Appendix-

DEPARTMENT OF HYDROLOGY
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **33** **P.G. Diploma/M.Tech. (Surface Water Hydrology)**
Department: **HYN** **Hydrology**
Year: **I**

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
Semester- I (Autumn)														
1.	HYN-516	Channel and fluvial hydraulics	PCC	4	3	1	2/2	3	-	25	-	25	50	-
2.	HYN-526	Deterministic hydrology	PCC	4	3	1	-	3	-	25	-	25	50	-
3.		Programme Elective Course -I	PEC	4	-	-	-	-	-	-	-	-	-	-
4.		Programme Elective Course -II	PEC	4	-	-	-	-	-	-	-	-	-	-
5.		Programme Elective Course -III	PEC	2/4*	-	-	-	-	-	-	-	-	-	-
		Total		18/20	6	2	1							
Semester-II (Spring)														
1.	HYN-522	Stochastic hydrology	PCC	4	3	1	-	3	-	25	0	25	50	0
2.	HYN-523	Surface water modeling and simulation	PCC	4	2	1	2	2	-	10	15	25	50	0
3.	HYN-532	Environmental planning and assessment of projects	PCC	4	3	1	-	3	-	25	-	25	50	-
4.	HYN-700	Seminar	SEM	2	-	-	-	-	-	-	-	-	100	-
5.		Programme Elective Course -I	PEC	4	-	-	-	-	-	-	-	-	-	-
6.		Programme Elective Course -II	PEC	4/2*	-	-	-	-	-	-	-	-	-	-
		Total		22/20	8	3	2							

*Credit requirement for PG Diploma/ Ist year M.Tech is 40 credits. Only one 2 credit elective course is permitted in any of the semesters.

DEPARTMENT OF HYDROLOGY
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **33** **P.G. Diploma/M.Tech. (Surface Water Hydrology)**
Department: **HYN** **Hydrology**
Year: **II**

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	**Subject Code**	**Course Title**	**Subject Area**	**Credits**	**L**	**T**	**P**	**Theory**	**Practical**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Semester- I (Autumn)														
1.	HYN-701A	Dissertation Stage–I (to be continued next semester)	DIS	12	-	-	-	-	-	-	-	-	100	-
		Total		12										
Note: Students can take 1 or 2 audit courses as advised by the supervisor, if required.														
Semester-II (Spring)														
1.	HYN-701B	Dissertation Stage–II (contd. From III semester)	DIS	18	-	-	-	-	-	-	-	-	100	-
		Total		18										

Summary				
Semester	1	2	3	4
Semester-wise Total Credits	**18/20**	**22/20**	**12**	**18**
Total Credits	**70**			

Program Elective Courses (Surface Water)

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
1.	HYN-540	Water Resources Economics	PEC	4	3	1	-	3	-	25	-	25	50	-
2.	HYN-525	Water Resources systems	PEC	4	3	1	-	3	-	25	-	25	50	-
3.	HYN-512	Computer Programming	PEC	2	1	-	2	1	-	10	15	25	50	-
4.	HYN-543	Flood forecasting	PEC	4	3	1	-	3	-	25	-	25	50	-
5.	HYN-538	Hydrological data collection, processing and analysis	PEC	4	3	1	2/2	3	-	25	-	25	50	-
6.	HYN-537	Remote sensing and GIS applications	PEC	4	3	1	2	3	-	10	15	25	50	-
7.	HYN-551	Physical Hydrology	PEC	4	3	1	-	3	-	25	-	25	50	-
8.	HYN-545	Surface Water quality modeling	PEC	4	3	1	-	3	-	25	-	25	50	-
9.	HYN-546	Hydroinformatics	PEC	4	3	1	2/2	3	-	25	-	25	50	-
10.	HYN-518	Water resources planning and Management	PEC	4	3	1	-	3	-	25	-	25	50	-
11.	HYN-513	Hydrometeorology and climate change	PEC	4	3	1	2/2	3	-	25	-	25	50	-
12.	HYN-527	Groundwater hydrology	PEC	4	3	1	2/2	3	-	25	-	25	50	-
13.	HYN-531	Watershed Behavior and Conservation Practices	PEC	4	3	1	-	3	-	25	-	25	50	-
14.	HYN-552	Numerical methods in hydrology	PEC	2	2	1/2	-	2	-	25	-	25	50	-
15.	HYN-553	Experimental hydrology	PEC	2	-	-	4	-	2	-	50	-	-	50
16.	HYN-542	Urban Hydrology	PEC	4	3	1	-	3	-	25	-	25	50	-
17.	HYN-554	Soil and Water Remediation	PEC	4	3	1	2/2	3	-	25	-	25	50	-
18.	HYN-511	Hydrologic elements and analysis	PEC	4	3	1	-	3	-	25	-	25	50	-
19.	HYN-555	Soft-computing techniques in hydrology	PEC	2	2	1/2	-	2	-	25	-	25	50	-
20.	HYN-556	Environmental Quality Lab	PEC	2	-	-	4	-	2	-	50	-	-	50

Appendix-

DEPARTMENT OF HYDROLOGY
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **33** **P.G. Diploma/M.Tech. (Ground Water Hydrology)**
Department: **HYN** **Hydrology**
Year: **I**

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
Semester- I (Autumn)														
1.	HYN-527	Groundwater hydrology	PCC	4	3	1	2/2	3	-	25	-	25	50	-
2.	HYN-529	Geophysical investigations	PCC	4	3	1	2/2	3	-	25	-	25	50	-
3.	HYN-535	Environmental quality	PCC	4	3	1	2/2	3	-	25	-	25	50	-
4.		Programme Elective Course -II	PEC	4	-	-	-	-	-	-	-	-	-	-
5.		Programme Elective Course -III	PEC	2/4*	-	-	-	-	-	-	-	-	-	-
		Total		18/20	9	3	3							
Semester-II (Spring)														
1.	HYN-528	Groundwater systems analysis	PCC	4	3	1	-	3	-	25	-	25	50	-
2.	HYN-560	Soil and groundwater contamination modelling	PCC	4	3	1	2/2	3	-	25	-	25	50	-
3.	HYN-700	Seminar	SEM	2	-	-	-	-	-	-	-	-	100	-
4.		Programme Elective Course -I	PEC	4	-	-	-	-	-	-	-	-	-	-
5.		Programme Elective Course -II	PEC	4	-	-	-	-	-	-	-	-	-	-
6.		Programme Elective Course -III	PEC	4/2*	-	-	-	-	-	-	-	-	-	-
		Total		22/20	6	2	1							

* Credit requirement for PG Diploma/ Ist year M.Tech is 40 credits. Only one 2 credit elective course is permitted in any of the semesters.

DEPARTMENT OF HYDROLOGY
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **33** **P.G. Diploma/M.Tech. (Ground Water Hydrology)**
Department: **HYN** **Hydrology**
Year: **II**

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	**Subject Code**	**Course Title**	**Subject Area**	**Credits**	**L**	**T**	**P**	**Theory**	**Practical**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Semester- I (Autumn)														
1.	HYN-701A	Dissertation Stage–I (to be continued next semester)	DIS	12	-	-	-	-	-	-	-	-	100	-
		Total		12										
Note: Students can take 1 or 2 audit courses as advised by the supervisor, if required.														
Semester-II (Spring)														
1.	HYN-701B	Dissertation Stage–II (contd. From III semester)	DIS	18	-	-	-	-	-	-	-	-	100	-
		Total		18										

Summary				
Semester	1	2	3	4
Semester-wise Total Credits	**18/20**	**22/20**	**12**	**18**
Total Credits	**70**			

Program Elective Courses (Ground Water)

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
1.	HYN-514	Hydrogeology	PEC	4	3	1	2/2	3	-	25	-	25	50	-
2.	HYN-561	Multi-phase flow through porous media	PEC	4	3	1	2/2	3	-	25	-	25	50	-
3.	HYN-539	Isotope hydrology	PEC	4	3	1	2/2	3	-	25	-	25	50	-
4.	HYN-544	Hydrogeology of hard rocks	PEC	4	3	1	-	3	-	25	-	25	50	-
5.	HYN-522	Stochastic hydrology	PEC	4	3	1	-	3	-	25	-	25	50	-
6.	HYN-537	Remote sensing and GIS applications	PEC	4	3	1	2	3	-	10	15	25	50	-
7.	HYN-562	Irrigation and drainage engineering	PEC	4	3	1	2/2	3	-	25	-	25	50	-
8.	HYN-545	Surface Water quality modeling	PEC	4	3	1	-	3	-	25	-	25	50	-
9.	HYN-546	Hydroinformatics	PEC	4	3	1	2/2	3	-	25	-	25	50	-
10.	HYN-518	Water resources planning and Management	PEC	4	3	1	-	3	-	25	-	25	50	-
11.	HYN-513	Hydrometeorology and climate change	PEC	4	3	1	2/2	3	-	25	-	25	50	-
12.	HYN-563	Vadose zone hydrology	PEC	4	3	1	2/2	3	-	25	-	25	50	-
13.	HYN-552	Numerical methods in hydrology	PEC	2	2	1/2	-	2	-	25	-	25	50	-
14.	HYN-553	Experimental hydrology	PEC	2	-	-	4	-	2	-	50	-	-	50
15.	HYN-566	Groundwater protection and regulation	PEC	2	2	1/2	-	2	-	25	-	25	50	-
16.	HYN-554	Soil and Water Remediation	PEC	4	3	1	2/2	3	-	25	-	25	50	-
17.	HYN-511	Hydrologic elements and analysis	PEC	4	3	1	-	3	-	25	-	25	50	-
18.	HYN-538	Hydrological data collection, processing and analysis	PEC	4	3	1	2/2	3	-	25	-	25	50	-
19.	HYN-555	Soft-computing techniques in hydrology	PEC	2	2	1/2	-	2	-	25	-	25	50	-
20.	HYN-556	Environmental Quality Lab	PEC	2	-	-	4	-	2	-	50	-	-	50

Appendix-

DEPARTMENT OF HYDROLOGY
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **33** **P.G. Diploma/M.Tech. (Watershed Management)**
Department: **HYN** **Hydrology**
Year: **I**

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
Semester- I (Autumn)														
1.	HYN-511	Hydrologic elements and analysis	PCC	4	3	1	-	3	-	25	-	25	50	-
2.	HYN-531	Watershed behavior and conservation practices	PCC	4	3	1	-	3	-	25	-	25	50	-
3.	HYN-537	Remote sensing and GIS applications	PCC	4	3	1	2	3	-	10	15	25	50	-
4.		Programme Elective Course -I	PEC	4	-	-	-	-	-	-	-	-	-	-
5.		Programme Elective Course -II	PEC	2/4*	-	-	-	-	-	-	-	-	-	-
		Total		18/20	9	3	2							
Semester-II (Spring)														
1.	HYN-571	Watershed modeling and simulation	PCC	4	2	1	2	2	-	10	30	20	40	-
2.	HYN-562	Irrigation and drainage engineering	PCC	4	3	1	2/2	3	-	25	-	25	50	-
3.	HYN-700	Seminar	SEM	2	-	-	-	-	-	-	-	-	100	-
4.		Programme Elective Course -I	PEC	4	-	-	-	-	-	-	-	-	-	-
5.		Programme Elective Course -II	PEC	4	-	-	-	-	-	-	-	-	-	-
6.		Programme Elective Course-III	PEC	4/2*	-	-	-	-	-	-	-	-	-	-
				22/20	5	2	3							

* Credit requirement for PG Diploma/ Ist year M.Tech is 40 credits. Only one 2 credit elective course is permitted in any of the semesters.

DEPARTMENT OF HYDROLOGY
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **33** **P.G. Diploma/M.Tech. (Watershed Management)**
Department: **HYN** **Hydrology**
Year: **II**

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	**Subject Code**	**Course Title**	**Subject Area**	**Credits**	**L**	**T**	**P**	**Theory**	**Practical**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Semester- I (Autumn)														
1.	HYN-701A	Dissertation Stage–I (to be continued next semester)	DIS	12	-	-	-	-	-	-	-	-	100	-
		Total		12										
Note: Students can take 1 or 2 audit courses as advised by the supervisor, if required.														
Semester-II (Spring)														
1.	HYN-701B	Dissertation Stage–II (contd. From III semester)	DIS	18	-	-	-	-	-	-	-	-	100	-
		Total		18										

Summary				
Semester	1	2	3	4
Semester-wise Total Credits	**18/20**	**22/20**	**12**	**18**
Total Credits	**70**			

Program Elective Courses (Watershed Management)

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
1.	HYN-516	Channel and fluvial hydraulics	PEC	4	3	1	2/2	3	-	25	-	25	50	-
2.	HYN-527	Groundwater hydrology	PEC	4	3	1	2/2	3	-	25	-	25	50	-
3.	HYN-540	Water Resources Economics	PEC	4	3	1	-	3	-	25	-	25	50	-
4.	HYN-513	Hydrometeorology and climate change	PEC	4	3	1	2/2	3	-	25	-	25	50	-
5.	HYN-522	Stochastic hydrology	PEC	4	3	1	-	3	-	25	-	25	50	-
6.	HYN-551	Physical Hydrology	PEC	4	3	1	-	3	-	25	-	25	50	-
7.	HYN-545	Surface Water quality modeling	PEC	4	3	1	-	3	-	25	-	25	50	-
8.	HYN-576	Rural water supply and Sanitation	PEC	2	0	0	-	2	-	25	-	25	50	-
9.	HYN-526	Deterministic hydrology	PEC	4	3	1	-	3	-	25	-	25	50	-
10.	HYN-530	Planning and management of watersheds	PEC	4	3	1	-	3	-	25	-	25	50	-
11.	HYN-532	Environmental planning and assessment of projects	PEC	4	3	1	-	3	-	25	-	25	50	-
12.	HYN-563	Vadose zone hydrology	PEC	4	3	1	2/2	3	-	25	-	25	50	-
13.	HYN-552	Numerical methods in hydrology	PEC	2	2	1/2	-	2	-	25	-	25	50	-
14.	HYN-553	Experimental hydrology	PEC	2	-	-	4	-	3	-	50	-	-	50
15.	HYN-535	Environmental quality	PEC	4	3	1	2/2	3	-	25	-	25	50	-
16.	HYN-554	Soil and Water Remediation	PEC	4	3	1	2/2	3	-	25	-	25	50	-
17.	HYN-555	Soft-computing techniques in hydrology	PEC	2	2	1/2	-	2	-	25	-	25	50	-
18.	HYN-556	Environmental Quality Lab	PEC	2	-	-	4	-	2	-	50	-	-	50

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-511** Course Title: **Hydrologic Elements and Analysis**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7.Subject Area**: PCC**

8. Pre-requisite**: NIL**

9. Objective: To provide necessary background about various hydrological processes, storages, instrumentation, recording of data and analytical techniques.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Hydrological cycle, storage, water balance.	2
2.	**Atmospheric Water System:**Characteristics of Atmosphere, Atmospheric circulation patterns, weather systems, water vapour, precipitable water**.**	4
3.	**Precipitation**: Precipitation types, measurements, analysis, mean precipitation, IDF and DAD analysis.	4
4.	**Hydrologic Abstractions:** Interception and depression storage; Evaporation: Evaporation processes, Influencing factors, measurement and estimation; Evapotranspiration: measurement and estimation; Infiltration: Infiltration processes, factors affecting infiltration, measurement of infiltration, empirical and analytical models of infiltration.	6
5.	**Hydrometry:** Gauge and discharge sites, site suitability, river stage, velocity measurement, area-velocity method, tracer techniques, stage-discharge relation.	5
6.	**Runoff:** Factor affecting, runoff characteristics of stream, hydrograph-unit hydrograph, S-hydrograph, IUH, Clark and Nash IUH;flow duration analysis, flow mass analysis, estimation of peak runoff, time-area method of runoff computation.	10
7.	**Frequency Analysis**: Random variables, Probability distribution functions: normal, log-normal, Gumbel, Pearson type-3 uniform distributions; Frequency analysis; Goodness of fit measures.	4
8.	**Groundwater:** Types of aquifers, Darcy's Law, Flow and storage parameters, well hydraulics.	3
9.	**Flood Routing:** Governing equations, Hydrologic routing: Reservoir flood routing, Muskingum method.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors /Books /Publishers	Year of Publication/ Reprint
1.	Subramanya, K., “Engineering Hydrology”, Tata McGraw Hill	2013
2	Dingman, S.L., Physical Hydrology, 2nd Edition, Prentice Hall.	2008
3.	Todd D.K. and Mays L., “Ground Water Hydrology”, John Wiley & Sons	2005
4.	Mays, L.W., “Water Resources Engineering”, John Wiley & Sons	2001
5.	Hornberger, G.M., Elements of Physical Hydrology, The John Hopkins University Press, Maryland, USA	1998
6.	Singh, V.P., "Elementary Hydrology", Prentice Hall of India	1994
7.	Chow, V.T., Maidment, D.R., and Mays, L., "Applied Hydrology", McGraw-Hill Book Company	1988
8.	Linsley, R.K., Kohler, M.A., and Paulhus, J.L.H., “Hydrology for Engineers”, McGraw Hill	1982
9.	Herschy, R.W.(Ed.), “Hydrometry: Principles and Practices”, Wiley Intersciences	1978
10.	Chow, V.T., “Handbook of Applied Hydrology”, McGraw Hill	1964

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
Name of the Department /Centre: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 512** Course Title: **Computer Programming**

2. Contact Hours: **L: 2** **T: 0** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 2 **Practical** 0

4. Relative Weightage**:** CWS 10 PRS 15 MTE 25 ETE 50 PRE 0

5. Credits**:** 2 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite**:** **Nil**

9. Objective: The objective is to introduce computer programming

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Number System:** Binary and decimal numbers system, integer and floating point representation	6
2.	**Programming Fundamentals:** Principle of object oriented programming, introduction to keywords, identifiers, constants, operators, expressions, type conversions	7
3.	**Conditional and Loop Control Structures:** if, if...else, switch, while and do...while, for loops	5
4.	**Arrays:** Single and multi-dimension arrays, pointers and strings	5
5.	**Functions:** Function prototyping and scope, passing parameters to functions including arrays, values return by functions	5
	Total	**28**

List of Practicals:

i. Development of programs for statistical analysis of hydrological time series viz rainfall, discharge and temperature etc.
ii. Development of programs for randomness and trend analysis of hydrological data.
iii. Development of programs for discharge computations using area-velocity methods, time-area methods etc.
iv. Development of programs for spatial interpolation and areal distribution of hydrological data like rainfall, high frequency groundwater levels etc.
v. Development of program using OOP in C++ for systematic data storage and retrieval for a river catchment.

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Hubbard, S.R., “Schaum's Outline of Programming with C++”, McGraw Hill International.	2005
2.	Krishnamurthy, E.V. and Sen, S.K., " Programming in MATLAB", East-West Press	2003
3.	Schildt, H., “The Complete Reference C++”, Tata McGraw Hill	2001
4.	Stallings, W., “Computer Architecture &Organization”; Prentice Hall Inc.	1998
5.	Lafore, R., “Object Oriented Programming in C++”, Galgotia Publications	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 513** Course Title: **Hydrometeorology and Climate Change**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS **15** PRS **15** MTE **30** ETE **40** PRE **0**

5. Credits**:** **4** 6. Semester**: Both** 7.Subject Area**: PEC**

8. Pre-requisite**:** **Nil**

9. Objective: To introduce the principles of atmospheric science for understanding impact of climate change.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Atmosphere:** General circulation, composition and structure of atmosphere, role of meteorology in hydrology	4
2.	**Precipitation Process**: Adiabatic process, stability and instability of atmosphere	2
3.	**Atmospheric Thermodynamics:** Equation of state, Dalton's of partial pressure, Poisson'slaw, equivalent potential temperature, concept of air parcel, virtual temperature, dry adiabatic lapse rate and saturated adiabatic lapse rate, hydrostatic equilibrium equation, dispersion of air pollutants	6
4.	**Clouds**: Classification, formation and characteristics,Monsoon circulation, monsoon troughs, monsoon depression and tropical cyclones	4
5.	**Climate and Climate Change**: Components, Phenomena, radiative forces, Energy budget and transport, atmospheric circulation, ocean circulation, land-surface process, carbon cycle	6
6.	**Physical processes:**Conservation of momentum, equation of state, temperature equation, continuity equation, conservation of mass	2
7.	**Climate Models:** Introduction to GCM and RCM simulations, SRES, downscaling GCM outputs	6
8.	**ENSO:** El Niño basic, Tropical pacific climatology, El Niño mechanism, ENSO indices, predictions and teleconnections	3
9.	**Greenhouse effects and climate feedbacks:**Global energy model, greenhouse effect and global warming, climate feedback	3
10.	**Climate Model scenarios for global warming:** Greenhouse gases, aerosols forcing, global-average response to GhG warming scenarios on temperature, rainfall, sea, ice/snow, extreme events	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Assessment Report 5, IPCC, WMO	2014
2.	David, J., "Climate change and Climate modelling", Cambridge University Press.	2011
3.	Shelton, ML, "Hydroclimatology", Cambridge University Press.	2009
4.	Singh, V.P. and Rakhecha, P. Book, Applied Hydrometeorology	2009
5.	Cotton R and Pielke RA, Human Impacts on Weather and Climate, Cambridge University Press.	2007
6.	Wallace, J.M. and Hubbs, P.V., "Atmospheric science – An Introductory Survey", Academic Press	1977
7.	Donn , W.,"Meteorology",Mc Graw Hill	1975
8.	Berry I.A., "Handbook of Meteorology", Mc Graw Hill	1973

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 514** Course Title: **Hydrogeology**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits**:** **4** 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite**:** **Nil**

9. Objective: The objective is to introduce the basic geological concepts in occurrence and movement of groundwater.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Hydrogeology and its scope, hydrologic cycle and its relation to groundwater, classification of natural waters, merits and demerits of groundwater age of groundwater, basic geology	4
2.	**Classification of Aquifers:**Hydrological classification of geological materials, types of aquifers, geological formations as aquifers.	4
3.	**Hydraulic properties of aquifers and related materials:** Porosity and its estimation, factors controlling porosity, hydraulic conductivity and methods of its estimation, transmissivity, storativity, specific yield leakage factor, hydraulic resistance and specific capacity.	4
4.	**Occurrence and Movement of Groundwater:**Geological controls in occurrence and movement of groundwater, role of land forms, geological structures, stratigraphic and sedimentation controls, geographic distribution of aquifer materials	4
5.	**Methods of Groundwater Exploration**: Geomorphological and geological techniques, hydrological techniques, remote sensing andits application in groundwater targeting, indicators of groundwater, use of geophysical techniques in pinpointing water well locations	5
6.	**Drilling Techniques:** Methods of shallow well drilling, percussion, hydraulic rotary, reverse rotary and down the hole hammer techniques	3
7.	**Ground Water in Different Geological Formations:**Hydrogeology of crystalline rocks, volcanic rocks, clastic and carbonates rocks and unindurated sedimentary formations, ground water quality in various geological formations.	6

8.	**Preparation of Hydrogeologic Maps:** Geologic andhydrogeologicmaps, field methods of hydrgeological mapping, representation of hydrogeological data on geological maps	4
9.	**Ground Water in Regions of Climatic Extremes:** Occurrence and movement of groundwater in Arid &semi arid regions and in glacial regions, groundwater management and quality in different regions	4
10.	**Hydrogeological Divisions of India:** Groundwater provinces of India and their hydrogeological features, aquifer characteristics and yield of wells, management of groundwater	4
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books / Publisher**	**Year of Publication/ Reprint**
1.	Singhal, B.B.S. and Gupta, R.P., "Applied Hydrogeology of Fractured Rocks", Springer	2010
2.	Fletcher, F.W., "Basic Hydrogeologic Methods", Technomic Publishing Company	1997
3.	Soliman, M. M., La Moreaux, P.E., Memon, B.A. , Assad, F.A. and La Moreaux, J.W., "Environmental Hydrogeology", Lewis Publishers	1998
4.	Karanth, K.R., "Hydrogeology", McGraw Hill	1989
5.	Davis, S. and Dewiest, R.J.M., "Hydrogeology", John Wiley& Sons	1966

INDIAN INSTITUTE OF TECHNOLOGY ROORKE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 516** Course Title: **Channel and Fluvial Hydraulics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**: CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Spring** 7.Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: The objective is to introduce the fundamentals of hydraulics of open channel flow and fluvial hydraulics.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Introduction:**Review of fundamentals of hydraulics, hydrostatics and hydrodynamics	3
2.	**Energy Depth Relationships:** Open channel flow, basic features, uniform flow, critical flow, specific energy, specific energy diagram, flow transitions, momentum principles, hydraulic jumps and computer assisted calculations	8
3.	**Gradually-Varied Flow Theory:**Steady state gradually varied flow, governing differential equation, characteristics and classification; step methods, direct integration method, graphical integration method of water surface profiles, computer oriented algorithms	8
4.	**Unsteady Flow:**Transient gradually varied flow, Saint Venant's equations, simplified hydraulic routing methods- diffusion wave theory, kinematic wave theory, approximate convection–diffusion equations, overland flow theory, computer oriented algorithms	8
5.	**Fluvial Hydraulics:**Introduction, bed forms, incipient condition, sediment load-bed, suspended and total loads, field measurements	8
6.	**Design of Channels:**Regime channels, design of stable channels-critical tractive force approach	4
7.	**Softwares:**Overview of hydraulic modeling softwares	3
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Ranga Raju, K.G., "Flow Through Open Channels", Tata-Mc Graw Hill Publisher Company Ltd.	2009
2.	Subramanya, K., "Flow in Open Channels", Tata-Mc Graw Hill Publisher Company Ltd.	2009
3.	Chanson, H., "The Hydraulics of Open Channel Flow: An Introduction", Elsevier-Butterworth-Heinemann Company	2004
4.	Garde, R.J. and Rangaraju, K.G., "Mechanics of Sediment Transportation and Alluvial Stream Problems", New Age International	2000
5.	Henderson, F.M., "Open Channel Flow", Macmillan Publishing Company, Inc.	1966
6.	Chow, V.T., "Open Channel Hydraulics", Mc Graw Hill	1959

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OFHYDROLOGY**

1. Subject Code: **HY- 518** Course Title: **Water Resources Planning and Management**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**: CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 4 6. Semester**: Both** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: The objective is to introduce the principles of water resources planning and management including engineering and economic aspects.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:**Introduction to water resources planning and management	2
2.	**Reservoir Capacity and Yield:**Finding reservoir capacity and yield using mass curves	3
3.	**Flow-duration Curve:** Determination of flows of various dependabilities using Ranking method and Class interval method	3
4.	**Reservoir Sediment Distribution:** Sediment distribution using empirical area reduction method and area increment method	2
5.	**Conjunctive Water-use Planning:** Combined use of surface and groundwater	3
6.	**Reservoir Operation and Flood Routing:** Reservoir routing using Pul's method for flood control, reservoir operation using SOP and Zoning methods	5
7.	**Integrated River-basin Development:** Interbasin river water transfers - modeling for trans-boundary river basins in India, river water disputes - modeling of various Indian river water disputes using reservoir yield models, environmental aspects of water resources projects	9
8.	**Cost benefit Analysis**: Mathematic of finance**,** discounting technique**;** Financial analysis	5
9.	**Reservoir Planning:**single purpose reservoir and multipurpose reservoir	4
10.	**Software Application:**Use of MIKE – BASIN software and CROPWAT software for planning water resources projects	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Dandekar, M.M., and Sharma, K.N., "Water Power Engineering", Vikas Publishing House	2008
2.	Mays, L.W., "Water Resources Engineering", John Wiley & Sons	2007
3.	Mays, L.W., "Water Resources Sustainability", McGraw Hill	2007
4.	Wood, A.J. and Wollenberg, B.F., "Power Generation, Operation and Control", John Wiley & Sons	2003
5.	Stephenson, D., "Water Resources Management", A.A. Balkema Publishers	2003
6.	Mays, L.W., "Water Resources Handbook", McGraw-Hill	1996
7.	Warnic, C.C., "Hydropower Engineering", Prentice Hall Inc	1984
8.	Goodman, A.S., "Principles of Water Resources Planning", Prentice Hall Inc	1984
9.	James, L.D. and Lee, R.R., "Economics of Water Resources Planning", Mc Graw Hill	1971

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT/CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code **:** **HY - 522** Course Title**: Stochastic Hydrology**

2. Contact Hour: **L:3** **T : 1** **P: 0**

3. Examination Duration (Hrs): **Theory :** **3** **Practical:** **0**

4. Relative Weightage: CWS : **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits : **4** 6. Semester: **Both** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce various probability and stochastic models for the modelling of hydrologic processes and the basic tools required for forecasting, simulation and frequency prediction.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Definition, objectives, components and importance of time series analysis	4
2.	Analysis for trends and periodicityusing non-parametric and parametric tests, peridogram, and, P_{max} and P_{min} test for selection of significant harmonics; spectral analysis,Tests for short term and long term dependence	10
3.	Auto correlation analysis, AR, MA, ARMA, ARIMA models and their application in data generation and forecasting	6
4.	Synthetic data generation for various distributions and their transformations	4
5.	Generation of streamflows usingThomas Fiering models, and other disagreegation and agreegation models, and multisite models Generation of rainfall using transition probability matrix method and multisite models	5
6.	At site, at site regional and regional frequency analysis; graphical and analytical methods for normal lognormal Gumbel GEV and generalized logistic distributions, L moments based methods, Goodness of fit tests like Chi square, K-S test and L moments based tests, Partial duration series, standard error of estimates, Risk analysis	9
7.	Analysis of low flows, forecasting of low and high flows, graphical and analytical methods, models adopted by Central Water Commission	4
Total		**42**

11. Suggested Books:

Sl. No.	Name of Authors/Books/Publisher	Year of Publication
1.	Hosking J. R. M. and Wallis J. R., "Regional Frequency Analysis: An Approach Based on L-Moments", Cambridge UniversityPress	2005
2.	Maidment, D.R., "Handbook of Hydrology", Mc Graw Hill Inc	1993
3.	"Manual on Flood Forecasting", River Management Wing, Central Water Commission, India	1989
4.	Reddy P.J., "Stochastic Hydrology", Laxmi Publications Ltd	1987
5.	Kottegoda N.T., "Stochastic Water Resources Technology", John Wiley & Sons	1980
6.	Salas J.D., Delleur J.W., Yevjevich V. and Lane W.L., "Applied Modeling of Hydrologic Time Series", Water Resources Publications	1980
7.	Haan C.T., "Statistical Methods in Hydrology", The lowa State University Press	1977
8.	Box G. P. and Jenkins G.M., "Time Series Analysis: Forecasting and Control", Holden Day Publisher	1976
9.	Clarke R.T., "Mathematical models in Hydrology", FAO Publication no. 19	1973
10.	Yevjevich, V., "Stochastic Processes in Hydrology", Water Resources Publications	1972

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-523** Course Title: **Surface Water Modeling and Simulation**

2. Contact Hours: **L: 2** **T: 1** **P: 2**

3. Examination Duration (Hrs.): **Theory** **2** **Practical** **4**

4. Relative Weightage**:** CWS **10** PRS **15** MTE **25** ETE **50** PRE **0**

5. Credits**:** **4** 6. Semester**: Spring** 7.Subject Area**:** **PCC**

8. Pre-requisite: **NIL**

9. Objective: The course aims at introducing Surface water modelling tools and techniques

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Hydrologic Simulation overview: Classification of Hydrological Models, Components of Hydrological Simulation Models, System identification, conceptualization, implementation and documentation,	4
2.	Overview of event based models and theoretical background	3
3.	Overview of continuous modelsand theoretical background	3
4.	Numerical solution techniques, parameter optimization, calibration and validation	6
5.	Overview of open source and commercial simulation models for hydrological modelling and forecasting	5
6.	Catchment scale modeling using TOPMODEL; Large scale modeling using VIC Model, Ethics in modeling	7
	Total	**28**

List of Practicals:

i. Hydrological Modelling using open source software like HEC-HMS, HEC-GeoHMS.
ii. Hydrodynamic modelling of River systems using open source softwarelike HEC-RAS, HEC-GeoRASetc.
iii. Hydrodynamic modelling of River systems using licensed software like Mike family software.
iv. Theoretical background of snow-melt runoff modelling including practical using open source software like WINSRM.

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Singh VP, "Computer Models of Watershed Hydrology", Water Resources Publications, Littleton	2012
2.	MIKE 11 Reference and Technical Manuals	2011
3.	HEC-RAS River Analysis System-Reference Manual	2010
4.	Hydrologic Modelling System HEC-HMS-Reference Manual	2010
5.	Gao H et al, Water Budget Record from Variable Infiltration Capacity (VIC) Model Algorithm Theoretical Basis Document, University of Washington	2009
6.	Martinec et al, Snowmelt Runoff Model (SRM) User's Manual	2008
7.	Anderson, M.G., and P.D. Bates. Model Validation: Perspectives in Hydrological Science. John Wiley and Sons Ltd. England.	2001
8.	Beven, K. J. Rainfall-Runoff Modeling: The Primer. John Wiley and Sons, NY.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 525** Course Title: **Systems Analysis and Surface Water Planning**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0

5. Credits**:** 4 6. Semester**: Both** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: The objective of the course is to introduce systems analysis techniques, i.e., linear, dynamic and non-linear programming and simulation of water resources systems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction to Systems Analysis	2
2.	Linear Programming, simplex method, graphical method, dual of linear programming, multipurpose reservoir planning (Single reservoir application, multi reservoir application), reservoir yield model (Complete model, implicit stochastic model)	9
3.	Dynamic programming, Bellman's principle, water allocation to different water users, distribution of canal water to different users	5
4.	Use of uncontrolled inventory DP model for water import, capacity expansion & sequencing, unit commitment,	6
5.	Non-linear programming, unconstrained non linear programming , constrained non linear programming, Kahn-Tucker conditions	5
6.	Reservoir planning - Single reservoir and multi reservoir applications using controlled output DP model and controlled inventory DP model, Multi-objective optimization	8
7.	Simulation techniques, reservoir planning	4
8.	Application of LINDO software to linear programming problems	2
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Simonovic, S. P., "Managing Water Resources: Methods and Tools for a Systems Approach", UNESCO Publishing, France.	2009
2.	Jain, S.K. and Singh, V.P, "Water Resources Systems Planning and Management", Elsevier	2006
3.	Loucks D.P. and van Beek E., "Water Resources Systems Planning and Management", UNESCO Publishing, The Netherlands.	2005
4.	Vedula, S., and Mujumdar, P.P., "Water Resources Systems", Tata Mc Graw Hill	2005
5.	Ravindran, A., "Operations Research Principles and Practice", John Wiley & Sons	2000
6.	Chaturvedi, M.C., "Water Resources System Planning and Management", Tata Mc Graw Hill	1987
7.	Rao, S.S., "Optimization Theory and Practice", Wiley Eastern Ltd	1985
8.	Loucks D.P., "Water Resources System Planning and Analysis", Prentice Hall Inc.	1981
9.	Hall, W.A. and Dracup, J.A., "Water Resources Systems Engineering", Mc Graw Hill	1970
10.	Dantzig, G.B., "Linear Programming and Extensions", Princeton University Press	1963

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 526** Course Title: **Deterministic Hydrology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits**:** **4** 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite: **HY-511 or equivalent**

9. Objective: To introduce the deterministic models for flood analysis and estimation

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Systems Concept**: Nature of systems approach, systems terminology, types of systems:linear, time invariant and time variant systems and nonlinear systems	3
2.	**Hydrological Systems**: The hydrological cycle as a system, unit hydrograph methods, identification of hydrological systems, simulation of hydrological systems	5
3.	**Linear Conceptual Models of Direct Runoff**: Conceptual models such as Nash, Dooge, Clark, Muskingum models; Comparison of conceptual models, generalized linear system models and their limiting forms	8
4.	**Calibration of Conceptual Models**: Use of moment matching, effect of data errors of conceptual models; parsimonious models, parameters optimisation , equi-finality concept in model parameters estimation, model evaluation measures	5
5.	**Physically Based Surface Flow Models**:Overland flow models, channel routing models - multilinear models, simplified hydraulic model, V-catchment model- Top model, basic concepts	5
6.	**Nonlinear Deterministic Models**: Nonlinearity in hydrology, nonlinear black-box models, problem of overland flow, linearization of nonlinear systems using multi-linear systems	4
7.	**Watershed Models:** Necessity for modeling, modeling philosophy, modeling protocol, event based hydrological models, continuous simulation models	3
8.	**Prediction in ungauged basins:** regional data analysis**;** development of relationships between parameters and catchment and flow characteristics, **GIUH and GcIUH**	3
9.	**Design storm and design flood estimation for gauged and ungauged basins-** CWC methods;	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Beven, Keith, "Rainfall Runoff modelling –The Primer" 2nd edition, Wiley- Blackwell	2012
2.	Dooge, J.C.I., and O'Kane, J.P., "Deterministic Methods in Systems Hydrology", A.A. Balkema	2003
3.	Singh, V.P., "Hydrologic Systems; Watershed Modelling Modelling" Vol. II, Prentice Hall	1989
4.	Singh, V.P., "Hydrologic Systems; Rainfall Runoff Modelling", Vol. I, Prentice Hall	1988
5.	Chow, V.T. , "Handbook of Applied Hydrology: A Compendium of Water Resources Technology", McGraw Hill	1964

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 527** Course Title: **Groundwater Hydrology**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS 15 PRS 15 MTE 30 ETE 40 PRE 0

5. Credits**:** 4 6. Semester**: Autumn** 7.Subject Area**: PCC**

8. Pre-requisite: **Nil**

9. Objective: To develop an overall comprehension of principles, methods and practices of well hydraulics & concepts of groundwater management.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Scope of groundwater hydrology and its historical development, aquifer types and properties, compressibility of aquifers, methods of estimation of hydraulic conductivity, anisotropy and heterogeneity of aquifers.	6
2.	Concept of representative elementary volume, Darcy law of groundwater flow in porous media and its validity, continuity equation, Derivation of groundwater flow equation, Dupits theory, Flow in ditches and galleries tapping confined, leaky confined aquifersflow in unconfined aquifers with and without surface recharge, unsaturated flow	10
3.	Steady and unsteady flow into wells, Unsteady radial flow in aquifers, equilibrium and nonequilibrium well pumping equations, analysis of test pumping data of wells tapping confined, semi confined and unconfined aquifers, recovery test, groundwater flow in partially penetrated aquifers, flow near aquifer boundaries, multiple well systems	12
4.	Evaluation of well loss parameters, specific capacity of wells, well development and design,artificialand natural gravel pack wells	4
5.	Groundwater budgeting and assessment, Methods of artificial groundwater recharge, Induced recharge and rain water harvesting, river bank filtration	4
6.	Groundwater quality, seawater intrusion in coastal aquifers and its abatement, Groundwater legislation in India and case histories	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Todd. D.K. and Mays, L.W., "Groundwater Hydrology", John Wiley & Sons	2005
2.	Schwartz, F.W. and Zhang, H., "Fundamentals of Groundwater", John Wiley & Sons	2003
3.	Kruseman, G.P. and Deridder, N.A., "Analysis and Evaluation of Pumping Test Data", ILRI Publication No. 47	1991
4.	Karanth, K.R., "Groundwater, Assessment, Development and Management", MC Graw Hill Publishing Company	1987
5.	Freeze, R.A. and Cherry, J., "Groundwater", Prentice Hall Inc.	1979

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 528** Course Title: **Groundwater Systems Analysis**
2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS 15 PRS 15 MTE 30 ETE 40 PRE 0

5. Credits**:** 4 6. Semester**: Spring** 7.Subject Area**:** **PCC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the basic tools of systems analysis and their role in planning of groundwater development under various conditions and constraints.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Systems Concepts**: System characteristics, component, typesandconstraints, groundwater development, calibration and validation	4
2.	**Linear Programming**: Graphical method, simplex method, big-M method and dual simplex method	6
3.	**Dynamic Programming**: Principal of optimality, recursive equation representation, tabular method, example applications of dynamic programming	6
4.	**Non Linear Programming**: Classical optimization techniques, constrained and unconstrained nonlinear algorithms, Lagrange multiplier method and Kuhn- Tucker conditions	6
5.	**Numerical Modelling of Groundwater Flow**:Review of differential equations, finite difference approach, one-dimensional flow solution using explicit, implicit methods, and Crank-Nicolson method, iterative methods, Thomas algorithm, inverse modeling, stream-aquifer interaction, recent modeling tools, embedded system	10
6.	**Planning of Groundwater Development**: Water balance, assessment of recharge, utilizable recharge, Indian practices, constraints on groundwater development, feasibility check, optimal groundwater developments, planning of groundwater development in canal command areas, planning of groundwater development in coastal aquifers	6
7.	**Groundwater Models**: Overview of existing modeling tools, Introduction to MODFLOW and its application	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Vedula, S., and Mujumdar, P.P., “Water Resources Systems”, Tata Mc Graw Hill	2005
2.	Schwartz, F.W. and Zang, H., “Fundamentals of Ground Water”, John Wiley & Sons	2003
3.	Ravindran, A., “Operations Research Principles and Practice”, John Wiley & Sons	2000
4.	Srinath, L.S, “Linear Programming: Principles and Applications”, Affiliated East –West Press	1982
5.	Wang, J.F., Anderson, M.P., 1982. Introduction to Groundwater Modelling. Freeman, San Francisco, CA: 237 pp	1982
6.	Remson, I., Hornberger, G.M. and Molz, F.J., “Numerical Methods in Subsurface Hydrology”, Wiley-Interscience	1971

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 529** Course Title: **Geophysical Investigations**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** CWS **15** PRS **15** MTE **30** ETE **40** PRE **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7.Subject Area**:** **PCC**

8. Pre-requisite: **Nil**

9. Objective: To impart knowledge of geophysical techniques in groundwater exploration.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Overview of geophysical techniques and their application in groundwater exploration	3
2.	Electrical resistivity methods for groundwater investigation; Principles, electric-potential distribution in homogenous half space; Apparent resistivity for common electrode configurations, current flow in horizontally stratified earth, Vertical electrical sounding; Electrical resistivity profiling and tomography; Inversion of Wenner and Schlumberger apparent resistivity field data by partial curve matching and Direct methods, correlation of interpreted resistivity data with local geology, summation of resistivity in geoelectric section, Dar Zarrouk parameters; Estimation of Transmissivity and Hydraulic conductivity from resistivity data	14
3.	Very low frequency (VLF), Ground penetration radar (GPR) methodsin groundwater exploration, use of TDEM method in groundwater exploration	8
4.	Induced polarisationmethod and its application in groundwater exploration of sandy zones in alluvial regions	3
5.	Seismic refraction method for evaluation of bedrock investigation; Applications in groundwater prospecting and limitations	4
6.	Magnetic and gravity methods in groundwater targetting, applications and their limitations	3
7.	Geophysical well logging and its applications in evaluation of aquifers,normal and lateral resistivity logs, self potential logs, natural	5

	gamma log, neutron gamma log, miscellaneous logs, estimation of aquifer properties and groundwater quality from geophysical logs	
8.	Case studies	2
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books / Publisher**	**Year of Publication/ Reprint**
1.	Zhdanov, M.S., "Geophysical electromagnetic theory and methods" Elsevier	2009
2.	Nath, S.K., Patra, H.P. and Shahid, S., "Geophysical Prospecting for Groundwater", Oxford & IBH Publishing Company	2000
3.	Parasnis, D.S., "Principles of Applied Geophysics",Chapman & Hall	1997
4.	Bhattacharya, P.K and Patra, H.P. "Direct Current Geoelectric Sounding: Principles and Interpretation", Elsevier	1968
5.	Keller, G.V. and Frischkhnechdt, F.C., "Electrical Methods in Geophysical Prospecting", PergamonPress	1966
6.	Lynch, E.J., "Formation Evaluation", Harper & Row	1962

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-530** Course Title: **Planning and Management of Watersheds**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0
4. Relative Weightage**:** CWS **25** PRS **0** MTE 25 ETE **50** PRE **0**
5. Credits**:** **4** 6. Semester**: Both** 7.Subject Area**:** **PEC**
8. Pre-requisite**: Nil**
9. Objective: To impart knowledge about planning of watershed projects using system concepts and economic aspects.
10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:**Principles of watershed management, objectives of planning watershed projects, watershed delineation, determination of priority critical areas, hydrological soil survey, land use survey and land suitability analysis, concepts of land use planning	4
2.	**Systems Concepts:** System component and constraints	2
3.	**Linear Programming:** Graphical method, simplex method, duality and dual simplex method	8
4.	**Nonlinear programming:** Classical optimization techniques, constrained and unconstrained nonlinear algorithms, Lagrange's function, Kuhn- Tucker conditions	6
5.	**Dynamic Programming:** Principal of optimality recursive equation representation, tabular method, water allocation to different water users	6
6.	**Economic Aspects:** Basic frame work of economic analysis, steps in economic analysis, discounting factors and discounting techniques; Project economics–pattern of financing and credit and economic evaluation	6
7.	**Multiple Use Concept:** Watershed resources management with multiple use concept	2
8.	**Modelling and Simulation Techniques:** Model taxonomy, model formulation, watershed simulation models, concept of integrated watershed modeling	6
9.	**Watershed Monitoring**: Watershed monitoring and impact evaluation	2
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors /Books /Publishers	Year of Publication/ Reprint
1.	Vedula, S., and Mujumdar, P.P., “Water Resources Systems”, Tata Mc Graw Hill	2005
2.	Ravindran, A., “Operations Research Principles and Practice”, John Wiley & Sons	2000
3.	Chaturvedi, M.C., “Water Resources System Planning and Management”, Tata Mc Graw Hill	1987
4.	Vajda, S., “Theory of Linear and Non-linear Programming”, Longman	1974
5.	Hall, W.A. and Dracup, J.A., “Water Resources Systems Engineering”, Mc Graw Hill	1970
6.	Dantzig, G.B., “Linear Programming and Extensions”, Princeton University Press, Princeton	1963

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 531** Course Title: **Watershed Behavior and Conservation Practices**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7.Subject Area**:** **PCC**

8. Pre-requisite: **Nil**

9. Objective: To understand the impact of land use changes on various hydrological cycle components, estimation of peak runoff, soil erosion, its measurement and control measures.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Physical elements of a watershed, effects of land use changes on hydrological cycle components	3
2.	Concept of vegetative management of water yield and quality; Ecosystem Services: Benefits to Human Societies	3
3.	Natural and Human-induced watershed changes: Agents of watershed changes; Climate change effects	4
4.	Watershed planning, monitoring and assessment, Watershed experiments, extrapolation of results from representative and experimental basins, regional studies; Natural resource inventories	4
5.	Estimation of Runoff using SCS and Rational Method suggested for Indian conditions	3
6.	Land capability classification	2
7.	Watershed development in India, Common Guidelines 2008, Institutional arrangements at National, State, District, Project and Village level, Allocation of funds, case studies; Corporate Social Responsibility (CSR)	4
8.	Watershed management - experiences and challenges; Role of socio-economic drivers	3
9.	Water erosion process, factors affecting erosion, types of erosion, assessment of erosion, universal soil loss equation, control measures for erosion, temporary and permanent measures	6
10.	Wind erosion and its assessment, vegetative and mechanical control measures	4

11.	Special Topics: Wetland systems, watershed consideration in engineering applications, Water harvesting techniques, elements, development of modern harvesting techniques; Watershed Ecology	6
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books / Publisher**	**Year of Publication/ Reprint**
1.	Brooks,K.N., P.F.Ffolliott, andJ.A.Magner."Hydrology and theManagement of Watersheds",4th edition.Ames, Iowa:Wiley Blackwell.	2012
2.	Krishnaswamy, J., Lele, S., Jayakumar, R., "Hydrology and watershed services in the Western Ghats, India.". Tata McGraw-Hill, New Delhi.	2006
3.	Paul DeBarry, "Watersheds: Processes, Assessment and Management", John Wiley andSons, New York, NY	2004
4.	Frevert, R.K., Schwab, G.O., Edminster, T.W. and Barnes, K.K., "Soil and Water Conservation Practices", John Wiley & Sons	2003
5.	Tideman E.M. Watershed Management–Guidelines for Indian Conditions, Omega Scientific Publishers, New Delhi	1999
6.	F.A.O. Conservation Guide No.l."Guidelines for Watershed Management",	1990
7.	Lee, R., "Forest Hydrology", Columbia University Press	1977

INDIAN INSTITUUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT. /CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-532** Course Title: **Environment Planning & Assessment of Projects**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs) **Theory** 3 **Practical** 0

4. Relative Weightage: CWS **25** PRS **0** MTE 25 ETE **50** PRE **0**

5. Credits: 4 6. Semester: **Spring** 7. Subject Area**:** **PCC**

8. Pre-requisite: **Nil**

9. Objective: The course aims at developing understanding of the basic principles of planning and assessment in respect of field projects without endangering the environment and ecosystems.

10. Details of Course:

S. No	**Contents**	**Contact Hours**
1.	Environment components and communities, concepts of integrative level and environmental planning, projection of human population growth and related demands; Type of projects, propelling issues and problem definition in planning,	6
2.	Description of environmental setting and indicators, assessments of physical environment; Geologic, hydrologic, climate and ecological considerations, Biogeochemical cycles and biodiversity resources and their classification, equitable use and conservation	6
3.	International and national legislation on environmental planning and assessment of projects; Introduction to various acts (Water, Air, Land and Wild Life), network and role of agencies involved at various stages of planning and implementation	5
4.	Assessment of natural and manmade hazards, Air, water and soil pollution: sources and impacts, vulnerability analysis, carrying capacity analysis, water and ecological footprint: concepts and assessment, environmental flows	8
5.	Environmental modeling and simulation process, prediction and scenario projection, introduction of appropriate air and water pollution models	6
6.	Impact assessment frameworks and methodologies, decision support prespective, conflict resolution, mitigation of hazards	6
7.	Case studies related to environmental planning and assessment of major projects	5
	Total	**42**

11. Suggested Books:

S. No	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Jorgensen, S.E.,"Introduction to Systems Ecology", CRC	2012
2.	Philippe Quevauviller et al., "The Water Framework Directive: Action programmes and adaptation to climate change", RSC	2011
3.	Hoekstra, A. Y. and A.K. Chapagain, "Globalization of Water: Sharing the planet's freshwater resources", Blackwell	2009
4.	Eccleston, C..H., "NEPA and Environmental Planning' , CRC	2008
5.	Adolf, E. and Vili, T.D., "Air water and Soil Quality Modelling for Risk and Impact Assessment", Springer	2007
6.	Edward J.K, "Concepts of Ecology", 4th Ed. Pearson Education	2007
7.	Lein J.K, "Integrated Environmental Planning", Blackwell Publishing	2003
8.	Robert, L.F., (Ed), "Handbook of Water Sensitive Planning and Design", CRC Press	2002
9.	Liu, D.H.F., Liptal, B.G. and Boris, P.A "Environmental Engineer's Handbook", Lewis Publishers	1997
10.	Canter, L.W., "Environmental Impact Assessment", McGraw Hill	1996
11.	Odum E.P., "Ecology", Oxford & IBH Publishing Company	1975
12.	Acts, Rules, Guidelines available from various National and International agencies (and their subsequent amendments)	Various

INDIAN INSTITUUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-535** Course Title : **Environmental Quality**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs) **Theory** 3 **Practical** 0

4. Relative Weightage: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0

5. Credits: 4 6. Semester: **Autumn** 7. Subject Area**:** **PCC**

8. Pre-requisite: **Nil**

9. Objective: The course aims to provide basic background for understanding the atmospheric, aquatic and terrestrial environment characteristics and skills for assessment of their quality.

10. Details of Course:

S. No	Contents	Contact Hours
1.	Overview of Environment, components of environment and their interaction, source and uses of water.	2
2.	Concepts from water, soil and air pollution chemistry, Microbiology and ecology, solution, electroneutrality, equilibrium, reaction kinetics, microbes in aquatic/terrestrial systems, types and functions, aquatic and terrestrial ecosystems.	8
3.	Introduction to water, soil and air quality concepts, impurities and quality characterization, physical, chemical and biological parameters, Soil and water quality issues, transport and transformation processes in surface and groundwater systems	8
4.	Introduction to analytical methods and instruments, field sampling methods, storage and preservation of samples, analytical estimation, analytical quality control and error analysis modeling concepts	10
5.	Mandates and existing monitoring networks of field surface and groundwater organizations, design and review of monitoring networks, evaluation and rationalization of networks, case studies.	5
6.	Analysis and interpretation of quality data, concepts of statistical techniques for data analysis, analysis for correlations, variability trends, violations, reporting and graphical presentation	6
7.	Legislation and management in environment quality, water and air quality criteria and standards, national and international perspective.	3
	Total	**42**

List of Practicals:

i. Concepts and methods of Gravimetric analysis, Measurement of Total Solids, Total Dissolved Solids, Total Suspended Solids, Measurement of Sulphates and Oil and Grease.
ii. Concepts and methods of Electrometric analysis, Measurement of EC, Types of sensors and their application in measurement of Fluoride, Nitrate and Dissolved Oxygen.
iii. Concepts and methods of Volumetric and optical analysis, Measurement of Total Alkalinity, Hardness and its constituents and Chloride, Measurement of Turbidity and Phosphates
iv. Measurement of Organics viz, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC)
v. Introduction to advanced instruments viz. Ion Chromatograph, Gas Chromatograph, Voltammeter

11. Suggested Books:

S. No	**Name Authors/Books/Publisher**	**Year of Publication/ Reprint**
1.	Ahuja S., "Monitoring Water Quality: Pollution Assessment, Analysis, and Remediation", Elsevier	2013
2.	Li Y., Migliaccio K., "Water Quality Concepts, Sampling, and Analyses", CRC Press	2010
3.	Kim, Y.J and Platt, U., "Advanced Environmental Monitoring",	2008
4.	Masters, G.M., "Introduction to Environmental Science and Engineering', Pearson Education	2007
5.	"Standard Methods for Water & Wastewater Analysis" 21st Edition, APHA	2005
6.	Crompton, T.R., 'Soil Analysis: Handbook for Reference Methods", CRC Press	2000
7.	Chapman, D., "Water Quality Assessment", 2nd Edition, Imprint of Chapman & Hall	1992
8.	Sawyer, C.N., and McCarty, P.L. "Chemistry for Environmental Engineering', 3rd Edition, McGraw Hill	1987
9.	Lloyd, J.W. and J.A. Heathcote, " Natural Inorganic Hydrogeochemistry in relation to Groundwater", Clarendon press, Oxford	1985
10.	Mathess, G., "The properties of Groundwater", John Wiley & sons	1982
11.	Acts, guidelines, standards as published by National and International agencies (and subsequent amendments)	Various

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 537** Course Title: **Remote Sensing and GIS Applications in Hydrology**

2. Contact Hours: **L: 3** **T: 1** **P: 2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** CWS **10** PRS **15** MTE **25** ETE **50** PRE **0**

5. Credits**:** **4** 6. Semester**: Autumn** 7.Subject Area**:** **PCC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the fundamentals of Remote Sensing and geographical information systems (GIS) and their applications in hydrology.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Principal of Remote Sensing**: Definition, active and passive remote sensing, aerial and space platforms	2
2.	**Electromagnetic Radiation**: EMR interaction with atmosphere, atmospheric windows and their significance, interaction with earth surface materials, specular and diffuse reflection surfaces, spectral reflectance curves and spectral signature, spectral reflectance curves of water, soil and vegetation	8
3.	**Satellite Programs and Sensors:** Classification, description of multi spectral scanning – along and across track scanners satellite sensors , resolution types, description of sensors in Landsat, SPOT, IRS series	4
4.	**Satellite Image Interpretations:** Basic principles of image interpretation, visual interpretation, elements of image interpretation, digital image processing, supervised and unsupervised classification	6
5.	**Introduction to GIS**: Components, data types – spatial, attribute and metadata, raster and vector data and their comparison, data abstraction, maps and map scale	3
6.	**Coordinate System:** Datum, geographical coordinate system, projected coordinate system and their need, basic projection types, polyconic and UTM projections	4
7.	**Data Input and Editing:** Raster and vector data formats, georeferencing, data input using scanner and on-screen digitization, input using XY data, data editing, attribute data	2
8.	**Basic Analysis:** Union, Intersection, clip, merge, append, map algebra	2
9.	**Spatial Analysis**: Reclassification, overlaying, buffering, unions, intersections; DEM, DEM analysis, contour and cut-fill analysis, process modeling using GIS, IDW, spline and kriging, interpolation	4

	techniques	
10.	**GPS and KML:**Introduction to global positioning system and KML format	2
11.	**Remote Sensing and GIS Applications:** LULC Classification,flood plain mapping and zoning, ground water studies, erosion sedimentation studies, watershed and drainage delineation	5
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books / Publisher**	**Year of Publication/ Reprint**
1.	Lillesand, T.M. and Kieffer, "Remote Sensing and Image Interpretation", - 6th Reprint, Joh Wiley and Sons	2012
2.	Chang, K, "Introduction to Geographical Systems", 4th Edition, Tata McGraw-Hill	2010
3.	DeMers, M.N., "Fundamentals of Geographical Information Systems", 3rd Edition, John Wiley & Sons	2009
4.	Schowengerdt, R.A., "Remote Sensing Models and Methods for Image Processing", 3rd Edition, Academic Press	2007
5.	Jensen, J.R., "Introductory Digital Image Processing: A Remote Sensing Perspective", 2nd Edition. Prentice Hall	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code : HY - **538** Course Title: **Hydrological Data Collection, Processing and Analysis**

2. Contact Hours : **L:3** **T : 1** **P: 2/2**

3. Examination Duration (Hrs) : **Theory :** 3 **Practical:** 0

4. Relative Weightage: CWS 15 PRS 15 MTE 30 ETE 40 PRE 0

5. Credits: 4 6. Semester**:** **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: The objective is to present the details of various methods for hydro-meteorological data collection, processing and analysis**.**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Types of hydro-meteorological data and their importance, time oriented, space oriented and relational data	3
2.	Observation of hydro-meteorological data - rainfall, temperature, evaporation, discharge and other parameters, observational and instrumental errors and quality control	4
3.	Storage, transmission and retrieval of data, different formats adopted by IMD, CWC and WMO	2
4.	Design and optimization of monitoring systems for rainfall, evaporation, gauge and discharge networks and groundwater data monitoring stations	4
5.	Simple and multiple linear and non-linear regression; hypothesis testing	4
6.	Estimation of missing data in rainfall, runoff and other parameters, record extension for rainfall and runoff data, interpolation and Kriging techniques, statistical rainfall- runoff models	5
7.	Development of stage discharge curves using graphical, physical and analytical methods for various types of streams	3
8.	Automatic weather stations, types, data storage and retrieval, automatic water level recorders, types, data storage,retrieval and analysis	3
9.	Analysis of randomness and trends in hydro-meteorological data; Computation of statistical parameters and standards errors, components of time series, concepts of short and long term dependence in hydro-meteorological data	5
10.	Estimation of extremes using frequency analysis; Graphical and analytical methods for normal, lognormal and Gumbel distributions	4
11.	Open sources of data and software assisted processing	5
Total		**42**

List of Practical:

i. Observation of rainfall, temperature and evaporation.
ii. Observation of groundwater levels in observatory.
iii. Observation of gauge and discharge in lab/field.
iv. Demonstration of hydrological processes using Total Hydrologic Station.
v. Measurement of infiltration rates.

11. Suggested Books:

S. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Subramanya K., "Engineering Hydrology", Tata McGraw Hill Ltd.	2008
2.	Viessman W. and Lewis G. L., "Introduction to Hydrology", Pearson Education	2007
3.	Hornberger G. M., Raffensperger J. P., Woberg P. L and Eshleman K. N., "Elements of Physical Hydrology", The Johns Hopkins University Press	1998
4.	Gupta R.S., "Hydrology and Hydraulic Systems", Prentice Hall	1997
5.	Singh V. P., "Elementary Hydrology", Prentice-Hall of India Private Ltd.	1994
6.	Maidment, D.R., "Handbook of Hydrology", McGraw Hill Inc.	1993
7.	Chow V. T., Maidment D. R. and Mays L. W., "Applied Hydrology", McGraw-Hill	1988
8.	Kottegoda N.T., "Stochastic Water Resources Technology", John Wiley & Sons	1980

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 539** Course Title: **Isotope Hydrology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS 15 PRS 15 MTE 30 ETE 40 PRE 0

5. Credits**:** 4 6. Semester**: Both** 7.Subject Area**: PEC**

8. Pre-requisite: **Nil**

9. Objective: This course discusses the basic concepts of Isotopes, principles of their detection and related instruments and their applications in hydrology.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Isotopes, their classifications and characteristics, law of radioactivity and radio isotopes and basic principles of absorption and scattering of alpha and beta particles, gamma rays and neutrons	6
2.	Principles of detection of radioactive and stable isotopes and related instruments	4
3.	Environmental isotopes and their variations in nature	5
4.	Isotope applications to hydrology; Isotopes as tracers for surface water and ground water studies	7
5.	Isotopes as sealed sources for soil moisture variation, recharge to ground water, snow melt equivalent and suspended sediment concentration studies	6
6.	Sediment and ground water dating technique for studying sedimentation in water bodies and dynamics of surface and ground water bodies	8
7.	Use of isotopes for study of interrelation of hydrologic elements and interconnection of water bodies	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	"Guide Book on Nuclear Techniques in Hydrology", IAEA, Vienna, Austria Technical Report Series No. 91	2000
2.	"Stable Isotope Hydrology, Deuterium and Oxygen- 18 in Water Cycle", IAEA, Vienna, Austria, Technical report series no. 210	2000
3.	Mazor, E., "Chemical and Isotopic Groundwater Hydrology",2nd Edition. Marcel Dekker Inc.	1997
4.	Clark, I. And Fritz. P, "Environmental Isotopes in Hydrogeology", Lewis Publishers	1997
5.	Fritz, P. and Fontes, J. Ch (Editors), "Handbook of Applied Isotope Hydrogeochemistry; The Marine Environment" Vol. 3., Elselvier	1989
6.	Hoefs, J., "Stable Isotope Geochemistry", 3rd Edition Springer-Verlag.	1987
7.	Fritz, P. andFontes, J. Ch (Editors), "Handbook of Applied Isotope Hydrogeochemistry; The Terrestrial Environment", Vol 2. Elselvier	1986
8.	Faure, G., "Principles of Isotope Geology", 2nd edition, Wiley Publishers.	1986
9.	Fritz, P. and Fontes, J. Ch (Editors), "Handbook of Applied Isotope Hydrogeochemistry". Vol. 1. Elselvier	1980

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Hydrology**

1. Subject Code: **HY- 540** Course Title: **Water Resources Economics**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS 25 PRS 0 MTE 25 ETE 50 PRE 0

5. Credits**:** 4 6. Semester**: Both** 7. Subject Area**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the concepts of water resources economics for optimal design of water resource projects.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Project evaluation, Benfit-cost measurement; Discounting factors: single payment factor, uniform annual series factors, uniform gradient series etc.	4
2.	**Discounting Techniques:** Present worth, annual cost, cost benefit ratio and internal rate of return methods	4
3.	**Cost Estimation:** Investigation cost, project cost	2
4.	**Economic Planning of Project Purpose:** Irrigation benefit at farmers level and at project level, hydropower benefits using alternate cost method, benefits from floods control measures (crops and urban floods)	8
5.	**Graphical Optimization:** Cost-benefit, marginal analysis.	3
6.	**Systems Applications:** Basics of linear programming, basics of dynamic programming.	6
7.	**Multiobjective and Multipurpose Analysis:** Weighing method, method of constraints, goal programming, surrogate worth trade-off method	7
8.	**Economic and Financial Analysis:** Economic feasibility**,** financial feasibility, cost allocation to different water uses in a multipurpose reservoir	4
9.	**Case Studies:** Single purpose projects, multi purpose projects	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Jeffrey J., Jack H. and Jeffrey M., "Water Resources Economics: Theory, Institutions and Applications", Routledge Publishers	2010
2.	Griffin, R.C., "Water Resources Economics: The Analysis of Scarcity", Policies and Projects, The MIT Press	2006
3.	Stephen M., "Introduction to the Economics of Water Resources: An International Perspective", Rowman and Littltfield, Inc.	1997
4.	Goodman, A.S., "Principles of Water Resources Planning", Prentice Hall Inc.	1984
5.	Warnic, C.C., "Hydropower Engineering", Prentice Hall Inc.	1984
6.	James, L.D. and Lee, R.R., "Water Resources Economics", McGraw Hill, Inc.	1971

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 542** Course Title: **Urban Hydrology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS 25 PRS 0 MTE 25 ETE 50 PRE 0

5. Credits**:** 4 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite: **Nil**

9. Objective: To study the process of urbanization and its influence on urban hydrological processes and urban water supply system including, storm water modeling.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Urbanization process, urban planning, landuse/landcover changes, hydrological impacts of urbanization	5
2.	Urban hydrologic cycle and processes, rainfall analysis, IDF Curves and design storm computation,	8
3.	Urban runoff computations; Abstractions, Rational Method, Computation of overland flow at design point, empirical methods, SCS method, time-area and unit hydrograph approaches, Stream flow routing	8
4.	Guidelines for the design of Urban drain and other structure	6
5.	Storages inside urban areas, storm run-off, piped and open channel drainage, mixed transport of storm and waste water	3
6.	Urban water supply; Estimate of demand, sources of surface and ground water, potable water quality	4
7.	Urban flood modelling using urban hydrologic models namely SWMM and MOUSE	6
8.	Rain water harvesting	2
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Iyyer, M.J., "Urban Water Supply and Sanitation A Management Perspective", ICFAI University Press	2008
2.	Shamsi, U.M., "GIS Applications for Water, Wastewater, and Stormwater Systems", CRC Press	2005
3.	Debo,T.N and Reese, A., "Municipal Stormwater Management", 2nd Edition, CRC Press	2002
4.	Twort, A.C. and Ratnayaka, D.D., "Water Supply", 5th Edition, Butterworth-Heinemann	2001
5.	James, W., "Advances in Modeling the Management of Stormwater Impacts", CRC Press	1997
6.	Akan, O.S., "Urban Stormwater Hydrology", CRC Press	1993
7.	Chow, V.T., "Applied Hydrology", Mc Graw Hill	1988
8.	Lazaro, T.R. "Urban Hydrology: A Multidisciplinary Perspective", Ann Arbor Science Publishers Inc.	1979

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code : **HY-543** Course Title: **Flood Forecasting**

2. Contact Hours : **L: 3** **T : 1** **P: 0**

3. Examination Duration (Hrs) : **Theory :** 3 **Practical:** 0

4. Relative Weightage**:** CWS 25 PRS 0 MTE 25 ETE 50 PRE 0

5. Credits : 4 6. Semester: **Both** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the details of various methods of flood estimation, forecasting and control.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Definitions, objectives and importance of flood estimation and real time forecasting; Classification of hydrological forecasts	3
2.	Flood estimation and forecasting methods, statistical and deterministic approaches, basic concepts and formulations	4
3.	Monitoring networks;Site selection and installation of instruments, river monitoring and raingauge networks design, automatic weather stations and G and D station; Data transmission	4
4.	Meteorological forecasting and quantitative precipitation forecasting	5
5.	Graphical and statistical models for flood forecasting adopted by CWC and other operational models; Case studies	6
6.	Unit hydrograph and Soil conservation service – curve number based deterministic models for flood forecasting; Autoregrenive (AR), Moving Average (MA), Autoregrenive moving average (ARMA) models: basic concepts, formulations and updating of parameters using adaptive filter models	6
7.	Physically based models for flood forecasting;Fundamentals and overview of operational models, Choice of appropriate methods or models for flood forecasting	6
8.	Calibration and validation of forecasts, dissemination of forecast, Early warning system	4
9.	Potential applications from emerging technologies	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/Books/Publisher	Year of Publication/ Reprint
1.	Manual on flood forecasting and warning- WMO publication no. 1072	2011
2.	Montgomery, D.C., Jennings, C.L. and Kulahci M., "Introduction to Time Series Analysis and Forecasting", John Wiley & Sons	2008
3.	Abraham, B. and Ledolter, J., "Statistical Methods for Forecasting", John Wiley & Sons	2005
4.	Maidment, D.R., "Handbook of Hydrology", McGraw Hill	1993
5.	"Manual on Flood Forecasting, River Management Wing", Central Water Commission, India	1989
6.	"Manual on Flood Forecasting, Central Flood Forecasting Organisation", Central Water Commission, India	1980
7.	Kottegoda N.T., "Stochastic Water Resources Technology", John Wiley & Sons	1980
8.	"Hydrological Forecasting Practices, Operational Hydrology", World Meteorological Organization, Report No. 6	1975

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 544** Course Title: **Hydrogeology of Hard Rocks**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0

5. Credits**:** 4 6. Semester**: Both** 7.Subject Area**: PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce principles of groundwater occurrence & movement in fractured heterogeneous geological formations.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Geographical distribution of consolidated geological formations in India	2
2.	Groundwater occurrence in crystalline rocks, hydraulic properties of fractured rock formations, porosity and hydraulic conductivity, Darcy law and Cubic law, groundwater flow in fractured rocks, flow models	6
3.	Hydrogeology of volcanic rocks and karstic formations, development of lava vesicles and nature of groundwater flow, development of cavernous zones in carbonate rocks and groundwater movement, hydraulic parameters of volcanic and karstic aquifers.	3
4.	Estimation of hydraulic parameters of fractured aquifers-relationship of permeability with depth, slug tests; interpretation of pumping test data of wells; fractured anisotropic aquifers, Equivalent porous medium models, double porosity models and discrete fracture models, Streltsova –Adams method and Warren and Roots method of interpretation of pumping test data	8
5.	Interpretation of pumping test data of large diameter wells in hard rocks,Papadopulousand Cooper method, and Boulton&Strelsova method	6
6.	Estimation of well characteristics by Jacob and Rorabaugh methods, step draw down tests;Evaluation of minimum spacing of wells by different approaches	5

7.	Groundwater assessment in hardrock areas; Evaluation of rainfall recharge and CGWB methodology of groundwater resources estimation,its limitations; stage of groundwater development	3
8.	Quality of groundwater in fractured crystalline and karstic aquifers, rock-water interaction and implications for groundwater geochemistry	3
9.	Artificial groundwater recharge in fractured aquifers, applicability of various methods of managed aquifer recharge, rainwater harvesting	3
10.	Groundwater legislation and implications in implementation, case studies	3
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books / Publisher**	**Year of Publication/ Reprint**
1.	Singhal, B.B.S., and Gupta, R.P., "Applied Hydrogeology of Fractured Rocks", Springer	2010
2.	Ahmed, S., Jayakumar, R. and Salih, A. (Eds.) "Groundwater Dynamics in Hardrock Aquifers", Capital Publishing Company	2007
3.	Kruseman, G.P., & Deridder, N.A., "Analysis and Evaluation of Pumping Test Data", 2nd Edition, ILRI Publication No. 47	1990
4.	Freeze, R.A.,and Cherry, J., "Groundwater", Prentice Hall Inc	1979

INDIAN INSTITUUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-545** Course Title : **Surface Water Quality Modeling**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs) **Theory** **3** **Practical** **0**

4. Relative Weightage: CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits: **4** 6. Semester: **Both** 7. Subject Area**:** **PEC**

8. Pre-requisite: **Nil**

9. Objective: The objective is to provide basic understanding of the transport and fate of contaminants and relationships of various processes in the surface water environment

10. Details of Course:

S. No	Contents	Contact Hours
1.	**Review of Water Quality:** Concept, Characterization and assessment, water quality issues in surface and groundwater bodies, monitoring and analysis protocol	5
2.	**Modeling:** Concept and process, Classification of models, selection of models, spatial and temporal resolution	3
3.	**Mathematical framework and solution techniques:** Overview of differential/ partial differential equations, analytical and numerical solutions, error and sensitivity analysis	4
4.	**Hydrodynamic Processes and Parameters in Surface and Groundwater Bodies:** Conservations laws, advection and dispersion, mass balance equation, governing equations in Cartesian and curvilinear coordinates, initial and boundary conditions	6
5	**Fate and transport of pollutants in aquatic environment:** Point and nonpoint sources of pollutants, sedimentation, degradation, decay, sorption processes and their kinetics, processes and governing equations for water quality variables (dissolved oxygen, biochemical oxygen demand, pathogens nutrients and algae etc.)	6
6	**Data Concerns:** Model needs, review of available monitoring networks, design of new networks, rationalization, field collection, storage and transportation of samples	4
7.	**Available Water Quality Models:** Introduction to QUAL2E, AWSP, AGNPS etc: Model frame work, process equations, solution techniques, boundary conditions, data formats, calibration and validation schedule, error analysis, TMDL concept and application, case studies	10

8.	**Water Quality Management:** Systems engineering concepts design of experiments, available methods, application to the polluted environment	4
	Total	**42**

11. Suggested Books:

S. No	**Name of Authors/Books/ Publisher**	**Year of Publication Reprint**
1.	Chin, D.A.,"Water Quality Engineering in Natural Systems: Fate and Transport processes in the water environment", Wiley	2012
2.	Zhen-Gang Ji, "Hydro-dynamics and Water Quality: Modeling Rivers, Lakes, Estuaries", John Wiley & Sons	2008
3.	Novonty, V., "Water Quality: Diffuse Pollution and watershed Management" , John Wiley & Sons	2003
4.	Wu Seng Lung, "Water Quality Modeling for Wasteload Allocation and TMDLs", John Wiley & Sons	2001
5.	Chapra, S. C., "Surface Water Quality Modeling", McGraw Hill	1997
6.	Thomann, R.V. and Mueller, "Principles of Surface Water Quality Modelling and Control", Prentice Hall	1997
7.	James A., "An Introduction to Water Quality Modelling", 2nd Edition, John Wiley & Sons	1993
8.	Jorgensen, S.E "Application of Ecological Modelling in Environmental Management", Part A & B, Elsevier	1983

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 546** Course Title: **Hydroinformatics**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS 15 PRS 10 MTE 25 ETE 50 PRE 0

5. Credits**:** 4 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite: **Computer Programming at UG or equivalent**

9. Objective: The course aims at introducing emerging techniques and tools developed in information and communication technology field to solve hydrological problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction to hydroinformatics and overview of emerging techniques	3
2.	Introduction to basics of Programing	8
3.	HTML, XML, Internet and their use for information display	4
4.	Databases design and connectivity	5
5.	Introduction to information systems, decision support system, spatial decision support systems, web-based information system, expert systems	6
6.	Data mining, artificial neural networks and their application in hydrology	6
7.	Introduction to fuzzy logic and applications	5
8.	Application of ANN and fuzzy logic using software like MATLAB	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Ross, T.J., "Fuzzy Logic with Engineering Application", 2nd Edition, John Wiley & Sons	2004
2.	Mallach, E.G., "Decision Support System and Data Warehouses Systems", Tata McGraw Hill	2000
3.	Witten, I.H., and Frank E, "Data Mining", Morgan Kaufmann Publishers	2000
4.	Waterman, D.A., "A Guide to Expert Systems", Addision-Wesley Longman Inc.	1999
5.	Babovic, V and Larsem, L.C., "Hydroinformatics '98", AA Balkema	1998
6.	Rao, V.B. and Rao, H.V., "Neural Network and Fuzzy Logic", BPB Publications	1996
7.	Fu, L., "Neural Networks and Fuzy Logic", Mc Graw-Hill Inc	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
Name of the Department /Centre: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 551** Course Title: **Physical Hydrology**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS 25 PRS 0 MTE 25 ETE 50 PRE 0

5. Credits**:** 4 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite**: NIL**

9. Objective: **To explain the theoretical basis and modelling of hydrological processes**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Introduction to Hydrologic Science: Hydrology, a distinct geo- science; The global hydrologic cycle; Multidisciplinary hydrology and its relation to other geosciences	4
2.	**Earth's Energy Budget:** Surface radiation distribution; Elementary radiation physics; Short wave radiation; Long wave radiation	4
3.	**Earth-Atmosphere System:** Atmospheric composition and structure; Pressure, temperature, moisture distributions; Principles of atmospheric thermodynamics; Principles of atmospheric stability.	4
4.	**Precipitation:** Rainfall generating mechanisms; Cloud physics; Storm structure; Precipitation modeling; Applications.	6
5.	**Evaporation and Transpiration:** The lower atmosphere and the atmospheric boundary layer(ABL); Mean profiles and similarity in a stationary and horizontally-uniform ABL; Evaporation process; Water and energy balance methods; Mass transfer method; Penman equation; Transpiration. Evapotranspiration; Modified Penman equation.	6
6.	**Sub-Surface Hydrology - Infiltration and Exfiltration:** Flow in unsaturated porous media; Infiltration and exfiltration; Empirical equations; Infiltration and surface runoff; Actual evapotranspiration; Percolation and capillary rise; Groundwater flow	6
7.	**Snowpack and Snowmelt:** Snowpack Density, Cold content, Thermal quality, Liquid-water content; Albedo; Energy budget and snowmelt; Air temperature and snowmelt; Snowmelt routing through snowpack; Snowmelt runoff modeling: Lumped models Distributed Models; Energy balance-based models; Temperature index-based models; Physiographic and climatic controls	6
8.	**Global hydrology and climate change:** Regional hydrology and climate change.	6
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors /Books /Publishers	Year of Publication/ Reprint
1.	Viessman, W., and Lewis, G.L., "Introduction to Hydrology", Pearson Education Ltd.	2012
2.	Dingman, L.S., Upper Saddle River, N.J., "Physical Hydrology", Prentice Hall.	1994
3.	Bras, R.L., "Hydrology, an Introduction to Hydrologic Science", Addison Wesley	1990
4.	Chow, V.T., Maidment, D. and Mays, L.W., "Applied Hydrology", McGraw Hill.	1988
5.	Bear, J., "Hydraulics of Groundwater", McGraw Hill.	1979
6.	Wallace, J. and Hobbs, P., "Atmospheric Science, an Introductory Survey", Academic Press.	1977
7.	Linsley, R., Kohler, M. and Paulhus, J., "Hydrology for Engineers", McGraw Hill.	1975
8.	Sellers, W. D., "Physical Climatology", The University of Chicago Press.	1974
9.	Eagleson, P.S., "Dynamic Hydrology", McGraw Hill	1970

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-552** Course Title: **Numerical Methods in Hydrology**

2. Contact Hours: **L: 2** **T: 0** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **2** **Practical** **1**

4. Relative Weightage**:** CWS **15** PRS **15** MTE **30** ETE **40** PRE **0**

5. Credits**:** **2** 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite: NIL

9. Objective: The course aims at introducing emerging techniques and tools developed in information and communication technology field in hydrology.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Water Resources systems, Introduction to hydrological modeling, types of models, model development, calibration and verification	5
2.	Review of differential equations in water resources, Introduction to numerical methods. Finite difference approximation of first and second order derivatives, Forward, backward and central difference methods; explicit, implicit and Crank Nicholson schemes, numerical errors, stability and convergence criteria, method of characteristics, ADI method for flow modeling, Basics of Finite element methods.	10
3.	Iterative methods; Jacobi, Gauss-Seidel, Successive over relaxation, Picards and Newton-raption techniques.Tridiagonalmatices, Thomas algorithm	7
4.	Minor project (analytical and numerical simulation homework assignments)	6
	Total	**28**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Sastry, S.S., "Introductory methods of Numerical Analysis" Prentice-Hall of India, New Delhi	2005
2.	Schwartz, F.W. and Zang, H., "Fundamentals of Ground Water", John Wiley & Sons	2003
3.	Wang, J.F., Anderson, M.P., 1982. Introduction to Groundwater Modelling. Freeman, San Francisco, CA: 237 pp	1982
4.	Vedula, S., and Mujumdar, P.P., "Water Resources Systems", Tata Mc Graw Hill	1982
5.	Remson, I., Hornberger, G.M. and Molz, F.J., "Numerical Methods in Subsurface Hydrology", Wiley-Interscience	1971

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 553** Course Title: **Experimental Hydrology**

2. Contact Hours: **L: 0** **T: 0** **P: 4**

3. Examination Duration (Hrs.): **Theory** **0** **Practical** **3**

4. Relative Weightage**:** CWS **0** PRS **50** MTE **0** ETE **0** PRE **50**

5. Credits**:** **2** 6.Semester**: Both** **7.** Subject Area**:** **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide hands-on experience in conducting various hydrologies experiments. In this process, students will learn to collect laboratory- and field-based data, analysis and interpretation of data.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Determination of Soil Physical Properties	4
2.	Soil Moisture Retention Curve using pressure plate	2
3.	Infiltration estimation using double ring, disk- and mini-disk infiltrometers	4
4.	Rainfall-Runoff Experiments: Hydrograph Generation, Drawdown, sediment transport using Advance Hydrologic System	4
5.	Rainfall Simulator Experiments: Uniformity Coefficient, Rainfall Generation and Drop size analysis	2
6.	Soil Hydraulic Conductivity experiments using AHS, ICW permeameter (Constant and Variable head)	2
7.	Flow through Open Channel using different hydraulic structures	4
8.	Groundwater Flow Experiments	4
	Total	**26**

11. Suggested Readings: Students will be given class handouts for each experiment including theory and practical procedure.
-User manuals of different equipments will be used.

INDIAN INSTITUUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT. /CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-554** Course Title : **Soil and Water Remediation**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs) **Theory** 3 **Practical** 0

4. Relative Weightage: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: 4 6. Semester: **Both** 7. Subject Area**:** **PEC**

8. Pre-requisite: **NIL**

9. Objective: The course aims to develop the understanding of contemporary treatment technologies that are used for remediation of soil and water pollution

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Surface and ground water characteristics, soil formation and classification; types, sources and properties of contaminants affecting water and soil water-soil-contaminant interactions, analytical methods	6
2.	**Membrane technologies:** Type and characteristics of membranes used for water remediation, basis of membrane selection, osmotic pressure, concentration polarization, electrolyte diffusion; Suspended particles removal from water by macro-filtration and ultra-filtration; Dissolve ions removal from water by nanofiltration and reverse osmosis, case studies	6
3.	**Nanotechnology**: Classification and characteristics of nano-scale materials, basic approach and methods of nanoparticles synthesis, theories of nanosized materials, functionalized nanomaterials, applications and perspectives of nanomaterials in water treatment; Nanoscale zero-valent iron (ZVI) for remediation of organic and inorganic contaminants; Magnetic nanoparticles for removal of heavy metals., case studies	6
4.	**Phytoremediation:** Mitigation of pollutants in soil and water by phytoextraction, phytostabilization, phytotransformation, rhizodegradation to degrade heavy metal, pesticides, hydrocarbons, etc.; influence of environmental factors on phytoremediation. natural and constructed wetlands, type of constructed wetlands, applications in wastewater and stormwater treatment, design considerations, case studies	6
5.	**Physical/Chemical Treatment Technologies:** Water Remediation: Electro-coagulation for removal of hydrocarbon, suspended solids and heavy metals; Wet-oxidation for the removal of dissolved and suspended components; Electro Dialysis and Ion exchange for water softening and NOM removal; Adsorption for the removal of atoms, ions and molecules. Soil Remediation: Dredging, vapor condensation and soil vapor extraction	8

	for volatile organic compounds; Solidification/ stabilization, verification, grouting and soil capping to reduce the mobility of contaminants; In situ oxidation and peroxide catalyzed remediation for removal of organic contaminants; Critical fluid extraction and soil flushing/washing for treatment of saline soil and the removal of ions, metals, gasoline, fuel oils and pesticides; Alkali soil remediation using gypsum, pyrite, sulphur; Acidic soil remediation using lime.	
6.	**Biological Treatment Technologies:** Bioreactor landfill, bioventing, biostimulation, bioaugumentation, microbial degradation, aerobic and anaerobic bio-transformations for removal of biodegradable organic contaminants from soil, case studies	5
7.	**Thermal Treatment Technologies:** Removal of organic contaminants from soil by thermal desorption, distillation, thermal evaporation, incineration, gasification, cement kiln, pyrolysis, thermal depolymerisation, waste autoclaves, gas and residue treatment plant; Energy recovery plant and emissions clean-up methods, case studies	5
	Total	**42**

List of experiments:

i. Determination of anion and cation removal efficiency of reverse osmosis and nano filtration membranes.
ii. Synthesis of nanoparticles, measurement of their characteristics by XRD and application.
iii. Removal of contaminants from water in constructed wetland batch reactors
iv. Removal of contaminants from water by electro-coagulation and electro-dialysis.
v. Use of adsorption batch reactors for removal of heavy metals.
vi. Batch experiments to study biological degradation of organic compounds from water and soil.
vii. Laboratory scale alkali soil remediation using gypsum.
viii. Laboratory scale acidic soil remediation using lime.

11. Suggested Books

S. No.	Authors / Name of Book / Publisher	Year of Publication
1.	J. D. Seader, Ernest J. Henley, D. Keith Roper, "Separation Process Principles", John Wiley & Sons	2013
2.	Ram M., Silvana E. A. and Hanming D., "Nanotechnology for Environmental Decontamination", McGraw-Hill.	2011
3.	Mao H., Chin H., Alan E. B., Honglin W., Rachid S. and Ian W., "Enviro-nanotechnology", Elsevier.	2010
4.	"Soil pollution: origin, monitoring & remediation" by I.A. Mirsal.. Springer	2010
5.	Krishna R.R.and Claudio C. "Electrochemical remediation technologies for polluted soils, sediments and groundwater",John wiley& sons.	2009
6.	Wankat P.C., "Separation Process Engineering", 2nd Ed., Prentice Hall.	2006
7.	Milton F. and Rachakonda N. "Bioremediation of Aquatic and	2005

	Terrestrial Ecosystems" Science publishers.	
8.	Singh A., Owen P. W., "Applied Bioremediation and Phytoremediation", Springer	2004
9.	"Reclamation of contaminated land" by C. P. Nathanail& P. Bardos.. John Wiley.	2004
10.	Donald L. W., "Bioremediation of Contaminated Soils", CRC Press.	2000
11.	Norman T., Gary S. B., "Phytoremediation of Contaminated Soil and Water", CRC Press	1999
12.	Ellen L. K., Todd A. A. and Joel R. C., "Phytoremediation of Soil and Water Contaminants", American Chemical Society	1997
13.	Donald L. Wise, "Remediation of Hazardous Waste Contaminated Soils", CRC Press	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 555** Course Title: **Soft Computing Techniques in Hydrology**

2. Contact Hours: **L: 2** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **2** **Practical** **1**

4. Relative Weightage**:** CWS **15** PRS **15** MTE **30** ETE **40** PRE **0**

5. Credits**:** **2** 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce emerging techniques and tools developed in information and communication technology for solving hydrological problems.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction to soft computing techniques and overview of emerging techniques	1
2.	Data mining, data normalization methods	3
3.	ARTIFICIAL NEURAL NETWORKS: Introduction to Artificial Neural Networks, General Properties of ANN, ANN Types, Architecture, Methods for Computing Net Information, Activation Functions, Network Training, Back-propagation algorithm, Radial basis function, Conjugate gradient algorithm, Cascade correlation algorithm, Generalized regression algorithm, Learning Rules, Learning Parameter, Model Testing, Over-training and Cross-training, Model Application in Water Resources Engineering.	9
4.	FUZZY LOGIC ALGORITHM: Introduction to Fuzzy Logic Algorithm , General View Basic Concept in Fuzzy Logic Fuzzy Systems, Fuzzy Membership Functions, Set Operations, and Fuzzy Relations Constructing Fuzzy Model, Fuzzification, Fuzzy Rule Base, Fuzzy Inference Engine Defuzzification , Fuzzy Model Application in Water Resources Engineering	7
5.	GENETIC ALGORITHMS: Introduction, Basic Units of GA, GA Operations,Forming initial gene pool, Evaluating fitness of each chromosome, Selection , Cross-over operation, Mutation Genetic Algorithm Model Applications in Water Resources Engineering	8
	Total	**28**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Tayfur, G., Soft Computing in Water Resources Engineering, WIT Press, Southampton, Boston, USA.	2012
2.	Vedula, S., and Mujumdar, P.P., "Water Resources Systems", Tata Mc Graw Hill.	2005
3.	Ross, T.J., "Fuzzy Logic with Engineering Application", 2nd Edition, John Wiley & Sons	2004
4.	Witten, I.H., and Frank E, "Data Mining", Morgan Kaufmann Publishers	2000
5.	Rao, V.B. and Rao, H.V., "Neural Network and Fuzzy Logic", BPB Publications	1996
6.	Fu, L., "Neural Networks and Fuzzy Logic", McGraw-Hill Inc.	1994

INDIAN INSTITUUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT. /CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 556** Course Title: **Environmental Quality Lab**

2. Contact Hours: **L: 0** **T: 0** **P: 4**

3. Examination Duration (Hrs) **Theory** 0 **Practical** 2

4. Relative Weightage: **CWS** 0 **PRS** 50 **MTE** 0 **ETE** 0 **PRE** 50

5. Credits: 2 6. Semester: **Both** 7. Subject Area**:** **PEC**

8. Pre-requisite: **Nil**

9. Objective: To provide the basic background for understanding the environmental characteristics and skills for their assessment and management.

10. Details of Course:

S. No	Contents	Contact Hours
	Water Analysis	
1.	Gravimetric analysis: Measurement of Total Solids, Total Dissolved Solids, Total Suspended Solids, Measurement of Sulphates and Oil and Grease.	3
2.	Electrometric analysis: Measurement of EC, Types of sensors and their application in measurement of Fluoride, Nitrate and Dissolved Oxygen.	2
3.	Volumetric and optical analysis: Measurement of Total Alkalinity, Hardness and its constituents and Chloride, Measurement of Turbidity and Phosphates	3
4.	Measurement of Organics viz, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC)	4
5.	Introduction to advanced instruments: Analysis of Anions and Cations by Ion Chromatograph (IC), Organic Residues by Gas Chromatograph Mass Spectrometry (GC-MS), Heavy Metals by Voltammeter and ICP-MS	4
6.	Demonstration of remediation technologies: Membrane systems, Electro-coagulation and Electro-dialysis systems	2
	Soil Analysis	
7.	Determination of pH, Conductivity, Temperature and Nutrients (Available-N, Available-P, Potassium, Sulphur)	3
8.	Determination of Organic matter and Heavy Metals	3
9.	Laboratory experiments of remediation of Alkali and Acidic soils	2
	Total	**26**

11. Suggested Books:

S. No	Name Authors/Books/Publisher	Year of Publication/ Reprint
1.	Ahuja S., "Monitoring Water Quality: Pollution Assessment, Analysis, and Remediation", Elsevier	2013
2.	Li Y., Migliaccio K., "Water Quality Concepts, Sampling, and Analyses", CRC Press	2010
3.	Yaduvanshi N.P.S., Methods of Soil, Plant and Climatic Analysis, IARI, CSIR New Delhi, India	2009
4.	"Standard Methods for Water & Wastewater Analysis" 21st Edition, American Public Health Association.	2005
5.	Crompton, T.R., 'Soil Analysis: Handbook for Reference Methods", CRC Press	2000
6.	Singh D., Chhonkar P.K. and Pandey R.N., "Soil Plant Water Analysis: A Methods Manual", IARI, New Delhi, India	1999
7.	Chapman, D., "Water Quality Assessment", 2nd Edition, Imprint of Chapman & Hall	1992
8.	Sawyer, C.N., and McCarty, P.L. "Chemistry for Environmental Engineering', 3rd Edition, McGraw Hill	1987

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-560** Course Title: **Soil and Groundwater Contamination Modeling**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS 15 PRS 10 MTE 25 ETE 50 PRE 0

5. Credits**:** 4 6. Semester**: Spring** 7.Subject Area**:** **PCC**

8. Pre-requisite: **Nil**

9. Objective: This course aims at exposing the student to basic concepts and principles related to the fate and transport of pollutants in soil and groundwater systems under various environmental conditions.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Sources and causes of soil and groundwater pollution;Various ways of classification of pollutants; Soil and groundwater parameters; Site specific soil and groundwater quality problems in Indian context	3
2.	Concepts and principles related to the movement of solutes in soil and groundwater systems; continuity equation and Ficks' law, mass transfer (adsorption, desorption, absorption, decay, dissolution, volatilization); mass transport (advective, dispersice and diffusice flux), Solute transport in double-porosity media	8
3	Description of adsorption: linear and nonlinear (Frendlich and Langmuir) isotherms, equilibrium and kinetic adsorption, Determination of adsorption coefficients, Determination of flow velocity and dispersivity coefficients, Hydrodynamics dispersion, longitudinal and lateral dispersivity	6
3.	Direct andinverse problems, Analytical solution of classical advective-dispersion equation, Finite difference methods, Numerical modeling of steady and transient flows in variably saturated domain, Contaminant transport modeling, Numerical dispersion, Discussion of initial and boundary conditions, Regional aquifer quality simulation, matrix solution techniques and iteration methods	10
4	Multiphase contamination, NAPLs, VOCs;Degradation processes, Biodegradation, Factors affecting biodegradation, Radioactive decay, Reactive processes.	5

5.	Concepts of pollution control and remediation measures;pump-and treat; Permeable reactive barriers and their design, Soil vapor extraction, Air sparing, bioremediation and phytoremediation processes, wetland processes	4
6.	Density driven flow, Upconing of saline groundwater, Ghijben-Hezberg principle, concepts of fresh saline interface in elongated Islands, salt water wedge in aquifers, Numerical modeling, Control of salt water intrusion.	6
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books / Publisher**	**Year of Publication/ Reprint**
1.	Schwartz, F.W. and Zang, H., "Fundamentals of Ground Water", John Wiley & Sons	2003
2.	Fetter, C.W., Contaminant hydrogeology, Macmillan, New York, (2nd ed.).	1999
3.	Domenico, P.A. and Schwartz, F.W. Physical and chemical hydrogeology (2nd ed.). John Wiley & Sons, New York. ISBN 0-471-59762-7.	1998
4.	Wang, J.F., Anderson, M.P., 1982. Introduction to Groundwater Modelling. Freeman, San Francisco, CA: 237 pp	1982
5.	Freeze, R.A., Cherry, J.A., 1979. Groundwater. Prentice-Hall, Englewood Cliffs: 604 pp.	1979
6.	Bear, J., 1972. Dynamics of Fluids in Porous Media. Am. Elsevier Publishing Co., New York: 764 pp.	1972

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-561** Course Title: **Multi-phase Flow through Porous Media**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** CWS **15** PRS **10** MTE **25** ETE **50** PRE **0**

5. Credits**:** **4** 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite: **HY-527 or Equivalent**

9. Objective: The aim of this course is to introduce the basic theory and computational methods for modeling multiphase flow in subsurface porous media**.**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Problems involving multiple fluids in subsurface, Nongaseous-phase liquids, Physical nature and properties of fluid (wetting and nonwetting) phases and porous media, Concept of representative elementary volume, imbibition and drainage	5
2.	Mass conservation equations in porous media, Darcy's Law for multifluid flow, Functional forms of relative permeability, fluid saturation and capillary pressure, behaviour of interface between two fluids	6
3	Governing equations for components within the fluids and solid, equations of state, partition coefficients, reactions, mole fractions, mass transfer and source/sink terms	8
4	Water and air dynamics in unsaturated zone, Henry's law, diffusion coefficients, mechanical dispersion, phase transitions	8
5	Solutions methods of multifluid flow equations: Analytical and Finite difference numerical methods, Discretization and iteration techniques, Linear system solvers, Boundary and initial conditions.	10
6	Upscaling multiphase flow in porous media, Case studies, Hands on experiments on STOMP simulator	5
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Essentials of Multiphase Flow in Porous Media, William G. Gray, John Wiley & Sons, 2008	2008
2.	Das, D.B. and S.M. Hassanizadeh, Upscaling multiphase flow in porous media: from pore to core and beyond, SpringerVerlag, 260 pages, Arpil 2005 (ISBN 1-4020-3513-6).	2005
3.	Computational Methods for Multiphase Flows in Porous Media (Computational Science and Engineering), by Zhangxin Chen. Published by Society for Industrial and Applied Mathematics. 1st edition (ISBN: 978-089871606)	2006
4.	Mayer, A.S., and S.M. Hassanizadeh, Soil and Groundwater Contamination: Nonaqueous Phase Liquids, American Geophysical Union, 224 pages, June 2005 (ISBN 0-87590-321-7).	2005
5.	Fluid Flow in Porous Media, by Zoltan Heinemann, 2003	2003
6.	Ven Chow, David Maidment, and Larry Mays, Applied hydrology, MacGraw- Hill Book company, New York.	1988
7.	Bear, J., 1972. Dynamics of Fluids in Porous Media. Am. Elsevier Publishing Co., New York: 764 pp.	1972

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-562** Course Title: **Irrigation and Drainage Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weightage**:** CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits**:** **4** 6. Semester**: Spring** 7.Subject Area**:** **PCC**

8. Pre-requisite**: Nil**

9. Objective: To understand the principles and processes necessary to effectively manage water resources through well designed drainage and irrigation systems

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction**: Historical perspective of irrigation and drainage, world and Indian scenario today.	1
2.	**Soil-water-plant relationship:** Soil Characteristics, water movement in soils, Measuring Soil-Water Content, Basic Concepts of Soil-Water Dynamics, Soil-Water Retention, Drainable Porosity, Unsaturated Hydraulic Conductivity, Water Extraction by Plant Roots, Soil-Water Dynamics in Relation to Drainage.	5
3.	**Irrigation:**Water requirement of crops; yield response and crop consumptive use, evapotranspiration,Irrigation water requirement,factors affecting irrigation requirement, duty-delta relationship, methods of determining duty of water, CROPWAT model.	7
4.	**Irrigation Methods:**Surface method of irrigation – border, check basin, furrow; Sub-surface method of irrigation, sprinkler irrigation, trickle irrigation. irrigation scheduling; design of irrigation channels; irrigation water and infiltration; Hydraulics of irrigation system.	7
5.	**Irrigation Efficiency**: Factors affecting irrigation efficiency, water conveyance efficiency, application efficiency, water storage efficiency, project efficiency, conjunctive use in irrigation.	2
6.	**Land Drainage:** The Need for Land Drainage, Types of drainage problems, drainage investigations, classes of drainage, surface drainage systems, sub-surface drainage systems, hydrologic and hydraulic design of drainage systems.	7
7.	**Sub-surface Flow to Drains:** Steady-State and Unsteady-State Equations, Special Drainage Situations, Drainage of Sloping Lands, Interceptor Drainage, Open Drains with Different Water Levels and of DifferentSizes, Drainage of Heavy Clay Soils.	7

8.	**Typical Problems of Agricultural Lands**: Soil Salinity and Sodicity, Salinity in relation to Irrigation and Drainage, Classification of Salt-Affected Soils, Salt Balance of the Rootzone, Salt Equilibrium and Leaching Requirement, Reclamation of Salt-Affected Soils, waterlogging, causes and remediation.	6
	Total	**42**

11. Suggested Books/References:

S. No.	**Name of Authors /Books /Publishers**	**Year of Publication/ Reprint**
1.	Michael A.M., "Irrigation, Theory and Practices", Vikas Publishing House Pvt. Ltd.	2008
2.	Hoffman, G.J., Evans,R.G., Jensen, M. E., Martin D.L.and Elliott,R.L. (Ed.). Design and Operation of Farm Irrigation Systems - Second Edition. Published by the American Society of Agricultural and Biological Engineers (ASABE), St. Joseph, MI, 863 pp.	2007
3.	Fangmeier, D. D., Elliot, W. J., Workman, S. R., Huffman R. L., and Schwab. G. O. Soil and Water Conservation Engineering - 5th edition. Thomson Delmar Learning. Clifton Park, NY. 552 pp.	2006
4.	U. S. Bureau of Reclamation. Drainage Manual: A Guide to Integrating Plant, Soil, and Water Relationships for Drainage of Irrigated Lands. University Press of the Pacific. Honolulu, HI. 308 pages	2005
5.	Butler, D. and J.W. Davies. *Urban Drainage*. Taylor & Francis, Inc. New York. 568 pages	2004
6.	Majumdar, D.K."Irrigation Water Management (Principles & Practices)", Prentice Hall of India (P), Ltd.	2000
7.	Basak, N.N, "Irrigation Engineering", Tata McGraw-Hill Publishing Co. New Delhi.	1999
8.	Keller, J. and R.D. Bliesner. Sprinkle and Trickle Irrigation. Van Nostrand Reinhold. New York. 652 pages.	1990
9.	James, L.G. Principles of Farm Irrigation System Design. John Wiley and Sons. New York. 480 pages.	1988
10.	Luthin, J.N., "Drainage Engineering", Wiley Eastern	1973

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-563** Course Title: **Vadose Zone Hydrology**

2. Contact Hours: **L: 3** **T: 1** **P: 2/2**

3. Examination Duration (Hrs.): **Theory** 3 **Practical** 0

4. Relative Weightage**:** CWS **15** PRS **10** MTE **25** ETE **50** PRE **0**

5. Credits**:** **4** 6. Semester**: Both** 7.Subject Area**:** **PEC**

8. Pre-requisite: **Nil**

9. Objective: This course unit covers the theory and principles of soil physics, evaporation, infiltration, soil moisture storage and soil moisture and solute dynamics in the unsaturated zone**.**

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Soil physics, Unsaturated permeability and soil water retention models, Hysteresis, anisotropy, Non-linear behaviour of the unsaturated permeability, Pedotransfer functions to estimate soil hydraulic properties	6
2.	Soil moisture measurement methods, soil moisture monitoring, Infiltration theories and measurement, Green-Ampt model, time of ponding, Deep percolation and recharge	5
3.	Soil-water-plant atmospheric relationship, Irrigation requirements, Evapotranspiration models, Leaf area index, crop coefficient, soil moisture stress, Root compensation mechanism, Hydraulic redistribution, Salinity stress and effects on crop biomass.	6
4.	The basic principles of moisture dynamics in the unsaturated zone, Derivation of Richards Equation. Quantifying water uptake by plants, Linear and non-linear models, Solute uptake kinetics by plant roots, Active and passive uptake.	8
5.	Analytical and numerical solutions of soil water flow (including hands-on experience of the Hydrus1D and 2/3D model, Numerical modeling of steady and transient flows in vadose zone, Iteration techniques, convergence and stability, mass balance, Initial and boundary conditions	10

6.	Macropore flow and the preferential principles (wetting front instability, fingered flow) - Solute transport in the unsaturated zone, breakthrough curves, sources and sink terms, macropore flow and preferential flow, soil thermal properties, heat flow in soils.	7
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/ Books / Publisher**	**Year of Publication/ Reprint**
1.	A M Michael, Irrigation Theory and Practices, Second Edition, Vikas Publishing House Limited	2010
2.	Domenico, P.A. and Schwartz, F.W. Physical and chemical hydrogeology (2nd ed.). John Wiley & Sons, New York. ISBN 0-471-59762-7.	1998
3.	Ven Chow, David Maidment, and Larry Mays, Applied hydrology, MacGraw- Hill Book company, New York.	1988
4.	Bear, J., 1972. Dynamics of Fluids in Porous Media. Am. Elsevier Publishing Co., New York: 764 pp.	1972

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 566** Course Title: **Ground Water Protection & Regulation**

2. Contact Hours: **L: 2** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** 2 **Practical** 0

4. Relative Weightage**:** CWS 25 PRS 0 MTE 25 ETE 50 PRE 0

5. Credits**:** 2 6. Semester**: Both** 7.Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To impart knowledge of widespread deterioration in ground water quality and need for protecting ground water resource from contamination.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Need for ground water protection. Common causes of ground water quality deterioration. Factors responsible for aquifer pollution and its Assessment. Ground water protection guidelines.	4
2.	**Methods :** Approaches of Mapping aquifer pollution vulnerability. Various indices of assessment of ground water vulnerability. DRASTIC Index approach. GOD Index. Ground water vulnerability maps: their uses and limitations. Guidelines for ground water protection. Case Studies.	7
3.	**Inventory :** Subsurface contaminant Load, classification and Estimation of Subsurface contamination load: Diffuse sources and Point sources of pollution.	4
4.	**Assessment :** Control of Ground Water Pollution Hazards: Evaluation of pollution hazard and water supply pollution Hazards. Strategies for control of ground water pollution. Mounting Ground Water Quality Protection programs.	6
5.	**Ground Water Legislation** and Protection Regulation: Model Ground Water Act in India; Status of its Implementation in Indian States. Ground Water Protection Regulation and Governance; Case Examples.	7
	Total	**28**

11. Suggested Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	GARDUNO, H., Romani, S., Sen Gupta, B., Tuinhoff, A and Richard Davis, India. Groundwater Governance Case Study, Water Papers, World Bank, 81p.	2011
2.	Foster, S., Hirata, R., Gomes, D., D'Elia, Monica and Marta Paris: Ground Water Quality Protection, The World Bank, Washington D.C. 103p.	2002
3.	Ground Water Survey and Development Agency (Maharashtra), Ground Water Act and its Implementation in Aurangabad region. (Proc. Workshop on Ground Water Act and its Management)Aurangabad.	2000
4.	VRBA, J. and A. Zoporozee (Eds.), Guide book on Mapping Ground Water Vulnerability. International Association of Hydrogeologists. 131p.	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY-571** Course Title: **Watershed Modelling and Simulation**

2. Contact Hours: **L: 2** **T: 1** **P: 2**

3. Examination Duration (Hrs.): **Theory** **2** **Practical** **0**

4. Relative Weightage**:** CWS **10** PRS **30** MTE **20** ETE **40** PRE **0**

5. Credits**:** **4** 6. Semester**: Spring** **7.** Subject Area**:** **PCC**

8. Pre-requisite: **Nil**

9. Objective: To understand process-based modeling of watershed with emphasis on concepts, fundamental modeling principles used to describe watershed hydrology.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	**Introduction:** Need for Watershed Modeling, Modeling Concepts and Objectives, Model Classification: Choice of Model Complexity	2
2.	**Spatial and Temporal Input Data:** Model User Interfaces, GIS and Remote Sensing	2
3.	**Pre-processing of data:** Time Series Analysis; Simple descriptive techniques, trend, seasonality	4
4.	Overview & Current models such as (for eg., AnnAGNPS, SWAT 2012, WEPP, MIKE SHE; HEC HMS, ANSWERS) etc.	7
5.	**Hydrological Processes:** Hydrologic Equations; Simulation of Streamflows; Erosion Equations and Simulations	3
6.	**Main Channel Processes:** Fate and Transport of Nutrients/Pesticides, Management Practices	2
7.	Sensitivity and Uncertainty Analysis, Parameter Identification and Estimation	3
8.	**Model Calibration and Validation; Model evaluation:** Mathematical model verification, Operational model verification, Graphical and Goodness-of-Fit procedures	2
9.	**Ethics in Modelling:** Case Studies/Projects	3
	Total	**28**

11. Suggested/Reference Books:

S. No.	Name of Authors/ Books / Publisher	Year of Publication/ Reprint
1.	Beven., K Rainfall-Runoff modelling: The Primer. John Wiley and Sons, Ltd	2012
2.	Singh, V. P. Computer models of watershed hydrology, Water Resources Publications, Littleton, Colorado	2000
3.	Haan, C. T., H. P. Johnson, and D. L. Brakensiek. Hydrologic Modeling of Small Watersheds. An ASAE Monograph Number 5 in a series published by American Society of Agricultural Engineers.	1982
4.	User Manuals of Current Watershed Models	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NAME OF DEPTT./CENTRE: **DEPARTMENT OF HYDROLOGY**

1. Subject Code: **HY- 576** Course Title: **Rural Water Supply and Sanitation**

2. Contact Hours: **L: 2** **T: 1/2** **P: 0**

3. Examination Duration (Hrs.): **Theory** **2** **Practical** **0**

4. Relative Weightage: CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits: **2** 6. Semester: **Both** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective: The objective of this course is to provide training on planning to water supply and sanitation programs in the rural sector.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Village environment, Sources of water: quantity, quality and accessibility; Assessment of demands, planning and construction of direct and community water supply schemes; Source protection measures; Cost effective water treatment technologies	5
2.	Type and source of wastes; Management of solid and liquid waste; Low cost sanitation planning and construction including household toilets, community toilets; Innovative and adaptable initiatives like compost pits, vermin composting, common and individual bio gas plants, and low cost drainage apart from collection, segregation, and disposal of household waste at the village level, Disposal and Reuse issues	5
3.	Public health concepts, review of key health determinants, public health priorities in emergency and development settings, sustainable community health/hygiene: mechanisms for delivery and management	4
4.	Social, cultural, political and economic aspects linked to water and sanitation practices, Initiatives of National and International agencies in empowerment of communities by promoting pro-community policies, programs and financial support and skill upgradation in developing countries	4
5.	Assesment of current conditions and trends in water and sanitation services in low and middle-income countries; Strategies to improve water and sanitation conditions; lessons learned; key interventions	3
6.	Soft Skills for Water and Sanitation Professionals	3
7.	Case studies and projects	4
	Total	**28**

11. Suggested Books:

S. No	Name of Author/ Books/ Publishers	Year of Publication/ Reprint
1.	Ministry of Drinking Water and Sanitation, Operation and Maintenance Manual for Rural Water Suppliers	2013
2.	Ministry of Drinking Water and Sanitation, Manual for preparation of detailed Project Report for Rural Piped Water Supply Schemes	2013
3.	Ministry of Drinking Water and Sanitation, Handbook on Technical Option for On-Site Sanitation	2013
4.	Community Led Total Sanitation (CLTS) Training Manual for Natural Leaders	2010
5.	Sustainable Water Supply and Sanitation (SWSS) Project	2010
	Manual on The Right to Water and Sanitation	2007
6.	The CPHEEO manuals on Water Supply	2002