course Content

Module 1: Fundamentals and Linear Systems

- Numerical errors: sources, round-off, truncation, and stability
- Direct methods for linear systems: Gauss elimination, Gauss-Jordan elimination, LU decomposition, Thomas method for Tri-diagonal system
- Iterative methods: Jacobi and Gauss-Seidel
- Engineering applications: flow networks

Module 2: Nonlinear Equations and Interpolation

- Root-finding techniques: Bisection, Newton-Raphson, and Secant methods
- Polynomial interpolation: Newton's and Lagrange's methods
- Spline interpolation: linear and cubic
- Engineering Applications:

Module 3: Numerical Integration and Differential Equations

- Numerical integration: Trapezoidal and Simpson’s rules
- Solution of ordinary differential equations (ODEs): Euler and Runge-Kutta methods
- Boundary value problems: finite difference method
- Applications: open channel hydraulics, groundwater flow modeling

Module 4: Curve Fitting and Regression Analysis

- Least squares fitting
- Linear and nonlinear regression
- Error analysis and model validation
- Applications: environmental data calibration, hydrologic prediction

Module 5: Classical Optimization Techniques

- Problem formulation in engineering optimization
- Unconstrained optimization: single and multi-variable problems
- Constrained optimization: Lagrange multipliers, Karush-Kuhn-Tucker (KKT) conditions

Module 6: Nonlinear and Multi-objective Optimization

- Nonlinear programming techniques
- Quadratic programming basics
- Penalty and barrier function methods
- Multi-objective optimization and Pareto efficiency
- Applications: reservoir operation planning, design trade-offs

Module 7: Introduction to Metaheuristic Methods

- Motivation for evolutionary and nature-inspired algorithms
- Genetic Algorithms: encoding, selection, crossover, mutation, fitness
- Particle Swarm Optimization and basic concepts of Differential Evolution
- Applications: model calibration, irrigation scheduling, watershed optimization

Module 8: Computational Tools and Case Studies

- Introduction to MATLAB and Python for numerical computing
- Use of solvers: SciPy, DEAP, PyGMO, Excel Solver
- Real-world case studies in civil, environmental, and water resources engineering
- Hands-on formulation and solution of optimization problems

Textbooks and References

1. Chapra, S.C., and Canale, R.P., *Numerical Methods for Engineers*, McGraw-Hill.
2. Rao, S.S., *Engineering Optimization: Theory and Practice*, Wiley.
3. Deb, K., *Optimization for Engineering Design*, PHI.
4. Kanti Swarup, Gupta, P.K., and Man Mohan, *Operations Research*, Sultan Chand & Sons.
5. Selected journal articles and open-source documentation (to be provided during the course).

CEO 502: Advanced Hydraulic Engineering (3-0-2-8)
Pre-Requisite: Nil

Course Objectives:

- To provide advanced knowledge of open channel flow and river hydraulics with emphasis on practical design.
- To develop skills for analyzing uniform, critical, and gradually varied flows including in compound channels.
- To introduce sediment transport, river mechanics, and river training works.
- To expose students to dam hydraulics, hydraulic modeling, and related environmental considerations.
- To train students in experimental techniques relevant to hydraulic engineering.

Course Structure:

Module 1: Open Channel Hydraulics and Flow Analysis

- Uniform flow concepts and equations
- Critical flow and flow profiles in gradually varied flow (GVF)
- Flow behavior in compound channels
- Applications in hydraulic channel design

Module 2: Rapidly Varied and Unsteady Flow

- Hydraulic jumps and energy dissipation
- Rapidly varied flow in prismatic and non-prismatic channels
- Fundamentals of unsteady flow analysis

Module 3: Channel Design and Sediment Transport

- Design principles for erodible and non-erodible channels
- Silt theories and sediment transport mechanisms
- Application of sediment transport in channel stability

Module 4: River Mechanics and River Training Works

- River morphology and erosion processes
- River training works: guide banks, spurs, groynes, revetments
- Case studies on river control and management

Module 5: Dam Engineering and Environmental Aspects

- Overview of dam types and hydraulic design
- Spillway design and energy dissipation structures
- Environmental impacts of hydraulic structures

Module 6: Hydraulic Models and Experimental Techniques

- Principles of hydraulic modeling and similitude

- Physical and numerical modeling approaches
- Use of hydraulic models in design and research

Laboratory Experiments:

- Uniform flow measurement in open channels
- Hydraulic jump characteristics
- Unsteady flow experiments
- Two-phase flow studies
- Flow measurement using weirs, notches, and mouthpieces

Textbooks & References:

1. Ranga Raju, K.G., *Flow through Open Channels*, Tata McGraw Hill, New Delhi, 1996
2. Chow, V.T., *Open Channel Hydraulics*, McGraw Hill, New York, 1959
3. Srivastava, R., *Flow through Open Channels,* Oxford Higher Education, 2007
4. Henderson, F.M., *Open Channel Flow*, McGraw Hill, New York, 1966
5. Chaudhry, M.H., *Open Channel Flow*, Prentice Hall of India, 1998
6. CBIP, *River Behaviour, Management and Training*, Vol. I & II, New Delhi, 1994
7. André Robert, *River Processes: An Introduction to Alluvial Dynamics*, Arnold, London, 1995

CEO 503: Applied Hydrology (3-0-0-6)
Pre-Requisite: Nil

Course Objectives:

- To introduce fundamental concepts of hydrology and atmospheric sciences relevant to water resources engineering.
- To develop understanding of precipitation, evaporation, and evapotranspiration processes.
- To teach methods of hydrologic data analysis, hydrograph interpretation, and flood routing.
- To familiarize students with hydrologic forecasting, urban hydrology, and time series analysis.
- To build skills for handling uncertainty, probability, and risk in hydrologic and hydraulic design.

Course Structure:

Module 1: Introduction to Hydrology and Atmospheric Concepts

- Basic hydrology concepts and water cycle overview
- Structure and composition of the atmosphere
- Air masses, cold and warm fronts
- Atmospheric temperature variations

Module 2: Atmospheric Moisture and Precipitation

- Vapor pressure, relative humidity
- Evaporation and evapotranspiration processes
- Types and forms of precipitation
- Measurement of precipitation and atmospheric parameters

Module 3: Hydrologic Data Analysis and Hydrograph Techniques

- Hydrograph analysis and interpretation
- Probability, risk, and uncertainty in hydrologic design
- Time series analysis of hydrologic data

Module 4: Flood Routing and Hydrologic Forecasting

- Hydrologic and hydraulic flood routing methods
- Algorithm development for routing
- Real-time hydrologic forecasting techniques

Module 5: Urban Hydrology and Applications

- Hydrology of urban watersheds
- Runoff estimation and stormwater management
- Impact of urbanization on hydrologic processes

Textbooks & References:

1. Chow, V.T., Maidment, D.R., Mays, L.W., *Applied Hydrology*, McGraw Hill, 1988
2. Jain, S. K., and Singh, V. P. (2019). *Engineering Hydrology: An Introduction to Processes, Analysis, and Modeling*. 1st ed. New York: McGraw-Hill Education.
3. Srivastava, R., Jain, A. *Engineering hydrology*. Mcgraw Hill Education. 2017
4. Mays, L.W., *Water Resources Engineering*, John Wiley & Sons, US, 2001
5. Haan, C.T., *Statistical Methods in Hydrology*, Iowa State University Press, 1977
6. Maidment, D.R., *Handbook of Hydrology*, McGraw Hill, 1993

CEO 504: Sediment Dynamics and River Morphodynamics (3-0-0-6)
Pre-Requisite: Nil

Course Objectives:

- To provide a comprehensive understanding of sediment characteristics, transport, and entrainment processes in fluvial systems.
- To explore the physical and chemical properties of sediments and their environmental significance.
- To introduce advanced sediment analysis techniques including laser particle analysis, X-ray diffractometry, and electron microscopy.
- To develop skills in interpreting sediment data and modeling sediment flux and concentrations.
- To connect sediment dynamics to river morphodynamics and environmental chemistry.

Course Structure:

Module 1: Sediment Characteristics and Fluvial Transport

- Types of fluvial sediments and sediment transport mechanisms
- Entrainment processes and sediment movement
- Physical and chemical characteristics of sediments

Module 2: Sediment Properties and Grain Size Analysis (6 hours)

- Grain size distribution, texture, shape, sorting, and packing
- Sediment density, porosity, permeability, and adsorption
- Textural maturity and orientation of sediments

Module 3: Analytical Techniques in Sedimentology

- Mechanical analysis: grade scales, frequency distributions
- Laser Particle Analysis (LPA), X-ray Diffractometry (XRD)
- Atomic Absorption Spectrophotometry (AAS) and Scanning Electron Microscopy (SEM)
- Shape analysis and graphical data representation

Module 4: Sediment Flux, Nutrient and Contaminant Transport

- Particulate nutrient and contaminant flux in river systems
- Environmental chemistry of sediments
- Modeling sediment flux and concentration dynamics

Laboratory:

- Experiments aligned with theoretical modules focusing on sediment analysis using XRD, SEM, LPA, and AAS techniques

Textbooks & References:

1. Miller, R.W., and Donahue, R.L., *Soils in Our Environment*, Prentice Hall, 2001
2. Griffiths, J.C., *Scientific Methods in Analysis of Sediments*, McGraw Hill, 2002
3. Grim, R.E., *Clay Mineralogy*, McGraw Hill, 1999
4. Chien, C.C., Medina, M.A., Pinder, G.F., Reible, D.D., Sleep, B., *Contaminated Ground Water and Sediment: Modeling for Management and Remediation*, CRC Press
5. DiToro, D.M., *Sediment Flux Modeling*, Wiley International, 2001

CEO 505: Water Resources Systems Analysis, Planning & Management (3-0-0-6)
Pre-Requisite: Nil

Course Objectives:

- To introduce the fundamentals of systems approach in water resources planning and management.
- To equip students with techniques for formulating and solving water resources system problems.
- To provide training in optimization and simulation methods applicable to water resources systems.
- To emphasize the importance of economic, social, and policy considerations in water planning and management.
- To develop analytical skills through real-world case studies and planning frameworks.

Course Structure:

Module 1: Introduction to Systems Approach

- Basic concepts of systems and systems engineering
- Need for systems approach in water resources
- Elements of water resources systems and system design principles

Module 2: Problem Formulation and Optimization

- Formulation of water resources problems
- Linear programming: graphical method, Simplex algorithm
- Dynamic Programming
- Sensitivity analysis and system reliability

Module 3: Reservoir Operation and Simulation Models

- Reservoir operation problems and capacity expansion planning
- Simulation techniques for water systems
- Multi-reservoir system analysis
- Case studies of reservoir system performance

Module 4: Planning and Decision-Making

- Role of planners in water resources development
- Public involvement and stakeholder engagement
- National Water Policies and legal-institutional frameworks

Module 5: Economic and Social Aspects

- Economic analysis of water resources projects
- Social impact assessment
- Cost-benefit analysis and sustainability considerations

Textbooks & References:

1. Loucks, D.P., Stedinger, J.R., Haith, D.A., *Water Resources Systems Planning and Management*, Prentice Hall, New Jersey, 1987
2. Hall, K.A., and Dracup, J.A., *Water Resources Systems Engineering*, Tata McGraw Hill, 1970
3. Grigg, N.S., *Water Resources Planning*, McGraw Hill, 1985
4. *National Water Policy*, Ministry of Jal Shakti, Government of India (latest version)

CEO 506: Stochastic Hydrology (3-0-0-6)
Pre-Requisite: Nil

Course Objectives:

- To introduce students to stochastic approaches for analyzing hydrologic processes.
- To build a strong foundation in probability, statistics, and random process theory applied to hydrology.
- To equip students with tools for modeling, simulation, and forecasting under uncertainty.
- To apply stochastic methods in surface water hydrology, including rainfall, runoff, and streamflow processes.

Course Structure:

Module 1: Fundamentals of Probability and Statistics

- Review of probability theory and statistical measures
- Conditional probability and Bayes' theorem
- Random variables and transformations
- Moments, quantiles, and commonly used hydrologic probability distributions

Module 2: Estimation, Hypothesis Testing, and Goodness of Fit

- Principles of hypothesis testing
- Goodness of Fit test
- Maximum likelihood estimation
- Least squares minimization methods
- Monte Carlo simulation techniques

Module 3: Theory of Random Processes

- Introduction to random processes in hydrology
- Stationarity and ergodicity
- Autocorrelation and spectral analysis
- Estimation of linear static systems

Module 4: Frequency Analyses

- Frequency analyses using different probability distributions
- Risk and Reliability in Hydrologic Design
- Uncertainty Analyses
- Kalman filter and its variants

Module 5: Principal Component Analyses

- Determining Principal components
- One-Way analysis of variance
- Two-way analysis of variance

Module-6: Stochastic Dynamic Systems and Kalman Filter

- Kalman filter and its variants
- Applications in real-time hydrologic forecasting

Module 7: Time Series Analyses

- Stationary and Non-stationary Time Series
- Ensemble and Realisation
- Trend Analyses
- AR; MA; ARMA; ARIMA; ARMAX models

Textbooks & References:

1. Haan, C. T., *Statistical Methods in Hydrology*, Iowa State University Press, 1977
2. Maity, R., *'Statistical Methods in Hydrology and Hydroclimatology'* Springer Nature Singapore, 2019
3. Zhang, Dongxiao, *Stochastic Methods for Flow in Porous Media*, Academic Press, 2002
4. Bras, R.L. and Rodriguez-Iturbe, I., *Random Functions and Hydrology*, Dover Publications, 1994
5. Gelhar, L.W., *Stochastic Subsurface Hydrology*, Prentice Hall, 1993

CEO 507: River Engineering and Structures (3-0-0-6)
Pre-Requisite: Nil

Course Objectives:

- To develop a comprehensive understanding of river morphology and fluvial processes.
- To provide analytical tools for evaluating river flow hydraulics, sediment transport, and river stability.
- To introduce concepts and techniques for river training, stabilization, and structure design in riverine environments.

Course Structure:

Module 1: Introduction to River Engineering and Morphology (5 hours)

- River classifications and types
- Thresholds in river morphology
- Hydraulic geometry and meander planforms
- Geomorphic responses of river channels to natural and anthropogenic influences

Module 2: Hydraulics of River Flow (6 hours)

- Alluvial channel flow fundamentals
- Uniform and unsteady flow in rivers
- Shear stress distribution and flow resistance
- Applications in natural river systems

Module 3: Sediment Transport and Scour (6 hours)

- Physical characteristics of sediments
- Mechanics of sediment entrainment and transport
- Shear stress, Shields parameter, and critical conditions
- Scour around bridge piers, abutments, and embankments
- River bedforms and flow-sediment interactions

Module 4: Regime Concepts and Stable Channel Design (6 hours)

- Meander analysis and prediction
- Regime theory and stable alluvial channel design
- Dimensional modeling of river behavior
- Braided rivers: scaling, hierarchy, and alternate bar formation
- Bedload transport dynamics in gravel-bed rivers

Module 5: River Training and Bank Stabilization (6 hours)

- Causes and mechanics of streambank erosion
- Techniques for bank protection (revetments, riprap, vegetation)
- Flow control and training structures (groynes, spurs, guide bunds)
- River stabilization in braided systems

Textbooks & References

1. Chang, H. H., *Fluvial Processes in River Engineering*, John Wiley, 1988.
2. Charlton, R., *Fundamentals of Fluvial Geomorphology*, Taylor and Francis, 2007.
3. Fluvial Hydrodynamics
4. Dey, S., *Fluvial Hydrodynamics: Hydrodynamic and Sediment Transport Phenomena* (GeoPlanet: Earth and Planetary Sciences Book 3). 2nd Edition. Springer, 2014.
5. Gregory H., *Braided Rivers: Process, Deposits, Ecology and Management*, Blackwell Publishing, 2006.
6. Yang, C. T., *Sediment Transport: Theory and Practice*, McGraw Hill, 1996.
7. Knighton, D., *Fluvial Forms and Processes*, Edward Arnold, 1984.
8. Richards, K., *Rivers: Form and Process in Alluvial Channels*, Methuen, 1982.
9. Shen, H.W., *River Mechanics*, Vol. I & II, Water Resources Publication, 1971.
10. Thorne, C.R., Hey, R.D., Newson, M.D., *Applied Fluvial Geomorphology for River Engineering and Management*, John Wiley & Sons, 1997.

CEO 508: Soft Computing Applications in Integrated Water Resource Management (3-0-0-6)
Pre-Requisite: Nil

Course Objectives:

- To introduce the fundamentals of soft computing techniques including fuzzy logic, artificial neural networks (ANN), and evolutionary algorithms.
- To demonstrate their relevance and application in modeling, optimization, and decision-making processes within Integrated Water Resources Management (IWRM).
- To build capacity for addressing non-linear, uncertain, and complex problems in water systems through computational intelligence.

Course Structure:

Module 1: Introduction to Soft Computing and IWRM

- Principles and challenges in Integrated Water Resources Management
- Role and necessity of soft computing in water resources
- Characteristics of soft computing and comparison with hard computing
- Components: Fuzzy Logic, ANN, Genetic Algorithms, hybrid models

Module 2: Fuzzy Logic in Water Resources

- Fuzzy set theory and membership functions
- Fuzzy inference systems: Mamdani and Sugeno models
- Decision-making under uncertainty using fuzzy logic
- Applications: water quality assessment, flood risk analysis, reservoir operation, and policy modeling

Module 3: Artificial Neural Networks in Hydrologic Modelling

- Feedforward and recurrent neural network architectures
- Training algorithms: backpropagation and variations
- Applications: rainfall-runoff modeling, groundwater prediction, sediment yield estimation, streamflow forecasting
- Comparison with traditional statistical models

Module 4: Evolutionary Algorithms and Optimization

- Basics of optimization in water resources engineering
- Genetic Algorithms: encoding, selection, crossover, mutation
- Particle Swarm Optimization (PSO), Differential Evolution (DE)
- Applications: optimal reservoir operation, irrigation planning, multi-objective optimization in IWRM

Module 5: Hybrid and Advanced Techniques

- Neuro-fuzzy modeling and its applications
- Hybrid soft computing models: ANN-GA, Fuzzy-GA, PSO-ANN

- Ensemble learning, Support Vector Machines in water systems
- Case studies on integrated watershed modeling and real-time allocation

Module 6: Applications and Case Studies in IWRM

- Role of soft computing in decision support systems for IWRM
- Basin-scale planning under uncertainty
- Case studies from India and international contexts
- GIS and remote sensing integration for spatial analysis and decision making

Module 7: Tools and Software

- MATLAB / Python toolboxes for fuzzy logic and neural networks
- Integration with GIS and DEM-based analysis
- Optional hands-on sessions and demonstrations (lab extension where applicable)

Textbooks & References

1. S. Rajasekaran and G.A. Vijayalakshmi Pai, *Neural Networks, Fuzzy Logic and Genetic Algorithms: Synthesis and Applications*, PHI.
2. Jang, Sun, Mizutani, *Neuro-Fuzzy and Soft Computing*, Pearson Education.
3. K. Srinivasa Raju and D. Nagesh Kumar, *Multicriterion Analysis in Engineering and Management*, PHI.
4. M. A. Marino and J. E. B. Smith, *Hydrology: An Integrated Approach*, Prentice Hall.

CEO 509: Flood Risk Assessment and Management (3-0-0-6)
Pre-Requisite: Nil

Course Objectives:

- To provide a comprehensive understanding of the causes, characteristics, and dynamics of flood events.
- To equip students with modern techniques and tools for flood hazard, vulnerability, and risk assessment.
- To introduce integrated strategies for flood risk management, considering uncertainty, climate change, and urbanization.
- To familiarize students with real-world flood risk management practices, policies, and case studies.

Course Content:

Module 1: Fundamentals of Flood Hydrology

- Classification and causes of different types of floods
- Catchment characteristics and extreme rainfall analysis
- Development of flood hydrographs; unit hydrograph theory
- Methods for design flood estimation: empirical, statistical, and rainfall-runoff approaches

Module 2: Flood Routing and Inundation Modeling

- Flood routing methods: hydrologic (Muskingum, Puls) and hydraulic (Saint Venant equations)
- One-dimensional and two-dimensional modeling using HEC-RAS, MIKE FLOOD, etc.
- Floodplain mapping using DEMs
- Calibration and validation of hydraulic models

Module 3: Flood Hazard, Vulnerability, and Risk Assessment

- Definitions and interrelationships: hazard, exposure, vulnerability, risk
- Frequency analysis using probability distributions
- Hazard mapping approaches: return-period and scenario-based
- Vulnerability assessment with socio-economic indicators
- Risk quantification using deterministic and probabilistic methods

Module 4: Flood Risk Management Strategies

- Structural interventions: embankments, flood walls, detention basins, reservoirs, channel improvements
- Non-structural measures: forecasting, early warning systems, zoning, insurance mechanisms
- Integrated Flood Management (IFM) and nature-based solutions
- Role of communities in participatory flood risk management

Module 5: Climate Change and Urban Flooding

- Climate change effects on flood frequency and intensity
- Urbanization and the emergence of pluvial flooding
- Urban drainage design and stormwater management
- Concepts and applications of LID and SUDS in urban environments

Module 6: Policies, Guidelines, and Case Studies

- Key policy documents: NDMA guidelines, CWC manuals, UNDRR frameworks, EU Floods Directive
- Case studies from national (e.g., Ganga, Brahmaputra) and international (e.g., Rhine, Mississippi) rivers
- Integration of remote sensing and GIS in flood risk analysis
- Governance, institutional frameworks, and stakeholder engagement

Module 7: Decision Support Systems and Emerging Technologies

- Real-time decision support systems (DSS) for flood monitoring and emergency response
- AI and machine learning applications in flood prediction
- Internet of Things (IoT), UAVs, and community-sourced data for flood monitoring
- Digital twins and smart flood resilience infrastructure planning

Textbooks & References:

1. Z. W. Kundzewicz, *Flood Risk and Vulnerability – A Global Perspective,* Springer.
2. K. Smith and R. Ward, *Floods: Physical Processes and Human Impacts*, Wiley-Blackwell.
3. NDMA, *Guidelines on Management of Floods*, Government of India.
4. Apel, H., et al., "Flood Risk Analysis: Concepts and Challenges," *Natural Hazards Journal*.

CEO 510 Integrated Water Management & Policy (3-0-0-6)
Pre-Requisite: Nil

Course Objectives:

- To introduce students to the broader dimensions of water management beyond technical interventions, incorporating social, cultural, economic, and policy aspects.
- To develop an understanding of the principles and evolution of Integrated Water Resources Management (IWRM) in India and globally.
- To explore institutional frameworks, stakeholder engagement, and participatory approaches in managing water resources.
- To critically analyze water-related conflicts, governance structures, and emerging tools and technologies in water policy and planning.

Course Outline:

Module 1: Introduction to IWRM and Water Resources in India

- Definition, scope, and evolution of IWRM
- Key principles: sustainability, equity, and efficiency
- Multi-dimensional view: environmental, social, and economic aspects
- Overview of India's water resources: rivers, groundwater, and basin characteristics
- Challenges of water scarcity, pollution, overexploitation, and climate variability

Module 2: Participatory Water Governance and Social Dimensions

- Stakeholder involvement and participatory approaches
- Water as a social good: access, equity, and justice
- Gender dimensions in water management
- Role of indigenous knowledge and local practices in water governance

Module 3: Institutional and Policy Frameworks

- National Water Policy and state policies
- Institutional structures: central and state agencies, water user associations
- Role of panchayats and urban local bodies in governance
- Implementation challenges and policy-practice gaps

Module 4: Water Conflicts and Dispute Resolution

- Inter-state and international water disputes in India
- Legal, administrative, and political mechanisms for conflict resolution
- Case studies: Cauvery, Krishna, and Indus river basins
- Federalism and cooperative frameworks

Module 5: Water, Livelihoods, and Development

- Linkages between water and agriculture, industry, and community livelihoods
- Water security and poverty alleviation
- Sustainability of water-based livelihoods under changing environmental conditions

Module 6: Public-Private Partnerships and Implementation Models

- PPP models in water supply, sanitation, and irrigation
- Pros and cons of private participation in water sector
- Regulatory and institutional safeguards
- Case examples of PPPs in India

Module 7: Emerging Trends and Future Directions

- Role of emerging technologies: AI, Big Data, and IoT in water management
- Integration of GIS and remote sensing in planning and monitoring
- Climate change adaptation and resilience strategies
- Global case studies and innovative practices

Textbooks & References:

1. Prakash, A. (Ed.). *Water Resource Management in South Asia*. Taylor & Francis, 2022.
2. Biswas, A. K. (2016). *Integrated Water Resources Management*. C. Tortajada (Ed.). Routledge Taylor & Francis Group.
3. Mollinga, P. P., Dixit, A., & Athukorala, K. (2006). *Integrated Water Resources Management: Global Theory, Emerging Practice and Local Needs*.
4. Whaley, L. (2022). *Water Governance Research in a Messy World: A Review*, *Water Alternatives*, 15(2), 218–250.
5. Allan, J. A. (2003). *IWRM is More a Political than a Technical Challenge*. In *Developments in Water Science*, Vol. 50, pp. 9–23. Elsevier.