CURRICULUM & SYLLABI

M. Tech. WATER RESOURCES ENGINEERING

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute
National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department
CIVIL Engineering

VISION

To be a knowledge nerve centre in civil engineering education, research, entrepreneurship and industry outreach services for creating sustainable infrastructure and enhancing quality of life.

MISSION

- Generate a specialized cadre of civil engineers by imparting quality education and training
- Attain international standards in teaching, research and consultancy with global linkages

Program: M.Tech. Water Resources Engineering

Program Educational Objectives

PEO-1	Apply knowledge of basic sciences and engineering to analyze water resources systems for socio-economic development.
PEO-2	Identify the sources of water and their characteristics.
PEO-3	Plan and design water resources systems.
PEO-4	Analyze complex field situations and provide engineering solutions for land and water management.
PEO-5	Communicate effectively, and lead multidisciplinary teams to solve water related issues with professional ethics.
PEO-6	Provide scientific inputs to decision makers.

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4	PEO-5	PEO-6
Generate a specialized cadre of civil engineers by imparting quality education and training	3	3	3	3	2	2
Attain international standards in teaching, research and consultancy with global linkages	3	3	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: M. Tech. Water Resources Engineering

Program Outcomes

PO-1	Engage in critical thinking and pursue investigations/research and development to solve practical problems.
PO-2	Communicate effectively, write and present technical reports on complex engineering activities by interacting with the engineering fraternity and with society at large.
PO-3	Demonstrate higher level of professional skills to tackle multidisciplinary and complex problems related to water resources engineering.
PO-4	Analyse hydro meteorological data and various components of hydrological cycle and assess surface and groundwater resources.
PO-5	Plan, design and operate water resources systems for meeting socio-economic and environmental needs and optimal utilization of available resources.
PO-6	Develop strategies to manage hydrologic extremes and mitigate the impacts of climate change.

Program Articulation Matrix

PEO / PO	PEO-1	PEO-2	PEO-3	PEO-4	PEO-5	PEO-6
PO1	3	1	3	3	1	2
PO2	2	-	-	-	3	3
PO3	2	2	2	1	3	2
PO4	2	3	2	2	-	-
PO5	3	3	3	2	1	2
PO6	1	2	1	2	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

CURRICULUM
M. Tech. Water Resources Engineering

1st Semester

S. No.	Code	Course Title	L-T-P	Credits
1	CE76001	Applied Hydrology	3-0-0	3
2	CE76003	Stochastic Hydrology	3-1-0	4
3	CE76005	Advances in Fluid Mechanics & Hydraulic Engineering	3-1-0	4
4	CE760XX	Professional Elective - I	3-0-0	3
5	CE760XX	Professional Elective - II	3-0-0	3
6	CE76007	Computational Lab	0-1-2	2
7	CE76009	Water Resources Engineering Lab	0-1-2	2
			Total Credits	**21**

2nd Semester

S. No.	Code	Course Title	L-T-P	Credits
1	CE76002	Water Resources Systems Planning and Management	3-1-0	4
2	CE76004	Groundwater Hydrology	3-0-0	3
3	CE760XX	Professional Elective - III	3-0-0	3
4	CE760XX	Professional Elective - IV	3-0-0	3
5	CE760XX	Professional Elective - V	3-0-0	3
6	CE76006	Geographic Information Systems (GIS) Applications Lab	0-1-2	2
7	CE76008	Hydrologic and Hydraulic Modelling Lab	0-1-2	2
8	CE76096	Minor Project	0-0-0	2
			Total Credits	**22**

3rd Semester

S. No.	Code	Course Title	L-T-P	Credits
1	CE76089	Seminar and Technical Writing	0-0-0	2
2	CE76093	Comprehensive Viva-Voce	0-0-0	2
3	CE76097	Dissertation: Part-A	0-0-0	8
4	CE76091	Summer Internship / Research Experience	0-0-0	2
		Total Credits		**14**

4th Semester

S. No.	Code	Course Title	L-T-P	Credits
1	CE76098	Dissertation: Part-B	0-0-0	12
		Total Credits		**12**

Professional Elective Courses:

Professional Electives I & II		
S. No.	**Code**	**Course Title**
1	CE76021	Design of Hydraulic Structures
2	CE76023	Integrated Watershed Management
3	CE76025	Computational Methods in Water Resources Engineering
4	CE76027	Hydropower Systems
5	CE76029	Climate and Climate Change Modelling

Professional Electives III, IV & V		
S. No.	**Code**	**Course Title**
1	CE76022	Remote Sensing & GIS in Water Resources
2	CE76024	Urban Hydrology
3	CE76026	Soft Computing Techniques
4	CE76028	Advanced Hydrologic Modelling
5	CE76030	Water Distribution Networks
6	CE76032	Fluvial Hydraulics
7	CE76034	AI and ML in Water Resources
8	CE76036	On Farm Development & Management
9	CE76038	Contaminant Transport Modeling in Porous Media

Note: In addition to the above elective courses, students can take elective courses from other specializations offered by the respective M. Tech programs in the department.

The Overall Credit Structure

Credits in Each Semester					
Cat. Code	**Sem-I**	**Sem-II**	**Sem-III**	**Sem-IV**	**Total**
PCC	15	11			**26**
PEC	6	9			**15**
MP/DP		2	8	12	**22**
STW			2		**2**
CVV			2		**2**
SI/RE			2		**2**
Total	**21**	**22**	**14**	**12**	**69**

Abbreviations:

PCC	Program Core Course
PEC	Professional Elective Course
MP/DP	Minor project / Dissertation Part- A/B
STW	Seminar and Technical Writing
CVV	Comprehensive Viva-Voce
SI/RE	Summer Internship / Research Experience

SYLLABI

M. Tech. Water Resources Engineering

1st Semester

CE76001 **3-0-0 (3)**

Applied Hydrology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze components of hydrologic cycle
CO-2	Predict hydrologic extreme events for hydraulic and hydrologic design
CO-3	Develop forecasting models for operation of hydrologic systems
CO-4	Assess surface water resources

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	–	2	3	–	1
CO-2	1	–	2	3	1	3
CO-3	1	–	3	3	–	2
CO-4	1	–	2	3	–	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Description of Hydrologic Cycle, Overview of application of hydrology in engineering, Historical aspects of development of hydrology, Eco-hydrology

Precipitation: Formation and process, Global Weather Systems, Characteristics of precipitation in India, Analysis of rainfall data, intensity-duration-frequency analysis and depth-area-duration analysis, development of design storms for typical regions in data scarce environment

Evaporation: Process, Measurement, Estimation – Energy Balance method, Aerodynamic method, Combination method, Empirical methods, Factors affecting evaporation rate.

Evapotranspiration: Process, Measurement, Penman-Monteith method, crop water requirement, estimation of effective rainfall.

Infiltration: Process, measurement of infiltration, infiltration models – Richard's equation, Horton's model and Green-Ampt model, factors affecting infiltration rate.

Runoff: runoff generation process, catchment characteristics, factors affecting runoff, advanced streamflow measurement techniques, yield from a catchment, Runoff Estimation methods, flow duration curve, flow mass curve analysis.

Hydrograph Theory: Components of hydrograph, base flow separation, direct runoff hydrograph, Unit hydrograph theory, derivation of unit hydrograph, S-hydrograph and instantaneous unit hydrograph, Derivation of unit hydrograph for ungauged catchments, conceptual models - synthetic unit hydrograph and its derivation

Flood Estimation: Peak discharge estimation procedures, deterministic and probabilistic approaches, enveloping curve, rational method, SCS and unit hydrograph methods

Flood Routing: Concepts of flow routing, hydraulic and hydrologic routing, St. Venant's equations, Reservoir routing, Channel routing, Muskingum and Muskingum-Cunge methods of channel routing and flood forecasting

Learning Resources:

Text Books:

1. Chow, V.T., Maidment, D.R., and Mays, L.W., Applied Hydrology, Tata McGraw Hill Edition, 2017, 2nd Edition
2. Subramanya, K., Engineering Hydrology, Tata McGraw Hill Publications, 2017, 4th Edition

Reference Books:

1. McCuen, R.H., Hydrologic Analysis and Design, Pearson Publications, 2017, 4th Edition
2. Mays, L.W., Water Resources Engineering, Wiley Publications, 2019, 3rd Edition
3. Viessman, W., and Lewis, G.L., Introduction to Hydrology, Prentice Hall of India, 2008, 5th Edition

Other Suggested Readings:

1. https://nptel.ac.in/courses/105/104/105104029/

CE76003 **3-1-0 (4)**

Stochastic Hydrology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze hydrologic data
CO-2	Perform frequency analysis of hydrologic extremes
CO-3	Apply multivariate analysis in hydrologic systems
CO-4	Analyze hydrologic time series
CO-5	Develop models for synthesis of hydrologic variables

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	3	-	1
CO-2	1	-	2	3	-	3
CO-3	1	-	3	3	1	1
CO-4	1	-	3	3	-	2
CO-5	2	-	3	3	1	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Deterministic and Stochastic Hydrology, review of concepts of probability, probability axioms, Random variables and their properties, probability distribution and probability density function.

Probability Distributions: Discrete and continuous probability distributions used in hydrology, moments and expectations of distributions, Parameter estimation, method of moments, maximum likelihood method and method of probability weighted moments.

Hypothesis testing: Goodness test of fit tests, Chi Square test and KS test.

Frequency Analysis: Frequency analysis of hydro-climatic extremes, extreme value distributions, analysis of floods, droughts and other natural hazards, Regional flood frequency analysis, Risk and reliability in hydrologic design, Analysis and measures of hydrologic uncertainty.

Correlation Analysis: Correlation analysis and correlation coefficient, Simple linear regression, Multivariate regression analysis, Correlation coefficient and its significance in regional analysis, analysis of variance, applications – rainfall-runoff analysis, rating curves, water quality modelling, Multivariate analysis, principal component analysis, cluster analysis.

Time Series Analysis: Hydrologic Time Series Analysis, Hydrologic time series, stationary and non-stationary time series, Ensemble and realization, trend analysis, trend removal, analysis of periodicity, Fourier transformation and harmonic analysis, autocorrelation function, spectral density function, Wavelet analysis.

Time Series Modelling: Modelling of Hydrologic Time Series, Time series models, autoregressive and moving average models, periodic models, Calibration and validation of hydrologic time series models,

data generation techniques, simulation of hydrologic time series, streamflow forecasting, First order Markov process, Markov chain, Multi-site time series model, cross- correlation, spatial and temporal disaggregation models.

Copulas: Theory of copula and its use in hydrology, commonly used copula functions, selection of best fit copula, uses of copula.

Learning Resources:

Text Books:

1. Haan T. C., Statistical Methods in Hydrology, East West Publishers, 2002
2. Kotteguda, N.T., and Resso, R., Statistics, Probability and Reliability for Civil and Environmental Engineers, Blackwell Publishing, UK, 2008

Reference Books:

1. Kotteguda, N.T., Stochastic Water Resources Technology, The Macmillan Press, New York, 1982
2. Maity, R., Statistical Methods in Hydrology and Hydro-climatology, Springer Nature Singapore Pte Ltd., 2018

Other Suggested Readings:

1. https://nptel.ac.in/courses/105/108/105108079/

CE76005 **3-1-0 (4)**

Advances in Fluid Mechanics & Hydraulic Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Formulate momentum, energy and mass transport models
CO-2	Analyze Potential Flows
CO-3	Develop approximate solutions for small and large Reynolds number flows
CO-4	Apply turbulent flow models
CO-5	Formulate and solve the problem of propagation of flood wave and surges in channels
CO-6	Perform Hydraulic routing and dam break analysis

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	–	3	3	–	–
CO-2	1	–	3	2	3	1
CO-3	2	–	3	2	3	2
CO-4	2	–	3	1	3	2
CO-5	2	–	3	–	2	2
CO-6	2	–	3	–	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Review of physical meaning of mathematics necessary for understanding of fluid mechanics.

Description of fluid flow: With reference to translation, rotation and deformation concept of continuum, control mass & control volume approach, Reynolds transport theorem.

Velocity field: One & two-dimensional flow analysis, circulation and vorticity, stream function and velocity potential function, potential flow, standard flow patterns, combination of flow patterns, flow net.

Dimensional Analysis: Dimensional analysis as a tool in design of experiments, identification of non-dimensional numbers and their significance, dimensional analysis methods.

Equations of Motion: Equations of motion for laminar flow of a Newtonian fluid - Viscous flow – Navier-Stoke's equations, simple exact solutions.

Boundary Layer Theory: Formation, growth and separation of boundary layer-Integral momentum principles to compute drag and lift forces-Mathematical models for boundary layer flows.

Turbulence: Origin of turbulence, universal velocity distribution laws of turbulence, smooth rough and transitional turbulent flow in pipes, pipe resistance equation for pipes design of pipe networks, Diffusion and dispersion of pollutants in natural streams.

Free surface Flow: Gradually varied flow, Specific energy, Critical flow, Channel transitions, Uniform flow formulae, Type of GVF profiles, Computation of GVF profiles, Steady and Unsteady Rapidly Varied Flow, Hydraulic jump in a horizontal rectangular channel, Positive and Negative surges, St. Venant's equation, Method of Characteristics, Hydraulic routing.

Learning Resources:

Text Books:

1. Fox, R.W., Pitchard, P.J., and Mcdonald, A.T., Fluid Mechanics, Wiley India Pvt. Ltd., 2009, 10th Edition
2. Chow, V.T., Open Channel Hydraulics, McGraw Hill Inc. N York, 1979

Reference Books:

1. Schlichting, H., and Gresten, K., Boundary Layer Theory, Springer Publications, 2004.
2. White, F.M., Viscous Fluid Flow, McGraw Hill Pub. Co, New York, 2011.
3. Yalin, M.S., Theory of Hydraulic Models, McMillan Co., 1971
4. French, R.H., Open Channel Hydraulics, McGraw Hill Pub Co., N York, 1986
5. Subramanya, K., Flow in Open Channels, Tata McGraw Hill Pub., 2008
6. Chung Fang, An Introduction to Fluid Mechanics, Springer International Publishing, 2018.

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/105/112105218/
2. https://nptel.ac.in/courses/112/105/112105287/
3. https://nptel.ac.in/courses/105/106/105106114/

CE76007 **0-1-2 (2)**

Computational Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Perform statistical analysis of hydrologic data
CO-2	Analyze hydrologic time series and develop hydrologic time series models
CO-3	Analyze and design water distribution networks
CO-4	Apply numerical methods for computation of backwater profile, hydraulic flood routing
CO-5	Use software tools like R and MATLAB for hydraulic and hydrologic design

Course Articulation Matrix:

PO / CO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	2	2	3	-	1
CO-2	1	2	3	3	-	1
CO-3	2	2	3	1	3	1
CO-4	2	2	3	2	2	2
CO-5	3	2	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Programming and Algorithms: Basic concepts and syntaxes of R, Python and MATLAB.

Statistical Analysis: Using R/MATLAB for statistical analysis, frequency analysis of hydrologic extremes, time series analysis and modelling.

Flood Routing: Reservoir flood routing modules using R/MATLAB.

Hydraulic Routing: Apply finite difference methods for hydraulic flood routing.

Learning Resources:

Other Suggested Readings:

1. https://rstudio-education.github.io/hopr/
2. https://in.mathworks.com/help/matlab/

CE76009 **0-1-2 (2)**

Water Resources Engineering Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop procedure for standardization of experiments
CO-2	Calibrate flow discharge measuring device used in pipes channels and tanks
CO-3	Determine fluid and flow properties
CO-4	Characterize laminar and turbulent flows
CO-5	Analyze open channel flow
CO-6	Test the performance of pumps and turbines

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	–	3	–	–
CO-2	2	2	2	3	–	–
CO-3	2	2	1	3	–	–
CO-4	–	–	2	3	1	–
CO-5	2	2	2	3	2	–
CO-6	2	2	2	3	2	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Calibration of Devices: Calibration of Venturimeter and Orifice meter (discharge measuring device in pipes), Orifice and mouthpiece (discharge measuring device in Tanks), triangular notch and rectangular notch (discharge measuring device in Channels).

Viscosity Measurement: Measurement of viscosity by Hazen- Poiseuille method and Stokes method.

Determination of various factors: Determination of Darcy's friction factor, relative roughness for laminar and turbulent flows, Determination of energy loss in hydraulic jump.

Hydraulic Machines: Performance Characteristics of single stage centrifugal pump, multi stage centrifugal pump, Submersible pumps, and varying speed centrifugal pump, Performance Characteristics turbines.

Open Channel flow Analysis: Determination Velocity distributions in open channels, Determination of Manning's and Chezy's coefficients for smooth and rough channels.

Infiltration Experiments: Single ring, Double ring infiltrometer.

Learning Resources:

Text Books:

1. K.L.Kumar, Engineering Fluid Mechanics, Eurasia Publishing House, 2016
2. Jagdish Lal, Hydraulic Machines including Fluidics, Metropolitan Book Co, Delhi, 2016

2nd Semester

CE76002 **3-1-0 (4)**

Water Resources Systems Planning and Management

Pre-Requisites: CE76001, CE76003

Course Outcomes:

CO-1	Apply concepts of systems analysis for planning of water resources systems
CO-2	Perform basic economic analysis to evaluate the economic feasibility of water resources and environmental engineering projects
CO-3	Formulate and solve deterministic optimization models for design and operation of water resources systems
CO-4	Formulate and solve stochastic and fuzzy optimization problems for decision making under uncertainty

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	3	1	3	1
CO-2	1	-	3	-	3	-
CO-3	2	-	3	-	3	3
CO-4	2	-	3	-	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Overview of the course, concepts of systems analysis, water resources planning, Modeling techniques, objectives and constraints, overview of optimization techniques.

Linear programming: Linear programming, Graphical method, simplex method, sensitivity analysis, duality. Dynamic programming, concepts, formulation of recursive equation.

Classical Optimization Techniques: Lagrange methods, Kuhn-Tucker conditions, Search techniques,

Stochastic Optimization Techniques: Chance constrained LP, stochastic dynamic programming, decision making under uncertainty, fuzzy optimization.

Multi Objective Optimization: Overview of multi objective optimization, multi criteria decision making, Simulation- optimizations.

Genetic Algorithm: Overview of Genetic Algorithm and other evolutionary algorithms

Economic analysis: Discounting techniques, benefit cost evaluation.

River basin modelling: Storage-yield relation, reservoir design and operation.

Applications of Optimization: Overview of applications of optimization and simulation techniques in hydrologic and water resources systems – irrigation management, water quality management, groundwater management, water conveyance and distribution systems.

Learning Resources:

Text Books:

1. Loucks, D.P., and Eelco van Beek, Water Resources Systems Planning and Management – An introduction to methods, models and applications, UNESCO and Springer, 2017
2. Vedula, S., and Mujumdar, P.P., Water Resources Systems Modeling Techniques and Analysis, Tata McGraw Hill Pub. Co., 2005

Reference Books:

1. Loucks, D.P., Stedinger, J.R., and Haith, D.A., Water Resources Systems Planning and Analysis, Prentice Hall Inc., 1982
2. Charles, S.R., Whitlatch, E.E., and Wright, J.R., Civil and Environmental Systems Engineering, Pearson Education Inc., 2004

Other Suggested Readings:

1. https://nptel.ac.in/courses/105/108/105108130/

CE76004 **3-0-0 (3)**

Groundwater Hydrology

Pre-Requisites: **CE76001**

Course Outcomes:

CO-1	Assess groundwater flow and model regional groundwater flow
CO-2	Identify of groundwater source by groundwater prospecting
CO-3	Design water wells
CO-4	Manage groundwater resources
CO-5	Plan and design artificial recharge systems

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	3	3	-	1
CO-2	1	-	3	3	-	1
CO-3	2	-	3	1	3	2
CO-4	2	-	3	1	3	2
CO-5	1	-	3	3	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Groundwater: Ground water availability, Groundwater in the hydrologic system, Hydrologic budget, Vertical distribution of subsurface strata, Types of aquifers, Aquifer characteristics.

Groundwater Movement: Darcy's law, Hydraulic conductivity and intrinsic permeability, Transmissivity, Homogeneity and isotropy, Stream function, Flownet.

Groundwater Flow Hydraulics: Well hydraulics, partial differential equations governing groundwater flow in aquifers, estimation of aquifer parameters by different methods, steady groundwater flow analysis for multi-well systems, Well flow near different boundary conditions, Method of images

Groundwater Modelling: Groundwater modelling, formulation of anisotropic and non- homogenous flow of groundwater, finite difference methods for solving groundwater flow problems, regional groundwater flow modelling

Groundwater Prospecting: Geologic method, Remote sensing, Geophysical exploration, Electric resistivity method, Seismic method, Gravity and magnetic methods

Well Logging and Construction: Type of wells, Selection of well site, Well logging, Well construction techniques, Well completion

Groundwater Management: Concept of basin management, Conjunctive use of surface water and groundwater, Groundwater management techniques

Managed Groundwater Recharge: Objective and purpose of MGR, Methods of MGR

Climate Change Impacts on Groundwater: Hydrological components affecting the groundwater, Direct impacts of climate change on groundwater, Indirect impacts of climate change on groundwater, Climate change impacts on water availability in an aquifer

Learning Resources:

Text Books:

1. Karamouz, M., Ahmadi, A., and Akhbari, M., Groundwater Hydrology: Engineering, Planning and Management, CRC Press, Taylor et Francis Group, 2020
2. Todd, D.K., and Mays, L.W., Groundwater Hydrology, John Wiley & Sons, Singapore, 2018

Reference Books:

1. Rastogi, A.K., Numerical Groundwater Hydrology, Penram International Publishing Pvt. Ltd., 2012
2. Davis, S. N., and De Weist, R. J. M., Hydrogeology, John Wiley & Sons, New York, 2013
3. Chahar, B. R., Groundwater Hydrology, McGraw Hill Education (India) Private Limited, New Delhi, 2015

Other Suggested Readings:

1. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2002WR001516
2. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/groundwater-management
3. https://www.usgs.gov/mission-areas/water-resources/science/artificial-groundwater-recharge

CE76006 **0-1-2 (2)**

Geographic Information Systems (GIS) Applications Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Prepare the different geospatial layers
CO-2	Compute geometric measurements and perform spatial analysis
CO-3	Create high-quality maps and associated graphics
CO-4	Integrate different geospatial layers

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	2	2	-	-
CO-2	1	2	3	3	-	1
CO-3	1	2	3	3	-	-
CO-4	1	2	3	2	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Basics of Map and Layer: Importing maps and layers from various sources

Online Data Acquisition: Accessing various online data resources for water resources applications

Projection: Geo-referencing and projection, Digitization of Points and Lines, Editing Map Elements

Data Analysis Tools: Attribute Data Entry and Manipulation Cleaning, Building and Transformation Data Analysis – Overlay, Buffer

Map Generation: Map Generation with Patterns and Legends
Buffering & Network: Buffer Analysis, Network Analysis

Map Delineation: Watershed delineation and Geomorphologic characteristics of watershed

RS Data Classification: Supervised and unsupervised classification of remote sensed data

Learning Resources:

Text Books:

1. ArcGIS user manuals
2. QGIS User Manuals

Other Suggested Readings:

1. https://docs.qgis.org/2.8/en/docs/training_manual/processing/hydro.html
2. https://hatarilabs.com/ih-en/watershed-and-stream-network-delineation-on-large-scale-basins-with-qgis-3-tutorial
3. https://support.esri.com/en/technical-article/000012346

CE76008 **0-1-2 (2)**

Hydrologic and Hydraulic Modelling Laboratory

Pre-Requisites: CE76001, CE76005

Course Outcomes:

CO-1	Compare and comprehend different hydrologic and hydraulic models
CO-2	Utilize hydrological models such as SWAT and HEC-HMS for hydrological analysis
CO-3	Make use of hydraulic models for analysis of water distribution and drainage networks
CO-4	Apply hydrologic and hydraulic models for design of urban water systems

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	–	2	1	1	–
CO-2	2	1	3	2	–	1
CO-3	2	1	3	2	1	1
CO-4	2	1	3	–	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Water Distribution Networks: Design and analysis of water distribution networks using EPANET

Open Source Data: Downloading and using data from various open sources

HEC-HMS: Event based flood modelling using HEC-HMS

SWAT: Continuous simulation modelling using SWAT

HEC-RAS: Flood inundation mapping using HEC-RAS

SWMM: Design and analysis of storm water drainage network using SWMM

Learning Resources:

Reference Books:

1. HEC-HMS: Hydrologic Engineering Center- Hydrologic Modelling System http://www.hec.usace.army.mil/software/hec-hms/
2. HEC-RAS: Hydrologic Engineering Center River Analysis System http://www.hec.usace.army.mil/software/hec-ras/
3. SWMM: Storm Water Management Model http://www2.epa.gov/water-research/storm-water-management-model-swmm
4. SWAT: Soil and Water Assessment Tool http://swat.tamu.edu/
5. EPANET: Hydraulic modelling of water distribution piping system http://www2.epa.gov/water-research/epanet

Other Suggested Readings:

1. https://web.ics.purdue.edu/~vmerwade/tutorial.html

CE76096 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a domain specific and contemporary topic
CO-2	Review literature to identify gaps and define objectives & scope of the work.
CO-3	Develop a prototype/model, experimental set-up or software systems to meet the objectives
CO-4	Analyze the results to draw valid conclusions

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	–	–	2	1
CO-2	2	2	–	–	1	2
CO-3	2	2	3	3	3	2
CO-4	2	2	–	3	3	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project. The project will be evaluated with following components:

Component	**Weightage**
Periodic evaluation by Guide	40 marks
Mid-term review	20 marks
End Semester viva-voce examination	40 marks
Total	100 marks

The midterm review and the end semester viva-voce examination will be conducted by a committee constituted by the Head of the Department. If the performance of a student is not satisfactory, he/ she can be awarded ‘F’ grade. Such a student will be given a maximum time of three months to improve his/her performance. If the performance of such a student is not satisfactory even after the extended time period, he/ she will have to repeat the project work in the next academic year.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	
II	Literature Survey	
III	Objectives and Solution Methodology	
IV	Performance of the Task and clarity on the work	
V	Report Preparation	
VI	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III		X		
IV			X	
V				X
VI				X

3rd Semester

CE76089 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	–	2	–	–	3
CO-2	2	–	2	–	–	3
CO-3	2	–	2	–	–	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Clarity on the topic	Weightage for each criterion will be determined by the panel and will be informed to the students.
II	List of lectures attended	
III	Report	
IV	Presentation	
V	Response to questions	

Learning Resources:

Reference Books:

1. Research Articles / Reports available on the Internet
2. Water Resources Engineering Journals
3. Water Resources Engineering Textbooks and Handbooks

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3
I	X		
II	X		
III		X	
IV			X
V			X

CE76093 **0-0-0 (2)**

Comprehensive Viva-Voce

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Demonstrate the ability in problem solving
CO-3	Communicate effectively using engineering terminology

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	–	–
CO-2	3	3	3	3	–	–
CO-3	2	2	2	2	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

Syllabus:

The entire course of study (All the required courses studied) up to the second semester of the I Year.

Learning Resources:

Textbooks:

1. Reading Material of all the courses.

Reference Books:

1. Case Studies / Consultancy Reports.

CE76097 **0-0-0 (8)**

DISSERTATION: PART-A

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a topic in advanced areas of Thermal Engineering.
CO-2	Review literature to identify gaps and define objectives and scope of the work.
CO-3	Employ the ideas from literature and develop research methodology.
CO-4	Develop a pilot model, experimental set-up and / or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	1	-	3
CO-2	3	2	3	1	-	3
CO-3	3	3	3	3	3	3
CO-4	3	3	3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

The midterm review and the end semester viva-voce examination will be conducted by a committee constituted by the Head of the Department.

iv. The marks may be distributed among various components like selection of topic, problem statement, literature review, methodology, oral and written presentation of the work done and performance in viva-voce examination.
v. If the performance of the student in Dissertation Part-A is not satisfactory, he/ she will be awarded 'F' grade. The student has to repeat the dissertation work by registering in the next semester. Such students may be given an option either to continue with the same topic and with the same guide or change the guide and the topic of his/ her dissertation.

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Selection of Topic	Weightage for each criterion will be determined by the panel and will be informed to the students.
II	Literature Survey	
III	Defining the Objectives and Solution Methodology	
IV	Performance of the Task	
V	Documentation and Report Preparation	
VI	Presentation and Student responses	

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X
VI				X

CE76091 **0-0-0 (2)**

Summer Internship / Research Experience

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	3	–
CO-2	2	2	2	2	2	–
CO-3	–	–	–	–	–	3
CO-4	–	–	–	–	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

There is no specific syllabus for this course. Students are expected to undergo at least eight weeks of training in an industry. Alternatively, he/she can work on a research project under the guidance of a faculty member in any HEI. Students must work on an assigned topic. The topic should be relevant and current. Students must assimilate their knowledge to investigate and find sustainable solutions to the identified field problem. They need to conduct suitable field studies/laboratory experiments. They must analyze the data and develop cost-effective solutions for the identified problem. Students must submit a report and present the work before an evaluation committee.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Relevance of the area of work	Weightage for each criterion will be determined by the panel and will be informed to the students.
II	Performance of the Task	
III	Crucial learnings from the work	
IV	Report Preparation	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

4th Semester

CE76098 **0-0-0 (12)**

DISSERTATION: PART-B

Pre-Requisites: **CE76097**

Course Outcomes:

CO-1	Assess the research problem statement.
CO-2	Evaluate the existing literature and establish research gaps.
CO-3	Formulate Methodology for the study.
CO-4	Analyze, discuss and justify the results/trends and draw valid conclusions.
CO-5	Documentation of methods and results.

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	3	2	3
CO-2	2	-	3	3	2	3
CO-3	3	-	3	3	2	3
CO-4	3	3	3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

The midterm review will be conducted by a committee constituted by the Head of the Department. The end semester examination will be conducted by an External Examiner along with the evaluation committee constituted by the Head of the Department.

iv. A student will be permitted to submit the dissertation only if he/she completes all the courses as required in the program.
v. The marks may be distributed among various components like selection of topic, problem statement, literature review, methodology, oral and written presentation of the work done and performance in end semester examination.

vi. Dissertation and Viva-Voce: A student shall be required to submit a report on the Dissertation work carried out by him/her. The template for the dissertation report may be downloaded from (https://www.nitw.ac.in/main/PGForms/NITW/). The students are required to submit a report showing that the plagiarism is within 20%. Three/four bound copies along with a soft copy of the dissertation shall be submitted to the Head of the Department/Centre within the last date prescribed in the Academic Calendar for the purpose. Dissertation viva - voce will be held within the date fixed in the academic calendar and the grades will be finalized by the committee.

vii. If the performance of the student in Dissertation Part-B is not satisfactory, he/ she will be awarded 'F' grade. The student has to repeat the dissertation work by registering in the next semester.

viii. Extension of dissertation work (Part-B) beyond the deadline of submission in very special case may be granted by the Dean (Academic) on recommendation of the department/center for a maximum period of 3 months and he/she will be awarded "I" Grade. The viva-voce has to be completed within the extension period. The student shall not be eligible either for award of scholarship during the extension period or any medal/prize. However, if the student had been absent on medical grounds and his/her dissertation had been extended, he/she may be eligible for award of medal or prize, if any. If the above-mentioned extension period encroaches into the next semester, the student will have to pay the tuition fee on par with full time student.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A.

Criteria	Description	Weightages
I	Introduction/Problem Statement	Weightage for each criterion will be determined by the panel and will be informed to the students.
II	Quality of Literature review	
III	Methodology with supporting ideas	
IV	Analysis of Results	
V	Documentation and reporting	
VI	Thesis Defense Presentation and Question and Answers	

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
I	X	X			
II				X	
III			X		
IV				X	
V					X

Professional Electives

CE7621 **3-0-0 (3)**

Design of Hydraulic Structures

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze and design earth and rockfill dams
CO-2	Analyze and design gravity dams
CO-3	Design spillways and energy dissipation structures
CO-4	Explain the principles of hydraulic modeling

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	2	3	
CO-2	1	-	3	2	3	
CO-3	1	-	3	1	3	2
CO-4	1	-	2		3	

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Hydraulic structures for water resources projects. Types of hydraulic structures, storage, diversion, conveyance and distribution structures, capacity of a reservoir, reservoir silting, types of dams

Hydraulic structures on permeable foundations: Seepage theories, Khosla's theory, design of diversion headworks and other structures on permeable foundations

Embankment Dams: Types, design considerations, seepage analysis and control, stability analysis, construction techniques.

Gravity Dams: Forces acting on failure of a gravity dam, stress analysis, elementary profile, design of gravity dam, other functional features of a gravity dam.

Dam Outlet Works: Types of outlet structures, ogee spillway, chute spillway, siphon spillway, side channel spillway, Labyrinth and Piano-key weir.

Terminal Structures: Hydraulic jump types, stilling basin, roller bucket, ski jump basin, baffled spillway, drop structure

Learning Resources:

Text Books:

1. Arora K.R., Irrigation, Water Power and Hydropower Engineering, Standard Book Publishing, New Delhi, 2018, 5th Edition
2. Modi, P. M., Irrigation Water Resources and Hydropower Engineering, Standard Book Publishing Company, New Delhi, 2014, 9th Edition

Reference Books:

1. Novak, P. and Nalluri, C., Hydraulic Structures, Taylor & Francis, 2007, 4th Edition
2. Asawa G.L., Irrigation and Water Resources Engineering, New Age International Publishers, New Delhi, 2006
3. Singh, B., and Varshney, R.S., Embankment Dam and Engineering, Nem Chand and Brothers, 2004
4. Singh B., and Sharma, H.D., Earth and Rockfill Dams, Saritha Prakashan, 1976
5. Peterka, A.J, Hydraulic Design of Stilling Basins and Energy Dissipators, USBR Engineering Monographs No. 25". 1984

Other Suggested Readings:

1. https://www.routledge.com/IAHR-Design-Manual/book-series/TFIAHRHSDM

CE76023 **3-0-0 (3)**

Integrated Watershed Management

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify and Prioritize Watersheds for Watershed Management
CO-2	Plan and design soil conservation measures in a watershed
CO-3	Plan and design water harvesting and groundwater recharge structures
CO-4	Plan measures for reclamation of saline soils

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	–	2	2	1	1
CO-2	2	–	3	1	3	2
CO-3	2	–	3	1	3	2
CO-4	2	–	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Introduction to Watershed and Watershed Management, Problems and Prospects in Watershed Management, History of Watershed Management in India, Land classification and Watershed based land use planning, Planning for Watershed Management, Participatory watershed management

Watershed Characteristics: Physical and Geomorphologic Factors affecting Watershed Management, Watershed Characteristics: Classification and Measurement, Importance of Watershed Properties for Watershed Management, Prioritizations of Watersheds.

Watershed Hydrology: Hydrology in soil and water conservation, Hydrologic Data for Watershed Planning, Rainfall- Runoff relationships, Water Yield Assessment and Measurement from Watersheds.

Soil Erosion: Principles of soil erosion, Soil Erosion Mechanism, Estimation of soil loss from small watersheds, Measurements and Estimation of Sediment Yield, Soil Erosion Control Measures – Engineering and Agronomical.

Water Harvesting: Concepts and Methods, Principles of water harvesting, methods of rainwater harvesting, Rainwater Conservation Technologies and Water Harvesting Structures, Farm Ponds, Earthen Dams, Artificial recharge of groundwater in small watersheds, methods of artificial recharge.

Learning Resources:

Text Books:

1. Murthy, J.V.S., Watershed Management, New Age International Publishers, 2017, 2nd Edition
2. Murthy, V.V.N., and Jha, M.K., Land and Water Management, Kalyani Publishers, 2013, 6th Edition

Reference Books:

1. Suresh, R., Soil and Water Conservation Engineering, Standard Publishers, 1998
2. Chatterjee, S.N., Water Resources Conservation and Management, Atlantic Publishers, 2008
3. Common Guidelines for Watershed Development Projects, Government of India, 2008

Other Suggested Readings:

1. https://nptel.ac.in/courses/105/101/105101010/
2. http://ecoursesonline.iasri.res.in/course/view.php?id=542

CE76025 **3-0-0 (3)**

Computational Methods in Water Resources Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply numerical methods for solution of differential equations in Water Resources and Environmental Engineering
CO-2	Apply finite difference schemes for solution of hydraulic and hydrologic models
CO-3	Apply method of characteristics for hydraulic transients in pipes and channels
CO-4	Formulate finite element model for solution of flow through porous media

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	1	2	
CO-2	2	-	3	2	2	
CO-3	2	-	3	2	2	1
CO-4	2	-	3	3	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Overview of the course, the need for computational and statistical methods, overview of the applications in Civil Engineering in general and Water Resources and Environmental Engineering in particular.

Review of Numerical Techniques: Review of numerical techniques for finding roots of non-linear equations and numerical integration.

Differential Equations: Ordinary differential equations, nature of problems, boundary and initial equations, Euler's method, modified Euler's method, Predictor-Corrector methods, Runge-Kutta methods, Boundary value problems, Applications for reservoir routing, gradually varied flow problems, pipe networks.

Partial differential equations: Classification, nature of problems, Concepts of finite difference method, finite difference schemes, Solution of parabolic equations, pollutant transport, Solution of elliptical equations, solution of Laplace equation and Poisson equation, flow through porous media, Solution of hyperbolic equation, method of characteristics, unsteady flow through open channels, propagation of waves, Concepts of finite volume method.

Finite Element Method: Basic concepts of Finite Element Method, FEM vs FDM, Element shapes, shape functions, development of shape functions for linear elements, Formulation of FEM for stress analysis problems, flow through porous media, Galerkin's method and Variational method for formulation of stiffness matrix.

Learning Resources:

Text Books:

1. Hoffman, J.D., Numerical Methods for Engineers and Scientists, CRC Press, 2011, Special Indian Edition
2. Kotteguda, N.T., and Renzo Resso, Statistics, Probability and Reliability for Civil and Environmental Engineers, McGraw Hill Companies Inc., New York, 1998

Reference Books:

1. Schilling, R.J., and Harris, S.L., Applied Numerical Methods for Engineering, Cengage Learning, 2007, India Edition,
2. Abbot, M.A. and Vervey, Computational Hydraulics, Elsevier Publications, 1996
3. Moukalled, F., Mangani, L., and Darwish, M., The Finite Volume Method in Computational Fluid Dynamics, Springer International Publishing, 2015

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/105/112105045/

CE76027 **3-0-0 (3)**

Hydropower Systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Estimate hydropower potential
CO-2	Identify types of hydropower plants
CO-3	Design penstocks and surge shaft
CO-4	Plan the layout of a hydropower plant
CO-5	Analyze water hammer and surges

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	2	2	-
CO-2	1	-	2	2	3	-
CO-3	2	-	3	1	3	-
CO-4	1	-	3	3		2
CO-5	1	-	2	2	2	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to Hydropower Systems: sources of energy, role of hydropower in a power system.

Estimation of Hydropower Potential: Flow duration curves of gauge and ungauged streams, load curve, load factor, capacity factor, utilization factor, diversity factor, load duration curve, firm power, secondary power, prediction of load.

Planning and layout of Hydropower Plants: Types of Hydropower Plants, Runoff river plants, general arrangement of runoff river plants, valley dam plants, diversion canal plants, high head diversion plants, storage and pondage, pumped storage power plants, micro power plants.

Penstocks: Classification of penstocks, economical design of penstocks, losses, anchor blocks, valves, bends and manifolds.

Trash racks: Types, losses, design, stability.

Intakes: Types, losses, air entrainment, anti-vortex device, air vent, power channels, forebay, tunnel.

Turbines: Introduction, types of turbines, hydraulics of turbines, draft tubes, cavitation in turbines, turbine model testing, characteristics of turbines, selection of turbine.

Water Hammer and Surges: Introduction, water hammer, transients caused by turbine, load acceptance and rejection, resonance in penstocks, channel surges.

Surge Tanks: Functions, types of surge tanks, differential surge tanks, design of surge tanks- Calame-Gaden equations, Johnson's method, stability of surge tanks.

Learning Resources:

Text Books:

1. Dandekar, M.M., and Sharma, K.H., Water Power Engineering, Vikas Publishing House Pvt. Ltd., 2000.
2. Varshney, R.S., Hydro Power Structures, Nem Chand & Bros, 2001.

Reference Books:

1. Barrows, H.K., Water Power Engineering, Tata McGraw Hill Publishing Company Ltd., 1943
2. Nigam, P.S., Hydro Electric Engineering, Nem Chand & Bros., 2001.
3. Choudhary, M.H., Applied Hydraulic Transients, Van Nostrand Reinhold Company, 1987.
4. Streeter, V.L., and Wylie, B., Fluid Transients, McGraw-Hill Book Company, 1967.
5. Warnick, C.C., Hydropower Engineering, Prentice-Hall, 1984.

Other Suggested Readings:

1. https://www.energy.gov/eere/water/hydropower-resource-assessment-and- characterization
2. https://www.hydropower.org/iha/discover-types-of-hydropower

CE76029 **3-0-0 (3)**

Climate and Climate Change Modelling

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the basic concepts of climate and climate systems
CO-2	Comprehend the drivers of climate change
CO-3	Explain the climate models
CO-4	Assess the impacts of climate change on Hydrology and Water Resources
CO-5	Develop strategies for adaptation for climate change

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	3	1	1	2
CO-2	1	-	3	2	-	3
CO-3	1	-	3	1	-	2
CO-4	2	-	3	3	-	3
CO-5	2	-	3	1	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Description of the climate system: Basic concept of climate, climate & weather, climatic classification, GHG emission, IPCC, Teleconnections, Climate and land-use feedback

Climate Change & Variability: Climate change drivers, past, present and future climate change, climate variability on various spatio-temporal scales, climate change scenarios over India

Climate Modelling: Simple climate models, General Circulation Models, Coupled Models Statistical and dynamic downscaling

Climate Change Impact: Impact of climate change on hydrological processes, and hydrological extremes, Assessment of future water resources

Climate Change Adaptation: Climate change adaptation capacity and methodology analysis, Adaptation aspects over India

Sustainable Development over India: Climate-friendly initiatives, sustainable development and national planning

Learning Resources:

Text Books:

1. Rao Y.S., Zhang, C.T., Ojha, C.S.P., Gurjar, B.R., Tyagi, R.D. & Kao C.M., Climate change modeling, mitigation, and adaptation, ASCE, 2013

2. Kevin E Trenberth, Climate System Modeling, Cambridge University Press, 2010

Reference Books:

1. Kendal M., and Ann H.S., The Climate Modeling Premier, Wiley- Blackwell, 2014, 4th Edition
2. Joseph J.R., Climate Change: What Everyone Needs to Know, Oxford University Press, 2016

Other Suggested Readings:

1. Climate Change synthesis report (2007), IPCC, https://www.ipcc.ch/reports/
2. Climate Change 2014: Impacts, Adaptation and Vulnerability, IPCC, https://www.ipcc.ch/reports/
3. Climate Change 2013: The Physical Science Basis, IPCC, https://www.ipcc.ch/reports/

CE76022 **3-0-0 (3)**

Remote Sensing & GIS in Water Resources

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply basic principles of remote sensing for resource mapping and evaluation
CO-2	Develop geospatial data base of water resources and environmental engineering systems
CO-3	Apply GIS models for hydrological simulation
CO-4	Apply GIS models for planning environmental engineering systems

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	3	2	-
CO-2	1	-	2	3	2	-
CO-3	2	-	3	2	3	-
CO-4	1	-	3	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Physics of Remote Sensing: Sources of Energy, Active and Passive Radiation, Electromagnetic Spectrum - Reflectance, Transmission, Absorption, Thermal Emissions, Interaction with Atmosphere, Atmospheric windows, Spectral reflectance of Earth's surface features, Multi concept of Remote Sensing, Fundamentals of Microwave Remote Sensing.

Data Analysis: Data Products and Their Characteristics, Data Pre-processing – Atmospheric, Radiometric, Geometric Corrections – Basic Pattern Recognition Concepts, Basic Principles of Visual Interpretation

Fundamentals of GIS: Information Systems, Modelling Real World Features Data, Data Formats – Spatial and Non-spatial, Components, Data Collection and Input, Data Conversion, Database Management – Database Structures, Files; Standard Data Formats, Compression Techniques, Hardware – Computing, printing and scanning systems

Spatial Analysis and Modelling: Proximity Analysis, Overlay Analysis, Buffer Analysis, Network Analysis, Spatial Auto Correlation, Gravity Modelling, DTM/DEM, Integration with Remote Sensing data

RS & GIS for Water Resources: Hydrologic Data, Spatial techniques for Surface-Water Hydrology Modeling, Surface-Water Hydrology Models, SWAT model and its applications; Groundwater Data, Ground water Models and spatial techniques for Groundwater Modeling and Visualization, The Arc Hydro Data Model, Geospatial techniques for planning and design of Water-Supply and Irrigation Systems, Spatial Database Development for Wastewater and Storm water Systems, Geospatial technologies for Water Resources Monitoring and Forecasting; Spatial Decision-Support, Systems in River Basin Management; Spatial systems for floodplain mapping and management, GIS for Water-Quality Management Decision Support

Learning Resources:

Text Books:

1. Agarwal, C.S., and Garg, P.K., Textbook on Remote Sensing in Natural Resources Monitoring and Management, Wheeler Publishing, Allahabad, 2000
2. Lillesand, T. M., and Keifer, R. W., Remote Sensing and Image Interpretation, John Wiley & Sons, N York, 1994

Reference Books:

1. Meijerink M. J., de Brouwer, H.A.M., Mannaerts, C. M., and Velenzuela, C. R., Introduction to the Use of Geographical Information Systems for Practical Hydrology, ITC publication no. 23, UNESCO, Paris, 1994
2. Swain, P.H., and Davis, S.M., Remote Sensing – The Quantitative Approach, McGraw- Hill Pub. Co. N York, 1987

Other Suggested Readings:

1. https://nptel.ac.in/courses/105/103/105103193/
2. http://civil.iisc.ernet.in/~nagesh/rs_gis.htm

CE76024 **3-0-0 (3)**

Urban Hydrology

Pre-Requisites: **CE76001**

Course Outcomes:

CO-1	Apply basic principles of remote sensing for resource mapping and evaluation
CO-2	Develop geospatial data base of water resources and environmental engineering systems
CO-3	Apply GIS models for hydrological simulation
CO-4	Apply GIS models for planning environmental engineering systems

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	3	2	-
CO-2	1	-	2	3	2	-
CO-3	2	-	3	2	3	-
CO-4	1	-	3	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: General introduction to urbanization and its effect on water cycle, urban hydrological cycle, water cycle and water balance in urban basins, trends in urbanization, effect of urbanization on hydrology, Concepts of Smart City.

Quantification of Hydrologic Variables: rainfall, runoff and losses in urban areas, time of concentration, importance of short duration of rainfall and runoff data, methods of estimation of time of concentration for design of urban drainage systems.

Urban Drainage Plans: issues to be concentrated upon, typical content of an urban drainage master plan, interrelation between water resources investigation and urban planning processes, planning objectives, comprehensive planning, use of models in planning.

Basic approaches to urban drainage: impacts of urban development on stormwater quantity and quality; management of urban stormwater including re-use and groundwater interaction; design of stormwater quantity and quality management structures including detention basins, retention basins, infiltration basins, gross pollutant traps.

Stormwater Analysis: Calculation of runoff and peak – Design of stormwater network systems, Performance evaluation of urban drainage systems,

Sustainable Urban Drainage Systems: Low Impact Development, Best Management Practices, sedimentation basins and artificial wetlands.

Operation and maintenance of urban drainage system: interaction between stormwater management and solid waste management, Various model available for stormwater management, Legal aspects.

Learning Resources:

Text Books:

1. Geiger, W.F., Marsalek, J. Z., and Rawls, G.J., Manual on Drainage in Urban Areas, 2 Volumes, UNESCO, 1987
2. Hall, M.J., Urban Hydrology, Elsevier, 1984

Reference Books:

1. Stahre, P. and Urbonas, B., Storm Water Detention for Drainage, water quality and CSO Management, Prentice Hall, 1990
2. Wanielista, M.P. and Yousef, Y.A., Storm Water Management, John Wiley and Sons Inc., 1993
3. Manual on Storm Water Drainage Systems, Central Public Health and Environmental Engineering Organization, MOHUA, 2019

Other Suggested Readings:

1. https://serc.carleton.edu/integrate/teaching_materials/water_cities/overview.html

CE76026 **3-0-0 (3)**

Soft Computing Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the characteristics of Soft Computing Techniques
CO-2	Develop neural network models with applications in hydrology and water resources
CO-3	Apply fuzzy logic and fuzzy reasoning for decision making
CO-4	Apply evolutionary optimization techniques in water resources

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	-	-	-
CO-2	2	-	3	2	2	1
CO-3	2	-	3	1	3	
CO-4	2	-	3		3	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Soft computing, and computational intelligence, Need for soft computing techniques, Components of soft computing, Characteristics of soft computing

Introduction to Artificial Neural Networks: Definition and Fundamental concepts, Biological Neural Network – Model of a Neuron, Activation functions, typical architectures, Knowledge representation, Artificial intelligence and neural networks, leaning process.

Supervised learning: Feed forward neural networks, Back propagation learning algorithm, Application of feed forward ANN for function approximation and prediction, Support Vector Machine (SVM), Applications of feed forward networks and SVM in Hydrology and Water Resources Engineering

Deep Learning: Recurrent neural networks, Long Short-term Memory, Gated recurrent unit, Convolution neural network, Deep learning applications for time series, spatial data sets, Hydro-meteorological and environmental applications of deep learning.

Information and uncertainty: Chance versus ambiguity, Classical sets and fuzzy sets, Logic and reasoning, Fuzzy set operations and fuzzy relations, Membership Functions, Fuzzy Systems, Fuzzy inference systems, Fuzzy Classification and Pattern Recognition, Neuro- Fuzzy Systems

Introduction to evolutionary optimization: concepts of genetic algorithm, genetic representation and selection mechanisms, genetic operators, overview of other evolutionary optimization techniques – Differential Evolution, Ant Colony Optimization, Particle Swarm Optimization and Simulated Annealing.

Learning Resources:

Text Books:

1. Jang, J.R, Sun C., and Mizutani E., Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, PHI Learning, 2009
2. Lee, T., Singh, V.P., and Cho, K.H., Deep Learning for Hydrometeorology and Environmental Science, Water Science and Technology Library, Springer, 2020

Reference Books:

1. Rajasekaran, S., and Vijayalakshmi Pai, G.A., Neural Networks, Fuzzy Logic and Genetic Algorithms – Synthesis and Applications, Prentice-Hall India, New Delhi, 2017
2. Dan, S., Evolutionary Optimization Techniques, Wiley, 2013
3. Yang, X.S., Nature-Inspired Optimization Algorithms, Academic Press, 2020
4. Sivanandam, S.N., and Deepa, S.N., Principles of Soft Computing, Wiley India, 2018

Other Suggested Readings:

1. https://www.sciencedirect.com/topics/engineering/artificial-neural-network
2. https://www.nature.com/articles/nbt1386
3. https://searchenterpriseai.techtarget.com/definition/fuzzy-logic

CE76028 **3-0-0 (3)**

Advanced Hydrologic Modelling

Pre-Requisites: **CE76001**

Course Outcomes:

CO-1	Classify forecasting and prediction problems in hydrology
CO-2	Develop a basic knowledge on modelling and simulation of a hydrologic system
CO-3	Build linkage between hydrological processes
CO-4	Make use of selected hydrological models

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	1	1	1
CO-2	1	-	3	1	2	1
CO-3	1	-	3	3	2	1
CO-4	2	-	3	3	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to Hydrologic Modelling: Systems Approach, Linear Models - Deterministic and Probabilistic; Nonlinear Models - Deterministic and Probabilistic.

Data availability and acquisition – Meteorological data, hydrologic data, geospatial data, climate projections, Data requirement for hydrological models.

Parameters and Variables: Introduction to Parameters and Variables; Introduction to Calibration of Models (Complexity); Introducing Model Calibration as an Optimization Problem; Introduction to Validation of Models-Different Validation Techniques; Performance Evaluation of Models.

Watershed Hydrological Models: Introduction to hydrological modelling concepts – Evolution of Rainfall-runoff models; Difference between conceptual and process-based models; Difference between lumped and distributed models; conceptualizing the interaction between hydrological processes; Data requirement for hydrological models.

Development of Hydrological Models: Introduction to a conceptual watershed model viz. GR4J, HYMOD, HBV etc.; Introduction to process-based watershed hydrologic models viz. SWAT Model, VIC, etc.

Sensitivity and Uncertainty Analysis: Simple methods - Linear; Monte Carlo Simulation; Sensitivity Analysis - Sobols' Method; Uncertainty Analysis - Introduction, First Order Uncertainty Analysis, GLUE

Application of Hydrological Models: Simulation-Optimization Framework - Watershed Management Decisions; Application of Simulation-Optimization Framework - Deficit Irrigation Management; Formulation of Case Examples of Simulation-Optimization Problems

Learning Resources:

Text Books:

1. Beven, K.J., Rainfall-Runoff Modelling: The Primer, John Wiley and Sons Ltd., 2006
2. Chow, V.T., Maidment, D.R., and Mays, L.W., Applied Hydrology, Tata McGraw Hill Edition, 2010, 2nd Edition

Reference Books:

1. Loucks, D.P. and Eelco van Beek, Water Resources Systems Planning and Management – An introduction to methods, models and applications, UNESCO and Springer, 2017
2. Neitsch, S. L., Arnold, J. G., Kiniry, J. R., Williams, J. R., and King, K. W., Soil Water Assessment Tool theoretical documentation. Version 2009, Texas Water Resource Institute, college station, Texas. TWRI Report, TR-191, 2009
3. Viessman, W., and Lewis, G.L., Introduction to Hydrology, Prentice Hall of India, 2008 5th Edition

Other Suggested Readings:

1. https://nptel.ac.in/courses/105/101/105101002/

CE76030 **3-0-0 (3)**

Water Distribution Networks

Pre-Requisites: **CE76005**

Course Outcomes:

CO-1	Design new water distribution systems with an understanding of the fundamentals
CO-2	Analyze existing systems, pinpoint the problems and take corrective action
CO-3	Use the design software EPANET2 and be familiar with its features
CO-4	Design and analyze the pumping system

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	2	1	3	-
CO-2	2	-	2	1	3	-
CO-3	3	-	2	1	3	-
CO-4	2	-	2	1	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction, water availability and uses; temporal and spatial distribution; key issues and concerns; features and elements of a water distribution systems, review of continuity, momentum and energy equations

Water Demand: Concept of water demand; Estimation of water demand; Factors affecting demand; Components of demand; Demand fluctuations; Demand forecasting; Population forecasting methods

Flow Analysis: Basic Equations of Flow, Friction and minor loss expressions, flow through single pipes, pipes in series and parallel, Steady State Analysis, Transient Analysis, Surge Protection Measures.

Water Distribution Networks: Water Distribution; Components of Water Distribution Network, Hydraulics of pipe network design; Layouts of Distribution Network; Pipe network analysis; Hardy Cross method

Water Losses and Control: Water-losses in water supply systems; Concepts of NRW and UFW; Apparent and real losses; water loss detection methods; water losses reduction strategies

Advanced Water Distribution Design Approaches: Sectorization of distribution networks; DMA Demarcation; Advantages and risks; Software for network design (EPANET)

Pumping System: Pump definitions, system and pump curves, operating points, pump design and selection, pump systems

Learning Resources:

Text Books:

1. Dey, S., Fluvial Hydraulics, Springer, 2014.

2. Garde, R.J., and Ranga Raju, K.G., Mechanics of Sediment Transportation and Alluvial Stream Problems, New Age Publishers, 2007.

Reference Books:

1. Nazih K. Shammas, Lawrence K. Wang, Water Supply and Wastewater Removal, John Wiley & Sons, Inc, 2011, 3rd Edition
2. Michael, A.M., Irrigation: Theory and Practice, Vikas Publishing House Pvt. Ltd. New Delhi, 2009

Other Suggested Readings:

1. https://nptelvideos.com/video.php?id=1128
2. https://archive.nptel.ac.in/content/storage2/courses/105104102/Lecture%2014.htm

CE76032 **3-0-0 (3)**

Fluvial Hydraulics

Pre-Requisites: **CE76005**

Course Outcomes:

CO-1	Identify the characteristics and properties of sediments
CO-2	Comprehend the concept of incipient motion
CO-3	Analyze and compute the bed load and suspended load
CO-4	Design guide bunds and other river training banks

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	3	-	-
CO-2	1	-	2	3	-	-
CO-3	1	-	3	3	1	
CO-4	1	-	3	1	3	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: The sediment problems, significant sediment properties, properties of sediment mixture, properties of fluid and suspended sediment mixture, terminal fall velocity of sediment in fluid, beginning of sediment movement – Shields analysis, incipient motion of uniform and non- uniform sediments, critical tractive stress of non-uniform materials.

Bed Forms and Resistance: Bed load and suspended load transport for uniform and non- uniform bed material, various approaches for bed load transport, suspended load profile and suspended load equations, total load equations, sediment sampling, discharge concept for bed-load transport, sediment pickup function, sediment sorting and streambed armouring, total-load transport.

Stable channel design: Stable channel design and sediment control, regime of flow, effective bed roughness, non- scouring erodible –boundary channels.

Scouring & Sedimentation: Bed level variations, degradation, aggradation, local scour, scour within channel contractions, scour downstream of structures, scour below horizontal pipelines, scour at bridge piers and abutments, scour counter measures, reservoir sedimentation and its monitoring.

Physical and mathematical models: dimensional analysis, concept of dynamic similitude for model studies, immobile bed model studies, mobile bed model studies, design of guide bunds and other river training banks.

Learning Resources:

Text Books:

1. Larry W. Mays, Urban Water Supply Handbook, McGraw Hill, 2002.

2. Mackenzie L.D., Water and Wastewater Engineering: Design Principles and Practice, Davis, McGraw Hill, 2010.

Reference Books:

1. Jansen, P.P.H., Principals of River Engineering, VSSD Publications, 1996.
2. Garde, R.J., River Morphology, New International Publishers, 2006
3. Julien, P.Y., Erosion and Sedimentation, Cambridge University Press, 1998.
4. Breusers, H.N.C., & Raudkivi, A.J., Scouring: hydraulic structures design manual series, vol. 2, CRC Press, 2020.
5. Armanini, A., Principles of River Hydraulics, Springer International Publishing, 2018.
6. River Hydraulics, U. S. Army Corps of Engineers, University Press of the Pacific, 2004.

Other Suggested Readings:

1. https://www.routledge.com/IAHR-Design-Manual/book-series/TFIAHRHSDM

CE76034 **3-0-0 (3)**

AI & ML in Water Resources

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the basic principles of artificial intelligence (AI) and machine learning (ML) algorithms
CO-2	Apply supervised and unsupervised techniques
CO-3	Evaluate the performance of different AI/ML algorithms
CO-4	Apply ML and AI for Water Resources management

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2			-
CO-2	2	-	3		3	-
CO-3	2	-	3	1	3	-
CO-4	2	-	3		3	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Machine Learning: Systems and Modeling, Fundamental concepts, Difference between AI, ML and DL, AI/ML models - Types of Learning, Challenges and Opportunities for water resources applications.

Data: Data Collection, Data Management, Big data, taxonomy of machine learning algorithms, Data Pre Processing, Normalization, Data Splitting.

Model Development: Review of calculus and probability theory, Types of Regression Models, Classification, Parameters Estimation, Method of least square estimation, Bias and Error, Model Performance Assessment, Autoregressive Model, Multi-Linear Regression, Logistic Regression, Model Evaluation Techniques, Model Evaluation Metrics.

Neural Networks: Feed Forward, Multilayer Perceptron, Logistic Regression, Chain Rule, Optimizers, Introduction to Deep Learning – CNN, LSTM

Supervised Learning: Classification, Bayesian Classifier, K-nearest Neighbors, Decision Trees, CART, Random Forest, Support Vector Machine (SVM) Algorithm

Unsupervised Learning: Clustering- K-means clustering algorithm and Hierarchical clustering algorithm

Deep Learning: Deep Neural Network for time-series analysis: RNN and LSTM, Introduction to Convolutional Neural Network.

Applications: Automation in water resource management, Rainfall-runoff modelling, Climate change monitoring, water distribution system monitoring, Flood forecasting, Flood and drought analysis.

Learning Resources:

Text Books:

1. Lee, T., Singh, V.P., and Cho, K.H., Deep Learning for Hydrometeorology and Environmental Science, Water Science and Technology Library, Springer, 2020
2. Joshi A.V., Machine Learning and Artificial Intelligence, Springer International Publishing, 2019, 2nd Edition

Reference Books:

1. Jang, J.R, Sun C., and Mizutani E., Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, PHI Learning, 2009
2. Das, L.B., Aprem, A., and George, S.N., Artificial Intelligence and Machine Learning Theory and Practice, IK International Pvt. Limited, 2023

Other Suggested Readings:

1. https://www.sciencedirect.com/topics/engineering/artificial-neural-network
2. https://www.nature.com/articles/nbt1386
3. https://searchenterpriseai.techtarget.com/definition/fuzzy-logic

CE76036 **3-0-0 (3)**

On Farm Development & Management

Pre-Requisites: **CE76001**

Course Outcomes:

CO-1	Plan irrigation systems and command area development programs
CO-2	Evaluate performance of an irrigation system
CO-3	Plan measures for reclamation of waterlogged lands
CO-4	Make use of selected hydrological models

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	1	3	1
CO-2	1	-	3	1	3	1
CO-3	1	-	3	1	3	1
CO-4	1	-	3	1	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Water resources of India- an overview, existing water distribution systems- their suitability and limitations, Social and legal aspects of water distributions systems, Scope for increasing the efficiency of the existing systems.

Farm water delivery systems and control: design criteria for field channels and underground pipelines, water regulation and diversion structures.

Irrigation Scheduling: Methods of measurement and estimation of evapotranspiration, irrigation scheduling strategies, crop production functions, use of crop growth models for effective management of irrigation water.

Farm Irrigations Systems: Surface irrigation systems- their suitability, limitations and efficient design;

Micro irrigation systems: familiarity with different components of drip and sprinkler systems, design of systems. Irrigation water quality requirements.

Drainage problems: In various agro-climatic regions of India, Assessment of soil salinity and groundwater balances, salt balance and leaching requirement.

Theories of field drainage: Steady and un-steady flow equations in sub-surface horizontal drainage system, Well drainage, Bio-drainage, Influence of irrigation on drainage,

Design and management of drainage System: Surface and subsurface field drainage systems, Vertical and bio-drainage systems, Performance assessment of the drainage system, Socioeconomic and environmental impact of the drainage projects,

Learning Resources:

Text Books:

1. Michael, A.M., Irrigation: Theory and Practice, Vikas Publishing House Pvt. Ltd. New Delhi, 2009
2. S.K. Gupta, Drainage Engineering: Principles and Practices, Scientific Publishers, 2019

Reference Books:

1. Scwabe, G.O., Fangmeir, D.D., and Elliot W.J., Soil and Water Management Systems, John Wiley and Sons, N York, 1996
2. Majumdar, D.K., Irrigation Water Management, Prentice Hall of India, New Delhi, 2013, 2nd Ed.

Other Suggested Readings:

1. https://www.iima.ac.in/c/document_library/4ParticipatoryIrrigation8f9a.pdf?uuid=a5eced82-3f75-4068-9aa1-57aef9de0876&groupId=62390
2. https://www.iwapublishing.com/news/integrated-water-resources-management-basic-concepts
3. https://www.indiawaterportal.org/articles/introduction-integrated-water-resource-management-iwrm-open-courseware-united-nations

CE76038 **3-0-0 (3)**

Contaminant Transport Modeling in Porous Media

Pre-Requisites: **None**

Course Outcomes:

Students will be able to:

CO-1	Analyze physical and chemical processes of contaminant transport in porous media.
CO-2	Develop models for contaminant transport through porous media.
CO-3	Apply computational techniques to solve contaminant transport models.
CO-4	Assess risk of tradition and emerging contaminants in groundwater systems.
CO-5	Design remediation strategies for addressing the contaminant transport problem.

Course Articulation Matrix:

CO \ PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	3	3	-	1
CO-2	1	-	3	3	-	1
CO-3	2	-	3	1	3	2
CO-4	2	-	3	1	3	2
CO-5	1	-	3	3	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Classes of pollutants in subsurface porous media, Groundwater quality degradation as a prolonged issue, hydrogeological properties of porous media, Aquifer types and heterogeneity, Darcy's law, Standard flow equations, Boundary conditions, Numerical solution methods.

Transport Processes in Porous Media: Transport by Concentration Gradients, Transport by Advection and Hydrodynamic Dispersion, Advection-Dispersion Equation (ADE) for Solute Transport, Moment-Based Transport Analysis, Boundary Conditions: First-, Second-, and Third- Type Boundary Conditions, Statistical Framework for Solute Transport, Deterministic Approaches to Solute Migration, Transport in Fractured Media.

Chemical and Physical Changes of Solutes: Types of Chemical Reactions, Sorption Dynamics Affecting Solute Transport, Surface Chemical Equilibria, Rate-Limited (Kinetic/Non-equilibirum) Sorption, Uniform-Phase (Homogeneous) Reaction Kinetics, Radioactive Decay, Biodegradation.

Particle-facilitated Contaminant Transport: True colloids, Pseudocolloids, ENPs (Engineered Nanoparticles), Colloid Filtration Theory (CFT), Particle Transport Mechanism—Aggregation, Straining, Blocking, Site-blocking, Ripening, Size exclusion, DLVO theory, Langmuir blocking model, Microplastics (MPs) and Nanoplastics (NPs) Transport, Governing Equations.

Flow and Solute Transport Modeling: Introduction, Governing Equations—Groundwater flow equations (Saturated and Unsaturated), ADE, Colloid Transport, Colloid-facilitated contaminant transport, Boundary and Initial Conditions, Numerical Solution Techniques—finite difference, finite element, and finite volume methods, stability, convergence, and accuracy considerations, time-stepping methods: explicit, implicit, and Crank–Nicolson schemes, TDMA (Tri-Diagonal Matrix Algorithm), Flow and Transport Coupling, Numerical Modeling Tools.

Multiphase Flow: Introduction, Basic Principles—Saturation Ratio, Interfacial Tension and Wettability, Capillary Pressure, Relative Permeability, Darcy's Law for Two-Phase Flow, Fluid Potential and Head, Dynamics of LNAPL and DNAPL Flow in Soil and Groundwater.

Site Remediation: Introduction, Source Management Strategies in Groundwater Protection, Pump-and-Treat Techniques for Subsurface Cleanup, Treatment Methods for Extracted Contaminated Water, Remediation and Recovery of NAPLs in Aquifers, Addressing Leaks in Underground Storage Systems, Bioremediation, Permeable Reactive Barriers, In Situ Thermal Treatment (ISTT), In situ Chemical Oxidation (ISCO), Phytoremediation.

Influence of Climate Change on Groundwater Pollution: Introduction, Climate Change Factors Affecting Groundwater, Mechanisms of Groundwater Contamination under Climate Change, Managed Aquifer Recharge (MAR) under changing climate conditions.

Learning Resources:

Text Books:

1. Zheng, Chunmiao, and Gordon D. Bennett. Applied contaminant transport modeling. Vol. 2. New York: Wiley-Interscience, 2002.
2. Bear, Jacob, and Alexander H-D. Cheng. Modeling groundwater flow and contaminant transport. Vol. 23. Dordrecht: Springer, 2010.
3. Fetter, Charles Willard, and David Kreamer. Applied hydrogeology. Waveland Press, 2021.

Reference Books:

1. Fetter, Charles Willard, Thomas Boving, and David Kreamer. Contaminant hydrogeology. Waveland Press, 2017.
2. Domenico, Patrick A., and Franklin W. Schwartz. Physical and chemical hydrogeology. John wiley & sons, 1997.
3. Ghadiri, Hossein, and Calvin Rose. Modeling chemical transport in soils: natural and applied contaminants. CRC Press, 1992.
4. Treidel, Holger, Jose Luis Martin-Bordes, and Jason J. Gurdak, eds. Climate change effects on groundwater resources: a global synthesis of findings and recommendations. CRC Press, 2011.
5. Maliva, Robert. Climate change and groundwater: Planning and adaptations for a changing and uncertain future: WSP Methods in Water Resources Evaluation Series No. 6. Springer Nature, 2021.