Master of Technology
(Water Resources Engineering and Management)

CURRICULUM
(Effective from 2026 - 27 Onwards)

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI - 620 015, INDIA.

VISION OF THE INSTITUTE

- To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

MISSION OF THE INSTITUTE

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

VISION OF THE DEPARTMENT

Shaping infrastructure development with societal focus

MISSION OF THE DEPARTMENT

Achieve International Recognition by:

- Developing Professional Civil Engineers
- Offering Continuing Education
- Interacting with Industry with emphasis on R&D

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1	Graduates will apply engineering principles, modern tools, and management practices to solve problems related to water resources, irrigation, hydraulics, and environmental sustainability.
PEO2	Graduates will develop efficient, sustainable, and climate-resilient solutions for planning, design, conservation, and management of water resources systems.
PEO3	Graduates will demonstrate ethical responsibility, teamwork, leadership, and continuous learning through professional practice, higher studies, and research activities.

PROGRAMME OUTCOMES (POs)

PO1	An ability to independently carry out research /investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

CURRICULUM STRUCTURE

M. Tech. (WATER RESOURCES ENGINEERING AND MANAGEMENT)

Components	Number of Courses	Credits	Total Credits
Programme Core (PC)	3 / Semester (6 / Year)	24	42
Programme Elective (PE)*	3 / Semester (6 / Year)	18	
Essential Laboratory Requirements (ELR)	3 / Year	6	6
Internship/Industrial Training/ Academic Attachment (I/A)	1	2	2
Open Elective (OE) / Online Course (OC)#@	2 (I – IV Semester)	6	6
Project Phase-I	1	12	12
Project Phase-II	1	12	12
Total	**20**	**80**	**80**

Note:

**** ONLINE COURSES EQUIVALENT TO PROGRAMME ELECTIVES (Optional):*** *Out of 6 programme electives, students have the option to study two online courses (Maximum of 1 per semester in the 1st year of Study) equivalent to programme elective courses through NPTEL / Swayam.*

 # OPEN ELECTIVES (OE) / ONLINE COURSE (OC) (Compulsory): *Students must complete 6 credits between I and IV semester either through online courses of their choice from NPTEL / Swayam (discipline electives / other electives) or through open electives offered by the PG programmes of the institute other than the progamme specialization.*

@ MICROCREDITS (Optional): *Students may opt 3 courses of 1 credit (4-week duration) each as microcredits or 2 courses (2 credits (8-week duration) & 1 credit (4-week duration) instead of 1 OE/OC).*

CURRICULUM

SEMESTER I

Code	Course of Study	Credit
MA601	Numerical Methods and Applied Statistics	4
CE851	Advanced Hydrological Analysis and Design	4
CE853	GIS and Remote sensing in Water resources	4
	Programme Elective I	3
	Programme Elective II	3
	Programme Elective III / Online (NPTEL)	3
CE857	Advanced Hydraulics laboratory	2
CE859	GIS for Water Resources Laboratory	2
		25

SEMESTER II

Code	Course of Study	Credit
CE852	Water Resources Systems Analysis, planning & Management	4
CE854	Numerical Modelling and Groundwater Engineering	4
CE856	Applied Hydraulic Engineering	4
	Programme Elective IV	3
	Programme Elective V	3
	Programme Elective VI / Online (NPTEL)	3
CE858	Hydroinformatics Laboratory	2
		23

SUMMER TERM (evaluation in the III semester)

Code	Course of Study	Credit
CE895	Internship / Industrial Training / Academic Attachment (I/A) (6 weeks to 8 weeks)	2

SEMESTER III

Code	Course of Study	Credit
CE897	Project Work (Phase I)	12

SEMESTER IV

Code	Course of Study	Credit
CE898	Project Work (Phase II)	12

OPEN ELECTIVES (OE) / ONLINE COURSE (OC)

Code	Course of Study	Credit
	# (To be completed between I to IV semester)	6

PROGRAMME ELECTIVES

Sl. No.	Code	Course of Study	Credit
1.	CE861	Advanced Fluid Mechanics	3
2.	CE862	River Engineering	3
3.	CE863	Mechanics of Sediment Transport	3
4.	CE864	Urban Water Management	3
5.	CE865	Computational Fluid Dynamics	3
6.	CE866	Water Security Policies	3
7.	CE867	Urban Climatology	3
8.	CE868	Advanced Geospatial and Hydroinformatics	3
9.	CE869	Disaster Risk Management and Hazard Modeling	3
10.	CE870	Climate Change Impact Modeling for Water Resource Management	3
11.	CE871	Thermal and Hyperspectral Remote Sensing	3
12.	CE872	Coastal Engineering	3
13.	CE873	Climate Adaptation in coastal and Hydraulic Engineering	3
14.	CE874	Flood and Drought Management	3
15.	CE875	Sustainability in River Basin Management	3
16.	CE876	Wave hydrodynamics	3
17.	CE877	Design of Hydraulic Structures	3
18.	CE878	Irrigation systems Engineering and Management	3
19.	CE879	Water, Energy and Climate Nexus	3
20.	CE880	AI/ML Applications in Water Resources Engineering	3
21.	CE881	Watershed Management	3
22.	CE882	Water Supply and Wastewater Engineering	3
23.	CE883	Glacial Hydrology	3
24.	CE884	Remote Sensing and Earth Observation	3
25.	CE885	Geographic Information Systems and Spatial Analytics	3
26.	CE886	Advanced Surveying and Geomatics	3
27.	CE887	Urban Planning and Infrastructure Planning	3
28.	CE888	Geospatial Data Analysis and Modelling	3
29.	CE889	Digital Image Processing and Computer Vision for Geospatial Applications	3

30.	CE890	Geoartificial Intelligence and Digital Earth System	3

OPEN ELECTIVES (OE)

Sl. No.	Code	Course of Study	Credit
1.	CE891	Climate Systems and Climate Modelling	3
2.	CE892	Integrated Water Resources Management	3
3.	CE893	Hydrological Extreme Risk Management and Adaptation	3

(For OE courses refer the curriculum of other PG specializations)

MICROCREDITS (MC) [Students can opt 3 courses of 1 credit (4-week duration) each as microcredits or 2 courses (2 credits (8-week duration) & 1 credit (4-week duration) instead of 1 OE/OC]

Sl. No.	Code	Course of Study	Credit
1.		Equivalent to OC (May be completed between Semester I to Semester IV)	3

Electives [Choices]

1. Program Elective (PE) Courses

Option 1:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	3	0	9
II	3	0	9

Option 2:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	2	1	9
II	3	0	9

Option 3:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	3	0	9
II	2	1	9

Option 4:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	2	1	9
II	2	1	9

2. Online Courses (OC) / Open Elective (OE) Courses

Option 1:

Semester	No. of Open Elective Courses	No. of online Courses		
		3 Credit courses	2 credit courses	1 credit course
I - IV	-	2	-	-
	-	1	1	1
	-	1	-	1+1+1

Option 2:

Semester	No. of Open elective Courses	No. of online Courses		
		3 credit courses	2 credit courses	1 credit course
I - IV	1	1	-	-
	1	-	1	1
	1	-	-	1+1+1

Option 3:

Semester	Open elective Courses	No. of online Courses		
		3 credit courses	2 credit courses	1 credit course
I - IV	2	-	-	-

COURSE OUTCOME AND PO MAPPING

PROGRAMME CORE

Course Outcomes: On successful completion of the course, students will be able to:

Course Code	Course Name	CO	Course Outcomes – Students will be able to:	PO1	PO2	PO3
MA601	Numerical Methods and Applied Statistics	CO1	Compute solution for linear, non-linear and system of equations	2	1	3
		CO2	Solve the mathematical problems through linear programming approaches	3	1	3
		CO3	Utilize the knowledge of standard distributions for solving real life case studies	3	2	3
		CO4	Use statistical knowledge in testing hypotheses on large and small samples	3	2	3
		CO5	Compute and interpret relationship between parameters in the design of experiments	2	3	3
CE851	Advanced Hydrological Analysis and Design	CO1	Explain the various processes involved in the hydrological cycle including precipitation, evaporation, infiltration, runoff, streamflow, and flood routing.	2	1	3
		CO2	Describe hydrologic systems approach, parameter estimation methods, watershed runoff modeling, and linear hydrologic models such as Unit Hydrograph, Clark, and Nash models.	3	1	3
		CO3	Apply hydrologic time series and stochastic models including AR, ARMA, and ARIMA for rainfall–runoff and hydrological data analysis.	3	2	3
		CO4	Apply hydrologic and hydraulic design principles for water supply systems, sewerage networks, storm water systems, reservoirs, and rainwater harvesting structures.	3	2	3
		CO5	Explain and apply soft computing, Artificial Intelligence (AI), and Machine Learning (ML) techniques.	2	3	3

CE853	GIS and Remote Sensing in Water Resources	CO1	Familiarize the basic concept of satellite image processing.	2	1	3
		CO2	Acquire knowledge about Geographic Information System.	3	1	3
		CO3	Getting idea about working on pre and post processing of satellite images.	3	2	3
		CO4	Acquire knowledge about geo-database development and spatial analysis for environmental applications	3	2	3
		CO5	Apply the geospatial and image processing techniques for various environmental problems.	2	3	3
CE852	Water Resources System Analysis, Planning and Management	CO1	Explain systems approach, mathematical modeling, simulation, and classical optimization techniques used in water resources engineering.	2	1	3
		CO2	Apply Lagrange multipliers, Kuhn–Tucker conditions, and linear programming methods to solve water resources optimization problems.	3	1	3
		CO3	Apply dynamic programming and uncertainty analysis methods for water allocation, reservoir operation, and hydrosystem planning.	3	2	3
		CO4	Analyze and evaluate reservoir systems for flood control, hydropower, irrigation, and water quality management using simulation and performance indices.	3	2	3
		CO5	Apply stochastic optimization, evolutionary algorithms, and multi-objective decision-making techniques in complex water resources management problems.	2	3	3

CE854	Groundwater Engineering and Management	CO1	Classify aquifers and interpret groundwater movement using Darcy's law.	2	1	3
		CO2	Analyze well hydraulics for steady and unsteady flow conditions in confined, unconfined, and leaky aquifers, and interpret flow nets.	3	1	3

		CO3	Explain the application of simulation and optimization problems in Ground water flow	3	2	3
		CO4	Apply surface and subsurface investigation techniques, evaluate artificial recharge potential, and understand saline water intrusion using the Ghyben-Herzberg relation.	3	2	3
		CO5	Utilize governing equations for groundwater flow, and understand groundwater modeling.	2	3	3
CE856	Applied Hydraulic Engineering	CO1	Apply the Reynolds Transport Theorem and Navier-Stokes equations for fluid flow analysis.	2	1	3
		CO2	Model turbulent flow and determine surface resistance using appropriate theoretical models.	3	1	3
		CO3	Analyze pipe networks and compute flow parameters using friction factors and iterative methods like Newton-Raphson	3	2	3
		CO4	Perform uniform flow computations and determine critical flow conditions in open channels.	3	2	3
		CO5	Evaluate flow transitions and compute unsteady flow profiles and hydraulics in non-uniform open channel flows.	2	3	3

ESSENTIAL LABORATORY REQUIREMENTS (ELR)

Course Code	Course Name	CO	Course Outcomes – Students will be able to:	PO1	PO2	PO3
CE857	Advanced Hydraulics Laboratory	CO1	Apply the principles of fluid mechanics to analyze pipe and open channel flows	2	1	3
		CO2	Analyze velocity profiles, shear stress distribution, friction loss and energy losses in hydraulic experiments.	3	1	3
		CO3	Synthesize acquired theoretical knowledge with experimental observations for open channel flow	3	2	3
		CO4	Identify and characterize flow patterns and regimes	3	2	3
		CO5	Apply the hydrological measurement technique for infiltration and saturated flow in porous media	2	3	3
CE859	GIS for Water Resources Laboratory	CO1	Acquire knowledge about various RS, GIS and image processing techniques	2	1	3
		CO2	Learning spatial data handling software and creation of spatial databases	3	1	3
		CO3	Ability to select a suitable geographical data and method integration and analysis	3	2	3
		CO4	Carryout spatial analysis by understanding the principles of GIS and basic GIS operations	3	2	3
		CO5	Apply remote sensing and GIS techniques for solving problems in the field of water resources engineering	2	3	3
CE858	Hydroinformatics Laboratory	CO1	understand the fundamentals of computer programming and perform engineering computations using MATLAB	2	1	2
		CO2	design and analyze water distribution systems using EPANET	2	2	3
		CO3	develop and apply hydrologic and reservoir simulation models using HEC-HMS, SWAT, MIKE SHE and HEC-ResSIM	3	2	3

		CO4	perform hydraulic and groundwater modeling using HEC-RAS and MODFLOW	3	2	3
		CO5	apply GIS and soft computing techniques in hydraulic and hydrologic modeling for water resources applications	3	3	3

PROGRAMME ELECTIVES

Course Code	Course Name	CO	Course Outcomes – Students will be able to:	PO1	PO2	PO3
CE861	Advanced Fluid Mechanics	CO1	Understand and apply fundamental equations governing fluid motion.	2	1	3
		CO2	Analyze ideal fluid flow using potential flow theory and its engineering applications.	3	1	3
		CO3	Distinguish between laminar and turbulent flows and analyze internal flows in conduits and between plates.	3	2	3
		CO4	Examine external viscous flows using analytical, exact, and approximate methods.	3	2	3
		CO5	Apply computational fluid dynamics (CFD) techniques to simulate and analyze fluid flow and heat transfer problems.	2	3	3
CE862	River Engineering	CO1	Classify rivers based on their morphological characteristics and understand the geomorphic responses of river channels.	2	1	3
		CO2	Calculate and analyze hydraulic parameters of river flow, including shear stress and flow resistance, for various channel conditions.	3	1	3
		CO3	Predict and analyze scouring phenomena around bridge piers and embankments using relevant criteria and diagrams.	3	2	3
		CO4	Apply regime concepts for the design of stable alluvial channels and describe the processes of bed load transport in braided rivers.	3	2	3
		CO5	Identify and propose appropriate river training and bank protection measures for different river engineering problems	2	3	3
CE863	Mechanics of Sediment Transport	CO1	Describe particle motion, differentiate sediment loads, and determine critical motion using the Shields diagram	2	1	3

		CO2	Apply transport relations to calculate total sediment load and analyze bedform mechanics/stability	3	1	3
		CO3	Explain material transportation via pipelines, rheology of complex mixtures, and two-phase flow.	3	2	3
		CO4	Analyze phase separation and settling behavior in fluid-solid mixtures.	3	2	3
		CO5	Design slurry pipelines, considering non-Newtonian fluid flow and turbulent conditions.	2	3	3
CE864	Urban Water Management	CO1	To understand how urbanization affects the water cycle and apply management practices like rainwater harvesting to address these effects.	2	1	3
		CO2	To create an urban drainage plan using planning tools and methods to effectively manage stormwater.	3	1	3
		CO3	To design and maintain urban drainage systems to manage stormwater and prevent pollution.	3	2	3
		CO4	To analyze how water management practices affect urban infrastructure and groundwater, and use mapping to support planning.	3	2	3
		CO5	To apply integrated water management strategies in urban contexts.	2	3	3
CE865	Computational Fluid Dynamics	CO1	Understand the fundamental theory of computational fluid dynamics	2	1	3
		CO2	Understand the concept of grid generation.	3	1	3
		CO3	Apply different discretization methods to governing differential equations and boundary conditions.	3	2	3
		CO4	Analyze and build up skills in the actual implementation of CFD methods	3	2	3
		CO5	To gain experience in the application of CFD analysis to real-life engineering problems	2	3	3

CE866	Water Security Policies	CO1	Explain key dimensions of water security and critically assess global and regional water security frameworks.	2	1	3
		CO2	Interpret and evaluate Indian water laws, policies, and institutional mechanisms for water governance.	3	1	3
		CO3	Apply the concepts of IWRM to real-world challenges involving watershed management and stakeholder engagement.	3	2	3
		CO4	Analyze the impact of climate variability on water systems and recommend policy measures to enhance climate resilience.	3	2	3
		CO5	Design policy-oriented strategies for water security using data-driven tools and best practices from international models.	2	3	3
CE867	Urban Climatology	CO1	To describe and differentiate the key atmospheric processes, climatic variables, and contrasts between urban and rural climates relevant to water systems.	2	1	3
		CO2	To analyze the effects of surface and canopy UHI on urban hydrology and air quality, and identify mitigation strategies based on global and Indian case studies.	3	1	3
		CO3	To assess the effects of impervious surfaces and climate extremes on urban hydrological processes and recommend adaptation strategies including green infrastructure.	3	2	3
		CO4	To apply geospatial and computational tools such as MODIS, Landsat, TROPOMI, WRF, ENVI-met, and data analysis platforms (Python/R/MATLAB) for urban climate studies.	3	2	3
		CO5	To evaluate sustainable urban water management strategies such as SUDS and WSUD, and interpret climate policies for resilient water planning in cities.	2	3	3

CE868	Advanced Geospatial and Hydroinformatics	CO1	Understand the fundamental concepts, principles, and applications of remote sensing technologies in environmental and water resource studies.	2	1	3
		CO2	Demonstrate comprehensive knowledge of hydroinformatics, including data-driven modeling approaches and their applications in water systems analysis.	3	1	3
		CO3	Apply supervised machine learning techniques for classification, prediction, and modeling of environmental datasets.	3	2	3
		CO4	Gain hands-on experience with unsupervised learning methods and develop skills to interpret clustering results for spatial and environmental data analysis.	3	2	3
		CO5	Acquire a solid foundation in Geographic Information System (GIS) concepts, tools, and spatial analysis techniques for solving geospatial and environmental problems.	2	3	3

CE869	Disaster Risk Management and Hazard Modeling	CO1	To understand the fundamental concepts of disasters, including classifications, hazard characteristics, and the interplay between natural and anthropogenic risks, exposure, and vulnerability.	2	1	3
		CO2	To apply appropriate hazard modeling approaches such as physical, empirical, statistical, and AI-based methods for disaster risk assessment and simulation.	3	1	3
		CO3	To develop and implement predictive hazard mapping techniques using geospatial datasets, statistical tools, and programming-based data-driven models to forecast disaster risks.	3	2	3

		CO4	To comprehend and evaluate disaster risk reduction frameworks, including the disaster management cycle, structural and non-structural mitigation strategies, and climate-resilient planning.	3	2	3
		CO5	To apply geospatial technologies and emergency communication systems in real-world disaster preparedness and response scenarios, integrating tools like GIS, remote sensing, and early warning systems for effective decision-making.	2	3	3
CE870	Climate Change Impact Modeling for Water Resource Management	CO1	To develop a foundational understanding of the global carbon cycle and its key components.	2	1	3
		CO2	To gain insights into climate change science, including causes, trends, and global responses.	3	1	3
		CO3	To understand climate change models and evaluate their impacts on hydrological processes.	3	2	3
		CO4	To acquire comprehensive knowledge of Geographic Information Systems (GIS) and spatial data analysis.	3	2	3
		CO5	To apply GIS tools and techniques to assess the impacts of climate change on hydrology and water resources.	2	3	3
CE871	Thermal and Hyperspectral Remote Sensing	CO1	Understand thermal radiation, and data gathering environmental conditions.	2	1	3
		CO2	Use thermal and hyperspectral sensors to acquire and preprocess remote sensing images.	3	1	3
		CO3	Getting idea about Hyper spectral remote sensing basics	3	2	3
		CO4	Interpret and compress data using hyperspectral remote sensing technologies	3	2	3
		CO5	Apply the geospatial and image processing techniques for various environmental problems.	2	3	3

CE872	Coastal Engineering	CO1	Apply the concepts of wave deformation for planning of ports and harbours.	2	1	3
		CO2	Understand the concepts of coastal sediment and littoral drift and its impact coastal environment	3	1	3
		CO3	Plan beach profile and coastal protection works	3	2	3
		CO4	Design breakwaters and its application in coastal planning	3	2	3
		CO5	Provide planning guidelines and deign principles for ocean structures	2	3	3
CE873	Climate Adaptation in Coastal and Hydraulic Engineering	CO1	Understand the fundamental concepts of climate changes and downscaling approaches	2	1	2
		CO2	Apply appropriate climate change models for Risk Assessment on coastal protection structures	2	1	2
		CO3	Develop and implement predictive modeling tools for water infrastructure in prioritized areas due to climate change	2	2	3
		CO4	Comprehend and evaluate various methods and technologies of climate adaption for coastal and hydraulic engineering	2	2	3
		CO5	Apply computational methods and modeling tools for hydrologic and hydraulic analysis	3	3	3
CE874	Flood and Drought Management	CO1	Explain the causes, processes and hydro-climatic characteristics governing floods and droughts.	2	1	2
		CO2	Perform flood and drought assessment, forecasting and risk analysis using hydrological and geospatial techniques.	2	1	2
		CO3	Apply hydrologic and hydraulic models for flood routing, drought analysis and early warning systems.	2	2	3
		CO4	Evaluate structural, non-structural and nature-based mitigation measures for flood and drought management.	2	2	3

		CO5	Develop sustainable and climate-resilient flood and drought management strategies considering policy.	3	3	3
CE875	Sustainability in River Basin Management	CO1	Analyze the hydrological, ecological, and geomorphological processes governing river basins.	2	1	2
		CO2	Use GIS, remote sensing, and modeling tools to evaluate water resources and allocation.	2	1	2
		CO3	Assess environmental, social, and economic impacts of human activities and climate variability on river basins.	2	2	3
		CO4	Develop integrated management plans for flood/drought mitigation, water allocation, and ecosystem restoration.	2	2	3
		CO5	Implement data-driven decision support systems and adaptive strategies for sustainable river basin management.	3	3	3
CE876	Wave Hydrodynamics	CO1	Apply the concepts of small amplitudes theory and higher order wave theories	2	1	2
		CO2	Analyze Wave Characteristics and wave transformation	2	1	2
		CO3	Design and Compute wave loads for offshore structures	2	2	3
		CO4	Gain knowledge on Wave structure interaction	2	2	3
		CO5	Gain Knowledge on wave current interaction	3	3	3
CE877	Design of Hydraulic Structures	CO1	Apply analytical methods for analyzing different hydraulic structures	2	1	2
		CO2	Design different types of Dams	2	1	2
		CO3	Design of Collector wells and Infiltration Galleries	2	2	3
		CO4	Analyze Grouting methods and its impact on Hydraulic structures.	2	2	3
		CO5	Apply Dam safety concepts to all types of Dams	3	3	3

CE878	Irrigation Systems Engineering and Management	CO1	Demonstrate in-depth understanding of soil-water-plant relationships, estimation of evapotranspiration, crop water requirement, infiltration, etc.	2	1	2
		CO2	Design conveyance and regulation systems (open channel, pipelines), control structures, and drainage (surface & subsurface) for irrigation schemes.	2	1	2
		CO3	Compare and choose among irrigation methods (surface, sprinkler, drip etc.), compute efficiencies, assess economic & environmental trade-offs.	2	2	3
		CO4	Plan and implement irrigation schedules, optimise water allocation and scheduling under uncertainties (climate, availability) to improve water use efficiency.	2	2	3
		CO5	Apply modern tools (sensor networks, GIS/RS, automation), and consider sustainability issues (waterlogging, salinity, environmental impacts, institutional/policy aspects) in irrigation project management.	3	3	3
CE879	Water, Energy and Climate Nexus	CO1	Comprehend the Water-Energy-Climate Nexus and its relevance to SDGs	2	1	2
		CO2	Analyze water-energy system interactions and case studies.	2	1	2
		CO3	Assess climate impacts on water and energy systems.	2	2	3
		CO4	Use nexus assessment tools (LCA, GIS, modeling) for analysis.	2	2	3
		CO5	Evaluate policies, governance, and sustainable strategies for integrated management.	3	3	3
CE880	AI/ML Applications in Water Resources Engineering	CO1	Explain AI/ML concepts and agent-based architectures for water resource problems.	2	1	2
		CO2	Implement supervised and unsupervised learning models for hydrological applications	2	1	2
		CO3	Extract and analyze remote sensing data for water resource assessment.	2	2	3

		CO4	Develop integrated AI-remote sensing solutions for prediction and monitoring.	2	2	3
		CO5	Assess model accuracy and reliability for informed water resource decision-making.	3	3	3
CE881	Watershed Management	CO1	Explain watershed components, degradation causes, and delineation methods	2	1	2
		CO2	Conduct morphometric analysis and prioritize sub-watersheds using GIS and RS tools.	2	1	2
		CO3	Propose suitable soil and water conservation and land reclamation measures.	2	2	3
		CO4	Recommend appropriate irrigation, water harvesting, and budgeting strategies.	2	2	3
		CO5	Evaluate watershed programs incorporating participatory approaches, monitoring, and policy perspectives.	3	3	3
CE882	Water Supply and Wastewater Engineering	CO1	Estimate water demand and design components of a municipal and building-level water supply system, including fire protection.	2	1	2
		CO2	Analyze and design water treatment systems based on raw water quality and required standards.	2	1	2
		CO3	Plan and design wastewater collection and treatment systems using appropriate design criteria and models.	2	2	3
		CO4	Integrate sustainable practices and technologies (reuse, energy efficiency) into system planning.	2	2	3
		CO5	Utilize modern software and decision-support tools for simulation and analysis of water and wastewater infrastructure for Smart Water Management	3	3	3
CE883	Glacial Hydrology	CO1	Explain glacier dynamics, mass balance, and hydrological processes in mountain and river basin contexts.	2	1	2

		CO2	Implement remote sensing-based analysis – for glacier extent, snow cover, flow dynamics, and temporal changes.	2	1	2
		CO3	Design and execute glacier hydrology models – including AI/ML-enhanced runoff estimation and uncertainty analysis.	2	2	3
		CO4	Apply integrated remote sensing and AI methods – for glacier lake monitoring, GLOF assessment, and hydrological forecasting.	2	2	3
		CO5	Assess climate change impacts on glaciers and downstream hydrology and provide actionable insights for water resource planning.	3	3	3
CE884	Remote Sensing and Earth Observation	CO1	Explain the principles of electromagnetic radiation, Earth observation systems, and remote sensing imaging geometry.	2	1	2
		CO2	Analyze and interpret multispectral, hyperspectral, microwave, SAR, LiDAR, and UAV-based remote sensing datasets.	2	1	2
		CO3	Apply digital image processing, geospatial analytics, and cloud computing techniques for Earth observation data analysis.	2	2	3
		CO4	Develop geospatial solutions for applications in agriculture, hydrology, urban planning, disaster management, and climate studies.	2	2	3
		CO5	Integrate machine learning, deep learning, and GeoAI methods with GIS and remote sensing workflows for advanced environmental and engineering applications.	3	3	3
CE885	Geographic Information Systems and Spatial Analytics	CO1	Explain the principles of GIS, cartography, spatial data models, coordinate systems, and geospatial data acquisition techniques.	2	1	2
		CO2	Design and manage spatial databases using geodatabases, PostgreSQL/PostGIS, and enterprise GIS architectures.	2	1	2

		CO3	Apply spatial analysis, geospatial modeling, and multi-criteria decision-making techniques for environmental and engineering problem solving.	2	2	3
		CO4	Develop Web GIS and smart geospatial applications using cloud GIS platforms, APIs, IoT integration, and real-time geospatial systems.	2	2	3
		CO5	Analyze spatial datasets using geostatistics, spatial machine learning, and predictive geospatial analytics for sustainable and intelligent urban applications	3	3	3
CE886	Advanced Surveying and Geomatics	CO1	Apply EDM and Total Station techniques for engineering surveys.	2	1	2
		CO2	Analyze aerial photographs and perform photogrammetric mapping.	2	1	2
		CO3	Explain geodetic principles and apply map projection systems.	2	2	3
		CO4	Perform GPS/GNSS surveys and process positioning data.	2	2	3
		CO5	Evaluate and apply modern surveying technologies such as UAVs and LiDAR in water resources projects.	3	3	3
CE887	Urban Planning and Infrastructure Planning	CO1	Understand urban planning principles and their relationship with water resources management.	2	1	2
		CO2	Analyze LULC dynamics, urban growth patterns and urban sprawl using geospatial tools.	2	1	2
		CO3	Plan and evaluate urban infrastructure systems with emphasis on urban water management	2	2	3
		CO4	Assess urban livability, sustainability and SDG compliance in urban development projects	2	2	3
		CO5	Apply GIS-based land suitability and decision-support techniques for sustainable urban and water resources planning	3	3	3

CE888	Geospatial Data Analysis and Modelling	CO1	Understand spatial data structures, coordinate systems, and geospatial databases	2	1	2
		CO2	Apply spatial statistical and interpolation techniques for geospatial analysis.	2	1	2
		CO3	Develop and evaluate geospatial models for hydrological and environmental applications.	2	2	3
		CO4	Utilize GIS and remote sensing tools for water resources planning and management.	2	2	3
		CO5	Analyze advanced geospatial technologies and emerging modeling approaches.	3	3	3
CE889	Digital Image Processing and Computer Vision for Geospatial Applications	CO1	Explain digital image processing concepts and geospatial imaging principles	2	1	2
		CO2	Apply image enhancement, segmentation, and restoration techniques for Earth observation data.	2	1	2
		CO3	Develop machine learning-based classification and pattern recognition models for geospatial analysis.	2	2	3
		CO4	Implement deep learning frameworks for object detection, segmentation, and geospatial computer vision tasks	2	2	3
		CO5	Analyze hyperspectral, SAR, UAV, and remote sensing datasets using advanced AI techniques.	3	3	3
CE890	Geoartificial Intelligence and Digital Earth System	CO1	Explain AI and GeoAI concepts for geospatial problem solving	2	1	2
		CO2	Apply machine learning methods for predictive spatial analytics.	2	1	2
		CO3	Implement deep learning models for remote sensing applications	2	2	3
		CO4	Develop intelligent geospatial systems using IoT, GIS, and digital twin technologies	2	2	3

		CO5	Use cloud-native platforms such as Google Earth Engine for Earth observation applications and Evaluate ethical and governance issues in GeoAI systems	3	3	3
CE891	Climate Systems and Climate Modelling	CO1	Describe the functioning of the Earth's climate system and its major components.	2	1	2
		CO2	Assess the drivers of climate variability and change using observational and proxy records.	2	1	2
		CO3	Explain the working principles of different types of climate models and their applications.	2	2	3
		CO4	Apply climate model outputs to assess climate impacts on water systems.	2	2	3
		CO5	Analyze and interpret climate projections, including uncertainty analysis and downscaling.	3	3	3
CE892	Integrated Water Resources Management	CO1	Understand the principles, processes and challenges associated with Integrated Water Resources Management and sustainable water governance.	2	1	2
		CO2	Apply hydrological and economic concepts for integrated water resources planning and decision-making.	2	1	2
		CO3	Analyze rainfall–runoff processes, basin-scale hydrology and hydroinformatics tools for water resources assessment.	2	2	3
		CO4	Evaluate sustainable water management strategies in agriculture, urban systems and watershed management.	2	2	3
		CO5	Interpret legal, institutional and policy frameworks for integrated and sustainable water resources	3	3	3
CE893	Hydrological Extreme Risk Management and Adaptation	CO1	Explain the hydrological and climatological processes governing extreme events including floods, droughts and cloudbursts.	2	1	2
		CO2	Analyze vulnerability, resilience and socio-economic impacts associated with hydrological extreme risks.	2	1	2

		CO3	Apply forecasting, modeling and geospatial tools for risk assessment and early warning of extreme events.	2	2	3
		CO4	Evaluate structural, non-structural and ecosystem-based mitigation and adaptation measures for hydrological extremes.	2	2	3
		CO5	Develop disaster preparedness, recovery and climate-resilient adaptation strategies for sustainable water resources management.	3	3	3

PROGRAMME CORE
SEMESTER I

Course Code	:	MA601
Course Title	:	**Numerical Methods and Applied Statistics**
Type of Course	:	Programme Core
Prerequisites	:	-
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize with various numerical methods for solving linear, non-linear and system of linear equations
CLO2	To learn linear and integer programming
CLO3	To recall the basic probability concepts, introduce random variables and some of the special distributions
CLO4	To impart knowledge on hypothesis testing for large and small sample
CLO5	To discuss about experimental design and time series analysis

Course Content

Linear system – Gaussian elimination and Gauss – Jordan methods – matrix inversion – Gauss Seidel method – Nonlinear equations – Regula Falsi and Newton- Raphson methods – interpolation – Newton's and Lagrange's interpolation.

Linear Programming – Graphical and Simplex methods – Big-M method - Two phase method - Dual simplex method - Dual theory – Sensitivity analysis – Integer programming – applications.

Random variable – two dimensional random variables – standard probability distributions – Binomial, Poisson and normal distributions - moment generating function.

Sampling distributions – confidence interval- estimation of population parameters – testing of hypotheses – Large sample tests for mean and proportion – t-test, F-test and Chi-square test.

Curve fitting – method of least squares – regression and correlation – rank correlation – multiple and partial correlation – analysis of variance-one way and two-way classifications – experimental design – Latin square design – Time series analysis. Introduction and hands-on practice on popular / available tools in the context of engineering applications.

References

1.	Bowker, A. H., Lieberman, G. J., *Engineering Statistics*. Prentice Hall, 1972.
2.	Venkatraman, M. K., *Numerical Methods in Science and Engineering*. National Publisher Company, 5^{th} Edition, 1999.
3.	Jain, M. K., Iyengar, S. R. K., Jain, R. K., *Numerical Methods for scientific and engineering computation*. 6^{th} edition, New Age International (p) Limited, 2012.
4.	Hamdy A. Taha, *Operations Research: An introduction*. 10^{th} edition Pearson Prentice Hall, 2007.
5.	S. C. Gupta, *Fundamentals of Statistics*. Himalaya Publishing House, 7^{th} Revised and Enlarged Edition, 2014.
6.	S.C. Gupta., V. K. Kapoor, *Fundamentals of Mathematical Statistics*. Sultan Chand and Sons, 2014.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Compute solution for linear, non-linear and system of equations
CO2	Solve the mathematical problems through linear programming approaches
CO3	Utilize the knowledge of standard distributions for solving real life case studies
CO4	Use statistical knowledge in testing hypotheses on large and small samples
CO5	Compute and interpret relationship between parameters in the design of experiments

Course Code	:	CE851
Course Title	:	**Advanced Hydrological Analysis and Design**
Type of Course	:	Programme Core
Prerequisites	:	-
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To explain the hydrological cycle and the significance of precipitation, evaporation, infiltration, runoff, and streamflow processes.
CLO2	To describe watershed runoff modeling, parameter estimation methods, Unit Hydrograph theory, and hydrologic system models.
CLO3	To apply stochastic and hydrologic time series models such as AR, ARMA, and ARIMA in rainfall–runoff analysis
CLO4	To apply hydrologic and hydraulic design concepts in water supply systems, sewerage networks, storm water management, and reservoir capacity

	estimation.
CLO5	To explain and apply soft computing and modern hydrologic modeling techniques including ANN, Genetic Programming, Chaos Theory, and Singular Spectrum Analysis.

Course Content

Review of Various Processes in the Hydrological Cycle: Precipitation, Abstracts, Evaporation, Infiltration, Evapotranspiration, Runoff, Streamflow and its measurements, floods, flood routing.

Problems and Models in Hydrology: Systems Approach, Parameter Estimation methods, Watershed Runoff Modeling, Response Time Characteristics, Linear Models: Rational Method, Time Area Methods, Unit Hydrograph Method, Derivation of UH and IUH, Clark Model, Nash Model, Time-Variant Linear Reservoir, Time-Area Method.

Hydrologic Time Series Models: Time series introduction, Introduction to stochastic models like AR, ARMA and ARIMA. Rainfall-runoff models-case studies, case studies of other hydrological time series models.

Hydrologic and Hydraulic Design: Design of Water Supply, Sewerage and Storm Water Networks, standards and case studies, finding the capacity of reservoir, rain water harvesting systems, case studies on conventional water storage structures.

Introduction and applications of soft computing, Artificial Intelligence (AI), and Machine Learning (ML) techniques including Artificial Neural Networks, Genetic Programming, Model Tree, Support Vector Machine, Deep Learning, Chaos Theory, and Singular Spectrum Analysis in hydrologic modeling.

References

1.	Chow, V. T., Maidment, D. R., Mays, L. W., Applied Hydrology, McGraw Hill, 1988.
2.	Vijay, P. Singh (1989) Hydrologic systems, Vol. I & II, Prentice Hall, New Jersey, 1989
3	Rajib Maity, Statistical Methods in Hydrology and Hydroclimatology, Springer, 2nd Edition, 2022.
4.	Mc.Cuen, R.H., (1989) Hydrologic Analysis and Design, Prentice Hall, New Jersey, 1989.
5.	Subramanya K., "Hydrology,Tata McGraw Hill Co., New Delhi, 1994.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain the various processes involved in the hydrological cycle including precipitation, evaporation, infiltration, runoff, streamflow, and flood routing.
CO2	Describe hydrologic systems approach, parameter estimation methods, watershed runoff modeling, and linear hydrologic models such as Unit Hydrograph, Clark, and Nash models.
CO3	Apply hydrologic time series and stochastic models including AR, ARMA, and ARIMA for rainfall–runoff and hydrological data analysis.
CO4	Apply hydrologic and hydraulic design principles for water supply systems, sewerage networks, storm water systems, reservoirs, and rainwater harvesting structures.
CO5	Explain and apply soft computing, Artificial Intelligence (AI), and Machine Learning (ML) techniques.

Course Code	**:**	CE853
Course Title	**:**	**GIS and Remote Sensing in Water Resources**
Type of Course	**:**	Programme Core
Prerequisites	**:**	-
Contact Hours	**:**	45
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To demonstrate the potential applications of remote sensing and GIS.
CLO2	To familiarize various satellite's data products and image classification algorithms.
CLO3	To introduce GIS data structures, data input and data pre and post processing
CLO4	To give an idea about the various geospatial operations.
CLO5	To provide exposure on applicability of geo-spatial data products and methods to deal with environmental applications.

Course Content

Introduction to Remote sensing - Active, Passive, Optical Remote sensing - Electro Magnetic Radiation - EM spectrum - EMR interaction with atmosphere - Scattering - Atmospheric Windows and its Significance – EMR interaction with Earth Surface Materials - EMR interaction with atmosphere, water, soil and Earth surface – imaging spectrometry - Atmospheric windows - Spectral signature.

Types of Platforms, orbit of Satellites, Satellite characteristics - types and classification of sensors, imaging modes, characteristics of optical sensors, sensor resolution-spectral, radiometric and temporal, characteristics of detectors, LiDAR, drone surveys..

Introduction to image processing - pre-processing, geometric corrections – image enhancement - spatial filtering technique - image classification techniques - visual and digital interpretation of Satellite Images-Environmental Satellites – NISAR, GOES, NOAA, AVHRR, CZCR, OCM, OCEANSAT, Sentinel, LandSat, SARAL, IceSAT and MODIS.

Fundamentals of Geographic Information System - Geodata - type - Input Sources - Raster and Vector data model - Comparison of Raster and Vector data - errors in data – Geospatial analysis using Raster and Vector data – File format, Data conversion between Raster and vector Projection and transformation - Reclassification - Neighborhood and Regional Operations – Map Algebra – Vector Data Analysis - Proximity analysis - Attribute data Analysis- concepts of SQL. Tools for map Analysis: Weighted overlay, Boolean logic models – Index overlay models – Fuzzy logic method

Monitor and mapping of atmosphere constituents - Spectral responses of clear and contaminated water - Site suitability analysis for disposal of solid waste using Multi Criterion Analysis - GIS for groundwater vulnerability for pollution - Seawater intrusion modeling - Remote Sensing application on soil degradation assessment, soil erosion, soil salinity mapping - Eutrophication and reservoir sedimentation- water quality mapping- air quality mapping- case studies

References

1.	Agarwal, C. S., Garg P. K., Remote Sensing in Natural Resources Monitoring and Management, A. H. Wheeler & Co. Ltd., New Delhi.
2.	Gibson, P. J. Introductory Remote Sensing-Principles and Concepts, Taylor and Francis Press.
3.	Gibson, P. J. and C.H. Power, Introductory Remote Sensing-Digital Image Processing and Application, Taylor and Francis Press.
4.	Lillesand, T. M. and R.W. Kiefer, remote Sensing and Image Interpretation, Fourth Edition, John Wiley.
5.	Ramkumar, Mu, (2009) Geological Hazards: Causes, Consequences and Methods of Containment, New India Publishing Agency, New Delhi.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Familiarize the basic concept of satellite image processing.
CO2	Acquire knowledge about Geographic Information System.
CO3	Getting idea about working on pre and post processing of satellite images.

CO4	Acquire knowledge about geo-database development and spatial analysis for environmental applications
CO5	Apply the geospatial and image processing techniques for various environmental problems.

Course Code	:	CE857
Course Title	:	**Advanced Hydraulics Laboratory**
Type of Course	:	Laboratory
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To develop a comprehensive understanding of free surface and enclosed flow dynamics in real-world conditions.
CLO2	To investigate the relationship between dependent hydraulic variables and independent variables in both pipe flow and open channel flow
CLO3	To study various open channel flow conditions such as Critical flow, Gradually varied flow and Rapidly varied flow.
CLO4	To verify the theoretical results with the experimental results.
CLO5	To determine the infiltration losses and saturated flow in soils through experiments

Course Content

1. Comparison of water surface profiles of free and forced vortex.
2. Determination Hydraulic conductivity using Darcys column experiment.
3. Determination of Infiltration capacity using infiltrometer
4. Determination of Co-efficient of Drag for different Bluff bodies.
5. Development of uniform flow and estimation of normal depth in open channel.
6. Establishment of subcritical, critical and supercritical flows in open channel, plotting of specific energy diagram.
7. Measurement and computation of flow profiles in open channel.
8. Characteristics of hydraulic jump in open channel.
9. Determination of reflection, transmission coefficient of coastal structures against Regular waves.
10. Determination of reflection, transmission, runup coefficient of coastal structures against Solitary waves.
11. Determination of reflection, transmission, runup coefficient of coastal structures against Cnoidal waves.
12. Wave Generation and regular wave profile computation
13. Computation of Wave forces

14. Water Hammer Pressure and Surge tank Analysis
15. Measurement of field infiltration capacity using Double ring Infiltrometer.

References

1.	Frank M. White, *Fluid Mechanics*, McGraw-Hill Education, 8th Edition, 2016.
2	Yunus A. Çengel and John M. Cimbala, *Fluid Mechanics: Fundamentals and Applications*, McGraw-Hill Education, 4th Edition, 2018.
3.	V. T. Chow, Open Channel Hydraulics, McGraw-Hill Publishing Company, New Delhi, 1993 , Knowledge on hydrology and hydraulics
4.	V. T. Chow, D. R. Maidment, and L. W. Mays, Applied Hydrology, McGraw Hill, 1988

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Apply the principles of fluid mechanics to analyze pipe and open channel flows
CO2	Analyze velocity profiles, shear stress distribution, friction loss and energy losses in hydraulic experiments.
CO3	Synthesize acquired theoretical knowledge with experimental observations for open channel flow
CO4	Identify and characterize flow patterns and regimes
CO5	Apply the hydrological measurement technique for infiltration and saturated flow in porous media

Course Code	:	CE859
Course Title	:	**GIS for Water Resources Laboratory**
Type of Course	:	Laboratory
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To develop an understanding of different of GIS methodologies, and image processing techniques, with an emphasis on their practical applications
CLO2	To gain expertise in spatial data handling software and the creation of spatial databases, focusing on methods for organizing, managing, and analyzing geographic information.

CLO3	To evaluate different data sources, understanding their relevance, and applying the best analytical techniques to solve spatial problems in fields
CLO4	To utilize spatial data and perform different GIS techniques to extract significant insights.
CLO5	To implement remote sensing and GIS technologies which aids to address critical challenges in water resources engineering.

Course Content

1. Basics of Mapping: Importing maps and layers from various sources
2. Projection: Image registration/geo-referencing and projection,
3. Digitization and preparation of vector GIS database of well locations, drainage network, water bodies
4. Map Delineation: Watershed delineation and Geomorphologic characteristics of watershed
5. Land use /Land cover map preparation: Supervised and unsupervised classification
6. Generating DEM and groundwater contours using spatial interpolation techniques
7. Extraction of drainage network from DEM and watershed delineation using GIS
8. Computation of Area-Capacity for a reservoir using GIS

References

1.	ArcGIS User Manuals
2.	QGIS User Manuals
3.	ERDAS Imaging Software

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Acquire knowledge about various RS, GIS and image processing techniques
CO2	Learning spatial data handling software and creation of spatial databases
CO3	Ability to select a suitable geographical data and method integration and analysis
CO4	Carryout spatial analysis by understanding the principles of GIS and basic GIS operations
CO5	Apply remote sensing and GIS techniques for solving problems in the field of water resources engineering

PROGRAMME CORE
SEMSETER II

Course Code	**:**	CE852
Course Title	**:**	**Water Resources System Analysis, Planning and Management**
Type of Course	**:**	Programme Core
Prerequisites	**:**	-
Contact Hours	**:**	45
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To explain the concepts of systems approach, mathematical modeling, simulation, and constrained and unconstrained optimization in water resources.
CLO2	To apply Lagrange multipliers, Kuhn–Tucker conditions, simplex method, duality theory, and sensitivity analysis in linear programming problems.
CLO3	To apply dynamic programming and uncertainty analysis techniques for reservoir operation, water allocation, and hydrosystem planning.
CLO4	To analyze reservoir systems and evaluate their performance using reliability, resiliency, vulnerability, and sustainability measures.
CLO5	To apply stochastic optimization, genetic algorithms, evolutionary algorithms, and multi-objective optimization techniques in water resources management.

Course Content

Importance of Systems Approach in Water Resources; Introduction to system concepts, mathematical modeling, Simulation, Optimization, Unconstrained and Constrained Optimization. Classical Optimization methods: Calculus based methods; Single and multiple variable optimization;

Lagrange Multipliers; Kuhn Tucker conditions; applications in water resources. Linear Programming: Definitions; Graphical solutions; Simplex method; Duality theory; Sensitivity Analysis in LP; Numerical examples; applications in water resources.

Dynamic Programming: Definitions; recursive equations; numerical examples; applications in water resources: water allocation, capacity expansion, reservoir operation. Uncertainty and risk analysis in Water Resources Planning: methods of uncertainty analysis and application to design and operation of hydro systems

Reservoir Systems: Reservoir sizing, modeling of reservoir systems for flood control, hydropower, irrigation, water quality control; optimal operation for single and multi-reservoir systems; simulation models for hydropower systems and examples;

Performance evaluation of water resources projects- reliability, resiliency, vulnerability, sustainability measures.

Stochastic Optimization: Chance constrained optimization; stochastic dynamic programming; Applications in water resources & reservoir operation. Evolutionary algorithms for optimization - Genetic algorithms (GA)and other EAs, applications in water resources. Decision making with multiple objectives: conventional and non-conventional approaches; multi-objective GAs; applications in water resources.

References

1.	Loucks, D.P., Stedinger, P.J.R., Haith, D.A., Water Resources Systems Planning and Management, Prentice Hall, New Jersey, 1987.
2.	Hall, K., A and Draoup, J.A., Water Resources Systems Engineering, Tata McGraw Hill, 1970.
3.	Neil, G.S., Water Resources Planning, McGraw Hill, 1985.
4.	National Water Policy, Ministry of Water Resources, Government of India, 1987.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain systems approach, mathematical modeling, simulation, and classical optimization techniques used in water resources engineering.
CO2	Apply Lagrange multipliers, Kuhn–Tucker conditions, and linear programming methods to solve water resources optimization problems.
CO3	Apply dynamic programming and uncertainty analysis methods for water allocation, reservoir operation, and hydrosystem planning.
CO4	Analyze and evaluate reservoir systems for flood control, hydropower, irrigation, and water quality management using simulation and performance indices.
CO5	Apply stochastic optimization, evolutionary algorithms, and multi-objective decision-making techniques in complex water resources management problems.

Course Code	:	CE854
Course Title	:	**Groundwater Engineering and Management**
Type of Course	:	Programme Core
Prerequisites	:	-
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the fundamental principles governing the occurrence, movement, and quality of groundwater.
CLO2	Analyze groundwater flow in various aquifer types using analytical solutions and numerical methods.
CLO3	Comprehend the processes of groundwater contamination and the principles of contaminant transport.
CLO4	Learn about different techniques for groundwater investigation, artificial recharge, and management, including remote sensing applications.
CLO5	Gain an introduction to groundwater flow modeling using software like MODFLOW and understand its application in real-world scenarios.

Course Content

Introduction to groundwater resources, occurrence and movement, Aquifers and their characteristics/classification, Darcy's law, Dupit's assumptions; Flow nets, Groundwater tracers.

Well hydraulics – steady/unsteady, uniform/radial flow to a well in a confined/unconfined/leaky aquifer, Well flow near aquifer boundaries/for special conditions; Groundwater levels, Quality of groundwater, Contaminant transport processes.

Advection-dispersion equation, Treatment of contaminated groundwater, Climate change and groundwater.

Artificial recharge, Saline water intrusion in aquifers - Ghyben-Herzberg relation, Remote sensing-based groundwater studies

Introduction to Groundwater flow modeling, Governing equations, Finite difference solutions, Introduction to MODFLOW and FEFLOW Software; Surface and sub-surface investigations

References

1.	Groundwater Hydrology by Todd, D. K. and Mays, L. W., John Wiley & Sons, Inc.
2.	Bjerg P L et al. (Eds), Groundwater 2000, A A Balkema, Rotterdam, 2000.
3.	Karamouz M et al. Groundwater Hydrology, Engineering, Planning and Management,
4.	Hydrogeology: Principles and Practice by Hiscock, K. M. and Bense, V. F., Wiley-Blackwell
5.	Numerical Groundwater Hydrology, A. K. Rastogi, 2007, Penram International Publishing.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Classify aquifers and interpret groundwater movement using Darcy's law.
CO2	Analyze well hydraulics for steady and unsteady flow conditions in confined, unconfined, and leaky aquifers, and interpret flow nets.
CO3	Explain the application of simulation and optimization problems in Ground water flow
CO4	Apply surface and subsurface investigation techniques, evaluate artificial recharge potential, and understand saline water intrusion using the Ghyben-Herzberg relation.
CO5	Utilize governing equations for groundwater flow, and understand groundwater modeling.

Course Code	:	CE856
Course Title	:	**Applied Hydraulic Engineering**
Type of Course	:	Programme Core
Prerequisites	:	-
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce students to control volume and differential approaches using fundamental fluid dynamics equations such as continuity, momentum, and energy.
CLO2	To explain the behavior of turbulent flow and surface resistance using Prandtl's mixing length theory and boundary layer concepts.
CLO3	To develop skills for analyzing and designing pipe flow systems using head loss equations and numerical techniques.
CLO4	To understand the principles of open channel flow including geometric elements, energy-depth relationships, and uniform flow conditions.
CLO5	To provide knowledge of gradually and rapidly varied open channel flows, including profile classification and hydraulic jumps.

Course Content

Control volume approach - Reynolds transport theorem, continuity equation, momentum equation, energy equation; differential approach for fluid flow analysis Navier-Stokes equations, Reynolds-averaged Navier-Stokes (RANS) equations;

Surface resistance to flows, turbulent flow - governing equations, Prandtl's mixing length hypothesis, Boundary layer theory

Pipe Flow: Fundamentals of pipe flow, fully developed laminar and turbulent flows, head loss – friction factor; pipe network analysis - system of head and discharge equations; Solving the system of equations by Newton-Raphson method; design of pipe networks - solving for pipe diameters

Open Channel Flow: Governing equation of 1-D flows, Geometric elements of a channel, concept of pressure in open channel flow; energy-depth relationships; critical flow; uniform flow – concept, uniform flow computations;

Non-uniform flow - Unsteady flow in open channels, surges in channels, Transients in closed conduits, water hammer analysis

References

1.	Crowe, C. T., Elger, D. F., Williams, B. C., Roberson, J. A. (2009). Engineering Fluid Mechanics.
2.	Wiley, USA. Cengel, Y. A., Cimbala, J. M. (2012). Fluid Mechanics, Tata McGraw-Hill, India. Larock, B. E.,
3.	Jeppson, R. W., Watters, G. Z. (1999). Hydraulics of Pipeline System. CRC Press, USA.
4.	Daily and Harleman, “Fluid Dynamics”, Addition Wesley, New York, 1973.
5.	R.H. French, “Open Channel Hydraulics”, Mc Graw Hill, New York, 1986

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Apply the Reynolds Transport Theorem and Navier-Stokes equations for fluid flow analysis.
CO2	Model turbulent flow and determine surface resistance using appropriate theoretical models.
CO3	Analyze pipe networks and compute flow parameters using friction factors and iterative methods like Newton-Raphson
CO4	Perform uniform flow computations and determine critical flow conditions in open channels.
CO5	Evaluate flow transitions and compute unsteady flow profiles and hydraulics in non-uniform open channel flows.

Course Code	:	CE858
Course Title	:	**Hydro informatics Laboratory**
Type of Course	:	Laboratory
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide hands-on training in computer programming and engineering computations using MATLAB for water resources applications.
CLO2	To develop practical skills in designing and analyzing water distribution systems using EPANET.
CLO3	To impart hands-on experience in hydrologic, hydraulic, reservoir, and groundwater modeling using standard hydroinformatics software tools.
CLO4	To enable students to apply simulation models such as HEC-HMS, SWAT, MIKE SHE, HEC-RAS, HEC-ResSIM, and MODFLOW for solving real-world water resources problems.
CLO5	To introduce GIS and soft computing techniques, including machine learning applications, in hydraulic and hydrologic modeling.

Course Content

1. Basics: Introduction to computer programming and computation with MATLAB.
2. Design of water distribution system using EPANET.
3. Hydrologic modeling using HECHMS/SWAT/MIKESHE
4. Reservoir operation using HEC-ResSIM
5. Water surface profile computation using HEC-RAS
6. Groundwater modeling using MODFLOW;
7. Application of soft computing methods and GIS in Hydraulic and Hydrologic modeling.

References

1.	User Manual: MATLAB, HECRAS, EPANET, HECHMS, SWAT, MIKESHE, HEC-ResSIM, HEC-RAS, MODFLOW

Course Outcomes (CO)

At the end of the course student will be able to gain hands-on experience in using hydro-systems simulation models

CO1	Understand the fundamentals of computer programming and perform engineering computations using MATLAB
CO2	Design and analyze water distribution systems using EPANET

CO3	Develop and apply hydrologic and reservoir simulation models using HEC-HMS, SWAT, MIKE SHE and HEC-ResSIM
CO4	Perform hydraulic and groundwater modeling using HEC-RAS and MODFLOW
CO5	Apply GIS and soft computing techniques in hydraulic and hydrologic modeling for water resources applications

PROGRAMME ELECTIVES

Course Code	**:**	CE861
Course Title	**:**	**Advanced Fluid Mechanics**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Derive and apply the continuity, Euler's, Navier-Stokes, and Bernoulli's equations for fluid flow analysis.
CLO2	Use velocity potential and stream function concepts to solve and superimpose elementary plane flows and analyze flow around bodies.
CLO3	Evaluate flow behavior in laminar and turbulent regimes within circular/non-circular conduits and between stationary/moving plates.
CLO4	Apply boundary layer theory, including Blasius solution and turbulent boundary layer concepts, to external flow problems.
CLO5	Develop and implement numerical solutions using CFD for modeling laminar, turbulent, and heat transfer flows, including open channel flow scenarios.

Course Content

Introduction basic equations of motion of fluid flow, Equation of continuity, Navier-Stokes equations, Energy equations, Euler's equations Bernoulli's equation

Potential flow theory: Velocity potential and Stream functions, Elementary plane flow solutions-Uniform stream-, Source and Sinks, Vortex, Superposition of plane flows, flow past closed body-Rankine oval, circular cylinder, Lift and Drag- Kutta-Zhukovsky theorem

Internal flows- Laminar and Turbulent flows in circular and non-circular closed conduits, entrance region, boundary layer, Flow between plates-stationary and moving plates.

External flows-Parallel flow over flat plate, Effect of surface roughness, Uniform stream, Flow past circular cylinder with and without circulation, Aerofoil viscous fluid flow, Exact solutions of Navier Stokes equations, Prandtl's boundary layer equations, Blasius solution, Approximate methods, Transition and turbulent flows, Flow through pipe sandflow past a flat plate, Turbulent boundary layer.

Introduction to CFD, Numerical solutions to Laminar flows, Turbulent flows and Heat transfer problems, CFD calculations in open channel.

References

1.	Frank M. White, “Viscous Fluid Flow”
2	G. K. Batchelor, “An Introduction to Fluid Mechanics”
3.	Kundu, P. K., Cohen, I. M., & Dowling, D. R. *Fluid Mechanics*. Academic Press.
4.	John D. Anderson Jr., “Modern Compressible Flow”
5.	H. Schlichting & K. Gersten, “Boundary Layer Theory”

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand and apply fundamental equations governing fluid motion.
CO2	Analyze ideal fluid flow using potential flow theory and its engineering applications.
CO3	Distinguish between laminar and turbulent flows and analyze internal flows in conduits and between plates.
CO4	Examine external viscous flows using analytical, exact, and approximate methods.
CO5	Apply computational fluid dynamics (CFD) techniques to simulate and analyze fluid flow and heat transfer problems.

Course Code	:	CE862
Course Title	:	**River Engineering**
Type of Course	:	Programme Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Provide an overview of river engineering principles, including river classifications, morphological thresholds, and hydraulic geometry.
CLO2	Understand the hydraulics of river flow, including uniform and unsteady cases, shear stress distribution, and flow resistance in alluvial channels.
CLO3	Analyze scouring mechanisms and criteria around various river structures, considering sediment properties and movement.
CLO4	Explore the concepts of regime rivers, stable alluvial channel design, and the characteristics and transport processes in braided rivers.
CLO5	Learn about different river training and stabilization techniques, including bank protection and flow control structures.

Course Content

Overview of river engineering- river classifications, thresholds in river morphology, hydraulic geometry, meander plan form, geomorphic analysis of river channel responses;

Hydraulics of river flow- fundamentals of alluvial channel flows, uniform and unsteady cases, shear stress distribution, flow resistance in rivers;

Scouring and its criteria- physical properties of sediments, sediment movement in rivers, shear stress, Shields diagram, scouring around bridge piers and embankments, river bed forms;

Regime rivers- analysis of river meanders, design of stable alluvial channels-regime concept, dimensional model studies for rivers, braided rivers, scaling and hierarchy in braided rivers, alternate bars, bed load transport in braided gravel-bed rivers;

River training and stabilization- stream bank erosion, bank protection, flow control structures, bank protection and river training along braided rivers.

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.	Gregory H., Braided Rivers: Process, Deposits, Ecology and Management Blackwell Publishing, 2006.
4.	Yang, C. T., Sediment Transport-Theory and Practice, McGraw Hill Companies, Inc., New Delhi, 1996.
5.	Knighton, D., Fluvial Forms and Processes. Edward Arnold, Baltimore, MD., 1984.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Classify rivers based on their morphological characteristics and understand the geomorphic responses of river channels.
CO2	Calculate and analyze hydraulic parameters of river flow, including shear stress and flow resistance, for various channel conditions.
CO3	Predict and analyze scouring phenomena around bridge piers and embankments using relevant criteria and diagrams.
CO4	Apply regime concepts for the design of stable alluvial channels and describe the processes of bed load transport in braided rivers.
CO5	Identify and propose appropriate river training and bank protection measures for different river engineering problems

Course Code	**:**	CE863
Course Title	**:**	**Mechanics of Sediment Transport**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand particle motion, turbulence, and the macroscopic view of sediment transport (bedload, suspended load).
CLO2	Analyze threshold conditions for sediment motion and apply bedload/suspended sediment transport relations.
CLO3	Describe and analyze bedforms, their stability, and the rheology of complex mixtures.
CLO4	Learn fundamentals of two-phase flow and phase separation in pipelines.
CLO5	Apply design methods for slurry pipeline transportation, including non-Newtonian fluid flow.

Course Content

Introduction; Equations of Particle Motion particle in a moving fluid, collision with the bed, diffusion of turbulence; Macroscopic View of Sediment Transport – bedload, suspended load;

Threshold Condition for Sediment Motion – Critical stress for flow over a granular bed, Shields diagram; Mechanics of Bedload Transport: Bagnold hypothesis of bedload transport, bedload transport relations; Mechanics of Suspended Sediment Transport; Total load transport;

Descriptive Analysis of Bedforms – introduction of bedform mechanics, dunes, antidunes, ripples, bars; Stability Analysis of Bedforms;

Mechanism of transportation of materials by fluid flow through pipeline; Rheology and classification of complex mixtures; Fundamentals of two-phase flow; Phase separation and settling behaviour;

Flow of non-Newtonian fluids through pipes: Turbulent flows of Complex mixtures, Slurry pipeline transportation, Design methods.

References

1.	Chih Ted Yang, Sediment Transport, Theory and Practice, Mcgraw Hill, ISBN 0-07-114884-5, 1996.
2.	Graf, W.H., Hydraulics of sediment transport, McGraw Hill, 1971.
3.	Raudkivi, A.J., Loose Boundary Hydraulics, Pergamon Press, ISBN 0-08-018771-4.
4.	Ranga Raju and garde, R.J., Mechanics of sediment transport, Mcgra Hill, 1977.
5.	M.Selim Yalin, Mechanics of Sediment Transport, Elsevier, 1977.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Describe particle motion, differentiate sediment loads, and determine critical motion using the Shields diagram
CO2	Apply transport relations to calculate total sediment load and analyze bedform mechanics/stability
CO3	Explain material transportation via pipelines, rheology of complex mixtures, and two-phase flow.
CO4	Analyze phase separation and settling behavior in fluid-solid mixtures.
CO5	Design slurry pipelines, considering non-Newtonian fluid flow and turbulent conditions.

Course Code	**:**	CE864
Course Title	**:**	**Urban Water Management**
Type of Course	**:**	Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To analyze how urbanization alters the natural water cycle and identify solutions to manage increased stormwater and runoff.
CLO2	To apply urban drainage principles and planning criteria to develop effective drainage systems that address urban water challenges.
CLO3	To design and operate drainage system components with an emphasis on efficiency, maintenance, and pollution control.
CLO4	To examine the effects of different water management practices on urban infrastructure and groundwater, incorporating mapping techniques.
CLO5	To define integrated water management and develop a plan for implementing

	strategies in urban areas.

Course Content

Urban hydrologic cycle, effect of urbanization on hydrology, storm water management and limitations; urban storm water management practices; rain water harvesting; managed aquifer recharge; constructed/engineered wetlands; sprinkler and drip irrigation; water use efficiencies.

Objectives of urban drainage and planning criteria - drainage option and system layout - planning tools and data requirement - drainage master plan - drainage structures; calculation methods and mathematical tools: rational method and SCS method, hydrologic models, hydrodynamic models, spreadsheets, regression rating curve approaches.

Design of drainage system elements: operation and maintenance of urban drainage systems - maintenance requirements and planning - cleansing of sewers and drains - repair options - control of storm water pollution.

Effect of water management practices on urban water infrastructure; hydrology and groundwater regime; surface and subsurface mapping of water supply and sewerage networks; structural safety and mitigating plans against natural and human caused threats.

Integrated water management: definition and significance, principles of integrated water management, benefits and challenges of integrated approaches, developing integrated water management plans, case studies in integrated water management.

References

1.	Mohammad Karamouz and Ali Moridi, Sara Nazif “Urban Water Engineering and Management” CRC Press, 2010
2.	Larry W Mays “Urban Water Supply Handbook” Mcgraw-hill, 2002
3.	Butler and Davis, Urban Drainage, 3rd edition, 2010
4.	Ministry of Urban Development, “Manual on Water Supply and Treatment”, CPHEEO. 1999

Course Outcomes (CO)

At the end of the course student will be able to

CO1	To understand how urbanization affects the water cycle and apply management practices like rainwater harvesting to address these effects.
CO2	To create an urban drainage plan using planning tools and methods to effectively manage stormwater.
CO3	To design and maintain urban drainage systems to manage stormwater and

	prevent pollution.
CO4	To analyze how water management practices affect urban infrastructure and groundwater, and use mapping to support planning.
CO5	To apply integrated water management strategies in urban contexts.

Course Code	:	CE865
Course Title	:	**Computational Fluid Dynamics**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce with the knowledge base essential for application of computational fluid dynamics to engineering flow problems
CLO2	To provide knowledge on conservation law and the numerical approach to solve by converting different form of partial differential equation to algebraic equations.
CLO3	Solve iteratively the set of linear algebraic equations
CLO4	Discretize the governing equations using Finite Difference or Finite Volume Method
CLO5	Demonstrate numerical solution techniques to reveal underlying physics

Course Content

Conservation equation; mass; momentum and energy equations; Navier-Stokes Equation; convective forms of the equations and general description. Mathematical behavior of Ordinary and partial differential equations; Classification of mathematical equations: Hyperbolic, Parabolic, Elliptic and Mixed type equations; boundary and initial conditions; over view of numerical methods.

Solution of linear equation systems: Direct methods, iterative methods, coupled equations and their applications, non-linear equation and their application, convergence criteria, error analysis

Introduction to numerical methods: Approaches to Fluid dynamics problems, possibilities and limitation of numerical methods, components of numerical solution methods, properties of numerical solution methods, discretization approaches.

Finite difference method, implicit and explicit scheme, accuracy, convergence and stability; approximation of first, second and mixed derivatives, boundary conditions; algebraic equation system; discretization errors

Finite volume method, approximation of surface and volume integrals, interpolation and differentiation practices, boundary conditions, algebraic equation system; applications to steady and unsteady flows

References

1.	Anderson, J.D., "Computational Fluid Dynamics: The Basics with Applications", McGrawHill, 1995.
2.	Ferziger, J. H. and Peric, M. (2003). Computational Methods for Fluid Dynamics. Third Edition, Springer-Verlag, Berlin.
3.	Anderson, D.A., Tannehill, J.C. and Pletcher, R.H. (1997). Computational Fluid Mechanics and Heat Transfer. Taylor & Francis.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the fundamental theory of computational fluid dynamics
CO2	Understand the concept of grid generation.
CO3	Apply different discretization methods to governing differential equations and boundary conditions.
CO4	Analyze and build up skills in the actual implementation of CFD methods
CO5	To gain experience in the application of CFD analysis to real-life engineering problems

Course Code	**:**	CE866
Course Title	**:**	**Water Security Policies**
Type of Course	**:**	Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the global and national context of water security and its relevance to water resources engineering.
CLO2	Analyze legal, institutional, and policy frameworks governing water resources in India.

CLO3	Evaluate integrated and participatory approaches to water governance through IWRM.
CLO4	Examine the interlinkages between climate change, water risk, and resilience strategies.
CLO5	Apply practical tools, policy instruments, and international case studies to design effective water security interventions.

Course Content

Introduction to Water Security: Definition and dimensions of water security (availability, accessibility, quality, and risk), Global water security issues and the UN Water Security Framework, Water–energy–food nexus, Human right to water and sustainable development goals (SDG 6), Case studies of water-secure and water-insecure regions

National Water Governance and Legal Frameworks: Constitutional provisions related to water in India, Overview of major water-related acts: Environment (Protection) Act, Water (Prevention & Control of Pollution) Act, Inter-State Water Disputes Act, Groundwater (Sustainable Management) Bill, National Water Policy (2012) and Jal Shakti Abhiyan, River basin management and inter-basin transfer debates, Institutional roles: Central Water Commission (CWC), Central Ground Water Board (CGWB), NITI Aayog Water Index

Integrated Water Resources Management (IWRM): Principles and implementation of IWRM, Stakeholder engagement and participatory water governance, Watershed-based planning approaches, Role of public-private partnerships (PPP) in water management, Water security indicators and performance metrics

Climate Change, Risk and Resilience in Water Policy: Impact of climate variability on water availability and quality, Urban and rural water stress under climate change, Drought and flood risk policies and management frameworks, Role of early warning systems and climate-resilient infrastructure, Nature-based solutions (NbS) for water security

Water Security Strategies, Tools and Global Practices: Urban water security planning and water-sensitive cities, Pricing, subsidies, and water markets, Water accounting and auditing tools (e.g., AQUASTAT, WEAP), International water treaties and transboundary water governance, global case studies

References

1.	Mays, L.W. (1996). Water resources handbook, McGraw-Hill.
2.	National Water Policy, Ministry of Water Resources, Government of India, 1987.
3.	Watershed Management, Murthy, J.V.S., New Age International Publishers, 2017 2nd Edition
4.	Jan C. Van Dam, Impacts of Climate Change and Climate Variability on Hydrological Regimes, Cambridge University Press, 2003.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain key dimensions of water security and critically assess global and regional water security frameworks.
CO2	Interpret and evaluate Indian water laws, policies, and institutional mechanisms for water governance.
CO3	Apply the concepts of IWRM to real-world challenges involving watershed management and stakeholder engagement.
CO4	Analyze the impact of climate variability on water systems and recommend policy measures to enhance climate resilience.
CO5	Design policy-oriented strategies for water security using data-driven tools and best practices from international models.

Course Code	:	CE867
Course Title	:	**Urban Climatology**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide a fundamental understanding of climatology, urban climate dynamics, and the relevance of urban climatology in water resources engineering.
CLO2	To examine the causes, types, and implications of Urban Heat Islands (UHI), their interactions with air pollution, and mitigation measures.
CLO3	To evaluate the impact of urbanization on hydrometeorological extremes such as floods and droughts, and explore adaptation strategies and governance.
CLO4	To train students in the use of tools such as remote sensing, GIS, satellite data, and urban climate models for climate analysis.
CLO5	To explore and assess urban water management strategies in the context of climate adaptation and resilient infrastructure planning.

Course Content

Introduction to Urban Climatology: Fundamentals of climatology and atmospheric science, Concept of urban climatology and need in water resources, Urban vs. rural climate dynamics, Key climatic variables: temperature, humidity, precipitation, wind, Impacts of urbanization on natural climate systems

Urban Heat Island and Microclimates: UHI types: surface vs. canopy, Causes and effects of UHI on urban hydrology and energy use, Diurnal and seasonal variations of UHI, interaction between urban heat and air pollution, mitigation measures, Case studies from Indian and global cities, Urban microclimate mapping and monitoring

Urbanization and Hydro meteorological Extremes: Impact of impervious surfaces on runoff and temperature, Urban flooding and storm water management, Urban droughts and water scarcity, Interaction between extreme weather and urban infrastructure, Urban adaptation policies, strategies & governance, Role of green infrastructure and blue-green solutions

Tools and Techniques for Urban Climate Analysis: Remote sensing and GIS applications, Satellite data (MODIS, Landsat, TROPOMI) for climate indicators, In-situ climate data monitoring networks, Climate modeling for urban areas (e.g., WRF, ENVI-met), Urban climate data analysis using Python/R/MATLAB

Urban Climate Adaptation and Water Management Strategies: Urban hydrology and climate, Climate and residential use of water supply, Climate-resilient urban design, Sustainable urban drainage systems (SUDS), Water-sensitive urban design (WSUD), Policy frameworks and urban climate action plans, Integration of urban climate data in urban water planning

References

1.	Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge university press.
2.	Souch, C., & Grimmond, S. (2006). Applied climatology: urban climate. Progress in physical geography, 30(2), 270-279.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	To describe and differentiate the key atmospheric processes, climatic variables, and contrasts between urban and rural climates relevant to water systems.
CO2	To analyze the effects of surface and canopy UHI on urban hydrology and air quality, and identify mitigation strategies based on global and Indian case studies.
CO3	To assess the effects of impervious surfaces and climate extremes on urban hydrological processes and recommend adaptation strategies including green infrastructure.
CO4	To apply geospatial and computational tools such as MODIS, Landsat, TROPOMI, WRF, ENVI-met, and data analysis platforms (Python/R/MATLAB) for urban climate studies.
CO5	To evaluate sustainable urban water management strategies such as SUDS and WSUD, and interpret climate policies for resilient water planning in cities.

Course Code	:	CE868
Course Title	:	**Advanced Geospatial and Hydroinformatics**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To develop a solid foundational understanding of GIS and remote sensing technologies.
CLO2	To grasp the core principles of GIS-based and model-driven management of water resources and the environment.
CLO3	To become proficient in GIS analytical and problem-solving methods for sustainable water-resource and environmental planning.
CLO4	To identify and evaluate the various types of remotely sensed imagery and datasets applicable to water-resource studies.
CLO5	To acquire expertise in advanced geomatics applications within diverse water-resource contexts.

Course Content

Satellite image products – types and classification of remote sensing sensors – active and passive sensing systems – imaging modes – optical sensor characteristics – sensor resolutions: spectral, radiometric, spatial, and temporal – detector performance and calibration – data acquisition platforms and orbits – overview of satellite missions (e.g., Landsat, Sentinel, MODIS, etc.) – fundamentals of raster and vector data structures – geospatial data formats and file handling – data conversion between raster-vector models – projection systems and coordinate transformation – geospatial preprocessing: reclassification – neighborhood and regional operations – spatial modeling through map algebra – vector data operations: buffer, overlay, and proximity analysis – attribute query and analysis using SQL – geospatial modeling tools: weighted overlay – Boolean logic – index-based overlay – fuzzy logic and uncertainty representation in spatial analysis.

Introduction to hydroinformatics – scope and interdisciplinary nature – components of water information systems – real-time data collection and integration – data-driven modeling approaches for hydrological processes – model classification: deterministic vs. stochastic – model structure and calibration – performance evaluation and validation – fundamentals of machine learning and artificial intelligence in hydrological applications – basics of scientific computing – introduction to MATLAB and Python for environmental data analysis – data visualization and basic scripting – programming tools for automation in GIS and remote sensing workflows.

Linear regression models – generalized linear models (GLMs): logistic, Poisson, gamma, and exponential models – introduction to non-linear regression – k-nearest neighbors (kNN) – polynomial regression – generalized additive models (GAMs) – kernel-based learning methods – decision trees and ensemble learning: CART, bagging, boosting, and random forests – support vector machines (SVM) for classification and regression – introduction to deep learning models: architecture of artificial neural networks (ANN) – overfitting, regularization techniques – model selection, training-validation split, cross-validation – bootstrap resampling – basics of designing an effective machine learning system for environmental modeling.

Unsupervised learning and data clustering – hard clustering (k-means) – fuzzy clustering (fuzzy c-means) – application of fuzzy logic in environmental modeling – hierarchical clustering approaches – multivariate statistical techniques for environmental data – dimension reduction methods – principal component analysis (PCA) – singular value decomposition (SVD) – independent component analysis (ICA) – canonical correlation analysis (CCA) – visualization of high-dimensional data – application of multivariate analysis in land-use mapping, water quality analysis, and change detection.

Application of hydroinformatics in water-resource and climate-change impact assessment – integrated modeling for water quality and quantity under changing climate conditions – regional flood-frequency analysis using statistical and machine-learning approaches – flood-risk mapping using satellite-derived hydrological indicators – drought monitoring and assessment using remote sensing indices such as Normalized Difference Vegetation Index (NDVI), Standardized Precipitation Index (SPI), and Vegetation Health Index (VHI) – drought classification and early warning systems – coupled GIS-hydrologic models for flood-drought simulation – real-time flood forecasting and inundation mapping – hydrological response modeling under extreme climate scenarios – uncertainty analysis in climate projections – statistical and dynamical downscaling techniques – hydrologic information systems and data infrastructure for decision support – development of climate-resilient water management plans – case studies on early warning systems, flash flood detection, drought vulnerability mapping, and disaster risk mitigation using hydroinformatics tools.

References:

1.	Lillesand, T. M. and R.W. Kiefer, remote Sensing and Image Interpretation, Fourth Edition, John Wiley.
2.	Von Storch and Zwiers, 1999, Statistical Analysis in Climate Research, Cambridge Univ. Press, U.K.
3.	Myers, R. H., Montgomery, D. C., Vining, G. G., & Robinson, T. J. (2012). Generalized linear models: with applications in engineering and the sciences (Vol. 791). John Wiley & Sons.
4.	Abbott, 1991, Hydroinformatics- Information Technology and the Aquatic Environment, Avebury Technical, Aldershot, U.K.

5.	James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An introduction to statistical learning (Vol. 112). New York: Springer. (Alternatively, Hastie et al., 2008, The Elements of Statistical Learning - for advanced)

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the fundamental concepts, principles, and applications of remote sensing technologies in environmental and water resource studies.
CO2	Demonstrate comprehensive knowledge of hydroinformatics, including data-driven modeling approaches and their applications in water systems analysis.
CO3	Apply supervised machine learning techniques for classification, prediction, and modeling of environmental datasets.
CO4	Gain hands-on experience with unsupervised learning methods and develop skills to interpret clustering results for spatial and environmental data analysis.
CO5	Acquire a solid foundation in Geographic Information System (GIS) concepts, tools, and spatial analysis techniques for solving geospatial and environmental problems.

Course Code	**:**	CE869
Course Title	**:**	**Disaster Risk Management and Hazard Modeling**
Type of Course	**:**	Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To develop a comprehensive understanding of disaster risk assessment, reduction strategies, and management frameworks.
CLO2	To identify, acquire, and apply relevant spatial and temporal datasets for targeted risk assessment, tailored to specific scales and objectives.
CLO3	To apply and critically evaluate integrated qualitative and quantitative methodologies for assessing hazards, vulnerabilities, and overall disaster risk.
CLO4	To utilize risk assessment outcomes effectively across all phases of disaster management, enhancing community resilience and preparedness.
CLO5	To understand the roles and responsibilities of federal, state, and local governments in disaster planning, including policy development, mitigation strategies, recovery planning, and the contributions of planners and decision-makers in post-disaster rebuilding.

Course Content

Introduction to disasters – Definitions and key concepts including hazard, exposure, vulnerability, and risk – Classification of disasters into natural and anthropogenic (man-made) categories. Natural disasters such as earthquakes, liquefaction, landslides, floods, dam breaks, cyclones, tsunamis, flash floods, droughts, and forest fires. Man-made disasters including chemical spills, industrial accidents, and transportation-related hazards. Understanding disaster causes, spatial-temporal dynamics, and the relationship between human development and vulnerability.

Model selection for simulating specific hazard processes – Overview of physical, empirical, and statistical modeling approaches – Underlying modeling principles, assumptions, strengths, and limitations. Application of Multi-Criteria Decision Making (MCDM), Artificial Neural Networks (ANN), Fuzzy Logic, and Artificial Intelligence (AI) techniques in hazard prediction. Critical evaluation of hazard-inducing factors and their relative significance in determining risk. Introduction to sensitivity and uncertainty analysis in modeling.

Use of statistical modeling for predictive hazard mapping – Understanding spatial and temporal datasets for hazard forecasting. Methods to integrate and interpret large geospatial datasets through machine learning and geostatistics. Implementing data-driven techniques through programming and scripting for hazard prediction (e.g., Python, R). Introduction to ensemble modeling and hybrid models combining physical and statistical frameworks for improved accuracy in disaster risk prediction.

Understanding the Disaster Management Cycle – Hazard identification and risk characterization – Pre- and post-disaster activities including early warning, emergency response, and recovery planning. Search and rescue (SAR) operations – Structural and non-structural mitigation strategies. Integration of soft computing tools for vulnerability and risk assessments. Climate change adaptation in disaster risk reduction (DRR) – Community-based DRR and infrastructure resilience planning. Integration of probabilistic modeling and scenario analysis to inform policy.

Emergency management planning – Tools and strategies for implementing risk reduction measures – Early warning systems, simulation exercises, communication protocols. Development and operation of Emergency Operation Plans (EOPs), evacuation planning, and training programs. The role of geospatial and information technologies in disaster communication – GPS, HAM radio, Bluetooth, wireless networks. Applications of Remote Sensing and GIS in disaster monitoring and response – UNOSAT Humanitarian Rapid Mapping Service. Case studies on risk and vulnerability mapping for floods, landslides, droughts, forest fires, liquefaction, and earthquakes. Emphasis on real-world disaster modeling applications, rapid assessment methods, and technology-enabled decision-making.

References

1.	Etkin, D. Disaster Theory: An Interdisciplinary Approach to Concepts and Causes,Elsevier Science & Technology, 2015.
2.	Gibson, P. J. Introductory Remote Sensing-Principles and Concepts, Taylor and Francis Press.
3.	Gibson, P. J. and C.H. Power, Introductory Remote Sensing-Digital Image Processing and Application, Taylor and Francis Press.
4.	Lillesand, T. M. and R.W. Kiefer, remote Sensing and Image Interpretation, Fourth Edition, John Wiley.
5.	Carter, W. N. Disaster Management: A Disaster Management Handbook, Asian Development Bank, Bangkok, 1991.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	To understand the fundamental concepts of disasters, including classifications, hazard characteristics, and the interplay between natural and anthropogenic risks, exposure, and vulnerability.
CO2	To apply appropriate hazard modeling approaches such as physical, empirical, statistical, and AI-based methods for disaster risk assessment and simulation.
CO3	To develop and implement predictive hazard mapping techniques using geospatial datasets, statistical tools, and programming-based data-driven models to forecast disaster risks.
CO4	To comprehend and evaluate disaster risk reduction frameworks, including the disaster management cycle, structural and non-structural mitigation strategies, and climate-resilient planning.
CO5	To apply geospatial technologies and emergency communication systems in real-world disaster preparedness and response scenarios, integrating tools like GIS, remote sensing, and early warning systems for effective decision-making.

Course Code	**:**	CE870
Course Title	**:**	**Climate Change Impact Modeling for Water Resource Management**
Type of Course	**:**	Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand Learn atmospheric dynamics, global carbon cycle's history and dynamics, including non-CO2 greenhouse gases and the greenhouse effect.

CLO2	To analyze climate change scenarios, sensitivity, and human-climate change links using econometric models and GHG emissions estimates.
CLO3	To learn how climate change affects precipitation patterns, evaporation and transpiration, and surface and groundwater systems.
CLO4	To gain knowledge of GIS and remote sensing for hydrological modeling, including watershed delineation, spatial data integration, and climatic data management.
CLO5	Use GIS to monitor water quality, analyze flood and drought risks, and perform spatial analysis and mapping in water resource management.

Course Content

Understanding the historical evolution of Earth's climate – major climatic events and natural variability – causes and consequences of tropical cyclones – introduction to the Global Carbon Cycle and its components: oceanic, terrestrial, and atmospheric – interactions between the Ocean and Terrestrial Carbon Cycles – carbon sequestration and storage dynamics – modeling the carbon cycle under anthropogenic influence – analysis of non-CO_2 greenhouse gases and atmospheric aerosols – greenhouse effect mechanisms involving temperature, radiation, and Earth's energy balance – role of feedback loops in climate regulation.

Overview of climate scenario development using Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) – structure and function of climate system models – climate simulation processes and modeling drift – evaluation of model performance using historical climate data – comparison of Regional Climate Models (RCMs) and Global Climate Models (GCMs) – techniques for model downscaling and bias correction – observed trends in global warming and climate variability – climate change mitigation policies and international frameworks – role of the Intergovernmental Panel on Climate Change (IPCC) – Kyoto Protocol and its mechanisms including Clean Development Mechanism (CDM) and carbon credit systems – regional cooperation and climate action strategies..

Analysis of climate-induced variations in hydrological processes – changes in precipitation intensity, frequency, and seasonality – altered surface runoff patterns and implications for extreme flow events such as flash floods – impacts on groundwater recharge and base flow – effects of rising temperature on evaporation and plant transpiration – coastal vulnerability and sea-level rise – drought classification, frequency, and severity – integration of climate indicators in hydrological impact assessment – mapping vulnerable regions using climate and hydrological data

Types of hydrological models – conceptual, empirical, and physically based – calibration and validation procedures using observed and projected climate data – integration of climate change scenarios (RCPs/SSPs) into hydrological models – statistical and dynamical downscaling techniques – scenario analysis, risk assessment, and uncertainty quantification – data sources: CMIP6, CORDEX, NASA Earthdata, Indian Meteorological Department (IMD), and NOAA – methods for extracting and processing climate model outputs – adaptation strategies for water systems under climate stress – climate-resilient infrastructure design – sustainable water resource management frameworks under uncertain future climates.

Assessment of flood and drought risks under future climate scenarios – trend analysis of rainfall and temperature using historical and model-projected datasets – evaluation of sediment yield and reservoir capacity under climate-altered hydrological regimes – impact of climate change on water availability, quality, and inter-basin transfers – integration of remote sensing and GIS in climate impact analysis – use of machine learning in climate-hydrology modeling – case studies on water resource planning and management under changing climatic conditions – strategies for enhancing the resilience of watersheds, irrigation systems, and urban water infrastructure.

References

1.	Kevin E. Trenberth: Climate System Modeling, Cambridge University Press.
2.	Neelin David J, Climate Change and Climate Modeling, 2011, First Edition, Cambridge University Press,UK.
3.	Thomas Stocker, Introduction to Climate Modeling, Advances in Geophysical and Environmental Mechanics and Mathematics. 2011, Springer, UK.
4.	Stephen Peak and Joe Smith, Climate Change: From science to sustainability, Oxford University Press.
5.	IPCC (1995) Climate Change 1995: The Science of Climate Change, Cambridge Niv Press, Cambridge, UK.
6.	Robert T. Watson, Marufu C. Zinyowera, Impacts, Richard H. Moss, Adaptation and mitigation of climate change-Scientific Technical Analyses, 1996, Cambridge University Press, Cambridge, USA.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	To develop a foundational understanding of the global carbon cycle and its key components.
CO2	To gain insights into climate change science, including causes, trends, and global responses.
CO3	To understand climate change models and evaluate their impacts on hydrological processes.
CO4	To acquire comprehensive knowledge of Geographic Information Systems (GIS) and spatial data analysis.
CO5	To apply GIS tools and techniques to assess the impacts of climate change on hydrology and water resources.

Course Code	**:**	CE871
Course Title	**:**	**Thermal and Hyperspectral Remote Sensing**
Type of Course	**:**	Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To Learn thermal infrared and hyperspectral remote sensing basics and history.
CLO2	To familiarize thermal radiation laws, terrain thermal properties, data gathering procedures, and environmental factors.
CLO3	To understand thermal and hyperspectral sensors and picture acquisition, preprocessing, and correction.
CLO4	To Learn to understand thermal and hyperspectral images, focusing on emissivity, image analysis components, and data preprocessing.
CLO5	To provide exposure on satellite missions and applications

Course Content

Introduction- History - Thermal Infrared radiation principles – Thermal Radiation Laws – Thermal Properties of Terrain – Data collection methods – Environmental Consideration - Thermal sensors and characteristics – thermal image characters–image degradation sources & correction

Interpretation of thermal images, Emissivity conservation, Thermal inertia considerations, Factors effecting analysis of thermal images- Data Preprocessing- Image Normalisation -Radiometric calibration, atmospheric correction, and geometric correction.

Introduction to Hyperspectral Remote Sensing- Diffraction principles - field spectrum – BDRF and spectral reflectance & imaging spectrometry- sensors - virtual dimensionality-Viewing – Hughe‘s phenomenon - Data reduction, Calibration and normalization

Spectral library – response functions – MNF transformation – library matching, spectral angle mapper, BBMLC-spectral mixture analysis – end member extraction – spectral unmixing- MIA analysis concepts - PCF, PCA, WPCA spectral transformation – band detection, reduction and selection principles-data compression

Satellite Missions- Applications- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)-MODIS-Landsat TIRS- Sentinel 2- Case studies – Land surface Temperature- Sea surface Temperature-Vegetation Monitoring-forest fire mapping- Mineral Mapping- Urban heat islands-Geological Mapping- Volcanic Monitoring.

References

1.	Thomas M. Lillesand, Ralph W.Kiefer and Jonathan W.Chipman, Remote Sensing and Image interpretation, JohnWiley and Sons, Inc, New York,2015.
2.	Richards, Remote sensing digital Image Analysis-An Introduction Springer - Verlag, 5th edition 2013.
3.	John R. Jenson: Remote Sensing of the environment, Pearson, 2011, 2nd edition Gibson, P. J. Introductory Remote Sensing-Principles and Concepts, Taylor and Francis Press.
4.	Hyperspectral Remote Sensing – Fundamentals & Practices by Ruiliang Pu, CRC Press 2017
5.	Thermal Infrared Remote Sensing Sensors, Methods, Applications Springer Publication 2013

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand thermal radiation, and data gathering environmental conditions.
CO2	Use thermal and hyperspectral sensors to acquire and preprocess remote sensing images.
CO3	Getting idea about Hyper spectral remote sensing basics
CO4	Interpret and compress data using hyperspectral remote sensing technologies
CO5	Apply the geospatial and image processing techniques for various environmental problems.

Course Code	:	CE872
Course Title	:	**Coastal Engineering**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide the students the knowledge of waves in shallow waters
CLO2	To provide the students the knowledge of Littoral drifts and its impacts
CLO3	To provide the students the knowledge of coastal erosion and protection
CLO4	To provide the students to gain knowledge on design of shore defense structures
CLO5	To provide the students the knowledge on planning guidelines for ocean structures

Course Content

Waves in shallow waters – Shoaling, refraction, diffraction and breaking– Interaction currents and waves- near shore currents-wave run-up and overtopping

Coastal sediment characteristics- Initiation of sediment motion under waves-Radiation stress-wave set-up and wave set- down- mechanics of coastal sediment transport –Limits for littoral drift – Suspended and Bed Load – alongshore sediment transport rate – Distribution of alongshore currents and Sediment transport rates in Surf zone

Physical modeling in Coastal Engineering - Onshore offshore sediment transport – Stability of tidal inlets- Coastal features – Beach Features – Beach cycles– Beach Stability – Beach profiles -Coastal erosion, Planning and methods of coast protection works.

Design of shore defense structures, Non-breaking and breaking wave forces on coastal structures -Breakwaters- Classification, Design and application in coastal protection and harbor planning- Case studies on coastal erosion and protection-Generation, propagation and effect of tsunami.

Types of environmental loads- structural action of ocean structures- planning guidelines and design principles- regulations and codes of practice- foundation of ocean structures- sea bed anchors- dredging methods and equipment.

References

1.	Coastal Engineering, J S Mani, PHI, 2016
2.	Coastal Engineering Thoery and Practice, Vallam Sundar and Sannasiraj, World Scientific, 2019
3.	River and Coastal Engineering: Hydraulics, Water Resources and Coastal Engineering (Water Science and Technology Library Book 117) Springer Edition, 2016

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Apply the concepts of wave deformation for planning of ports and harbours.
CO2	Understand the concepts of coastal sediment and littoral drift and its impact coastal environment
CO3	Plan beach profile and coastal protection works
CO4	Design breakwaters and its application in coastal planning
CO5	Provide planning guidelines and deign principles for ocean structures

Course Code	:	CE873
Course Title	:	**Climate Adaptation in coastal and Hydraulic Engineering**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide the students the knowledge of Climate change scenarios
CLO2	To provide the students the knowledge of climate change impacts on hydrology and hydraulic system
CLO3	To provide the students the knowledge of impact of coastal protection methods due to climate change
CLO4	To provide the students the knowledge of climate change adaptation approaches
CLO5	To provide the students the knowledge on water infrastructures and its effect due to climate change

Course Content

Climate Change Scenario, Causes and Impacts of Scenario, Climate Change projections and scenarios, Climate Risk Assessment, Climate Change in Coastal Areas, Physical Impacts of Climate Change on the Coastal Zone

Coastal Hazard Assessment, Sealevel rise, Shore line change assessment, Impact of LULC due to sea-level rise, Coastal Vulnerability index, Socio-economic Impacts of SLR, Prioritisation of Risks and Opportunities

Adaptation Technologies and Practices -Protection Approaches, Beach Nourishment, Artificial Sand Dunes and Dune Rehabilitation, Seawalls, Sea Dikes, Storm Surge Barriers and Closure Dams, Land Claim, Accommodation Approaches. Flood-Proofing, Wetland Restoration, Floating Agricultural Systems

Flood Hazard Mapping, Flood Warnings, Retreat Approaches, Managed Realignment, Coastal Setbacks Climate Adaptation from global to local level approach, Prioritisation of coastal adaptations towards climate change

Downscaling and Adaptation to Urban Hydrology Scale, Climate Change Adaptation of Water Infrastructure – Vulnerability Assessment, Sensitivity Analysis, Risk Assessment Analysis, Likelihood analysis, Impact Analysis, Assessment of Adaptation measures – Case studies- Water Supply systems, Storm water system, Irrigation system, Flood control system

References

1.	Understanding Climate Change- Its Mitigation, Ranjit Chavan, Partridge India, 2016.
2.	Design of Coastal Structures and Sea Defenses Young C Kim, World scientific, 2022
3.	Statistical Methods in Hydrology and Hydroclimatology, Raji Maity, Springer, 2022

Course Outcomes (CO)

At the end of the course student will be able to

CO1	To understand the fundamental concepts of climate changes and downscaling approaches
CO2	To apply appropriate climate change models for Risk Assessment on coastal protection structures
CO3	To develop and implement predictive modeling tools for water infrastructure in prioritized areas due to climate change
CO4	To comprehend and evaluate various methods and technologies of climate adaption for coastal and hydraulic engineering
CO5	To apply computational methods and modeling tools for hydrologic and hydraulic analysis

Course Code	**:**	CE874
Course Title	**:**	**Flood and Drought Management**
Type of Course	**:**	Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the hydrological, climatological, and catchment processes governing flood and drought occurrence and their impacts under varying hydro-climatic conditions.
CLO2	Analyse flood and drought severity, frequency, spatial extent and associated risks using statistical, hydrological and geospatial techniques.
CLO3	Develop/apply hydrologic and hydraulic models for flood forecasting, drought assessment and early warning systems.
CLO4	Evaluate structural, non-structural and nature-based mitigation measures for improving flood and drought resilience.
CLO5	Incorporate climate change adaptation, sustainability, policy, institutional and community aspects in integrated flood and drought management planning

Course Content

Fundamentals & Hydro-Climatology of Floods & Droughts: Hydrological and climatological basis: precipitation, evapotranspiration, infiltration, runoff generation, soil moisture and catchment response - – Types and causes of floods and droughts – Flood and drought indices, severity and vulnerability assessment – Hydro-meteorological data sources: rainfall, streamflow, groundwater and remote sensing datasets – Climate variability and climate change impacts on flood and drought characteristics.

Risk Assessment, Forecasting & Early Warning Systems: Flood frequency analysis, extreme events and design flood estimation, – Rainfall-runoff modeling, hydrograph analysis and flood routing – Drought assessment, forecasting and water balance approaches – Flood inundation mapping and drought monitoring using GIS and Remote Sensing.

Structural & Non-Structural Mitigation & Adaptation Measures: Structural measures: reservoirs, levees, detention basins, floodways and check dams – Non-structural measures: floodplain zoning, watershed management, afforestation and rainwater harvesting – Urban stormwater management and nature-based solutions – Drought mitigation measures: water conservation, conjunctive use, irrigation scheduling and demand management – Integrated watershed and basin management approaches.

Operation, Management, Policy, Socio-economic & Institutional Aspects: Flood and drought risk management frameworks and resilience concepts – Institutional mechanisms, governance and stakeholder participation – Policies, land-use regulations, disaster preparedness and recovery planning – Socio-economic impacts, vulnerability assessment and community-based adaptation.

Sustainability, Climate Change Adaptation & Emerging Tools: Climate change adaptation, uncertainty analysis and sustainable water management. – Environmental impacts: erosion, sedimentation, ecosystems and water quality – Applications of GIS, Remote Sensing, IoT, hydroinformatics and AI/ML in flood and drought management – Integrated basin planning and case studies on flood and drought resilience.

References

1.	Chow V.T., Maidment D.R., Mays L.W., "Applied Hydrology", McGraw Hill Publications, New York, 1995.
2.	Andreas H. Schumann., “Flood Risk Assessment and Management”, Springer Science+Business Media B.V.2011.
3.	Vijay P.Singh., "Elementary Hydrology", Prentice Hall of India, New Delhi, 1994.
4.	Rangapathy V., Karmegam M., and Sakthivadivel R., Monograph in Flood Routing Methods as Applied to Indian Rivers.
5.	Yevjevich V., Drought Research Needs, Water Resources Publications, Colorado State University, USA, 1977.
6.	Linda Courtenay Botterill, Geoff Cockfield., “Drought, Risk Management, and Policy: Decision-Making Under Uncertainty”, Drought and Water crises, CRC press, 2013.
7.	National Disaster Management Authority, Government of India, “National Disaster Management Guidelines”, Management of Drought, 2010.
8.	Wilhite, Donald A., “Drought Assessment, Management, and Planning: Theory and Case Studies”, Kluwer Academic Publishers, 1993.
9.	Subramanya K., "Hydrology,Tata McGraw Hill Co., New Delhi, 1994.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain the causes, processes and hydro-climatic characteristics governing floods and droughts.
CO2	Perform flood and drought assessment, forecasting and risk analysis using hydrological and geospatial techniques.
CO3	Apply hydrologic and hydraulic models for flood routing, drought analysis and

	early warning systems.
CO4	Evaluate structural, non-structural and nature-based mitigation measures for flood and drought management.
CO5	Develop sustainable and climate-resilient flood and drought management strategies considering policy.

Course Code	:	CE875
Course Title	:	**Sustainability in River Basin Management**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the physical, hydrological, and ecological processes of river basins.
CLO2	Assess water availability, quality, and allocation in river basins using analytical and geospatial tools.
CLO3	Evaluate the impacts of human interventions, land-use changes, and climate variability on river basin sustainability.
CLO4	Formulate integrated management strategies, including structural, non-structural, and ecosystem-based approaches.
CLO5	Apply governance frameworks, stakeholder engagement, and decision-support systems for sustainable river basin management.

Course Content

Fundamentals of River Basins: River basin characteristics, hydrological cycle, geomorphology, streamflow, groundwater interactions, river ecology.

Water Resources Assessment: Water availability & demand analysis, surface & groundwater interactions, water quality assessment, GIS & remote sensing for basin analysis, E-flows.

Impacts of Human Activities & Climate Variability: Land use land cover changes, urbanization, dams and reservoirs, agricultural water use, climate change impacts, ecosystem stress.

Integrated River Basin Management: Water allocation strategies, flood/drought management, structural & non-structural interventions, ecosystem restoration, sectoral water management (agriculture, urban, industry), case studies.

Governance, Decision Support & Sustainability: Institutional & governance frameworks, stakeholder engagement, policy and legal frameworks, decision support systems, adaptive management, case studies, emerging technologies (IoT, AI, big data).

References

1.	Tideman E.M. (1999). Watershed Management–Guidelines for Indian Conditions, Omega Scientific Publishers, New Delhi.
2.	Jones, J. A. A. 2010. Water sustainability - a global perspective. Hodder Education: London.
3.	Loucks,D.P.; Gladwell,J.S.1999. Sustainability criteria for water resource systems. Cambridge University Press: Cambridge.
4.	S. L. Dingman, 2002, Physical hydrology, Prentice-Hall.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Analyze the hydrological, ecological, and geomorphological processes governing river basins.
CO2	Use GIS, remote sensing, and modeling tools to evaluate water resources and allocation.
CO3	Assess environmental, social, and economic impacts of human activities and climate variability on river basins.
CO4	Develop integrated management plans for flood/drought mitigation, water allocation, and ecosystem restoration.
CO5	Implement data-driven decision support systems and adaptive strategies for sustainable river basin management.

Course Code	:	CE876
Course Title	:	**Wave Hydrodynamics**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide the students the knowledge of wave transformation,
CLO2	To provide the students the knowledge of sediment transport,
CLO3	To provide the students the knowledge of different types of Wave theories
CLO4	To provide students' knowledge on Wave Current interaction
CLO5	To make the students to understand the concepts of wave loads

Course Content

Review of Basic Fluid Mechanics: Conservation of mass and momentum, Euler Equations, Bernoulli's equation, velocity potential, stream function.

Ocean Environment, Waves: Classification of water waves – Two-dimensional wave equation and wave characteristics – wave theories – Small amplitude waves – Finite amplitude waves – Stokian, Solitary and Cnoidal wave theories – Water particle kinematics – wave energy, power.

Wave deformation – Reflection, Refraction, Diffraction, Breaking of waves – Spectral description of Ocean Waves – Design wave. Wave-Currents Interactions, Radiation Stress.

Forces: Wave forces – Morison equation – Wave loads on vertical, inclined and horizontal cylinders. Diffraction theory – wave slamming and slapping. Lab: Measurement of wave properties such as L, H, T, C and Cg.

Wave Reflection, pressure measurements, force estimations, mass transport velocity, random waves, wave paddle transfer function, Wave Structure Interaction – Types and Case studies.

References

1.	Dean, R.G. and Dalrymple, R.A., Water wave mechanics for Engineers and Scientists, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1994
2.	Sarpkaya, T. and Isaacson, M., Mechanics of Wave Forces on Offshore Structures, Van Nostrand Reinhold Co., New York, 1981
3.	Weigel, R.L.Oceanographical Engineering, Prentice Hall Inc, 1982
4.	Sorenson, R.M., Basic Coastal Engineering, A Wiley-Interscience Publication, New York, 1978

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Apply the concepts of small amplitudes theory and higher order wave theories

CO2	Analyze Wave Characteristics and wave transformation
CO3	Design and Compute wave loads for offshore structures
CO4	Gain knowledge on Wave structure interaction
CO5	Gain Knowledge on wave current interaction

Course Code	**:**	CE877
Course Title	**:**	**Design of Hydraulic Structures**
Type of Course	**:**	Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide the students the knowledge of different types of hydraulic structures
CLO2	To provide the students the knowledge of analysis of various structures such as Dams and Weirs
CLO3	To provide the students the knowledge of Design of various structures such as Dams and Weirs
CLO4	To study the different methods of Grouting and foundation treatment
CLO5	To carryout studies on Creep and Khosla's theory

Course Content

Investigation and Planning -Preliminary investigations and preparation of reports, Layout of projects, Geological and hydrological investigations. Analysis and Design of Dams - Earthen Dam and Gravity Dam.

Analysis and Design of Arch Dam, Infiltration Gallery, Collector wells. Construction of Dams - Masonry, Concrete and Earthen Dams, Foundation for Dams – Principles of Foundation treatment, Grouting method.

Design of Weirs on Permeable foundation - Creep theory, Potential theory, Flow nets, design of weirs - Khosla's theory – Dam break Analysis- Various scenarios - HEC RAS software

Dam safety Importance of seepage in dam safety and rehabilitation, Flow through porous media, Darcy's law, seepage velocity, Dupuit's theory, Phreatic lines, free surface and seepage discharge. Flow nets, Boundary conditions, Numerical techniques;

Measurement of seepage, seepage control, Seepage detection, control and monitoring; Selection of core materials, Dam filters and Design criteria; use of geo-textiles, stability conditions, Drainage of embankments, Dam Grouting, Design and installation of grout curtain

References

1.	Creager, W.P. Justin D, and Hinds, J., Engineering for Dams Vol. I, II and III.
2.	Kushalani, K.B., Irrigation (practice and design) Vol. III and IV.
3.	Nalluri C., “Hydraulic Structures” Taylor & Francis,2000

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Apply analytical methods for analyzing different hydraulic structures
CO2	Design different types of Dams
CO3	Design of Collector wells and Infiltration Galleries
CO4	Analyze Grouting methods and its impact on Hydraulic structures.
CO5	Apply Dam safety concepts to all types of Dams

Course Code	:	CE878
Course Title	:	**Irrigation Systems Engineering and Management**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Analyse soil, water and crop interactions, and determine crop water requirements under various climatic and soil conditions.
CLO2	Design conveyance networks (canals, pipelines), regulation structures, and drainage systems used in irrigation schemes with appropriate hydraulic, geotechnical, and structural considerations.
CLO3	Evaluate different irrigation methods (surface, sprinkler, drip, micro-irrigation etc.), their efficiencies, advantages/disadvantages, and suitability under various environmental, economic, and social constraints.

CLO4	Develop irrigation scheduling and management strategies, including estimation of water demands, water allocation, monitoring, and decision making for efficient water use.
CLO5	Incorporate modern tools / technologies (GIS, remote sensing, sensors, automation), as well as sustainability, environmental and socio-economic issues into design and management of irrigation projects.

Course Content

Fundamentals & Soil-Water-Crop Relations: Overview: Need, history, types, benefits & issues of irrigation systems; classification of irrigation & drainage systems. Soil properties relevant to irrigation: infiltration, percolation, hydraulic conductivity, moisture retention curves. Evapotranspiration: methods for estimation, crop coefficients. Crop water requirement, irrigation requirement, duty, delta, base period. Climatic factors, soil water balance.

Conveyance & Regulation Structures: Open channel hydraulics: uniform flow, gradually varied flow, principles of canal alignment. Design of secondary and tertiary canals. Pipelines for irrigation: pressurized flow, pipe material, losses. Hydraulic structures: weirs, head regulators, escapes, drop structures, cross-drains, syphon aqueducts. Conveyance efficiency, lining, maintenance issues.

Irrigation Methods & Drainage Systems: Irrigation methods: surface, sprinkler, micro/drip irrigation. Components, layout, uniformity, selection criteria. Bureau of Irrigation Efficiency, effectiveness; case studies. Design of sprinkler and drip systems: emitter spacing, pressure requirements, filtration etc. Drainage: need, types (surface, subsurface), drainage design, layout, system hydraulics. Soil salinity, waterlogging, leaching – remedial measures.

Scheduling, Management & Operation: Water demand estimation: gross vs net irrigation requirement. Irrigation scheduling: fixed vs dynamic, sensor-based scheduling. Water allocation & distribution: canal operation, rotational scheduling, equity issues. Operation & maintenance of systems; monitoring performance (efficiencies, losses). Institutional, economic and policy aspects; cost-benefit, pricing, stakeholder participation.

Modern Tools, Sustainability & Environmental Issues: GIS & Remote Sensing applications in irrigation & drainage: mapping, monitoring, water balance. Use of sensors (soil moisture, weather), automation, IoT in irrigation. Modeling of irrigation systems: hydraulic models, crop models. Environmental effects: salinization, waterlogging, habitat impacts; groundwater-surface water interactions. Climate change & adaptation; sustainable irrigation practices; policies, regulation.

References

1.	Majumdar D. P., "Irrigation Water Management Principles and Practices", Prentice Hall of India, New Delhi, 2004.
2.	Michael A. M., "Irrigation Theory and Practice", Vikas Publishing House, New Delhi, 2009.
3.	Sharma R.K and Sharma T.K., "Irrigation Engineering", S.Chand, New Delhi, 2008. 6. Bhattacharya A.K. and Michael A.M., "Land Drainage Principles, Methods and Applications", Konark Publishers Pvt. Ltd., New Delhi. 2003.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Demonstrate in-depth understanding of soil-water-plant relationships, estimation of evapotranspiration, crop water requirement, infiltration, etc.
CO2	Design conveyance and regulation systems (open channel, pipelines), control structures, and drainage (surface & subsurface) for irrigation schemes.
CO3	Compare and choose among irrigation methods (surface, sprinkler, drip etc.), compute efficiencies, assess economic & environmental trade-offs.
CO4	Plan and implement irrigation schedules, optimise water allocation and scheduling under uncertainties (climate, availability) to improve water use efficiency.
CO5	Apply modern tools (sensor networks, GIS/RS, automation), and consider sustainability issues (waterlogging, salinity, environmental impacts, institutional/policy aspects) in irrigation project management.

Course Code	**:**	CE879
Course Title	**:**	**Water, Energy and Climate Nexus**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the concept and scope of the Water-Energy-Climate Nexus and SDGs
CLO2	To explain interdependencies between water and energy systems.
CLO3	To analyze climate change impacts on water and energy.

CLO4	To apply nexus assessment tools and decision-making methods
CLO5	To evaluate governance, policy, and sustainability strategies

Course Content

Concept and scope of the nexus approach; Systems perspective: interdependencies between water, energy, and climate; Global and Indian context; Role of SDGs in nexus approach.

Water for energy: hydropower, thermal power plants, and hydrogen economy; Energy for water: pumping, treatment, and desalination; Selected case studies on inter-sectoral conflicts.

Climate variability and change: impacts on hydrology, water supply reliability, and groundwater; Effects on energy demand and renewable energy variability; Infrastructure resilience.

Analytical frameworks: Integrated Water-Energy Modeling, Life Cycle Assessment (LCA); Remote sensing and GIS approaches; Multi-criteria decision making for nexus planning.

Governance in India and global context; Integrated resource management policies; Role of pricing and regulations; Case studies: urban water-energy nexus and agriculture-energy-water nexus.

References

1.	Leck, H., Conway, D., Bradshaw, M., Rees, J., Implementing the Water–Energy–Food–Ecosystems Nexus and Achieving the Sustainable Development Goals, Routledge, London, 2020.
2.	Dansie, A., Alleway, H., Böer, B., The Water, Energy, and Food Security Nexus in Asia and the Pacific, Springer, Singapore, 2021.
3.	Pahl-Wostl, C., Gupta, J., Bhaduri, A., The Water-Energy Nexus: Challenges and Opportunities, Routledge, New York, 2018.
4.	Saundry, P., Ruddell, B. L., The Food-Energy-Water Nexus, Springer, Cham, 2019.
5	Gleick, P. H., The Future of California's Water-Energy-Climate Nexus, Island Press, Washington D.C., 2013.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Comprehend the Water-Energy-Climate Nexus and its relevance to SDGs

CO2	Analyze water-energy system interactions and case studies.
CO3	Assess climate impacts on water and energy systems.
CO4	Use nexus assessment tools (LCA, GIS, modeling) for analysis.
CO5	Evaluate policies, governance, and sustainable strategies for integrated management.

Course Code	:	CE880
Course Title	:	**AI/ML Applications in Water Resource Engineering**
Type of Course	:	Program Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

CLO 1	To understand AI/ML fundamentals and learning paradigms for environmental applications.
CLO 2	To apply linear, statistical, and ensemble learning methods for hydrological data analysis.
CLO 3	To utilize remote sensing data for surface water, groundwater, and evapotranspiration mapping.
CLO 4	To develop AI-based models for flood, drought, and reservoir predictions.
CLO 5	To evaluate model performance using statistical, spectral, and accuracy metrics.

Course content

Fundamentals and evolution of artificial intelligence – definition, significance and types of AI (Narrow AI and General AI) – intelligent agents and environments – principle of rationality – agent architectures – learning paradigms in AI (supervised learning, unsupervised learning and reinforcement learning) – learning problems – data preprocessing and feature engineering – model selection criteria – generalization challenges – concept learning examples – introduction to probabilistic models and Bayesian learning concepts.

Linear classification and statistical learning methods – linear classifiers – logistic regression – decision boundaries – cost function optimization – multi-class classification – bias–variance trade-offs – support vector machines with kernel methods – random forests – gradient boosting – Gaussian processes – ensemble learning methods such as bagging and boosting. Unsupervised learning methods – clustering approaches, K-means, fuzzy C-means, possibilistic C-means – similarity and distance measures – dimensionality reduction techniques such as Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA). Accuracy and validation metrics – RMS error – correlation coefficient – ROC analysis – inferential statistics and hypothesis testing – spectral divergence – spectral angle mapping – spectral correlation.

Introduction to water resource management challenges and the role of remote sensing – overview of AI and machine learning techniques in hydrological modeling and prediction – satellite data sources for water applications (optical, thermal, microwave, and SAR datasets). River discharge estimation using remote sensing and machine learning models – surface water body extraction from optical and SAR imagery – groundwater potential zone mapping using remote sensing indicators and ML classifiers such as Random Forest and Support Vector Machines – groundwater vulnerability mapping – feature selection and training dataset preparation for hydrological applications.

Basics of surface water hydrology – groundwater hydrology – water quality parameter estimation using satellite imagery and regression-based machine learning models – evapotranspiration estimation using vegetation indices and AI models. Flood and drought prediction using machine learning models – hydrological extreme analysis – introduction to deep learning approaches, such as convolutional neural networks (CNNs) for spatial data analysis and recurrent neural networks (RNNs) for time-series hydrological forecasting.

Reservoir level and inflow prediction using satellite altimetry and hybrid AI techniques – reservoir sedimentation analysis – streamflow routing – AI-based decision support systems for water resource planning and management. Case studies on integrated AI and remote sensing based decision-making tools – model explainability and interpretability in AI models (Explainable AI) – accuracy assessment and validation techniques – limitations, ethical considerations, and challenges in AI applications – future trends in AI, machine learning, and remote sensing for water resource management.

References

1.	Bratko, "Prolog: Programming for Artificial Intelligence", Fourth edition, Addison Wesley Educational Publishers Inc., 2011.
2.	M. Tim Jones, "Artificial Intelligence: A Systems Approach (Computer Science)", Jones and Bartlett Publishers, Inc.; First Edition, 2008

3.	Christopher Bishop, Pattern Recognition and Machine Learning, Springer
4.	Singh, V. P. (1995). *Computer Models of Watershed Hydrology*. Water Resources Publications.
5.	Singh, V. P., & Jain, S. K. (2003). *Water Resources Systems Planning and Management.*

Course Outcomes

At the end of the course, the student is expected to

CO1	Explain AI/ML concepts and agent-based architectures for water resource problems.
CO2	Implement supervised and unsupervised learning models for hydrological applications
CO3	Extract and analyze remote sensing data for water resource assessment.
CO4	Develop integrated AI-remote sensing solutions for prediction and monitoring.
CO5	Assess model accuracy and reliability for informed water resource decision-making.

Course Code	**:**	CE881
Course Title	**:**	**Watershed Management**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the structure, components, and hydrologic behavior of watersheds.
CLO2	Analyze watershed characteristics and perform sub-watershed prioritization using morphometric and socio-economic indicators.
CLO3	Design soil and water conservation and land treatment measures based on watershed needs.
CLO4	Evaluate water management practices including irrigation, conservation, and harvesting, ground water management.
CLO5	Integrate participatory planning, monitoring, and policy frameworks into sustainable watershed development.

Course Content

Introduction to Watershed Management: Concept and philosophy of watershed management - Components: land, water, vegetation - Watershed delineation - Watershed degradation: natural and human-induced.

Watershed Characteristics & Prioritization: Physical, climatic, and socio-economic characteristics - Morphometric parameters - Land capability classification - Watershed/sub-basin prioritization using Morphometric Analysis, Land Use/Land Cover (LULC) Analysis, Multi-Criteria Decision Analysis (MCDA) Techniques, case studies.

Soil & Water Conservation and Land Reclamation: Types of erosion and control measures - Contour bunding, check dams, vegetative barriers - Soil Characteristics and Erosion Hazard Mapping- Arable and non-arable land management - Wasteland classification, causes, and reclamation.

Water Resource Management in Watersheds: Irrigation scheduling and crop planning - Water application methods: surface, sprinkler, drip, subsurface - Rainwater harvesting and water budgeting- ground water management- Delineation of groundwater potential zones and identification of artificial recharge sites, case studies.

Participatory Planning, Monitoring, and Policy: Participatory Rural Appraisal (PRA) - Institutional mechanisms: SHGs, watershed committees - Capacity building and stakeholder engagement - Monitoring and evaluation methods - Policy frameworks (IWMP, MGNREGA, Neeranchal Project) - Gender and legal aspects.

References

1.	J. V. S. Murty, “Watershed Management”, 2nd Edition, New Age International Publishers, 2013.
2.	R.A. Wurbs and WP James, “Water Resource Engineering”, 3rd Edition Prentice Hall of India, 2002.
3.	V.V.N. Murthy and Madan K Jha. “Land and Water Management”, 6th Edition, Kalyani Publishers, 2015.
4.	D.K. Majumdar, “Irrigation Water Management”, 3rd Edition, Prentice Hall of India, 2004.
5.	Elango, L., Jayakumar, R., 2001. Modeling in Hydrology, UNESCO, and New Delhi.
6.	Murty, J.V.S., 1994. Watershed Management in India, Wiley Eastern Ltd, New Delhi.
7.	Rajesh Rajora, 2002. Integrated Watershed Management, R. Rawat Publications, New Delhi.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain watershed components, degradation causes, and delineation methods
CO2	Conduct morphometric analysis and prioritize sub-watersheds using GIS and RS tools.
CO3	Propose suitable soil and water conservation and land reclamation measures.
CO4	Recommend appropriate irrigation, water harvesting, and budgeting strategies.
CO5	Evaluate watershed programs incorporating participatory approaches, monitoring, and policy perspectives.

Course Code	**:**	CE882
Course Title	**:**	**Water Supply and Wastewater Engineering**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the components and principles of water supply and wastewater systems in urban and rural settings.
CLO2	Design water demand estimation, treatment, and building-level supply systems.
CLO3	Analyze sewerage systems and wastewater treatment processes.
CLO4	Evaluate sustainable and smart water management practices.
CLO5	Apply codes, standards, and modeling tools for efficient system design.

Course Content

Water Demand and Supply Systems: Introduction: objectives of water supply and wastewater engineering - Water demand estimation (domestic, institutional, industrial, fire demand) - Population forecasting and peaking factors - Source selection (surface vs. groundwater) - Water quality parameters and IS:10500 standards - Fire hydrant system design: spacing, flow requirement - Building-level water supply system design: downfeed/upfeed, storage tanks, plumbing standards (IS 2065, IS 1172)

Water Treatment and Distribution: Conventional and advanced treatment processes: sedimentation, coagulation, filtration, disinfection - Design of key units: sedimentation tank, rapid sand filter, chlorination system - Modular and decentralized water treatment options - Water distribution systems: layouts (dead-end, grid, ring), zoning - Design of pipe networks and pump selection - Software: EPANET for pipe network analysis, case studies

Wastewater Generation and Collection: Wastewater sources and characteristics (BOD, COD, TSS, nutrients) - Sewerage system types: separate, combined, partially combined - Flow estimation and peaking factors - Design of sewer systems, manholes, pumping stations - Building-level drainage and sanitary plumbing - Stormwater drainage basics - Software: SWMM, case studies

Wastewater Treatment and Reuse: Treatment stages: primary, secondary, tertiary - Design concepts of ASP, UASB, MBBR, trickling filters - Decentralized systems: septic tank, DEWATS, root zone treatment - Sludge handling and disposal - Treated water reuse in agriculture, industry, non-potable urban use - Regulations: CPCB, NGT norms for discharge and reuse

Smart and Sustainable Water Management: Water audit, leakage control, NRW reduction - Energy efficiency in pumping and treatment - Urban Water Management (UWM), water safety planning or risk management, Water-Sensitive Urban Design (WSUD) - SCADA, IoT and sensor-based monitoring in water systems - Use of AI and decision-support tools - Cost estimation, lifecycle costing, and project planning

References

1.	Garg, S.K. Environmental Engineering, Vol.I Khanna Publishers, New Delhi, 2010.
2.	Modi, P.N., Water Supply Engineering, Vol.I Standard Book House, New Delhi, 2016.
3.	Garg, S.K., Environmental Engineering Vol.II, Khanna Publishers, New Delhi, 2015.
4.	Duggal K.N., “Elements of Environmental Engineering” S. Chand and Co. Ltd., New Delhi, 2014.
5.	“Manual on Sewage and Sewerage Treatment” 3rd Ed. Pub: CPH & Env. Engg. Organization, Ministry of Urban Development, Govt. of India, New Delhi, 1991.
6.	“Manual on Water Supply & Treatment” 3rd Ed. Pub: CPH & Env. Engg. Organization, Ministry of Urban Development, Govt. of India, New Delhi, 1991

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Estimate water demand and design components of a municipal and building-level water supply system, including fire protection.
CO2	Analyze and design water treatment systems based on raw water quality and required standards.
CO3	Plan and design wastewater collection and treatment systems using appropriate design criteria and models.
CO4	Integrate sustainable practices and technologies (reuse, energy efficiency) into system planning.
CO5	Utilize modern software and decision-support tools for simulation and analysis of water and wastewater infrastructure for Smart Water Management

Course Code	**:**	CE883
Course Title	**:**	**Glacial Hydrology**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the fundamentals of glaciers – morphology, dynamics, mass balance, and hydrological significance.
CLO2	To apply remote sensing techniques – optical, SAR, LiDAR, and DEMs – for glacier mapping, snow cover monitoring, and flow dynamics.
CLO3	To develop glacier hydrology models – degree-day, energy balance, coupled hydrological, and AI/ML-based runoff estimation.
CLO4	To utilize remote sensing and AI for glacier lake monitoring, GLOF risk assessment, snowmelt/runoff forecasting, and reservoir inflow prediction.
CLO5	To evaluate glacier hydrology and climate change impacts – on glacier mass, downstream water availability, floods, droughts, and decision-support tools.

Course content

Fundamentals of glacier hydrology – study of glacier types, morphology, and dynamics – understanding glacier mass and energy balance – exploration of surface and subglacial hydrology – analysis of meltwater generation, routing, and storage – examination of glacier-climate interactions and their hydrological significance.

Remote sensing and GIS in glacier studies – utilization of satellite sensors such as optical, SAR, LiDAR, and DEMs for glacier monitoring – techniques for glacier mapping and inventory – monitoring of snow cover and glacier extent – estimation of glacier velocity and flow dynamics – change detection methods for assessing glacier retreat, advance, and thinning.

Glacier hydrology modeling – melt modeling approaches including degree-day and energy balance methods – glacier runoff modeling techniques – coupled glacier-hydrological models – estimation of glacier runoff using remote sensing and AI/ML techniques – calibration, validation, and uncertainty analysis of glacier hydrology models.

Applications of remote sensing and AI in glacier hydrology – glacier lake inventory and monitoring, including GLOF risk assessment – snowmelt and runoff forecasting using AI/ML and remote sensing data – glacier volume and mass change estimation using DEM differencing and InSAR – reservoir inflow prediction – integrated case studies demonstrating AI-remote sensing based glacier hydrology applications.

Climate change Impacts - Glacier - glacier mass balance and hydrological regime – glacier retreat and downstream water availability – floods, droughts, and GLOF hazards – glacier hydrology in transboundary river basins – future trends, research gaps, and decision-support tools for sustainable glacier and water resource management.

References

1.	DeWalle, D. R., & Rango, A. (2008). Principles of Snow Hydrology. Cambridge University Press.
2.	Kargel, J. S., Bishop, M. P., et al. (2005). Global Land Ice Measurements from Space. Springer.
3.	Abramov, A., & Ponti, S. (Eds.). (2021). Remote Sensing of Cryosphere and Related Processes. MDPI.
4.	Haritashya, U. K. (Ed.). (2011). Encyclopedia of Snow, Ice and Glaciers. Springer.
5.	Raup, B. H. (2013). Remote Sensing of Glaciers. In Remote Sensing Handbook (pp. 145-176). Wiley.

Course Outcomes

At the end of the course, the student is expected to

CO1	Explain glacier dynamics, mass balance, and hydrological processes in mountain and river basin contexts.
CO2	Implement remote sensing-based analysis – for glacier extent, snow cover, flow dynamics, and temporal changes.
CO3	Design and execute glacier hydrology models – including AI/ML-enhanced runoff estimation and uncertainty analysis.
CO4	Apply integrated remote sensing and AI methods – for glacier lake monitoring, GLOF assessment, and hydrological forecasting.
CO5	Assess climate change impacts on glaciers and downstream hydrology and provide actionable insights for water resource planning.

Course Code	**:**	CE884
Course Title	**:**	**Remote Sensing and Earth Observation**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the fundamentals of Earth observation and remote sensing systems.
CLO2	To gain knowledge of modern sensors and geospatial data acquisition technologies
CLO3	To learn digital image processing and geospatial analytics techniques.
CLO4	To apply remote sensing and GIS for environmental and engineering applications
CLO5	To explore machine learning, deep learning, and GeoAI in geospatial sciences

Course Content

Electromagnetic radiation principles – interaction of radiation with atmosphere and terrain – atmospheric scattering and absorption – spectral– remote sensing resolutions and imaging geometry – Earth observation systems and CubeSat technologies.

Optical, thermal, hyperspectral and microwave remote sensing systems – active and passive sensors – SAR imaging geometry – LiDAR systems – UAV remote sensing – IRS, Landsat, Sentinel, MODIS, RISAT, Cartosat, PlanetScope and WorldView missions – orbit characteristics –

Radiometric and geometric corrections – orthorectification – image enhancement –– texture analysis – object-based image analysis – change detection – time-series analytics – Google Earth Engine based cloud processing – terrain and DEM analysis.

Applications in agriculture, forestry, geology, hydrology, coastal zone management, urban planning and climate studies – glacier monitoring and snow cover analysis – GLOF hazard mapping – flood inundation modeling – drought monitoring – landslide susceptibility mapping – urban heat island analysis – environmental sustainability assessment and disaster management systems.

Machine learning and deep learning for remote sensing – digital twins – geospatial big data processing – edge computing for Earth monitoring – planetary remote sensing – climate informatics – quantum remote sensing – ethical and policy dimensions of Earth observation systems.

References

1.	Lillesand, T. M., & Kiefer, R. W. (2000). *Remote sensing and image interpretation* (4th ed.). New York, NY: John Wiley & Sons.
2.	Schowengerdt, R. A. (2007). *Remote sensing: Models and methods for image processing* (3rd ed.). Burlington, MA: Academic Press.
3.	Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information systems and science* (4th ed.). Hoboken, NJ: John Wiley & Sons.
4.	Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. Cambridge, MA: MIT Press.
5.	Campbell, J. B., & Wynne, R. H. (2011). *Introduction to remote sensing* (5th ed.). New York, NY: Guilford Press.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain the principles of electromagnetic radiation, Earth observation systems, and remote sensing imaging geometry.
CO2	Analyze and interpret multispectral, hyperspectral, microwave, SAR, LiDAR,

	and UAV-based remote sensing datasets.
CO3	Apply digital image processing, geospatial analytics, and cloud computing techniques for Earth observation data analysis.
CO4	Develop geospatial solutions for applications in agriculture, hydrology, urban planning, disaster management, and climate studies.
CO5	Integrate machine learning, deep learning, and GeoAI methods with GIS and remote sensing workflows for advanced environmental and engineering applications.

Course Code	:	CE885
Course Title	:	**Geographic Information Systems and Spatial Analytics**
Type of Course	:	Programme Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand GIS, cartography, and geospatial data concepts
CLO2	To learn spatial databases and enterprise GIS systems.
CLO3	To apply spatial analysis and geospatial modeling techniques
CLO4	To explore Web GIS, IoT-integrated GIS, and digital twins
CLO5	To use geospatial data science and AI for smart applications.

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Course Content

GIS concepts and components – raster and vector data models – coordinate systems and projections – georeferencing techniques – cartographic principles – metadata standards – spatial data quality and uncertainty analysis – geospatial data acquisition methods.

Database management concepts – relational and object-oriented databases – geodatabases – PostgreSQL/PostGIS – spatial indexing and querying – enterprise GIS architecture – cloud-based spatial data systems – data security and interoperability standards.

Overlay analysis – buffer analysis – network analysis – terrain and watershed modeling – suitability analysis – multi-criteria decision analysis – fuzzy logic and FAHP methods – predictive spatial modeling – hydrological and environmental

GIS applications.

Web GIS architecture – OGC standards – GeoJSON and APIs – cloud GIS platforms – ArcGIS Online and GeoServer – mobile GIS – IoT integrated GIS systems – real-time dashboards – digital twin technologies and smart city applications.

Spatial statistics and geostatistics – kriging and interpolation – hotspot analysis – spatial autocorrelation – spatial machine learning – predictive geospatial analytics – transportation GIS – climate resilience GIS – utility GIS – disaster risk reduction and intelligent urban systems.

References

1.	Lillesand, T. M., & Kiefer, R. W. (2000). *Remote sensing and image interpretation* (4th ed.). New York, NY: John Wiley & Sons.
2.	Schowengerdt, R. A. (2007). *Remote sensing: Models and methods for image processing* (3rd ed.). Burlington, MA: Academic Press.
3.	Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information systems and science* (4th ed.). Hoboken, NJ: John Wiley & Sons.
4.	Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. Cambridge, MA: MIT Press.
5.	Campbell, J. B., & Wynne, R. H. (2011). *Introduction to remote sensing* (5th ed.). New York, NY: Guilford Press.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain the principles of GIS, cartography, spatial data models, coordinate systems, and geospatial data acquisition techniques.
CO2	Design and manage spatial databases using geodatabases, PostgreSQL/PostGIS, and enterprise GIS architectures.
CO3	Apply spatial analysis, geospatial modeling, and multi-criteria decision-making techniques for environmental and engineering problem solving.
CO4	Develop Web GIS and smart geospatial applications using cloud GIS platforms, APIs, IoT integration, and real-time geospatial systems.
CO5	Analyze spatial datasets using geostatistics, spatial machine learning, and predictive geospatial analytics for sustainable and intelligent urban applications

Course Code	**:**	CE886
Course Title	**:**	**Advanced Surveying and Geomatics**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide advanced knowledge in modern electronic and satellite-based surveying techniques.
CLO2	To develop competency in photogrammetry, geodesy, and map projection systems.
CLO3	To introduce GPS/GNSS technologies for precise positioning and mapping applications.
CLO4	To familiarize students with modern surveying equipment such as UAVs and LiDAR systems
CLO5	To apply advanced surveying methods in water resources engineering and management projects.

Course Content

Principles of Electronic Distance Measurement (EDM) – Electromagnetic waves and distance measurement techniques – Types of EDM instruments –– Total Station: components, working principle, and field procedures – Applications in canal alignment, reservoir surveys, and hydraulic structure layout.

Principles of photogrammetry – Types of photographs and cameras –– Photogrammetric measurements – Relief displacement and image distortions – Digital photogrammetry – Generation of orthophotos and Digital Elevation Models (DEM) – Applications in watershed mapping, terrain analysis, and floodplain studies.

Introduction to geodesy – Shape and size of the Earth – Geoid, spheroid, and ellipsoid – Datum concepts and coordinate systems – Principles of map projections – Classification of map projections – UTM and Polyconic projections – Coordinate transformations – Applications in geospatial and hydrological mapping.

Principles of Global Positioning System (GPS) – Segments and working of GPS – GNSS systems – ethods of positioning: Static, Differential GPS (DGPS), and Real-Time Kinematic (RTK) surveying – Sources of errors and corrections – GPS data processing and mapping – Applications in water resources and irrigation engineering.

Unmanned Aerial Vehicles (UAVs)/Drone surveying – Flight planning and image acquisition – LiDAR principles and terrain modeling – 3D laser scanning – Ground Penetrating Radar (GPR) – Acoustic Doppler Current Profiler (ADCP) – SONAR and echo sounding techniques for bathymetric surveys; hydrographic surveying - Smart sensors and IoT-enabled surveying systems – Integration of GIS and modern surveying technologies – Case studies in flood mapping, reservoir monitoring, and watershed management.

References

1.	Agarwal, C. S., Garg P. K., Remote Sensing in Natural Resources Monitoring and Management, A. H. Wheeler & Co. Ltd., New Delhi.
2.	Gibson, P. J. Introductory Remote Sensing-Principles and Concepts, Taylor and Francis Press.
3.	Gibson, P. J. and C.H. Power, Introductory Remote Sensing-Digital Image Processing and Application, Taylor and Francis Press.
4.	Lillesand, T. M. and R.W. Kiefer, remote Sensing and Image Interpretation, Fourth Edition, John Wiley.
5.	Ramkumar, Mu, (2009) Geological Hazards: Causes, Consequences and Methods of Containment, New India Publishing Agency, New Delhi.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Apply EDM and Total Station techniques for engineering surveys.
CO2	Analyze aerial photographs and perform photogrammetric mapping.
CO3	Explain geodetic principles and apply map projection systems.
CO4	Perform GPS/GNSS surveys and process positioning data.
CO5	Evaluate and apply modern surveying technologies such as UAVs and LiDAR in water resources projects.

Course Code	:	CE887
Course Title	:	**Urban Planning and Infrastructure Planning**
Type of Course	:	Programme Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide an understanding of urban planning principles with emphasis on water-sensitive urban development.
CLO2	To study urban growth patterns, LULC dynamics and urban sprawl in relation to water resources and environmental sustainability.
CLO3	To develop knowledge on planning and management of urban infrastructure systems, particularly urban water infrastructure.
CLO4	To evaluate urban livability, sustainability and SDGs in the context of resilient urban water management.
CLO5	To apply GIS and land suitability analysis techniques for urban and water resources planning.

Course Content

Introduction to urban and regional planning – Urbanization trends and challenges – Evolution of cities and planning concepts – Relationship between urbanization and water resources – Concepts of integrated urban water management (IUWM), water-sensitive urban design (WSUD) and sustainable urban drainage systems (SUDS) – Smart and resilient cities.

Land use and land cover (LULC) concepts and classification – Urban land use planning – Urban growth theories and urban growth patterns – Effects of urbanization on hydrology, groundwater recharge and drainage systems – Remote sensing and GIS applications in urban planning — Watershed-based urban growth assessment

Urban infrastructure systems and service delivery – Urban water supply systems and demand forecasting – Sewerage and wastewater management – Urban stormwater drainage and flood management – Rainwater harvesting and groundwater recharge – Solid waste management and environmental impacts – Urban hydrology and low-impact development (LID) practices –

Concepts of urban livability and quality of life – Sustainable urban development and climate-resilient infrastructure – Green infrastructure and blue-green urban systems – Sustainable Development Goals (SDGs) related to water and cities (SDG 6 and SDG 11) – Disaster risk reduction and urban flood resilience – Smart water management practices.

Principles of land suitability analysis — Site suitability analysis for reservoirs, wastewater treatment plants, recharge zones and solid waste disposal facilities – Urban flood zonation and risk mapping – Applications of geospatial technologies, AI and big data in urban planning and water management – Contemporary case studies and planning practices.

References

1.	A. Osman Akan & Robert J. Houghtalen. Urban Hydrology, Hydraulics, and Stormwater Quality: Engineering Applications and Computer Modeling. Hoboken, NJ: John Wiley & Sons, 2003.
2.	M. Anji Reddy. Remote Sensing and Geographic Information Systems (4th Edition). Hyderabad, India: BS Publications, 2008.
3.	George B. Korte. The GIS Book (5th Edition). Santa Fe, NM: OnWord Press, 2001.
4.	National Research Council. Urban Stormwater Management in the United States. Washington, DC: The National Academies Press, 2009.
5.	United Nations. World Urbanization Prospects: The 2018 Revision. New York, NY: United Nations Department of Economic and Social Affairs, 2018.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand urban planning principles and their relationship with water resources management.
CO2	Analyze LULC dynamics, urban growth patterns and urban sprawl using geospatial tools.
CO3	Plan and evaluate urban infrastructure systems with emphasis on urban water management
CO4	Assess urban livability, sustainability and SDG compliance in urban development projects
CO5	Apply GIS-based land suitability and decision-support techniques for sustainable urban and water resources planning

Course Code	:	CE888
Course Title	:	**Geospatial Data Analysis and Modeling**
Type of Course	:	Programme Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce concepts and techniques of geospatial data analysis and spatial modeling

CLO2	To develop understanding of spatial data structures, databases, and geostatistical methods.
CLO3	To apply spatial analysis techniques for hydrological and environmental studies
CLO4	To integrate GIS, Remote Sensing, and modeling approaches for water resources applications.
CLO5	To familiarize students with emerging tools such as AI, machine learning, and cloud geospatial platforms.

Course Content

Introduction to geospatial data – Spatial and non-spatial data – Raster and vector data models – Coordinate systems, map projections, and datum concepts – Spatial data acquisition methods – Topology and spatial relationships – Digital Elevation Models (DEM), Digital Terrain Models (DTM), and Digital Surface Models (DSM) –.

Spatial data preprocessing and integration – Georeferencing and coordinate transformation –Point pattern analysis – Terrain analysis and surface modeling – Network analysis – Multi-criteria decision analysis (MCDA) – Spatial sampling techniques - Applications in watershed and hydrological studies.

Concepts of spatial modeling – Deterministic and stochastic models – Hydrological and environmental spatial models – Terrain and watershed modeling – Runoff estimation and drainage analysis using GIS – Spatial suitability analysis – Cellular automata and agent-based models – Land Use/Land Cover (LULC) change modeling – Spatial regression models – Time-series geospatial analysis - Introduction to model calibration and validation.

Watershed delineation and morphometric analysis – Flood risk and inundation modeling – Groundwater potential mapping – Drought monitoring and vulnerability assessment – Reservoir sedimentation analysis – Irrigation and command area management – Urban hydrology and stormwater modeling – Climate change impact assessment – River basin planning and integrated water resources management - Case studies using Indian and global datasets.

Big geospatial data analytics – Cloud GIS and web GIS – Google Earth Engine applications – Artificial Intelligence and Machine Learning in geospatial analysis – Deep learning for image classification and prediction –Spatial Decision Support Systems (SDSS) – IoT and smart water management systems – Digital twins for water infrastructure – Future trends in geospatial modeling.

References

1.	Lillesand, T. M., & Kiefer, R. W. (2000). *Remote sensing and image interpretation* (4th ed.). New York, NY: John Wiley & Sons.
2.	Schowengerdt, R. A. (2007). *Remote sensing: Models and methods for image processing* (3rd ed.). Burlington, MA: Academic Press.
3.	Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information systems and science* (4th ed.). Hoboken, NJ: John Wiley & Sons.
4	Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. Cambridge, MA: MIT Press.
5	Campbell, J. B., & Wynne, R. H. (2011). *Introduction to remote sensing* (5th ed.). New York, NY: Guilford Press.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand spatial data structures, coordinate systems, and geospatial databases
CO2	Apply spatial statistical and interpolation techniques for geospatial analysis.
CO3	Develop and evaluate geospatial models for hydrological and environmental applications.
CO4	Utilize GIS and remote sensing tools for water resources planning and management.
CO5	Analyze advanced geospatial technologies and emerging modeling approaches.

Course Code	**:**	CE889
Course Title	**:**	**Digital Image Processing and Computer Vision for Geospatial Applications**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the fundamentals of digital image processing and geospatial imaging systems
CLO2	To apply image enhancement, restoration, and feature extraction techniques for satellite imagery analysis
CLO3	To develop classification and pattern recognition models for geospatial datasets.
CLO4	To implement deep learning and computer vision techniques for remote sensing applications
CLO5	To analyze advanced geospatial imaging applications using AI-driven approaches

Course Content

Digital image representation – image acquisition systems – sampling and quantization – color models – histogram analysis – image transformations – spatial and frequency domain concepts – visualization and image interpretation principles.

Noise models and filtering – edge detection – image segmentation – Fourier transform and wavelet analysis – morphological operations – image restoration techniques – feature extraction methods – enhancement algorithms for satellite imagery.

Supervised and unsupervised classification – dimensionality reduction – object-based image analysis – support vector machines – Random Forest and XGBoost classifiers – ensemble learning – accuracy assessment and validation techniques.

Artificial neural networks – convolutional neural networks – transfer learning – semantic segmentation – object detection – vision transformers – TensorFlow and PyTorch frameworks – AI optimization for geospatial imagery analytics.

Hyperspectral image analytics – SAR image classification – UAV image processing – deep learning-based land cover mapping – automated feature extraction – change detection using CNNs – generative AI in remote sensing – explainable AI and ethical dimensions in geospatial intelligence.

References

1.	Lillesand, T. M., & Kiefer, R. W. (2000). *Remote sensing and image interpretation* (4th ed.). New York, NY: John Wiley & Sons.

2.	Schowengerdt, R. A. (2007). *Remote sensing: Models and methods for image processing* (3rd ed.). Burlington, MA: Academic Press.
3.	Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information systems and science* (4th ed.). Hoboken, NJ: John Wiley & Sons.
4.	Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. Cambridge, MA: MIT Press.
5.	Campbell, J. B., & Wynne, R. H. (2011). *Introduction to remote sensing* (5th ed.). New York, NY: Guilford Press.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain digital image processing concepts and geospatial imaging principles
CO2	Apply image enhancement, segmentation, and restoration techniques for Earth observation data.
CO3	Develop machine learning-based classification and pattern recognition models for geospatial analysis.
CO4	Implement deep learning frameworks for object detection, segmentation, and geospatial computer vision tasks
CO5	Analyze hyperspectral, SAR, UAV, and remote sensing datasets using advanced AI techniques.

Course Code	**:**	CE890
Course Title	**:**	**Geoartificial Intelligence and Digital Earth Systems**
Type of Course	**:**	Programme Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the fundamentals of AI, Machine Learning, and GeoAI for geospatial applications.
CLO2	To apply machine learning and predictive modeling techniques for spatial data analysis.

CLO3	To develop deep learning-based workflows for remote sensing and spatiotemporal analytics.
CLO4	To explore Digital Earth, digital twins, IoT-GIS integration, and smart environmental systems.
CLO5	To utilize cloud-based geospatial platforms for real-time Earth observation and decision-making.

Course Content

Artificial intelligence fundamentals – machine learning principles – geospatial intelligence systems – spatial cognition – intelligent spatial decision support systems – Earth system intelligence and cognitive geospatial analytics.

Regression, classification and clustering methods – ensemble learning – feature engineering – predictive geospatial modeling – Random Forest, XGBoost, LightGBM and gradient boosting techniques – AI-driven spatial analytics.

Convolutional neural networks – recurrent neural networks and LSTMs – transformers and self-supervised learning – foundation models for Earth observation – spatiotemporal analytics – AI-driven remote sensing workflows.

Digital Earth framework – digital twin technologies – IoT and GIS integration – edge computing – cyber physical systems – smart city intelligence – urban digital ecosystems – intelligent environmental monitoring systems.

Google Earth Engine – distributed geospatial computing – cloud-native analytics – real-time Earth monitoring systems – AI applications in glacier monitoring, GLOF prediction, disaster intelligence, precision agriculture and climate modeling – ethics and governance in GeoAI

References

1.	Lillesand, T. M., & Kiefer, R. W. (2000). *Remote sensing and image interpretation* (4th ed.). New York, NY: John Wiley & Sons.
2.	Schowengerdt, R. A. (2007). *Remote sensing: Models and methods for image processing* (3rd ed.). Burlington, MA: Academic Press.
3.	Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information systems and science* (4th ed.). Hoboken, NJ: John Wiley & Sons.
4.	Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. Cambridge, MA: MIT Press.
5.	Campbell, J. B., & Wynne, R. H. (2011). *Introduction to remote sensing* (5th ed.). New York, NY: Guilford Press.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain AI and GeoAI concepts for geospatial problem solving
CO2	Apply machine learning methods for predictive spatial analytics.
CO3	Implement deep learning models for remote sensing applications
CO4	Develop intelligent geospatial systems using IoT, GIS, and digital twin technologies
CO5	Use cloud-native platforms such as Google Earth Engine for Earth observation applications and Evaluate ethical and governance issues in GeoAI systems

OPEN ELECTIVES

Course Code	**:**	CE891
Course Title	**:**	**Climate Systems and Climate Modeling**
Type of Course	**:**	Elective
Prerequisites	**:**	-
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the components, feedback mechanisms, and energy balance of the Earth's climate system.
CLO2	Analyze natural variability and anthropogenic influences on past, present, and future climate.
CLO3	Understand the structure, types, and governing equations of climate models.
CLO4	Use climate model data to assess future scenarios and their implications on hydrology and water resources.
CLO5	Evaluate climate model outputs and interpret uncertainty, downscaling methods, and model intercomparisons.

Course Content

Climate System Fundamentals: Components of the climate system (atmosphere, ocean, land, cryosphere), energy balance, greenhouse effect, global warming, climate feedbacks, radiative forcing, Hydrological and carbon cycles.

Climate Variability and Change: Natural climate variability (ENSO, AMO, PDO), anthropogenic influences- greenhouse gases, aerosols, land-use and land-cover changes, paleoclimate and observational records, IPCC assessments, Brief history of climate: causes and mechanisms of past changes.

Climate Modeling-Concepts and Types: Introduction to climate models: Energy Balance Models (EBM), Regional Climate Models (RCM), General Circulation Models (GCM), Earth System Models (ESM); governing equations; resolution, parameterization; CMIP6 framework.

Model Applications and Scenario Analysis: Use of climate models for projections (SSPs, RCPs), climate impacts on hydrology, agriculture, and water management, Scenario analysis for regional and global scales, Interpreting climate model outputs, data, and trend analysis, case studies.

Downscaling, Uncertainty & Evaluation: Statistical and dynamical downscaling; bias correction; multi-model ensembles; model validation and intercomparison; Sources of uncertainty in climate projections and strategies.

References

1.	Kendal McGuffie and Ann Henderson-Sellers (2005). A Climate Modeling Primer, 3rd edition. John Wiley & Sons Ltd.
2.	F. W. Taylor (2005). Elementary Climate Physics, 1st edition. Oxford University Press
3.	Introduction to Three-dimensional Climate Modeling (2nd edition) by Warren M. Washington, Claire L. Parkinson
4.	Mathematical Modeling of Earth's Dynamical Systems: A Primer by Rudy Slingerland and Lee Kump, Princeton University Press,2011, 248 pages, ISBN-13: 978-0691145143.
5.	McGuffie, K. and A. Henderson-Sellers: A climate modeling primer, 2nd ed. Chichester; New York: Wiley, c1997.
6.	Trenberth, K. E., ed., 1993: Climate system modeling, Cambridge Univ. Press, New York, 817 pp.
7.	L. M. Krauss (2021), “The Physics of Climate Change”, Post Hill Press
8.	H. Goosse (2015), “Climate System Dynamics and Modeling”, Cambridge University Press

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Describe the functioning of the Earth’s climate system and its major components.
CO2	Assess the drivers of climate variability and change using observational and proxy records.
CO3	Explain the working principles of different types of climate models and their applications.
CO4	Apply climate model outputs to assess climate impacts on water systems.
CO5	Analyze and interpret climate projections, including uncertainty analysis and downscaling.

Course Code	:	CE892
Course Title	:	**Integrated Water Resources Management**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Explain the concepts, principles and components of Integrated Water Resources Management (IWRM) and Integrated Urban Water Management (IUWM) in the context of sustainable development.
CLO2	Apply hydrological, economic and policy approaches for sustainable and equitable water resources planning and management.
CLO3	Analyze rainfall–runoff processes, basin-scale water systems and hydroinformatics tools for integrated water resources assessment.
CLO4	Evaluate water management strategies in agriculture, urban systems and watershed management considering environmental and socio-economic aspects.
CLO5	Interpret legal, institutional and governance frameworks for integrated and sustainable water resources management.

Course Content

Foundations of Integrated Water Resources Management: Water as a global issue – challenges in water availability, quality and sustainability – Principles and components of IWRM and IUWM – River basin and watershed approaches – Stakeholder participation and decision-making – Sustainable development goals and integrated planning frameworks.

Hydrological Processes, Rainfall–Runoff Modeling & Basin Studies: Hydrological cycle and basin characteristics – Rainfall–runoff processes and catchment response – Water balance analysis – Rainfall–runoff modeling concepts and applications – Basin-scale assessment and integrated river basin planning – Experimental studies and field measurements in watersheds – Case studies on basin management.

Water Economics, Policy Instruments & Governance: Economic concepts in water resources management – Water valuation and pricing – Water conservation policies and economic instruments – Public-private participation in water sector management – Institutional frameworks and governance mechanisms – Policy approaches for sustainable and equitable water allocation.

Hydroinformatics & Sustainable Water Management: Application of GIS, Remote Sensing and hydroinformatics in water resources management – Hydrological databases and decision support systems – Smart water management, IoT and sensor-based monitoring – Water quality management and environmental sustainability – Urban water systems and integrated management approaches.

Agriculture, Legal & Regulatory Frameworks: Water for agriculture and food security – Irrigation efficiency and conjunctive water use – Blue and green water concepts and virtual water trade – Water laws, groundwater regulations and international water treaties – Managed aquifer recharge and regulatory frameworks – Community participation and integrated policy implementation.

References

1.	Mays, L. W. (2011). *Water Resources Management: Principles and Practice* (2nd ed.). Hoboken, NJ: John Wiley & Sons.
2.	Young, R. A., & Loomis, J. B. (2014). *Determining the Economic Value of Water: Concepts and Methods* (2nd ed.). Routledge.
3.	K. Biswas, Ed., *Integrated Water Resources Management: A Reassessment*. London, U.K.: Routledge, 2004.
4.	Cech Thomas V., *Principles of water resources: history, development, management and policy*. John Wiley and Sons Inc., New York. 2003.
5.	Mollinga .P. etal " *Integrated Water Resources Management*", Water in South Asia Volume I, Sage Publications, 2006

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Understand the principles, processes and challenges associated with Integrated Water Resources Management and sustainable water governance.
CO2	Apply hydrological and economic concepts for integrated water resources planning and decision-making.
CO3	Analyze rainfall–runoff processes, basin-scale hydrology and hydroinformatics tools for water resources assessment.
CO4	Evaluate sustainable water management strategies in agriculture, urban systems and watershed management.
CO5	Interpret legal, institutional and policy frameworks for integrated and sustainable water resources

Course Code	:	CE893
Course Title	:	**Hydrological Extreme Risk Management and Adaptation**
Type of Course	:	Elective
Prerequisites	:	-
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the hydrological and climatological processes governing extreme events such as floods, droughts, cloudbursts and cyclones.
CLO2	Analyze hazard, vulnerability, resilience and socio-economic dimensions associated with hydrological extreme risks.
CLO3	Apply statistical, hydrological and geospatial tools for forecasting and risk assessment of extreme events.
CLO4	Evaluate structural, non-structural and ecosystem-based adaptation and mitigation strategies for hydrological extremes.
CLO5	Develop preparedness, early warning and climate adaptation approaches for resilient water resources management.

Course Content

Hydrological Extremes and Climate Drivers: Types of hydrological extremes: floods, droughts, cloudbursts, cyclones, storm surges and heatwaves – Hydrological and meteorological processes governing extreme events – Monsoon variability, climate change and extreme precipitation – Cloudburst mechanisms, impacts and case studies in Himalayan and urban regions – Historical extreme events in India and globally.

Risk, Vulnerability and Resilience Assessment: Concepts of hazard, exposure, vulnerability, resilience and risk perception – Socio-economic and ecological impacts of hydrological extremes – Risk system representation and integrated risk frameworks – Community vulnerability and adaptive capacity – Multi-hazard risk assessment approaches.

Forecasting, Modeling and Early Warning Systems: Extreme value analysis, return period and frequency analysis – Flood and drought indices: SPI, PDSI and NDVI – Rainfall-runoff modeling and hydro-meteorological forecasting – Flood inundation mapping using GIS and Remote Sensing – Real-time monitoring, early warning systems and decision support tools.

Mitigation, Adaptation and Nature-Based Solutions: Structural measures:

reservoirs, embankments, flood diversion and groundwater recharge – Non-structural measures: floodplain zoning, land-use planning, insurance and watershed management – Urban stormwater management and cloudburst risk mitigation – Ecosystem-based adaptation and nature-based solutions – Climate-resilient water resources planning.

Crisis Management, Recovery and Sustainable Adaptation: Disaster preparedness and emergency response planning – Communication systems and participatory approaches – Post-disaster recovery, rehabilitation and aftercare – Institutional and policy frameworks for disaster risk reduction – Long-term adaptation, resilience building and sustainable management strategies.

References

1.	Chow, V.T., Maidment, D.R., and Mays, L.W. (1988). Applied Hydrology. McGraw-Hill.
2.	Wilhite, D.A. (2005). Drought and Water Crises: Science, Technology, and Management Issues. CRC Press.
3.	Plate, E.J. (2002). Flood Risk and Flood Management. Springer
4.	Kundzewicz, Z.W. (2005). Flood Risk Management in Europe. Springer.
5.	Smith, K., and Petley, D.N. (2009). Environmental Hazards: Assessing Risk and Reducing Disaster. Routledge.
6.	Schanze, J., Zeman, E., and Marsalek, J. (Eds.) (2006). Flood Risk Management: Hazards, Vulnerability and Mitigation Measures. Springer.

Course Outcomes (CO)

At the end of the course student will be able to

CO1	Explain the hydrological and climatological processes governing extreme events including floods, droughts and cloudbursts.
CO2	Analyze vulnerability, resilience and socio-economic impacts associated with hydrological extreme risks.
CO3	Apply forecasting, modeling and geospatial tools for risk assessment and early warning of extreme events.
CO4	Evaluate structural, non-structural and ecosystem-based mitigation and adaptation measures for hydrological extremes.
CO5	Develop disaster preparedness, recovery and climate-resilient adaptation strategies for sustainable water resources management.