Curriculum and Syllabus for M. Tech. (Water Resources Engineering)

Compliance Report of M. Tech. (WRE) Curriculum

Proposed M. Tech. Curriculum					
Components	Subjects	As per Institute Guideline		M. Tech. (WRE)	
		No.s	Credits		Credits
1. Theory	(i) Total	9-10		9 No.s	29-34
	(ii) Core			4 No.s	14
	(iii) Electives			5 No.s	15-20
2. Labs		3-4 No.s		3 No.s	6
3. Seminars				1 No.s	2
4. Thesis		3 Parts		3 Parts	2+14+14
TOTAL			65-74		67-72

Water resources engineering curriculum

SEMESTER - I

Subject Name	Subject Code	L-T-P	Credit	Contact Hour	Syllabus Page No.
Open Channel Hydraulics	CE6L501	3-1-0	4	4	3
Surface Hydrology	CE6L502	3-0-0	3	3	3
Departmental Elective-I/Open Elective-I	CE6L×××	3-0-0/3-1-0	3/4	3/4	
Departmental Elective-II/ Open Elective-II	CE6L×××	3-0-0/3-1-0	3/4	3/4	
Departmental Elective-III Open Elective-III	CE6L×××	3-0-0/3-1-0	3/4	3/4	
Advanced Hydraulics Laboratory	CE6P501	0-0-3	2	3	12
Seminar I	CE6S501	0-0-0	2	2	
	Total		**20/23**	**21/24**	

SEMESTER – II

Subject Name	Subject Code	L-T-P	Credit	Contact Hour	Syllabus Page No.
Hydraulics of Sediment Transport	CE6L503	3-1-0	4	4	4
Ground Water Hydrology	CE6L504	3-0-0	3	3	4
Departmental Elective-IV/Open Elective-IV	CE6L×××	3-0-0/3-1-0	3/4	3/4	
Departmental Elective-V/Open Elective-V	CE6L×××	3-0-0/3-1-0	3/4	3/4	
Advanced Water Resources Engineering Laboratory	CE6P502	0-0-3	2	3	12
Design of Hydraulic Structures	CE6P503	0-0-3	2	3	12
Thesis: Part I	CE6D501	0-0-0	2	0	
	Total		**19/21**	**19/21**	

*Industrial internship (Optional subject included in the curriculum for the benefit of the student and **does not carry any credit**. The duration of this internship shall be a maximum of **six months**. The student is permitted to go for an industrial internship based on the consent from the allotted supervisor after the completion of the second semester from the month of **May, which shall continue up to the month of October**.)

SEMESTER – III

Subject Name	Subject Code	L-T-P	Credit	Contact Hour	Syllabus Page No.
Thesis : Part-II	CE6D502	0-0-0	14	0	
	Total	0-0-0	**14**	**0**	

SEMESTER - IV

Subject Name	Subject Code	L-T-P	Credit	Contact Hour	Syllabus Page No.
Thesis : Part-III	CE6D003	0-0-0	14	0	
	Total	0-0-0	**14**	**0**	
		Total Credit:	**67/72**		

Electives (I to V)					
Subject Name	**Subject Code**	**L-T-P**	**Credit**	**Contact hrs.**	**Syllabus Page No**
Viscous Fluid Flow	CE6L505	3-0-0	3	3	5
Stochastic Hydrology	CE6L506	3-0-0	3	3	5
Coastal Hydraulics and Coastal Zone Management	CE6L507	3-0-0	3	3	6
Hydraulic Structures	CE6L508	3-0-0	3	3	6
Turbulent Fluid Flow	CE6L509	3-0-0	3	3	7
Hydropower Engineering	CE6L510	3-1-0	4	4	7
River Engineering	CE6L511	3-1-0	4	4	8
Advanced Computational Hydraulics	CE6L512	3-1-0	4	4	8
Water Resources Planning and Management	CE6L513	3-1-0	4	4	9
Design of Pipe Networks	CE6L514	3-1-0	4	4	9
GIS & Remote Sensing Applications in Civil Engineering	CE6L515	3-0-0	3	3	10
Non-Point Source Pollution of Water Resources	CE6L516	3-0-0	3	3	10
Fluid Structure Interaction	CE6L517	3-0-0	3	3	11
Integrated Watershed Management	CE6L518	3-0-0	3	3	11

NB: Any other subjects of same level floated by any other specialisations of SIF or any other Schools can also be taken as an elective, as suggested by faculty advisor/PG Coordinators

Subject Code: CE6L501	Name: Open Channel Flows	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Energy and momentum of flow; Critical flow; Channel control and transitions; Discharge measurement methods; Uniform flow and flow resistance; Composite roughness and compound channels; Gradually varied flow; Classifications and computations of free surface profiles; Spatially varied flow; Supercritical flows and oblique flows; Rapidly varied flow; Hydraulic jump; Continuity and dynamic equations of unsteady flow; Wave propagation and surge; Method of characteristics; Dam-break problem; Flow in channel bends; Buoyant and submerged jets.

Text/Reference Books:

- Subramanya, K., Flow in Open Channels, Third Edition, Tata McGraw Hill Publishing Company Ltd., New Delhi, 2009.
- Chanson, H., The Hydraulics of Open Channel Flow: An Introduction, Second Edition, Elsevier, 2004.
- Ven Te Chow, Open Channel Hydraulics, Reprint, Blackburn Press, 2009.
- French, R. H., Open Channel Hydraulics, Water Resources Publications, LLC, 2007.
- Sturm, T. W., Open Channel Hydraulics, Second Edition, McGraw-Hill, New York, 2010.

Subject Code: CE6L502	Name: Surface Hydrology	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Hydrologic cycle; Systems concept; Reynold's transport theorem; Hydrologic processes; Atmospheric water; Precipitation; Evapotranspiration; Abstractions; Surface water; Streamflow hydrographs; Baseflow separation; Unit hydrograph; Hydrograph analyses; Flow routing; Streamflow; Subsurface water; Richards's equation; Green-Ampt infiltration model; Frequency analysis; Hydrologic modeling; Hydrologic design; MATLAB/R/Python exercises for hydrologic analysis; HEC-HMS based hydrologic modeling.

Text/Reference Books:

- Ven Te Chow (Editor), Handbook of Applied Hydrology: A Compendium of Water-resources Technology, McGraw-Hill, New York, 1964.
- VenTe Chow, Maidment, D. and Mays, L.W., Applied Hydrology, Second Edition, McGraw-Hill Inc., New York, 2013.
- Yevjevich, V., Probability and Statistics in Hydrology, Water Resources Publications, Fort Collins, Colorado, 1972.
- Singh, V. P., Elementary Hydrology, Prentice Hall, 1992.
- Maidment, D. R., Handbook of Hydrology, McGraw-Hill Inc., 1993.

Subject Code: CE6L503	Name: Hydraulics of Sediment Transport	L-T-P: 3-1-0	Credit: 4

Prerequisite: Free Surface Flows
Sediment properties; Initiation of motion; Bed Load; Bed Forms; Effective bed roughness; Armouring;
Suspended load; Total load; Transport of sediment due to unsteady flow; Meandering of rivers; Braided river; Local scour at different
structures; Sediment sampling; Mathematical models of sediment transport.
Text/Reference Books:

- Yang, C. T., Sediment Transport: Theory and Practice, McGraw-Hill, 1996
- Graf, W. H., Hydraulics of Sediment Transport, Water Resources Publications, LLC, Colorado, USA, 1984.
- Fredsoe, J. and Deigaard, R., Mechanics of Coastal Sediment Transport, Advanced Series on Ocean Engineering - Volume 3, World Scientific, New Jersey, 2005.
- Garde, R. J., History of Fluvial Hydraulics, New Age International (P) Ltd. Publishers, New Delhi, 1995.

Subject Code: CE6L504	Name: Groundwater Hydrology	L-T-P: 3-0-0	Credit: 3

Prerequisite: None
Groundwater in hydrologic cycle; Occurrence and movement; Aquifers and their characteristics/classification, Darcy's law, Dupuit'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 and environmental influences; Global climate change and groundwater; Quality of groundwater; Contaminant transport processes; Advection–dispersion equation; Treatment of contaminated groundwater; Groundwater flow modeling techniques; Governing equations; Finite difference modelling; Introduction to MODFLOW; Management of groundwater resources; Surface and sub-surface investigations; Artificial recharge; Saline water intrusion in aquifers: Ghyben-Herzberg relation; Remote sensing-based groundwater studies.
Text/Reference Books:

- Todd, D. K. and Mays, L. W., Groundwater Hydrology, Third Edition, John Wiley & Sons, Inc., 2005.
- Mays, L. W., Ground and Surface Water Hydrology, John Wiley & Sons, Inc., 2011.
- Mackay, R. & Riley, M., Groundwater Modeling, in *An Introduction to Water Quality Modelling* Second Edition, Ed: A. James, Wiley Publishers, 1992.
- Hiscock, K. M. and Bense, V. F., Hydrogeology: Principles and Practice, Second Edition, Wiley-Blackwell, 2014.

Subject Code: CE6L505	Name: Viscous Fluid Flow	L-T-P: 3-0-0	Credit: 3

Pre-requisite: None

Introduction to tensors and tensor equations in fluid mechanics, concept of continuum and fluid definition, body forces and surface forces, formulation of the stress tensor, scalar and vector fields, Eulerian and Lagrangian perspectives of fluid motion, motion of a fluid element including translation, volumetric expansion, deformation, and rotation, concepts of vorticity, strain rate tensor and rotation rate tensor, continuity equation and its physical significance, stream function and velocity potential in ideal flow, transport theorems including Reynolds transport theorem, constitutive relations for different types of fluids, derivation of the Navier-Stokes equations for compressible fluids, simplification for Newtonian fluids and incompressible constant-property conditions, exact analytical solutions of Navier-Stokes equations under simplified assumptions, creeping flow approximations including Stokes and Oseen formulations, theory and application of hydrodynamic lubrication, boundary layer theory with emphasis on exact, approximate, and numerical methods of solution.

Text/Reference Books:

- White, F. M., Viscous Fluid Flow, Third Edition, McGraw-Hill Education, New York, 2005.
- Fundamentals of Fluid Mechanics 6ed - Bruce R. Munson, Donald F. Young, Theodore H. Okiishi, Wade W. Huebsch – Wiley.
- Fluid mechanics. Kundu, P. K., et al. 2024. Elsevier.
- Incompressible Flow 3ed - R. L. Panton Wiley.

Subject Code: CE6L506	Name: Stochastic Hydrology	L-T-P: 3-0-0	Credit: 3

Pre-requisite: None

Statistical methods in hydrology; Probability distributions; Hypothesis testing; Goodness of fit statistics; Frequency analysis; Stochastic processes; Regression models; Multivariate modelling of hydrologic time series; Markov models; Time series analysis; Hydrologic time series modelling; AR, ARMA, ARIMA, and DARMA models.

Text/Reference Books:

- Hann, C.T., Statistical Methods in Hydrology, Second edition, Iowa State Press, Iowa, USA, 2002.
- Box, G. E. P., Jenkins, G. M., and Reinsel, G. C., Time Series Analysis, Forecasting and Control, Fourth Edition, John Wiley and Sons, New York, 2008
- Reddy, P. J., Stochastic Hydrology, Laxmi Publications Ltd., New Delhi, 1997
- Yevjevich, V., Probability and Statistics in Hydrology, Water Resources Publications, LLC, Fort Collins, Colarado, 1972.
- Yevjevich, V., Stochastic Processes in Hydrology, Water Resources Publications, LLC, Fort Collins, Colarado, 1970.

Subject Code: CE6L507	Name: Coastal Hydraulics and Coastal Zone Management	L-T-P: 3-0-0	Credit: 3

Pre-requisite: None

Coastal environment and coastal zone; Introduction to wave mechanics; Classification of waves; Wave transformation; Breaking of waves; Finite amplitude waves; Stokes wave theory; Higher order wave theories; Numerical wave theory; Tsunamis; Short term and long term wave statistics; Wind generated waves; Causes of coastal erosion; Shore protection; Methods of shore protection; Wave structure interaction; Morison Equation; Wave force on submarine pipelines; Coastal processes, Application of mathematical models; Integrated coastal zone management; Coastal ecosystems.

Text/Reference Books:

- Ippen, A. T., Estuary and Coastline Hydrodynamics, Engineering Societies Monographs Series, First Edition, McGraw-Hill Inc., New York, 1966.
- Sorenson, R. M., Basic Coastal Engineering, Third Edition, Springer, USA, 2006.
- Reeve, D., Chadwick, A., & Fleming, C., Coastal Engineering, Processes, Theory and Design Practice, Spon Press, New York, 2005.

Subject Code: CE6L508	Name: Hydraulic Structures	L-T-P: 3-0-0	Credit: 3

Pre-requisite: None

Advanced topics in design and construction of gravity, earth and rockfill dams; Dynamic analysis of gravity dams under earthquake loading; Theories of seepage, Design of weirs and barrages; Spillways and energy dissipators; Gates; Sluices; Galleries; Contraction joints; Seepage control measures; Principles of foundation treatment.

Text/Reference Books:

- Garg, S. K., Irrigation Engineering and Hydraulic Structures, 19th Edition, Khanna Publishers, New Delhi, 2006.
- Novak, P., Moffat, A. I. B., Nalluri, C., and Narayanan, R., Hydraulic Structures, Fourth Edition, Taylor and Francis, New York, 2007.
- Varshney, R. S.,Hydro Power Structures, Second Edition, Nem Chand and Bros., Roorkee, 1977.

Subject Code: CE6L509	Name: Turbulent Fluid Flow	L-T-P: 3-0-0	Credit: 3

Pre-requisite: None

Statistical structures of turbulence; two-dimensional flow structures and effect of roughness; measurements of turbulence; three-dimensional flow structures driven by turbulence; secondary currents; diffusion and dispersion; turbulence model calculations; Coherent structures; bursting phenomena; large scale vortical motions; physical models of coherent structures; numerical simulations of coherent structures; wave boundary layer.

Text/Reference Books:

- Pope, S. B., Turbulent Flows, Cambridge University Press, UK, 2003.
- Lesieur, M., Turbulence in Fluids, Third Edition, Kluwer Academic Publishers, the Netherlands, 1997.
- Hinze, J. O., Turbulence, An Introduction to Its Mechanism and Theory, McGraw-Hill, New York, 1959.
- Biswas, G. and Eswaran, V., Turbulent Flows, Fundamentals, Experiments and Modeling, CRC Press, Boca Raton, 2002.
- Garde, R. J., Turbulent Flows, Third Edition, New Age Science Limited, New Delhi, 2010.

Subject Code: CE6L510	Name: Hydropower Engineering	L-T-P: 3-1-0	Credit: 4

Pre-requisite: None

Fundamentals of hydropower; Classification of hydro power plants; Water power estimates; Pondage and storage; Load curve and load factor; Utilization factor; Capacity factor; Diversity factor; Firm power and secondary power; Prediction of load;

Run of the river plants; Pumped storage plants; Mini and micro hydel plants; Tidal power plants; Design of hydropower installation components; Intake structures; Water conductor systems; Transients in water conductor systems; Tunnels; Water hammer; Surge-tanks, Penstocks, valves and anchor-blocks; Types of powerhouse: underground, semi-underground; Turbines and generators and their foundations; Flood routing through reservoirs and channels; Dam breach analysis; Cost and value of water power; Introduction to structural and geotechnical aspects of powerhouse design.

Text/Reference Books:

- Barrows, H. K., Water Power Engineering, McGraw-Hill Inc., New York, 1943.
- Dandekar, M. M., Sharma, K. N., Water Power Engineering, Second Edition, Vikas Publishing House (P) Ltd., Noida, 2013.
- Subramanya, K., Fluid Mechanics and Hydraulic Machines, Tata McGraw-Hill Education (P) Ltd., New Delhi, 2011.
- Daugherty, R. L., Hydraulic Turbines, McGraw-Hill Book Company, Inc., 1920.
- Varshney, R. S., Hydro Power Structures, Second Edition, Nem Chand and Bros., Roorkee, 1977.

Subject Code: CE6L511	Name: River Engineering	L-T-P: 3-1-0	Credit: 4

Pre-requisites: None

River hydraulics; Structure, controls and boundary conditions; Steady and unsteady flow in rivers; Resistance to flow; River morphology; Channel characteristics; River equilibrium and dynamics (regime channels, aggradation and degradation processes); *River bank erosion and protection;* River engineering measures; River training works; Discharge, water level and water quality aspects; Restoration and remediation of rivers and streams; Case studies.

Text/Reference Books:

- Chang, H.H., Fluvial Processes in River Engineering, John Wiley & Sons, New York, 1988.
- Petersen, M. S., River Engineering, Prentice Hall, Englewood Cliffs, NJ, 1986.
- Thorne, C. R., Hey, R. D., and Newson, M. D., Applied Fluvial Geomorphology for River Engineering and Management, John Wiley & Sons, New York, 1997.
- Sturm, T. W., Open Channel Hydraulics, Second Edition, McGraw-Hill Education, New York, 2009.
- Chanson, H., The Hydraulics of Open Channel Flow: An Introduction, Second Edition, Elsevier Butterworth-Heinemann, Oxford, 2004.

Subject Code: CE6L512	Name: Advanced Computational Hydraulics	L-T-P: 3-1-0	Credit: 4

Pre-requisites: Mathematical Methods

Ordinary and partial differential equations, finite difference schemes - implicit and explicit types, accuracy, convergence and stability, applications to steady and unsteady flows, pollutant dispersion, flood wave propagation, applications with computer programming.

Text/Reference Books:

- Koutitas, C., & Scarlatos, P. D. (2015). *Computational modelling in hydraulic and coastal engineering*. CRC Press.
- LeVeque, R. J. (2007). *Finite difference methods for ordinary and partial differential equations: steady-state and time-dependent problems.* Society for Industrial and Applied Mathematics.
- Fletcher, C. A. (2012). *Computational techniques for fluid dynamics: Specific techniques for different flow categories.* Springer Science & Business Media.

Subject Code: CE6L513	Name: Water Resources Planning and Management	L-T-P: 3-1-0	Credit: 4

Pre-requisites: None

Introduction to issues in planning and management; Role of water resources systems modelling; Decision support systems (DSS); Simulation models; Optimization methods; Dynamic programming; Application in reservoir operation, etc.; Linear programming; Multi-objective optimization; Modelling uncertainty; Sensitivity and uncertainty analyses; Advances in modelling; Fuzzy optimization-applications in reservoir storage, water quality studies, etc.; Artificial neural networks; Genetic algorithms; Data mining; Flood management; Flood plain modelling; Managing risk; Risk reduction; Decision support and prediction; Reliability-resilience-vulnerability (RRV) analysis; Drought management; Causes, types and impacts; Impact of climate change; Drought monitoring; Drought triggers; S-D-F analysis of droughts using copulas.

Books:

- Loucks, D. P., and Van Beek, E., Water Resources Systems Planning and Management: An Introduction to Methods, Models and Applications, the UNESCO, Paris, 2005.
- Loucks, D. P., Stedinger, J.R., and Haith, D. A., Water Resources Systems Planning and Analysis, Prentice-Hall, NJ, 1981.
- Vedula, S., and Mujumdar, P. P., Water Resources Systems: Modelling Techniques and Analysis, Tata McGraw Hill, New Delhi, 2007.
- Jain, S.K., and Singh, V. P., Water Resources Systems Planning and Management, Developments in Water Science, Vol. 51, Elsevier Science, New York, 2003.
- Govindaraju, R. S., and Rao, A. R., Artificial Neural Networks in Hydrology, Water Science and Technology Library, Volume 36, Springer Netherlands, 2000.
- Raju, K. S., and Kumar D. N., Multicriterion Analysis in Engineering and Management, Prentice-Hall, India, 2014.

Subject Code: CE6L514	Name: Design of Pipe Networks	L-T-P: 3-1-0	Credit: 4

Pre-requisites: None

Introduction to flow hydraulics and network analysis; Basic principles of pipe flow; Fittings and valves; Pipe network analysis, pipe network geometry, branched and looped networks; Multi-Input source water network analysis; Cost considerations, Life cycle costing, Relative cost factor General principles of network synthesis, constraints, parameters for network sizing, reliability considerations; Water transmission lines, gravity mains, pumping mains; Water distribution mains; Single-input source branched systems; Single-input source looped systems; Multi-input source branched systems; Multi-input source looped systems; Decomposition of a large multi-input, looped network; Optimal water supply zone size.

Books:

- Swamee, P. K., and Sharma, A. K.,Design of Water Supply Pipe Networks, John Wiley & Sons, Inc., New Jersey, 2008.
- Bhave, P. R., Analysis of Flow in Water Distribution Networks, Technomic Publishing; Lancaster, 1991.

- Surhone, L. M., Tennoe, M. T., Henssonow, S. F.,Pipe Network Analysis, VDM Publishing, Germany, 2010.
- Jeppson, R. W., Analysis of flow in pipe networks, Ann Arbor Science Publishers, Inc., Ann Arbor, 1976.
- Mays, L. W., Water Distribution Systems Handbook, McGraw-Hill Education, New York, 1999.

Subject Code: CE6L515	Name: GIS and Remote Sensing Applications in Civil Engineering	L-T-P: 3-0-0	Credit: 3

Pre-requisites: None

Remote sensing; Energy source; Spectral signatures; Remote sensing satellites and sensors; Radar image interpretation; Digital image processing; Image classification; Principal component transformation; Applications in watershed management, flood management, groundwater quality, reservoir sedimentation, irrigation management. Geographic information systems (GIS); Raster and vector data; GIS for Surface-Water Hydrology; Digital elevation models; Hydrographic vector data; Arc-hydro model; GIS for groundwater modeling; GIS for flood plain management; HEC-RAS and HEC-GeoRAS; Case studies.

Books:

- Lillesand, T., Kiefer, R. W., and Chipman, J., Remote Sensing and Image Interpretation, Seventh Edition, John Wiley & Sons, New York, 2015.
- Burrough, P. A., and McDonnell, R. A., Principles of Geographical Information Systems, Second Edition,Oxford University Press, Oxford, 1998.
- Richards, J. A., Remote Sensing Digital Image Analysis: An Introduction, Fifth Edition, Springer-Verlag Berlin Heidelberg, 2013.
- Johnson, L. E., Geographic Information Systems in Water Resources Engineering, CRC Press, Boca Raton, 2008.

Subject Code: CE6L516	Name: Non-Point Source Pollution of Water Resources	L-T-P: 3-0-0	Credit: 3

Pre-requisites: None

Basic concept of water pollution; Water quality standards pertaining to drinking, irrigation and aquatic life; Water quality analysis methods and instruments used; Concept and behaviour of point and nonpoint source pollution (NPS); Sources of NPS pollution; Pathways and assessment of NPS pollutants; linkage between water pollution and hydrology; Application of hydrologic models in NPS pollution assessment at watershed scale; Quantification and control of NPS pollution from agricultural watersheds; Nitrogen, Phosphorus, pesticides and water quality impacts; Impacts of mining and forestry; Watershed-scale NPS pollution models; Optimum management strategy; Best management practices for NPS pollution control.

Books:

- Novotny, V., Water Quality: Diffuse Pollution and Watershed Management, Second Edition, John Wiley and Sons, New York, 2003.

- Ritter, W. F., Shirmohammadi, A., Agricultural Nonpoint Source Pollution: Watershed Management and Hydrology, CRC Press, Boca Raton, 2001.
- Brooks, K. N., Ffolliott, P., F., and Magner, J. A., Hydrology and the Management of Watersheds, Fourth Edition, Wiley-Blackwell, New York, 2012.
- Das, M. M., Saikia, M., Watershed Management, PHI Learning, Delhi, 2012.

Subject Code: CE6L517	Name: Fluid Structure Interaction	L-T-P: 3-0-0	Credit: 3

Pre-requisites: Numerical Methods

Basic interaction models; Examples of fluid-structure interactions, Lagrangian-Eulerian description of kinematics; Model equations for flexible structures; Fluid models for small-amplitude inviscid fluids; Internal fluid-structure interaction: reduced-order models for structures and interaction compatibility; The problem of internal fluid waves with gravity; Liquid sloshing under surface tension; Dynamics of structures interacting with internal fluid waves; External fluid-structure interaction: external fluid waves interacting with flexible structures; Approximate models for external acoustics-structure interactions; Examples of external acoustic-structure interaction problems; Winds and large ocean waves interacting with rigid and flexible structures; Eulerian and Lagrangian coupling procedures; Methods for incompressible fluids interacting with structures.

Text/Reference Books:

- Paidoussis, M. P., Price, S. J., and de Langre, E., Fluid-Structure Interactions: Cross-Flow-Induced Instabilities, Cambridge University Press,New York, 2011.
- Sigrist, J-F., Fluid-Structure Interaction: An Introduction to Finite Element Coupling, John Wiley & Sons, New York, 2015.
- Bazilevs, Y., Takizawa, K., Tezduyar, T. E., Computational Fluid-Structure Interaction: Methods and Applications, First Edition, John Wiley & Sons, UK, 2013.
- Finnemore, E. J., Franzini, J. B., Fluid Mechanics with Engineering Applications, McGraw-Hill Series in Industrial Engineering and Management, Tenth Edition, McGraw-Hill Education, 2001.

Subject Code: CE6L518	Name: Integrated Watershed Management	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Introduction to integrated approach for the management of watersheds; Watershed hydrology: runoff and sediment load estimation; Instrumentation, and monitoring of hydro-meteorological variables at watershed-scale; Discharge measurement, sediment (suspended and bed load) measurement; Control of soil erosion; GIS for integration of different aspects of watersheds; Rainwater management: rainwater harvesting, artificial recharge, types and design of water harvesting and recharge structures; Irrigation management: use of conserved water; Land degradation, soil quality and water quality aspects, soil conservation strategies, water conveyance structures-spillways, culverts, etc.; Droughts: causes, types, drought indices, control and adaptation strategies; Drainage: estimation of drainage coefficient, design of surface and subsurface drainage systems, control of soil salinity; Climate change: general circulation models (GCMs), IPCC climate

change scenarios, impacts of climate change and land use change on watersheds; Case studies

Books:

- Brooks, K. N., Ffolliott, P., F., and Magner, J. A., Hydrology and the Management of Watersheds, Fourth Edition, Wiley-Blackwell, New York, 2012.
- Das, M. M., Saikia, M., Watershed Management, PHI Learning, Delhi, 2012.
- Ven Te Chow, Maidment, D. and Mays, L.W., Applied Hydrology, Second Edition, McGraw-Hill Inc., New York, 2013.
- Heathcote, I. W., Integrated Watershed Management: Principles and Practice, Second Edition, John Wiley and Sons, Inc., NJ, 2009.
- Gregersen, H. M., Ffolliott, P. F., Brooks, K. N., Integrated Watershed Management: Connecting People to Their Land and Water, CAB International, UK, 2007.
- Climate Change 2014: Impacts, Adaptation and Vulnerability, Working Group Report II, IPCC Fifth Assessment Report of the IPCC.
- Climate Change 2014: Mitigation of Climate Change, Working Group Report III, IPCC Fifth Assessment Report of the IPCC.
- Mujumdar, P. P., and Kumar D. N., Floods in a Changing Climate: Hydrologic Modeling, International Hydrology Series, Cambridge University Press, Cambridge, U.K., 2012.

Subject Code: CE6P501	**Name: Advanced Hydraulics Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**

Pre-requisites: None

Measurement of velocity profile in straight open channel (with and without obstruction); Experiments on boundary layer; Discharge measurement by weir and end-depth methods; Determination of Reynolds shear stress and bed shear stress; Measurement of flow field around fully and partially submerged hydraulic structures, Computer programs and software applications for solving free surface flow problems.

Subject Code: CE6P502	**Name: Design of Hydraulic Structures**	**L-T-P: 0-0-3**	**Credit: 2**

Pre-requisites: None

Design of lined and unlined canal systems; Design and drawing for irrigation structures, diversion works, cross-drainage works, canal falls, dams; Software applications for the design of hydraulic structures; Design of hydropower structures; turbines, penstocks, surge tanks.

Subject Code: CE6P503	**Name: Advanced Water Resources Engineering Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**

Pre-requisites: None

Measurement of rainfall, evaporation, infiltration - laboratory and field tests; Measurement of sediment load; Water balance studies, Computer programs and software applications for hydrologic analysis and simulation problems.