

Tribhuvan University
Institute of Engineering
Pulchowk, Lalitpur
Course Structure 2024
MSc in Water Resources Engineering

Year : I

Part I

Teaching Schedule				Examination Scheme			Total	Remarks
SN	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENCEWR501	Advanced Hydrology	4	40	3	60	100	
2	ENCEWR502	Advanced Hydraulics	4	40	3	60	100	
3	ENCEWR503	Water Resources System Engineering	4	40	3	60	100	
4	ENCEWR504	Sedimentation Engineering	4	40	3	60	100	
Total			16	160	-	240	400	

Year : I

Part II

Teaching Schedule				Examination Scheme			Total	Remarks
SN	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENCEWR551	Water Induced Disaster Engineering	4	40	3	60	100	
2	ENCEWR552	Design of Hydraulic Structures	4	40	3	60	100	
3	ENCEWR56X	Elective-I	4	40	3	60	100	
4	ENCEWR57X	Elective-II	4	40	3	60	100	
Total			16	160	-	240	400	

Tribhuvan University
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Course Structure 2024
MSc in Water Resources Engineering

Year : II

Part I

Teaching Schedule				Examination Scheme			Total	Remarks
SN	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENCEWR61X	Elective -III	4	40	3	60	100	
2	ENCEWR62X	Elective -IV	4	40	3	60	100	
3	ENCEWR601	Project	4	100	-		100	
Total			12	180	-	120	300	

Year: II

Part II

Teaching Schedule				Examination Scheme			Total	Remarks
SN	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENCEWR651	Thesis	16	100	-	-	100	

Note: Students will write a thesis in the fourth semester. However, the thesis work must start from the beginning of third semester, which may be associated to the project work. Students can carry out the research thesis with one or more supervisors.

Elective Courses

Elective courses will be offered as per the availability of resource persons. The lists of electives are as follows:

Elective I

1. River Engineering [Code: ENCEWR561]
2. Water Resources Simulation and Modelling [Code: ENCEWR562]
3. Climate Change, Water Security, and Nexus [Code: ENCEWR563]

Elective II

1. Water Resources Planning and Management [Code: ENCEWR571]
2. Rock Slope Engineering [Code: ENCEWR572]
3. Glacier and Glacio-hydrological Modelling [Code: ENCEWR573]

Elective III

1. Groundwater Assessment, Development and Management [Code: ENCEWR611]
2. Design of Underground Structures [Code: ENCEWR612]
3. Remote Sensing in Water Resources [Code: ENCEWR613]

Elective IV

1. Water Resources Contract Management [Code: ENCEWR621]
2. Fish Passage Engineering [Code: ENCEWR622]

Further Explanation about Project and Thesis works

The project and thesis component theme could be one of the following:

- Industrial/organizational problem assessment (Mainly done at industry/organization)
- Community based problem assessment (Mainly done at community)
- Literature based problem assessment (Mainly done at institution)
- Analytical or experimental or prototype based problem assessment (Mainly done at institution)
- Case study based problem assessment (Mainly done at case specific site)
- Field work based problem assessment (Mainly done at specific site)
- Any other relevant and deemed suitable by department
- The project component will be of approximately 3 months (full - time) duration

Eligibility and Degree Award

Eligibility: **BE in Civil Engineering**

Degree Award: **MSc in Water Resources Engineering (Civil Engineering)**

ADVANCED HYDROLOGY
ENCEWR501**Credits: 4****Year: I****Part: I****Course Objectives**

This course aims to give a practical approach to the various facets of the subject and emphasizes the application of hydrological knowledge to solving engineering problems. After the completion of this course, the students will be able to i) delineate and characterize a watershed; ii) estimate inflows at a location of interest; iii) understand approaches for watershed modelling and set-up a hydrological model for a watershed; and iv) perform hydrological analysis of a watershed.

1 Fundamentals of Hydrologic Analysis [9 hours]

- 1.1 Watershed characterization: Definition and delineation of a watershed; Biophysical characteristics (Area, shape, drainage pattern, drainage density, time of concentration, length of the longest flow path, slope, catchment relief and hypsometric curve, stream order); Climatic characteristics; Socio-economic characteristics
- 1.2 Hydro-climatic data: Types, sources (Local and global), and resolution of data; Data quality assessment; Identification of dry/normal/wet years; Spatial distribution of climatic data (Thiessen polygon, isohyet curves, spatial interpolation)
- 1.3 Water balance and water accounting: Branches of hydrology (Surface water hydrology, groundwater hydrology, hydrogeology, isotope hydrology, eco-hydrology, hydro-informatics); Dominant hydrological processes in a watershed; Components of water balance/budget; Concept of water accounting
- 1.4 Reporting of hydrological analysis: Objectives of hydrologic analysis; Contents of hydrologic analysis report (Watershed characteristics, hydro-meteorological data and quality assessment, estimation of inflows, high flow analysis or design flood, low flow analysis, climate change impact assessment)

2 Inflows Estimation and Time-Series Analysis [12 hours]

- 2.1 Approaches for inflows estimation: Components of streamflow; Basic linear model of rainfall-runoff (Regression analysis of runoff versus rainfall and estimation of runoff from rainfall); Empirical methods; Regional analysis; Hydrological simulation
- 2.2 Fundamentals of hydrological modelling/simulation: Physical versus system approach; Types of hydrological models; Inputs and processes captured by different types of models; Steps in hydrological modelling; Problems in hydrological modelling
- 2.3 Analysis of hydrological regime: Time-series analysis of hydrological data; Hydrological regime and their significance; Characterization of hydrological regime using Indicators of Hydrologic Alterations (IHA)
- 2.4 Uncertainties in hydrological analysis: Concept, types, quantification approaches

3 Infiltration Modelling [9 hours]

- 3.1 Concept, affecting factors, significance, and estimation approaches for infiltration
- 3.2 Infiltration models (Empirical equations - Kostyakov, Horton, Holton equations; Green and Ampt equation; Mein and Larson equations)
- 3.3 Prediction of infiltration volume prior to runoff
- 3.4 Capillary potential at the wetting front; Prediction of infiltration capacity after runoff begins

4 Hydrological Models [12 hours]

- 4.1 Understanding hydrological modelling: Introduction; Classification of hydrological models on different basis; Modelling procedure and data requirements
- 4.2 Watershed conceptual models: Crawford model (Structure, set-up, application); Tank model (structure, set-up, application)
- 4.3 Linear black-box models: Types of catchment response; Rational method (Applicability, methodology, effect of catchment shape); Unit hydrograph (Concept, mathematical representation, direct and indirect methods); Composite hydrograph from UH, change in duration of UH (Superposition and S-curve methods); UH from complex storms (Collin's method)
- 4.4 Linear conceptual models: General hydrologic system model; Linear system in continuous time; Response functions of linear systems (Impulse, step and pulse response functions); Nash model

5 Hydrologic Analysis of Mid to Large Size Watersheds [18 hours]

- 5.1 Selection of methods as per catchment types: Criteria for defining small, mid and large size catchments; Suitable methods for different types of catchment
- 5.2 High flow analysis: Concept and types of design flood; Techniques for design flood estimation (Frequency-based floods and PMF); Creager curves
- 5.3 Low flow analysis: Frequency analysis of low flows; Environmental flows or E-flows (Concept, significance, and estimation approaches/tools)
- 5.4 Channel flow routing: Convex method, Muskingum method, Kinematic waves (Equation, discretization, order of accuracy of numerical scheme, Kinematic wave celerity, applicability); Diffusion waves (Equation, applicability, Muskingum-Cunge method); Dynamic waves (General introduction)
- 5.5 Catchment routing: Developing instantaneous unit hydrograph (Time area method and Clark UH method); Cascade of linear reservoirs; Catchment routing with Kinematic waves; Catchment routing with diffusion waves; Assessment of catchment-routing techniques

Assignments

1. Delineation and characterization of a watershed
2. Hydrological characterization using CRAWFORD model

3. Analysis of hydrological regime/extremes using indicators for hydrologic alterations (IHA) tool
4. Hydrological analysis of a hydropower or irrigation project using a suitable hydrological model (HEC-HMS, SWAT, JAMS-J2000, VIC)

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	9	8
2	12	12
3	9	8
4	12	12
5	18	20
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Ponce V.M. (2014). Engineering Hydrology, Principles and Practices. Available online at: <https://ponce.sdsu.edu/enghydro/index.html>
2. Chow V.T., Maidment D.R., Mays L.W. (1988). Applied Hydrology. McGraw-Hill Series in Water Resources and Environmental Engineering
3. Selected research materials/journal articles and lecture notes

ADVANCED HYDRAULICS
ENCEWR502**Credits: 4****Year: I****Part: I****Course Objectives**

The objective of this course is to enable the students to apply various numerical techniques to solve hydraulics problem. This course provides an overview of computational hydraulics, hydrological modeling, application of finite difference (FD) techniques in water resources development projects and data mining. The students will develop small programs and test their skills on programming of hydraulic problems. After completion of the course the students are expected to be able to develop conceptual knowledge about finite difference techniques in hydraulics and write simple computer programs for hydraulic and hydrological models.

1 Introduction**[6 hours]**

- 1.1 Pipe hydraulics basics: Head losses, transient flow
- 1.2 Basics of hydraulics: Flow classifications, conservation laws, critical flow, uniform flow, gradually varied flow (GVF), rapidly varied flow (RVF)
- 1.3 Computation of GVF: Numerical solution of ordinary differential equations, single step methods, predictor-corrector method, simultaneous solution procedure
- 1.4 Rapidly varied flow: Governing equations, oblique jump

2 Introduction to Numerical Techniques**[10 hours]**

- 2.1 Various numerical techniques in hydraulics (FD in focus)
- 2.2 Introduction to FD, types and methods of solutions
- 2.3 Saint-venant equations (Continuity and momentum equations)
- 2.4 Finite difference approximations: Explicit Finite difference schemes (Unstable, diffusive, MacCormack, LeapFrog, Lamda, Gabutti)
- 2.5 Implicit finite differences schemes (Preissmann scheme, consistency and stability)

3 Application of Finite Difference Schemes**[15 hours]**

- 3.1 Celerity of gravity waves, Kinematic wave model (Linear and non-linear), Diffusive model and Dynamic wave model, numerical solution of Muskingham methods Muskingham-Cunge model
- 3.2 Solution methods: method of characteristics, characteristic grid method, method of specified interval
- 3.3 Dam break analysis (For dry downstream channel bed and with water), simple wave analysis
- 3.4 Solution of linear reservoir problem, flood routing in river
- 3.5 Classical spatially varied flow equation and its solution using finite difference scheme (Steady flow analysis model)

4 Computational Solution of Two Dimensional Flow [8 hours]

- 4.1 Governing equations, continuity and momentum equations
- 4.2 Numerical solution: Mac Cormack scheme, Gabutti scheme, Beam and Warming schemes
- 4.3 Application: Partial breach or opening of sluice gate

5 Numerical River Hydraulics [6 hours]

- 5.1 Navier Stokes equation
- 5.2 Dispersion of pollutants
- 5.3 Dispersion modelling in 2D and 3D
- 5.4 Numerical modelling of water velocity, SIMPLE method

6 Computational Techniques in Unsteady Closed Conduit Flow [15 hours]

- 6.1 Unsteady flow analysis, Reynold transport theorem, water hammer with cavitation, effects and control of cavitation, cavitation descriptions
- 6.2 Transient analysis: Rigid water column theory, elastic water column theory, method of characteristics, various boundary conditions
- 6.3 Computation of transient pressure and discharges in pipe systems using MOC, explicit schemes and implicit schemes
- 6.4 General aspect of surge tank; Governing equations and design principles
- 6.5 Water surface oscillation in simple surge tank and its computation by finite difference scheme and stability of surge tank systems

Assignments

Case studies and individual presentation: Each student will be assigned an individual assignment related to study of a particular aspect of the computational scheme to solve any hydraulic problem. The evaluation will be based on the presentation and submission of a written report.

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	6	6
2	10	10
3	15	15
4	8	8
5	6	6
6	15	15
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Vreugdenhil, C. B. (1989). Computational hydraulics: An introduction (Latest Edition). Springer-Verlag.
2. Chaudhry, M. H. (2008). Open-Channel Flow. Springer Science + Business Media.
3. Chanson, H. (2004). The hydraulics of open channel flow: An introduction. Elsevier Butterworth-Heinemann.
4. Wylie, E. B., Streeter, V. L. (1983). Fluid transient (Latest Edition). Prentice Hall.
5. Chaudhry, M. H. (1987). Applied hydraulic transients (Latest Edition). Van Nostrand Reinhold Co.
6. Pandit, H. (1996). Modelling of cavitation flow in the pipeline (Unpublished MSc thesis). IHE, Netherlands.

WATER RESOURCES SYSTEM ENGINEERING
ENCEWR503**Credits: 4****Year: I****Part: I****Course Objectives**

This course aims to provide a comprehensive understanding of the needs of system engineering and its application for various processes and models related to water resources engineering.

- | | | |
|----------|--|-------------------|
| 1 | Introduction | [3 hours] |
| 1.1 | Definition of system | |
| 1.2 | Operation research and its brief history | |
| 1.3 | Models and principle of modelling | |
| 2 | Linear Programming | [10 hours] |
| 2.1 | Linear programming (LP) model, terminologies, assumptions, formulations | |
| 2.2 | Minimization and maximization problems | |
| 2.3 | Solution of LP models using graphical method | |
| 2.4 | Solution of LP models: Simplex method | |
| 2.5 | Simplex method: Use of Big-M/Penalty method | |
| 2.6 | Simplex method: Use of 2-phase method | |
| 2.7 | Sensitivity analysis using simplex tables | |
| 2.8 | Various numerical examples | |
| 3 | Dynamic Programming | [10 hours] |
| 3.1 | Dynamic programming (DP); Characteristics of DP | |
| 3.2 | Representation of DP using block diagram and multi stage decision problems | |
| 3.3 | Fibonacci numbers, divide and conquer rule and DP | |
| 3.4 | Matrix chain multiplication and DP | |
| 3.5 | Water allocation problem | |
| 3.6 | Reservoir operation problem | |
| 3.7 | Reservoir capacity expansion problem | |
| 3.8 | Shortest route problem | |
| 3.9 | Computational procedures for discrete and continuous systems | |
| 4 | Integer Linear Programming | [5 hours] |
| 4.1 | Integer linear programming (ILP) and its formulation; ILP algorithms | |
| 4.2 | Construction of Gomory's constraints for an all ILP | |
| 4.3 | Solution of ILP problems using Gomory's cutting plane method | |

- 4.4 Solution of IP problem using branch and bound techniques
- 4.5 Application of Zero-one integer programming

5 Non-Linear Programming [10 hours]

- 5.1 Non-linear programming (NLP); Concepts of concavity and convexity
- 5.2 Functions of single variables and its sufficient condition for optimization solutions
- 5.3 Functions of multiple variables and its solution techniques
- 5.4 Unconstrained optimization
- 5.5 Quadratic programming (Kuhn-Tucker conditions, Wolfe's modified simplex method and Beale's method)
- 5.6 Optimization with constraints
- 5.7 Functions with inequality constraints
- 5.8 Newton-Rapson method for NLP

6 Network Analysis and Project Management [10 hours]

- 6.1 Concepts and terminologies
- 6.2 Scheduling by PERT and CPM
- 6.3 Dummy activity and its positioning
- 6.4 Minimum spanning tree problem: CPM and PERT
- 6.5 Crashing network
- 6.6 Network principle using in project management
- 6.7 Formulation and solution of real project management problems

7 Decision Theory and Decision Tree [7 hours]

- 7.1 Decision-making process
- 7.2 Types of decision-making environments
- 7.3 Decision-making under uncertainty and risk
- 7.4 Posterior probabilities and Bayesian analysis
- 7.5 Decision trees analysis
- 7.6 Decision making with utilities

8 Theory of Games [5 hours]

- 8.1 Concepts and terminologies
- 8.2 Two-person Zero-sum games
- 8.3 Pure strategies: Games with saddle point
- 8.4 Mixed strategies: Games without saddle point
- 8.5 The rules of dominance
- 8.6 Solution methods of games without saddle point

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	3	3
2	10	10
3	10	10
4	5	5
5	10	10
6	10	10
7	7	7
8	5	5
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Loucks D. P., Stedinger J. R., Haith D. A. (1981). Water resources systems planning and analysis. Prentice-Hall, Inc.
2. Gill, P. E., Murray, W., Wright, M. H. (1981). Practical optimization. Academic Press.
3. Sharma R. K., Sharma T. K. (1990). Irrigation and Drainage Engineering. Oxford and IBH Publishing Co. Pvt. Ltd.
4. Karamouz M., Szidarovszky F., Zahraie B. (2003). Water resources system analysis. Lewis P.
5. Mays, L. W. (Ed.). (2005). Water resources systems management tools. McGraw-Hill.
6. Rao, K. C., Mishra, S. L. (2005). Operation research. Narosa Publishing House.
7. Deb, K. (2009). Optimization for engineering design. PHI Learning Pvt. Ltd.
8. Bhave, P. R. (2011). Water resources systems. Narosa Publishing House.
9. Dandekar, M. M., Sharma, K. N. (2015). Water power engineering (2nd ed.). Vikas Publishing House Pvt. Ltd.
10. Sharma, J. K. (2017). Operations research: Theory and applications. Trinity Press.
11. Research papers published in standard journals, with recent publications prioritized

SEDIMENTATION ENGINEERING
ENCEWR504**Credits: 4****Year: I****Part: I****Course Objectives**

Upon successful completion of this course, students will be able to gather field sediment data, and plan, design, and optimize sediment management strategies using advanced hydraulics, hydrology and modeling tools.

1 Introduction [6 hours]

- 1.1 Hydrologic cycle and rock cycle
- 1.2 Sediment induced problems in water infrastructure projects
- 1.3 Importance of storage and sediment management, dual nature of reservoirs
- 1.4 Design paradigms of reservoir projects
- 1.5 Mass, densities, specific weights and viscosity
- 1.6 Size and shapes of sediment particles, grain size distribution
- 1.7 Porosity, void ratio, angle of repose
- 1.8 Terminal fall velocity

2 Sediment Yield [6 hours]

- 2.1 Sources of sediment in a catchment
- 2.2 Mechanics of sheet erosion
- 2.3 Equations for predicting soil loss
- 2.4 Empirical equations of estimating sediment yield
- 2.5 Sediment delivery ratio

3 Sediment Transport and Dynamics [10 hours]

- 3.1 Hydraulics for sediment transport
- 3.2 Sediment transport: Types and threshold concept
- 3.3 Bed load transport: Principles and formulations
- 3.4 Suspended load transport: Principles and formulations
- 3.5 Sediment continuity principle
- 3.6 Sediment dynamics of river reaches
- 3.7 Flow and sediment transport at river bends

4 Sediment Monitoring [6 hours]

- 4.1 Suspended sediment monitoring
- 4.2 Laboratory analyses of suspended sediment samples
- 4.3 Bed load monitoring: Direct and indirect methods

4.4 Analysis of suspended sediment and bed load data

5 Sediment Management by Small Reservoir Water Infrastructure Projects [12 hours]

- 5.1 Principle of optimum sediment exclusion
- 5.2 Bed load handling
- 5.3 Suspended sediment handling
- 5.4 Design of conventional settling basin
- 5.5 Sediment guided operation and maintenance
- 5.6 Operation of small reservoirs

6 Sediment Management in Dams and Reservoirs [20 hours]

- 6.1 Hydraulics, sediment transport and sedimentation in reservoirs
- 6.2 Sediment management strategies in reservoir projects
- 6.3 Reducing upstream sediment yield
- 6.4 Sediment routing
- 6.5 Redistributing or removing sediment deposits
- 6.6 Combined management approaches
- 6.7 Adaptive strategies
- 6.8 Modelling and monitoring of reservoir sedimentation

Assignments

1. Literature review of at least one paper in different topics and case studies related to Sedimentation and River Engineering and presentation on the learning
2. Project work on reservoir sediment management study using a suitable model
3. Reservoir sedimentation management analysis using a suitable model

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	6	4
2	6	5
3	10	10
4	6	6
5	12	15
6	20	20
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Annandale, G. W., Morris, G. L., Karki, P. (2016). Extending the life of reservoirs: Sustainable sediment management for dams and run-of-river hydropower. World Bank.
2. Morris, G., Fan, J. (1998). Reservoir sedimentation handbook. McGraw-Hill.
3. Van Rijn, L. (1993 & 2006). Principles of sediment transport in rivers, estuaries, and coastal areas. Aqua Publications.
4. Lysne, D. K., Glover, B., Støle, H., Tesaker, E. (2003). Hydraulic design (1st ed.). Norwegian Institute of Technology, Division of Hydraulic Engineering.
5. García, M. H. (Ed.). (2008). Sedimentation engineering: Processes, measurements, modeling, and practice. American Society of Civil Engineers.
6. Julien, P. Y. (2010). Erosion and sedimentation (2nd ed.). Cambridge University Press.
7. Garde, R. J., Ranga Raju, K. G. (2000). Mechanics of sediment transportation and alluvial stream problems. New Age International Publishers.
8. Dey, S. (2014). Fluvial hydraulics: Hydrodynamic and sediment transport phenomena. Springer-Verlag Berlin Heidelberg.

WATER INDUCED DISASTER ENGINEERING

ENCEWR551

Credits: 4**Year: I****Part: II**

Course Objectives

The objective of this course are to equip students with the fundamental concepts of numerical modelling processes of water induced hazards and engineering of protection measures. It intends to develop the knowledge and skills in quantifying hazards required for planning and designing of protection measures.

- 1 Introduction** **[2 hours]**
 - 1.1 Concept of hazards, disasters, vulnerability and risk
 - 1.2 Water induced hazards and disasters in Nepal

- 2 Modelling of Landslide Hazards and Mitigation** **[12 hours]**
 - 2.1 Water movements and related hazards
 - 2.2 Hillslope runoff model (Kinematic Storage)
 - 2.3 Slope stability analysis (Infinite slope model)
 - 2.4 Preparation of hillslope domain landslide prediction model
 - 2.5 Analysis of stability in jointed rocks
 - 2.6 Modification of soil mechanical properties of hillslope by vegetation
 - 2.7 Bioengineering techniques for hillslope stabilization

- 3 River Bed Variation Modelling** **[10 hours]**
 - 3.1 Classification of riverbed variation analysis models
 - 3.2 Governing equations
 - 3.3 Characteristics of bed variation and computation direction
 - 3.4 Development and application of one-dimensional steady model
 - 3.5 Discretization of governing equations using Mc Cormack scheme
 - 3.6 Development and application of one-dimensional unsteady model

- 4 Modelling of Debris Flow Hazards** **[15 hours]**
 - 4.1 Rheology of debris-mud flows
 - 4.2 Unified understanding of the mechanism of debris-mud flows
 - 4.3 Mean concentration of steady and uniform debris flow over the movable bed
 - 4.4 Velocity profile and coefficient of velocity
 - 4.5 Concept of erosion and deposition in a stream channel with debris flow
 - 4.6 Governing equations for one-dimensional numerical simulation for debris flow

4.7 Numerical simulation methods (Leap frog scheme) and its applications

5 Design of Sabo Dam [6 hours]

- 5.1 Function of Sabo dam
- 5.2 Process for designing Sabo dam
- 5.3 Design loads and safety conditions

6 Flood Hazards [15 hours]

- 6.1 Mitigation methods
- 6.2 Aspects of flood forecasting
- 6.3 Methods of flood forecasting
- 6.4 Methods based on statistical approach
- 6.5 Multi tributary model
- 6.6 Flood hazards mapping using hydraulic models

Assignments

1. Development of hillslope domain model for landslide warning purpose using observed rainfall data
2. Development of steady and unsteady rainfall riverbed variation models
3. Application of debris flow model to experimental flume data set
4. Prepare a flood hazards map using ArcMap and HEC-RAS applications

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Marks distribution*
1 and 5	8	12
2	12	12
3	10	12
4	15	12
6	15	12
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Coppin, N. J., Richards, I. G. (1990). Use of vegetation in civil engineering. CIRIA.
2. Morgan, R. P. C., Rickson, R. J. (Eds.). (1995). Slope stabilization and erosion control. E & FN SPON.
3. Nakagawa, H., et al. (2001). Course manuals on water-induced hazards (M.Sc. Water Resources Engineering). IoE.
4. Shakya, N. M. (2001). Course manuals and class notes on water-induced hazards (M.Sc. Water Resources Engineering). IoE.
5. Ikeda, A. (n.d.). Design of sabo dam. Sabo Technical Center, Tokyo, Japan.
6. Shakya, N., Chander, S. (1998). Modelling of hillslope runoff processes. Environmental Geology, 35, 115–123.
7. U.S. Army Corps. (2002). User's manual. HEC-GeoRAS: An extension for support of HEC-RAS using ArcView

DESIGN OF HYDRAULIC STRUCTURES
ENCEWR552**Credits: 4****Year: I****Part: II****Course Objectives**

The objective of this course are to equip students with the fundamental concepts of numerical modelling processes of water induced hazards and engineering of protection measures. It intends to develop the knowledge and skills in quantifying hazards required for planning and designing of protection measures.

1 Planning of Hydraulic Structures [9 hours]

- 1.1 Types and importance of hydraulic structures
- 1.2 Design principles and methodologies
- 1.3 Hydrological cycle and its importance in design
- 1.4 Hydraulic analysis for design: Flow, pressure, and energy considerations
- 1.5 Safety and risk considerations, environmental consideration and climate change
- 1.6 Case studies and practical applications

2 Dam Engineering [15 hours]

- 2.1 Gravity dam: Forces on dam, load combination, failure modes
- 2.2 Earthquake forces (Seismic coefficient and response spectrum methods)
- 2.3 Design of low and high gravity dam
- 2.4 Elementary profile and its modification
- 2.5 Stabilizing and heightening of dam refurbishment
- 2.6 Design of buttress and arch dams
- 2.7 Embankment dams: Design principles, stability of slopes and foundations
- 2.8 Controlling seepage through foundation, design of impervious blankets
- 2.9 Design of filters for embankment dams

3 Design of Spillways [12 hours]

- 3.1 Types of spillways: Ogee, side channel, chute, Shaft
- 3.2 Various codal requirements for design of spillways
- 3.3 Ogee spillways: Shape of crest, design head, coefficient of discharge
- 3.4 Chute spillway: Control structure, vertical curve, approach channel
- 3.5 Side channel spillways: Basic equations, design principles
- 3.6 Siphon spillway: Saddle, design hydraulics, discharge
- 3.7 Dam outlet works, types and arrangements of outlets
- 3.8 Bottom outlets, valves, design of outlet works

4 Energy Dissipation Structures [10 hours]

- 4.1 Energy dissipation methods: Stilling basins, roller buckets, flip bucket
- 4.2 Stilling Basin: Design principles, codal provisions
- 4.3 Design of roller buckets, flip bucket, ski jump; Codal provisions
- 4.4 Plunge pool and scour prediction

5 Hydraulic Modelling [6 hours]

- 5.1 Numerical and physical modeling in hydraulic design
- 5.2 Computational fluid dynamics applications
- 5.3 Software for hydraulic design

6 Design of Hydraulic Machines [8 hours]

- 6.1 Turbines: Classification, selection of turbine types and varieties, velocity triangles, Euler-turbine equations, various efficiencies, specific speed and speed number, cavitation
- 6.2 Pelton turbines: General arrangements, functions and design of components
- 6.3 Francis turbines: General arrangements, functions and design of components
- 6.4 Kaplan and bulb turbines
- 6.5 Governing, turbine model and testing

Assignments

1. Develop comment report on hydraulic considerations for the given design sample of hydraulic structures
2. Design of low and high dam with earthquake considerations
3. Design of spillways problem based on given site and hydraulic condition
4. Design of energy dissipation structures based on given site and hydraulic condition
5. Sample tutorials for provided hydraulic models with pilot case

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Marks distribution*
1 and 5	15	12
2	15	12
3	12	12
4	10	12
6	8	12
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Novak, P., Moffat, A. I. B., Nalluri, C., Narayanan, R. (2007). Hydraulic structures (4th ed.). CRC Press.
2. Garg, S. K. (2012). Design of hydraulic structures (2nd ed.). Khanna Publishers.
3. Khatsuria, R. M. (2005). Hydraulic design of spillways and energy dissipators. CRC Press.
4. Vischer, D. L., Hager, W. H. (1998). Dam engineering. Routledge.
5. Mays, L. W. (2019). Water resources engineering (3rd ed.). Wiley.
6. U.S. Bureau of Reclamation. (1987). Design of small dams (3rd ed.). United States Government Printing Office.

RIVER ENGINEERING
ENCEWR561

Credits: 4

Year: I

Part: II

Course Objectives

Upon successful completion of this course, students will be able to plan and design sustainable river engineering and management solutions using advanced hydraulics, hydrology and modeling tools.

- | | | |
|----------|---|-------------------|
| 1 | Introduction | [4 hours] |
| | 1.1 Fluvial system | |
| | 1.2 River reaches and classifications | |
| | 1.3 Fundamentals of river morphodynamics | |
| | 1.4 Rivers, environment and uses | |
| | 1.5 River engineering problems in water infrastructure projects | |
| 2 | River Hydraulics and Morphodynamics | [8 hours] |
| | 2.1 River hydraulics: Lowland and mountain rivers | |
| | 2.2 Sediment processes and transport in rivers | |
| | 2.3 Sediment continuity and riverbed changes | |
| | 2.4 Longitudinal profile and downstream fining | |
| 3 | Bed Forms, Bars and Bifurcations | [5 hours] |
| | 3.1 Bed forms in sand and gravel bed rivers | |
| | 3.2 River bars | |
| | 3.3 River bifurcations | |
| | 3.4 River confluences | |
| 4 | Bank Erosion, River Stabilization and Flood Protection | [10 hours] |
| | 4.1 Bank erosion | |
| | 4.2 Regime theories and equilibrium width | |
| | 4.3 Groynes and embankments | |
| | 4.4 Bottom veins | |
| | 4.5 Guide banks | |
| | 4.6 Design of sediment traps and check dams | |
| | 4.7 Indigenous river training and nature based solutions | |

5 Bridge Scour and Protection [6 hours]

- 5.1 Bridge hydraulics and scour
- 5.2 Approach flow and morphology considerations
- 5.3 Estimation and modelling of bridge scour
- 5.4 Scour protection measures
- 5.5 Countermeasures for bridge scour
- 5.6 Abutment protections

6 Modelling of Morphological Changes [15 hours]

- 6.1 Concept of morphological equilibrium, principles and assumptions
- 6.2 Propagation of bed perturbations
- 6.3 Short-term development of shoals and trenches
- 6.4 Tools for investigating morphological changes
- 6.5 Morphological modelling at different scales
- 6.6 Analytical model for reach scale equilibrium
- 6.7 River response to anthropogenic interventions

7 Monitoring Tools in River Engineering [12 hours]

- 7.1 Discharge and velocity
- 7.2 Bed sediment measurement
- 7.3 Sediment transport
- 7.4 Aerial photography and remote sensing

Practical/ Assignments

1. Hydraulic laboratory visits and demonstration of field measurement equipment
2. Morphological modelling using a 2D numerical model

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	4	4
2	8	10
3	5	6
4	10	15
5	6	5
6	15	15
7	12	5
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Garcia, M. (Ed.). (2008). Sedimentation engineering. American Society of Civil Engineers. <https://doi.org/10.1061/9780784408148>
2. Jansen, P. P., Van Bendegom, L., van den Berg, J., De Vries, M., & Zanen, A. (1979). Principles of river engineering: Non-tidal alluvial river. Pitman.
3. Julien, P. (2002). River mechanics. Cambridge University Press.
4. Rice, S. P., Roy, A. G., & Rhoads, B. L. (Eds.). (2008). River confluences, tributaries, and the fluvial network. Wiley. <https://doi.org/10.1002/9780470760383>
5. Rickenmann, D. (2016). Methods for the quantitative assessment of channel processes in torrents (steep streams). CRC Press. <https://doi.org/10.1201/b21306>
6. Wohl, E. (2010). Mountain rivers revisited (Vol. 19). American Geophysical Union. <https://doi.org/10.1029/WM019>
7. Hand-outs, research papers, and e-resources

WATER RESOURCES SIMULATION AND MODELLING

ENCEWR562

Credits: 4**Year: I****Part: II**

Course Objectives

This course aims to give a practical approach to the various facets of the subject and emphasizes the application of hydrological knowledge to solving engineering problems. After the completion of this course, the students will be able to i) Understand the principle of integrated water resources modelling; ii) Develop and apply various modelling techniques to solve water resources management problems; iii) Understand approaches for watershed modelling and set-up a hydrological model for a given watershed; iv) Evaluate the suitability of different models for specific water resources projects; v) Interpret and communicate modelling result effectively; and vi) Gained practical proficiency in water resources system modelling, equipping them to tackle real-world engineering problems.

1 Integrated Water System Modelling

[6 hours]

- 1.1 Fundamentals of water system modelling and simulation: Concepts of simulation, steps in simulation study, advantages of simulation, limitation, areas of applications review of modelling approaches; Point-scale or watershed-scale models; Continuous or event-based models
- 1.2 Rational of integrated water system modelling (IWSM): Purpose of IWSM; Examples of integration of different types of models (Hydrological-Hydraulics modelling, hydrological-water allocation modelling, hydrological-river transport modelling, climate-hydrological-crop modelling, hydrological-reservoir simulation modelling, hydrological-economic modelling)
- 1.3 System dynamics: Understanding of water as a system; holistic perspective (Nexus between various water resources system components, definition of external factors such as climate, land use); Changes in intern- and intra-component dynamics in water system; mental models on system thinking encompassing various fields (Hydrology, geology, ecology, public health, critical infrastructure, climate)

2 Hydrological Modelling

[12 hours]

- 2.1 Fundamentals of hydrological modelling: Purpose, types, and steps of hydrological modelling; Developing conceptual model
- 2.2 Mathematical modelling of hydrological system for a selected model (e.g., HEC-HMS, SWAT, HBV): Translating conceptual model to a mathematical model; Governing equations; Input data requirement; Model parameters; Selecting appropriate models/equations for various hydrological processes
- 2.3 Demonstration of hydrological model development with a selected model (e.g., HEC-HMS, SWAT, HBV): Characterization of study area; Conceptual model; Mathematical model;

Input data preparation; Model performance evaluation; Parameter sensitivity analysis; Uncertainty analysis; Output analysis (including visualization); Scenario analysis; Challenges in hydrological modelling

3 Hydraulic Modelling [15 hours]

- 3.1 Fundamentals of hydraulic modelling: Purpose, types, and steps of hydrological modelling; Boundary conditions; Flood plain characteristics (Bed slope, roughness coefficient, river cross-sections, river bank lines, river center lines, crossing structures); Selection criteria for hydraulic model
- 3.2 Mathematical modelling hydraulic system with a selected model (HEC-RAS, Delft 3D): Developing and translating conceptual model to mathematical model; Governing equations; Input data requirements; Model parameters; Selecting appropriate models/equations for various hydraulic processes
- 3.3 Demonstration of hydraulic model development with a selected model (HEC-RAS, Delft 3D): Characterization of study area; Conceptual model; Mathematical model; Input data preparation; Model performance evaluation; Parameter sensitivity analysis; Uncertainty analysis; Output analysis (Hazard, vulnerability and risk maps); Scenario analysis; Challenges in hydraulic modelling

4 Water Allocation Modelling [12 hours]

- 4.1 Fundamentals of water allocation modelling: Purpose, types, and steps of water allocation modelling; Study area characteristics; Selection criteria for a water allocation model
- 4.2 Mathematical modelling water allocation with a selected model (e.g., WEAP): Developing and translating conceptual model to mathematical model; Governing equations; Input data requirements; Model parameters; Selecting appropriate models/equations for various processes, including water demand estimation
- 4.3 Demonstration of water allocation model development with a selected model (e.g., WEAP): Characterization of study area; Conceptual model; Mathematical model; Input data preparation; Model performance evaluation; Parameter sensitivity analysis; Uncertainty analysis; Output analysis; Scenario analysis (Including trade-off, policy assessment); Challenges in hydraulic modelling

5 Reservoir Simulation Modelling [15 hours]

- 5.1 Basics of reservoir simulation modelling: Purpose, types, and steps of reservoir simulation modelling; Reservoir characteristics/components; Developing a conceptual model
- 5.2 Mathematical modelling of reservoir simulation with a selected model (e.g., HEC-ResSIM): Translating conceptual model to a mathematical model; Governing equations; Input data requirement; Model parameters; Selecting appropriate models/equations for various reservoir processes

- 5.3 Demonstration of reservoir simulation modelling with a selected model (e.g., HEC-ResSIM): Characterization of study reservoir; Conceptual model; Mathematical model; Input data preparation; Model performance evaluation; Parameter sensitivity analysis; Uncertainty analysis; Output analysis (e.g., rule curve); Scenario analysis; Challenges in reservoir simulation modelling

Assignments

1. Development of Hydrological Model (e.g., HBV, HEC-HMS or SWAT) for a selected watershed
2. Development of Hydraulic Modelling (e.g., HEC-RAS, Delft3D) for a selected study area
3. Development of Water Resources Allocation Model (e.g., WEAP) for a selected study area
4. Development of Reservoir Simulation Model (e.g., HEC-ResSIM) for a selected reservoir

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	6	6
2	12	15
3	15	15
4	12	12
5	15	12
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Singh, V. P. (2016). Applied hydrology. CRC Press
2. Gupta, H. V., Sorooshian, S. (2018). Modeling and analysis with hydrologic applications. Springer
3. Singh, V. P., Donald, K. F. (2002). Mathematical models for small watershed hydrology and applications
4. Singh, V. P., Donald, K. F. (2002). Mathematical models for large watershed hydrology.

5. Roberto, L., Mike, M. (2009). Integrated water resources management in practice: Better water management for development
6. Ahmed, T. (2010). Reservoir engineering handbook
7. Relevant research papers and articles on integrated water system modeling, water allocation modeling, water resource management, reservoir simulation, and management
8. Manuals and documentation for specific hydrological modeling software like HEC-HMS, SWAT, and HBV
9. Manuals and documentation for specific reservoir simulation modeling software like HEC-ResSIM
10. Manuals and documentation for specific hydraulic modeling software like HEC-RAS, Delft 3D
11. Selected materials, journal articles, and lecture notes

CLIMATE CHANGE, WATER SECURITY, AND NEXUS
ENCEWR563

Credits: 4

Year: I

Part: II

Course Objectives

After the completion of this course, the students will be able to i) Understand fundamentals of climate system, climate change/variability, and water security issues; ii) Detect and attribute to climate change; iii) Assess climate change impacts on water sector; iv) Measure water security and its link to climate change; v) Familiarize with nexused relationship of water and other resources and understand pathways of operationalizing nexus gain solutions; and vi) Understand various ways for responding to climate change.

1 Climate System, Climate Variability/Change, and Drivers [10 hours]

- 1.1 Global climate system and energy balance: Atmosphere, hydrosphere, cryosphere, lithosphere, biosphere, global energy budget, greenhouse effect
- 1.2 Interaction among the climate components: Atmosphere and hydrosphere; Atmosphere and lithosphere; Atmosphere and biosphere; Atmosphere and cryosphere
- 1.3 The hydrological cycle and its interaction with climate variability/change: Storage, fluxes, and resident times
- 1.4 Natural and anthropogenic drivers of climate variability/change: Ocean-atmosphere circulation and interactions; Earth-Sun-Moon interactions; Atmospheric chemistry and aerosols; Human-induced increase to greenhouse gases and enhanced greenhouse effect; Human-induced increase to aerosols and other pollutants; Land use/cover change (Including urbanization)

2 Detection, Attribution and Projection of Climate Change [10 hours]

- 2.1 Detection to climate change: Climate data; Physical evidence; Global climate teleconnections; Trends in climatic indices, and Climatic extremes
- 2.2 Attribution to climate change: Fundamentals of attribution science; Approaches of attribution of climate change to extreme events; Partitioning changes to natural or anthropogenic sources
- 2.3 Climate models and scenarios: Global and regional climate models; Evolution of future scenarios (e.g. SRES, RCPs, SSPs)
- 2.4 Future climate projection: Statistical and dynamic downscaling; Bias correction

3 Climate Change Impact and Risk Assessment [12 hours]

- 3.1 Potential impacts of climate change in various sectors: Water (water availability; water demands); Water-induced disasters; Public health; Ecosystem and environmental health; Agriculture and food security; Differential impacts to vulnerable social groups and gender

- 3.2 Climate change impact assessment: Concept, approach and case studies of climate change impact assessment on water availability and water demands
- 3.3 Climate risk assessment: Concept of risk; Vulnerability and risk to climate change (flood and drought risks); Economics of climate change (Damage and adaptation)
- 3.4 Uncertainties in climate change impact assessment: Definition, sources, methods, and case studies of uncertainty assessment; Confronting climate uncertainties in water resources planning and project design (decision-tree analysis)

4 Understanding Water Security and WEF E Nexus [12 hours]

- 4.1 Basics of water security: Multiple facets of water (Strategic dimensions of water); Contemporary issues on secured use of water; Changing concept of water security; Issues of scale in water security; Water security in changing climate; Interdependencies of water security with other security areas (i.e., nexused relationships, WEF E nexus)
- 4.2 Measuring water security: Various approaches for measurement; Description and demonstration of an indicator-based framework for water security assessment
- 4.3 Trends in WEF E nexus resources: Heterogeneity in natural resources endowment and demands across scale, space and time; Concept of footprints (water footprint, energy footprint); Planetary boundaries (Including science with/for people)
- 4.4 Fundamentals of WEF E nexus: Concepts, principles, and added-value of Nexus (trade-offs and synergies); Evolution of nexus thinking approach (Limits to growth, sustainability, IWRM, nexus); Entry points to inclusive (Gender, differently-abled, ethnicity, socio-economic status) WEF E interventions; WEF E nexus in the climate and market change contexts

5 Operationalizing and Managing WEF E Nexus [10 hours]

- 5.1 WEF E nexus assessment: Theoretical framework; Inclusivity analysis framework (Gender, differently-abled, ethnicity, socio-economic status) in WEF E nexus solutions/interventions; Nexus database; Nexus modelling (Approaches, tools); WEF E nexus assessment challenges/bottlenecks.
- 5.2 Case studies highlighting different aspects of nexus in practice: Synergies and trade-off across sectors; Benefits (Direct or indirect), risks and costs to different social groups to access six capitals (Natural, physical, finance, human, social, and political) in short- and long-term; Improved coordination (Among agencies/sectors, among intersectionality, etc.); Policy and institutional reforms; Indigenous knowledge
- 5.3 Nexus decision support system (NDSS): Framework, features, communication, uptake, and operationalization (Including making it people-focused) challenges for NDSS.
- 5.4 Streamlining WEF E nexus as a common agenda: Promoting dialogue (Between science, policy, practice/industry, private sector) on WEF E nexus gain solutions; Contribution of nexus solutions in achieving national goals and Sustainable Development Goals (SDGs); Strengthening cooperation and coordination across scales nexus gains

6 Responding to Climate Risk, Water Insecurity

[6 hours]

- 6.1 Frameworks for responding to climate change: International frameworks (e.g. IPCC, UNFCCC); National frameworks (e.g., NAP, NAPA, LAPA)
- 6.2 Climate change adaptation and mitigation: Concept, types, options, tools and strategies
- 6.3 Water security and nexus gain pathways: Scientific response; Policy and governance response; Innovation and changes in natural resources management practices (Typologies of practices; Variation of practices across the location and scales (e.g., on farm-level, using climate data for design and water infrastructures); Natural resources diplomacy (Different tracks of diplomacy) in the transboundary context
- 6.4 Addressing bottlenecks for implementing inclusive solutions for WEFE nexus gains: Technical/engineering solutions (Challenges: data/information, capacity); Nature-based solutions; Governance solutions (Challenges: mindset, capacity, education/awareness, ensuring sharing of benefits); Ensuring equitable (Gender, differently-abled, ethnicity socio-economic status, etc.) sharing of benefits; Market-based solutions; Demand-based solutions; Operationalizing regular review/monitoring and feedback system

Assignments

- 1. Climate indices analysis using tools such as ClimPACT
- 2. Future climate projection by downscaling or correcting biases in global/regional climate model outputs
- 3. Assessing climate change impacts on water resources and associated uncertainties using a hydrological model (e.g., HEC-HMS, SWAT, JAMS-J2000, VIC, ABCD)

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	10	8
2	10	8
3	12	12
4	12	16
5	10	8
6	6	8
Total	60	60

*There may be minor deviation in marks distribution.

References

1. ADB. (2009). The economics of climate change in Southeast Asia: A regional review. ADB.
2. Bates, B. C., Kundzewicz, Z. W., Wu, S., Palutikof, J. P. (Eds.). (2008). Climate change and water: Technical paper of the Intergovernmental Panel on Climate Change. IPCC Secretariat.
3. Dawson, B., Spannagle, M. (2009). The complete guide to climate change. London: Routledge.
4. Ludwig, F., Kabat, P., van Schaik, H., van der Valk, M. (2008). Climate change adaptation in the water sector. Earthscan Publications Ltd.
5. Garbrecht, J., Piechota, T. (2006). Climate variations, climate change, and water resources engineering. ASCE Publications.
6. Shrestha, S., Babel, M. S., Pandey, V. P. (2014). Climate change and water resources. CRC Press, Taylor & Francis Group.
7. Stern, N. (2007). The economics of climate change: The Stern review. Cambridge University Press.
8. Ray, P. A., Brown, C. M. (2015). Confronting climate uncertainty in water resources planning and project design: The decision tree framework. Washington, DC: World Bank.
9. Nepal, S., Neupane, N., Belbase, D., Pandey, V. P., Mukherji, A. (2021). Achieving water security in Nepal through unravelling the water-energy-agriculture nexus. International Journal of Water Resources Development, 37(1), 67-93.
10. Selected research materials, journal articles, and lecture notes

WATER RESOURCES PLANNING AND MANAGEMENT

ENCEWR571

Credits: 4**Year: I****Part: II****Course Objectives**

This course aims to address the water resources related problem using scientific tools and be able to give suitable solutions, so that the decision making will be effective.

1 Introduction [3 hours]

- 1.1 Definition of system and integrated water resources management
- 1.2 Water resources and hydropower systems
- 1.3 Modelling principles
- 1.4 River basin concepts

2 Engineering Economics [10 hours]

- 2.1 Economics and engineering economics
- 2.2 Time value of money: Economic interest formulas and its application with examples
- 2.3 Economic and financial analysis, future worth, present worth, cost benefit analysis
- 2.4 Project appraisal and its importance
- 2.5 Current rules and regulation: Economic cycle
- 2.6 Technical and economic efficiencies
- 2.7 Elements of costs; Types of costs (Marginal cost, marginal revenue, sunk cost, opportunity cost)
- 2.8 Break even analysis

3 System Modelling [10 hours]

- 3.1 Investment problems in water resources projects
- 3.2 Sequencing and scheduling with LP and DP
- 3.3 Power system planning tools (e.g., WASP) and other recent tools
- 3.4 Simulation modelling: Reservoir simulation, stochastic and deterministic simulation, stochastic hydrology, Thomas-Fiering methods, Matalas method
- 3.5 Reservoir operation policies: Standard operation policy and Hedging rules
- 3.6 Reservoir operations: Mass curve, Ripple method, Sequent peak method

4 System Modelling with Probabilistic Approach [10 hours]

- 4.1 Stochastic phenomena of water resources input parameters
- 4.2 Markov chain and its application in hydrology
- 4.3 Chance constrained models: Linear decision rule, deterministic and stochastic reservoir

operation

- 4.4 Deterministic and stochastic DP and its application in reservoir operation
- 4.5 Incremental dynamic programming for reservoir operation
- 4.6 River basin planning models and case studies: HEC ResSim, WEAP, MIKE Basin

5 Modern Techniques in Reservoir Operation [10 hours]

- 5.1 Artificial Neural Network (ANN), Genetic Algorithms/Programming (GA/GP); Particle Swarm Algorithms, Honey Bee Algorithms, Ant Colony Optimization
- 5.2 Fuzzy programming for reservoir operation
- 5.3 Support vector method and its application in river basin system analysis

6 System Assessment Techniques [8 hours]

- 6.1 General performances: Risk analysis, reliability, resiliency and vulnerability
- 6.2 Social assessment criteria
- 6.3 Environmental assessment criteria
- 6.4 Multiple criteria on decision making (MCDM): Compromise programming, Analytical hierarchical process (AHP), Goal programming, recent tools applicable to Water resources
- 6.5 Functions of multiple variables and its solution techniques
- 6.6 Unconstrained optimization
- 6.7 Quadratic programming (Kuhn – Tucker conditions, Wolfe’s Modified Simplex method and Beale’s method)

7 Legal Issues in Water Resources [5 hours]

- 7.1 National and international water laws
- 7.2 Regional co-operation for water issues (Nepal and India, Nepal and China)
- 7.3 National water resources (Act, policies, and rules)
- 7.4 International cooperation and issues for downstream benefits
- 7.5 Latest hydropower policy of Nepal

8 Institutional Issues [4 hours]

- 8.1 Water administration in Nepal
- 8.2 Institutional cooperation for the development for the boundary and transboundary rivers
- 8.3 Shared basins: Main issues and hydropower diplomacy
- 8.4 Lessons from international practices (Colombia and Mekong Rivers)
- 8.5 Regional water cooperation in South Asia (Water projects in Brahmaputra river)
- 8.6 Nepal-India water cooperation and diplomacy: Koshi, Gandak and Mahakali agreements
- 8.7 Future Projects: Pancheshwor Project, Sapta Koshi High Dam
- 8.8 Nepal-India water projects: Failure story and future opportunities

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark distribution*
1	3	3
2	10	10
3	10	10
4	10	10
5	10	10
6	8	8
7	5	5
8	4	4
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Loucks, D. P., Stedinger, J. R., Haith, D. A. (1981). Water resources systems planning and analysis. Prentice-Hall, Inc.
2. Gill, P. E., Murray, W., Wright, M. H. (1981). Practical optimization. Academic Press.
3. Sharma, R. K., Sharma, T. K. (1990). Irrigation and drainage. Oxford and IBH Publishing Co. Pvt. Ltd.
4. Karamouz, M., Szidarovszky, F., Zahraie, B. (2003). Water resources system analysis. Lewis Publishers.
5. Mays, L. W. (Ed.). (2005). Water resources systems management tools. McGraw-Hill.
6. Dhungel, D. N., Pun, S. B. (Eds.). (2009). The Nepal–India water relationship: Challenges. Springer.
7. Deb, K. (2009). Optimization for engineering design. PHI Learning Pvt. Ltd.
8. Bhave, P. R. (2011). Water resources systems. Narosa Publishing House.
9. Sharma, J. K. (2017). Operations research: Theory and applications. Trinity Press.
10. Research papers published in standard journals, with recent publications prioritized

ROCK SLOPE ENGINEERING

ENCEWR572

Credits: 4**Year: I****Part: II**

Course Objectives

This course covers the investigation, design, excavation, and remediation of man-made rock cuts and natural slopes, primarily for civil engineering applications. It presents design information on structural geology, shear strength of rock and groundwater, including weathered rock. Slope design methods are discussed for planar, wedge, circular, and toppling failures, including seismic design. Information is also provided on slope stabilization, movement monitoring, and civil engineering applications.

- 1 Introduction** **[2 hours]**
 - 1.1 Socioeconomic significance of landslides
 - 1.2 Future landslide activity
 - 1.3 Economic losses caused by landslides

- 2 Intact Rock and Rock Mass** **[6 hours]**
 - 2.1 Rock composition and texture
 - 2.2 Classification of rocks
 - 2.3 Physical properties of rocks
 - 2.4 Strength of rocks: The uniaxial compressive strength (σ_c), point load strength (I_s) and their correlation; Deformation moduli and Poisson's ratio; Compressive strength estimated from Schmidt hammer; Effect of saturation upon strength
 - 2.5 Discontinuities: Classification, rock joints characteristics, orientation of discontinuities and role of discontinuities in rock slope failure

- 3 Mechanics of Rock Slope Failure** **[4 hours]**
 - 3.1 Friction, cohesion and density
 - 3.2 Sliding due to gravitational loading
 - 3.3 Influence of water pressure on shear strength
 - 3.4 The effect of water pressure in tension cracks
 - 3.5 Reinforcement to prevent sliding
 - 3.6 Factor of safety of a slope

- 4 Graphical Presentation of Geological Data** **[4 hours]**
 - 4.1 Graphical techniques for data presentations
 - 4.2 Construction of great circle and a pole presentation of a plane
 - 4.3 Evaluation of potential slope problems

5 Rock Slope Stability Analysis [16 hours]

- 5.1 Definitions and aims of slope stability analysis
- 5.2 Factors affecting slope stability
- 5.3 Rock slope stability analysis: Empirical, deterministic and probabilistic methods; Numerical modeling
- 5.4 Planning a slope stability program
- 5.5 Practical examples: Plane, wedge, circular and toppling failure analyses

6 Groundwater [2 hours]

- 6.1 Occurrence and characteristics of groundwater
- 6.2 Porosity and permeability of rock and rock mass
- 6.3 Estimation of water pressure along sliding planes

7 Shear Strength Parameters of Discontinuities [2 hours]

- 7.1 Shear strength of planar surfaces
- 7.2 Shear strength of rough surfaces

8 Support Methods [15 hours]

- 8.1 Reduction in slope height
- 8.2 Reduction in slope angle
- 8.3 Reinforcement of slope
- 8.4 Slope drainage and depressurization measures
- 8.5 Comparison between alternative support methods
- 8.6 Control of rock falls

Assignments/Practical [15 hours]

- 1. Analysis of plane, wedge, and circular failure
- 2. Support design for unstable slopes
- 3. Measurement of attitude of discontinuities
- 4. Estimation of shear strength parameters of rock and rock mass

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Marks distribution*
1, 2 and 3	12	12
4 and 5	8	12
6, 7 and 8	5	12
9	12	12
10	8	12
Total	45	60

*There may be minor deviation in marks distribution.

References

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2. Department of Geology and Applied Geology, University of Natal, Durban, South Africa,
3. pp. 98 - 132.
4. Bolt, B. A. 1989. The nature of earthquake ground motion. In F Naeim ed., the seismic
5. design handbook, Van Nostrand Reinhold, New York.
6. Broch, E. 1979. Change in rock strength caused by water. Proc. 4 th ISRM Congress,
7. Montreux, I:71 - 75, Rotterdam: Balkema.
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9. surface mining (ed. C. O. Brawner), pp. 19 - 41. New York: Society of Mining
10. Engineering, AIME.
11. Chowdhury, R. N. 1978. Slope analysis, development in Geotechnical Engineering, Vol.
12. 22, 423p.
13. Nilsen, B. 2000. New trend in rock slope stability analysis. Bulletin of Engineering
14. Geology and the Environment (2000) 58, pp. 173 - 178.
15. Nilsen, B. and Palmstrom, A. 2000. Engineering Geology and Rock Engineering,
16. Norwegian Group of Rock Mechanics (NBG), Norway, 249p.
17. Hoek, E. and Bray, J. W. 1981. Rock Slope Engineering. Institute of Mining and
18. Metallurgy, London, 358p.
19. Hoek, E. 1998. Slope stability problem in Hong Kong (Chapter 7). Course notes, Internet
20. edition, <http://wwwrockeng.utoronto.ca/hoekcorner.htm>, pp. 92 - 104.
21. Hoek, E. 1998. Factor of safety and probability of failure (Chapter 8). Course notes,
22. Internet edition, <http://wwwrockeng.utoronto.ca/hoekcorner.htm>, pp. 105 - 114.
23. Hoek, E. 2000. Shear strength of discontinuities (Chapter 4). Course notes, Internet edition.
<http://wwwrockeng.utoronto.ca/hoekcorner.htm>, pp. 60 - 72

GLACIER AND GLACIO-HYDROLOGICAL MODELING

ENCEWR573

Credits: 4**Year: I****Part: II****Course Objectives**

This course aims to provide comprehensive understanding of cryosphere mainly snow, glacier and glacial lakes and how it could be integrated in to the hydrological modelling to understand the snow and ice melt contribution to the river system. After the completion of this course, the students will be able to i) Understand the types and importance of glaciers; ii) Computation of melt water from snow and glacier; iii) Setup Glacio-hydrological model; and iv) Probable change of snow and glacier and effect of glacier reduction in future river flows with climate change scenarios. This comprehensive curriculum ensures that graduates are well-equipped with both theoretical knowledge and practical skills to address the challenges and opportunities presented by glacial hydrology in a changing climate.

1 Introduction**[10 hours]**

- 1.1 Snow and glaciers: Definition, formation and types of snow, snow measurement techniques, snow water equivalent, definition and types of glaciers and their relevance to the mountain river system; Brief overview of evolution of glaciers, zone in a glacier, change of snow to ice and glacier ice flow
- 1.2 State of glacier and glacier studies in Nepal: Status of glacier and glacial lakes and opportunities and challenges in glacier research in Nepal and in regional and global context
- 1.3 Importance of glaciers: Direct contribution from glacier ice melt and its implication as natural reservoir; Glaciers as a buffer where the precipitation gets stored as a snow and replenishes the water system during the dry period; Glaciers as indicator of climate change; Mountain tourism; Glacier response to climate change

2 Glacier Mass and Energy Balance**[10 hours]**

- 2.1 Components of glacier surface mass balance, surface accumulation and ablation processes, estimation of ablation using positive degree-day method
- 2.2 Glacier mass balance by glaciological method
- 2.3 Glacier mass balance by energy balance method
- 2.4 Modeling of glacier surface mass balance

3 Glacial Hazards and Mitigation**[10 hours]**

- 3.1 Glacier hazards: snow and ice avalanches
- 3.2 Glacial lake and glacial lake outburst flood (GLOF) Modeling
- 3.3 Adaptation and mitigation techniques

4 Remote Sensing and Field Techniques for Cryospheric Studies [10 hours]

- 4.1 Advances in remote sensing techniques on the cryosphere, latest satellite images and other data products
- 4.2 Basic parameters of snow and ice: measurement of snow and ice densities and temperature, snow water equivalent, basic equipment for measuring these parameters
- 4.3 Glacier mass balance: measurement of accumulation and ablation
- 4.4 Major equipment useful in glacier study: Automatic weather station (AWS); Ground penetrating radar; snow/ice augers; steam driller; Unmanned aerial vehicle (UAV); DGPS; Echo-sounder

5 Glacio-hydrological Models [20 hours]

- 5.1 Introduction: Basic concept of hydrological models, types and concept of different glacio-hydrological models; Data requirements; Model calibration and validation
- 5.2 Snow and glacier melt integration to the hydrological model
- 5.3 Application: Water resource management in glaciated regions; Risk of glacial hazards (e.g., glacial lake outburst floods); Policy implications and decision-making based on model outputs

Assignments/Practical

- 1. Preparation of meteorological data for modelling
- 2. Pre-processing of DEM for modelling
- 3. Setup of integrated catchment model (ICHYMOD) for a glaciated basin in Nepal
- 4. Validation of the model results
- 5. Calculation of glacier melt and snow contribution to the runoff
- 6. Integration of global dataset such as ERA5 to the model

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks Distribution*
1	10	10
2	10	10
3	10	10
4	10	15
5	20	15
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Paterson, W. S. B. (1969). The physics of glaciers (3rd ed.). Pergamon Press.
2. Alen, M. H. J. (1992), Glaciers, Cambridge University Press.
3. Benn, D. I., Davis, J. A. E. (1998). Glacier and glaciation. Department of Geography and Topographic Science, University of Glasgow.
4. Menzies, J. (1998). Modern and past glacial environments (Revised Student ed.). Butterworth-Heinemann.
5. Nakawo, M., Hayakawa, N. (1998). Snow and ice science in hydrology. Prepared for the 7th IHP Training Course on Snow Hydrology, Institute for Hydrospheric-Atmospheric Sciences, Nagoya University, and UNESCO.
6. Hambrey, M. (1994) Glacier Environments, UCL Press Limited, University College London.
7. Zaramella, M., Borga, M., Zocatelli, D., Carturan, L. (n.d.). TOPMELT 1.0: A topography-based distribution function approach to snowmelt simulation for hydrological modelling at basin scale.
8. Shrestha, S., Zaramella, M., Callegari, M., Greifeneder, F., Borga, M. (2023). Scale dependence of errors in snow water equivalent simulations using ERA5 reanalysis over Alpine basins.

GROUNDWATER ASSESSMENT, DEVELOPMENT AND MANAGEMENT
ENCEWR611**Credits: 4****Year: II****Part: I****Course Objectives**

The objective of this course is to provide knowledge and skills related to assessment, development and management of groundwater resources. It focuses on groundwater occurrence and movement, groundwater data collection/interpretation/modelling, groundwater pollution/contamination, well hydraulics/design/construction/maintenance, groundwater-related environmental issues, and on various aspects of groundwater management. After the completion of this course, the students will be able to i) Strengthen understanding on groundwater occurrence, movement and assessment for sustainable development and management of groundwater resources for various uses; ii) Enhance learning on various environmental issues related to groundwater abstraction; iii) Strengthen knowledge on water well design, construction and maintenance; iv) Plan groundwater development and management at a basin scale for sustainable groundwater development.

1 Fundamentals of Groundwater and its Occurrence [6 hours]

- 1.1 Groundwater occurrence: Origin, age, and vertical distribution of groundwater; hydro-geologic layers; aquifer types
- 1.2 Aquifer characterization: Aquifer properties, heterogeneity and anisotropy of aquifers
- 1.3 Groundwater recharge: Storage, discharge and recharge; Infiltration, methods for estimating recharge
- 1.4 Groundwater surface water interaction: General introduction; Key issues; Conjunctive use and management
- 1.5 Evolution of groundwater development: Global; National

2 Groundwater Movement [6 hours]

- 2.1 Darcy's law: Darcy's experiment and equation, Darcy's versus actual velocity
- 2.2 Permeability and hydraulic conductivity: Concept, hydraulic conductivity determination
- 2.3 Groundwater flow: Fundamentals, flow direction, equations of groundwater flow
- 2.4 Groundwater flow/movement in unsaturated zone: Concepts; Unsaturated zone hydraulic properties
- 2.5 Groundwater potential assessment: Concept, approaches, case studies

3 Well Hydraulics and Aquifer Tests [6 hours]

- 3.1 Steady unidirectional and steady radial flow: Unidirectional flow to wells in confined and unconfined aquifers; Radial flow to wells in confined and unconfined aquifers
- 3.2 Unsteady radial flow in a confined aquifer: Non-equilibrium well pumping equation
- 3.3 Solutions to non-equilibrium well pumping equations: Theis and Cooper-Jacob methods

- 3.4 Multiple well systems: Concept and solution approach
- 3.5 Well flow near aquifer boundaries: Concept and solution approach

4 Groundwater Data Collection, Interpretation and Modelling [9 hours]

- 4.1 Groundwater exploration: Reconnaissance survey, surface and sub-surface geophysical investigation, test drilling
- 4.2 Hydrological assessment: Water balance method, rainfall-runoff models, regional groundwater flow model
- 4.3 Groundwater modelling: Steps in developing groundwater flow model; simulation of 2D and 3D groundwater system (Governing equations, solutions schemes, case study)
- 4.4 Interpretation of hydro(geo)logical time series and spatial data
- 4.5 Groundwater investigation programs: Planning, designing and implementation of groundwater investigation programs, optimizing a groundwater monitoring network

5 Groundwater Pollution/Contamination [6 hours]

- 5.1 Pollution/contamination sources: Point and non-point sources
- 5.2 Movement and attenuation of pollutants in aquifers: Attenuation process (Physical, chemical, biological)
- 5.3 Transport processes of solutes: Advection, dispersion, sorption and decay, mathematical treatment
- 5.4 Contaminant transport modelling: Steps, governing equations, initial and boundary conditions, solution schemes, case study
- 5.5 Groundwater vulnerability/risk assessment to pollution (e.g. DRASTIC model)

6 Water Wells Design, Construction and Maintenance [9 hours]

- 6.1 Well testing for yield: Pumping test (Drawdown, step-drawdown), slug test, aquifer and well losses and efficiencies; recovery test, safe yield, sustainable yield
- 6.2 Well design: Casing section, screen section, gravel pack, sand trap, pump (e.g., total pumping head, pumps for shallow and deep wells), design optimization
- 6.3 Well construction: Test holes and well logs; Construction methods for shallow and deep wells; Well completion
- 6.4 Well protection and rehabilitation: Sanitary protection, frost protection, abandonment of wells, well rehabilitation
- 6.5 Well maintenance: Need, methods, frequency

7 Groundwater Related Environmental Issues [6 hours]

- 7.1 Overexploitation: Drawdown, land subsidence, migration of low-quality groundwater, decline in environmental flows, impacts on groundwater-dependent ecosystems
- 7.2 Overcharging: Waterlogging induced by irrigation, impact on urban infrastructure due to rise

- in groundwater level
- 7.3 Groundwater quality degradation: Various sources and mechanisms for groundwater quality degradation (e.g., due to leakage from sewer lines, contamination from improperly sealed well-heads)
- 7.4 Delineating well-head protection areas: Delineating wellhead protection perimeters and other zones of aquifer protection using analytical and numerical simulations
- 7.5 Remediation of contaminated groundwater

8 Groundwater Management [12 hours]

- 8.1 Groundwater governance: Fundamentals, framework, and institutions (Structure, environment and change process) for water governance, conceptual framework for groundwater management
- 8.2 Groundwater laws and policies: Requirements, gaps in existing legal frameworks (In Nepal); integrated approach to groundwater/water-sector laws
- 8.3 Groundwater valuation: Basis for groundwater valuation, groundwater pricing, groundwater market
- 8.4 Groundwater augmentation: Concept and methods of artificial recharge
- 8.5 Groundwater management modelling: Scenario analysis, policy evaluation and allocation models (e.g., response matrix approach, heuristic optimization approach)

Assignments

1. Tutorials related to Darcy’s law and groundwater flow
2. Groundwater potential assessment
3. Well hydraulics and/or pumping test analysis
4. Groundwater vulnerability/risk assessment

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Marks distribution*
1	6	6
2	6	6
3	6	6
4	9	9
5	6	6
6	9	9
7	6	6
8	12	12
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Charbeneau, R. J. (2000). Groundwater hydraulics and pollutant transport. Prentice-Hall.
2. Delleur, J. (Ed.). (2007). The handbook of groundwater engineering (2nd ed.). CRC Press.
3. Pinder, G. F., Celia, M. A. (2006). Subsurface hydrology. John Wiley and Sons.
4. Rushton, K. R. (2003). Groundwater hydrology: Computational and computational models. John Wiley and Sons.
5. Shah, T. (2009). Taming the anarchy: Groundwater governance in South Asia. Resources for the Future; International Water Management Institute (IWMI).
6. Todd, D. K., Mays, L. W. (2005). Groundwater hydrology (3rd ed.). John Wiley and Sons.
7. USBR. (1995). Handbook of groundwater development. United States Bureau of Reclamation.

DESIGN OF UNDERGROUND STRUCTURES
ENCEWR612**Credits: 4****Year: II****Part: I****Course Objectives**

This course is designed to provide knowledge on planning, stability analysis and design of tunnels/shafts and underground caverns using different approaches. After having this course, students will be able to design the rock support required for the tunnels / shafts and caverns in specific ground conditions.

1 Planning and Investigations [12 hours]

- 1.1 Functions and purposes of tunnels and underground (UG) structures
- 1.2 Stages of design
- 1.3 Planning in locating tunnels and UG Structures; Selection of alignment
- 1.4 Investigations during planning and implementation
- 1.5 Rock and ground characterization

2 Tunneling Technology [12 hours]

- 2.1 Selection of tunnelling technology
- 2.2 Drill and blast tunnelling methods
- 2.3 Tunnel boring machine (TBM)
- 2.4 Road header
- 2.5 Shaft sinking; Raise boring

3 Stability of UG Structures [12 hours]

- 3.1 Factors affecting stability of underground excavation
- 3.2 In-situ stresses in rock mass
- 3.3 Structurally controlled failures
- 3.4 Stress induced problems
- 3.5 Tunneling/UG structures in weak rock condition

4 Assessment of Tunnel Stability [12 hours]

- 4.1 Potential causes of settlement (Tunnelling induced settlement; Groundwater drawdown; Inflow to a drained tunnel)
- 4.2 Tunnel deformation and estimation methods
- 4.3 Instantaneous and time dependent deformation
- 4.4 Interpretation of tunnel convergence
- 4.5 Rock mass strength and deformability

4.6 Convergence confinement method and rock support interaction

5 Tunnel Supports and Support Design

[12 hours]

- 5.1 Principles of rock support
- 5.2 Rock support types
- 5.3 Rock supports for caverns
- 5.4 Ground improvement
- 5.5 Long term stability
- 5.6 Tunnel instrumentation and monitoring

Assignments

- 1. Tunnel alignment
- 2. Stress induced problems in competent rock
- 3. Stress induced problems in weak rock
- 4. Rock support interaction

Practical

- 1. Field visit to tunnel sites
- 2. Laboratory visit for rock testing

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	12	12
2	12	12
3	12	12
4	12	12
5	12	12
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Carranza-Torres, C., Fairhurst, C. (2000). Application of the Convergence-Confinement method of tunnel design to rock masses that satisfy the Hoek-Brown failure criterion. *Tunnelling and Underground Space Technology*.
2. Hoek, E. (2023). *Practical rock engineering (2023 edition)*. Hoek's Corner. Retrieved from <https://www.rocscience.com>.
3. Hoek, E., Brown, E. T. (2018). The Hoek-Brown failure criterion and GSI – 2018 edition. *Journal of Rock Mechanics and Geotechnical Engineering*.
<https://doi.org/10.1016/j.jrmge.2018.08.001>
4. Hoek, E., Marinos, P. (2000). Predicting tunnel squeezing problems in weak heterogeneous rock masses. *Tunnels and Tunnelling International*.
5. Hoek, E., Kaiser, P. K., Bawden, W. F. (2005). *Support of underground excavations in hard rock*. A. A. Balkema/Rotterdam/Brookfield.
6. NGI (Norwegian Geotechnical Institute). (2022). *Updating the Q-method*.
7. Selected journals, literatures and lecture notes

REMOTE SENSING IN WATER RESOURCES

ENCEWR613

Credits: 4**Year: II****Part: I**

Course Objectives

The objective of this course is to provide concepts of remote sensing including satellites, sensors and their working principles, familiarizing students with various water resources related remote sensing products from NASA, ESA, and other relevant sources. The course emphasizes the practical application of remote sensing, including cloud-based platforms like Google Earth Engine (GEE), to deal with different elements of water resources management. Students will explore key topics such as use of remote sensing for water resource management, groundwater monitoring, irrigation management, water-induced disaster monitoring, and land use management. Through practical exercises and projects, the course is expected to bridge theoretical knowledge with real-world applications.

- | | | |
|----------|--|-------------------|
| 1 | Introduction | [10 hours] |
| | 1.1 Basic concepts | |
| | 1.2 Satellites and sensors | |
| | 1.3 Projections and coordinate systems | |
| | 1.4 Advantages and disadvantages of remote sensing | |
| | 1.5 Remote sensing terminology | |
| 2 | Remote Sensing and Water Resources Management | [10 hours] |
| | 2.1 Understanding water cycle | |
| | 2.2 Elements of water resources management | |
| | 2.3 Leveraging remote sensing for water resources management | |
| 3 | Remotely Sensed Data for Water Resources Application | [8 hours] |
| | 3.1 NASA: Landsat, GPM, GRACE, SMAP | |
| | 3.2 European Space Agency (ESA): Sentinel | |
| | 3.3 Digital Elevation Models (DEM) | |
| 4 | Hydrological Application | [10 hours] |
| | 4.1 Precipitation | |
| | 4.2 Surface water mapping | |
| | 4.3 Groundwater monitoring | |
| | 4.4 River morphology | |
| | 4.5 Snow cover | |

5 Water-Induced Disaster Management with Remote Sensing [10 hours]

- 5.1 Flood monitoring and mapping
- 5.2 Drought monitoring
- 5.3 Landslides

6 Irrigation and Agricultural Application [8 hours]

- 6.1 Soil Moisture, vegetation indices, yield prediction
- 6.2 Irrigated areas mapping and irrigation water use
- 6.3 Crop classification

7 Remote Sensing with Google Earth Engine [4 hours]

- 7.1 Understanding GEE interface
- 7.2 Image Interpretation: Manipulation, classification, accuracy assessment
- 7.3 Change detection

Practical

1. Imaging a disk storage, recovering disk content with Autopsy, sleuthKit, FTK
2. Analyzing memory content with Volatility and Rendell
3. Analyzing network traffic with wireshark
4. Analyzing mobile data with Andriker, Cellebrite
5. Malware analysis with Ghidra, Cuckoo sandbox

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	10	10
2	10	10
3	8	8
4	10	10
5	10	10
6	8	8
7	4	4
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Campbell, J. B., Wynne, R. H. (2011). Introduction to remote sensing. Guilford Press.
2. Thenkabail, P. S. (2016). Remote sensing handbook: Volume I, Remotely sensed data characterization, classification, and accuracies. CRC Press.
3. Thenkabail, P. S. (2016). Remote sensing handbook: Volume III, Remote sensing of water resources, disasters, and urban studies. CRC Press.
4. Thenkabail, P. S., Lyon, J. G., Turrall, H., Biradar, C. M. (2009). Remote sensing of global croplands for food security. CRC Press.
5. Cazenave, A., Champollion, N., Benveniste, J., Chen, J. (2016). Remote sensing and water resources. Springer.
6. Cardille, J. A., Crowley, M. A., Saah, D., Clinton, N. E. (2024). Cloud-based remote sensing with Google Earth Engine: Fundamentals and applications. Springer

WATER RESOURCES CONTRACT MANAGEMENT
ENCEWR621

Credits: 4

Year: II

Part: I

Course Objectives

The objective of this course is to enable the water resources students to understand key elements of construction contracts and relations between general conditions of contract and particular conditions of contract, prepare tender documents, draft particular conditions of contract, understand dispute resolution mechanism including the Engineer's determination, prepare documents to submit dispute adjudication board and referral documents to arbitration.

1 Introduction [6 hours]

- 1.1 Contracts; Types of contracts
- 1.2 Conditions of contract (Red book, silver book and yellow book)
- 1.3 Interpretations; Law and language; Compliance with laws
- 1.4 Priority of documents
- 1.5 Care and supply of documents
- 1.6 Delayed drawings or instructions

2 The Employer and Engineer [6 hours]

- 2.1 Right of access to the site
- 2.2 Permits, licenses or approvals
- 2.3 Employer's personnel
- 2.4 Employer's Financial Arrangement
- 2.5 Employer's claims
- 2.6 Delegation by the Engineer
- 2.7 Instruction of the Engineer
- 2.8 Determinations

3 The Contractor, Nominated Subcontractor [6 hours]

- 3.1 Contractor's general obligations, performance security, contractor's representative, subcontractors
- 3.2 Setting out, site data, safety procedures, sufficiency of accepted contract amount, unforeseeable physical conditions
- 3.3 Rights of ways and facilities, avoidance of interference, access routes, transport of goods
- 3.4 Contractor's equipment, protection of environment, progress reports, security of the site, contractor's operation on site
- 3.5 Definition of nominated subcontractors, objection to nomination, payments to nominate subcontractors, evidence of payments

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- 3.6 Engagement of staff and labour; Rates of wages and conditions of labour; labour laws, working hours; facilities for staff and labour
 - 3.7 Health and safety, contractor's superintendence, contractor's personnel, records of contractor's personnel and equipment, disorderly conduct
- 4 Commencement Delays and Workmanship [6 hours]**
- 4.1 Commencement of works, time for completion, programme, extension of time for completion, delays caused by authorities
 - 4.2 Rate of progress, delay damages
 - 4.3 Suspension of work, consequences of suspension, payment of plant and materials in event of suspension, prolonged suspension, resumption of work
- 5 Test on Completion, Employer's Taking Over and Defects Liability [6 hours]**
- 5.1 Contractor's obligations, delayed tests, retesting, failure to pass test on completion
 - 5.2 Taking over of works and sections
 - 5.3 Remediating
- 6 Measurement, Evaluation, Variations, Adjustments [6 hours]**
- 6.1 Method of measurement, evaluation, omissions
 - 6.2 Value engineering, variation procedure, adjustment
- 7 Contract Price and Payment [6 hours]**
- 7.1 The Contract Price, advance payment, delayed payment
 - 7.2 Retention money, statement at completion, final payment certificate, discharge
 - 7.3 Cessation of employer's liability
 - 7.4 Currencies of payment
- 8 Termination [6 hours]**
- 8.1 Termination by the Employer (Notice to correct, Valuation at date of termination, Payment after termination)
 - 8.2 Termination by the contractor (Contractor's entitlement to suspend work, termination by the contractor, cessation of work and removal of contractor's equipment, payment on termination)
- 9 Risk and Responsibilities, Insurance [6 hours]**
- 9.1 Indemnities, contractor's care of works
 - 9.2 Employer's risks, consequences of employer's risks
 - 9.3 Intellectual and industrial property rights, limitation of liabilities

- 9.4 Requirement of insurances; Insurance of works and contractor's equipment; Insurance against injury to persons and damage to properties; Insurance of contractor's personnel

10 Force Majeure, Claims, Disputes and Arbitration [6 hours]

- 10.1 Definition of force majeure; Notice of force majeure; Duty to minimize delay; Consequences of force majeure; Optional termination; Payment and release; Release from performance under law
- 10.2 Contractor's claims; Appointment of dispute adjudication board; Obtaining dispute adjudication board's decision; Amicable settlement; Arbitration

Assignment

Case studies and individual presentation: Each student will be assigned an individual assignment related to study of a particular conditions of contract, formation and proceedings of DAB and arbitration. Development of hillslope domain model for landslide warning purpose using observed rainfall data.

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Marks distribution*
1 and 2	12	10
3 and 4	12	10
5 and 6	12	10
7 and 8	12	10
9	6	10
10	6	10
Total	60	60

*There may be minor deviation in marks distribution.

References

1. FIDIC. (n.d.). Conditions of contract for construction for building and engineering works (Red Book).
2. FIDIC. (n.d.). Plant and design build contract (Yellow Book).
3. FIDIC. (n.d.). EPC/turnkey contract (Silver Book).

FISH PASSAGE ENGINEERING
ENCEWR622**Credits: 4****Year: II****Part: I****Course Objectives**

Upon successful completion of this course, students will be equipped to plan, design, optimize, operate, monitor, and maintain various types of fish passages. They will also gain the ability to recognize the significance of fish conservation from both environmental and socio-economic perspectives and collaborate effectively with a multidisciplinary fish passage study team.

1 Introduction [3 hours]

- 1.1 Connectivity issues in freshwater ecosystem due to damming of rivers
- 1.2 Methods for restoring the connectivity
- 1.3 History of fish passage: global and local context
- 1.4 Fish passage engineering: a multi-disciplinary science

2 Environmental and Policy Aspects [5 hours]

- 2.1 Stream function pyramid, types of aquatic ecosystem
- 2.2 Lotic ecosystem: Biotic factors and abiotic factors
- 2.3 Processes within ecosystem
- 2.4 Productivity: Primary and secondary
- 2.5 Tropic levels, food chain, food web, energy flow and ecological pyramids
- 2.6 Ecosystem services of river and fish
- 2.7 Impacts of water resources development on riverine environment
- 2.8 Impact mitigation measures
- 2.9 Major environment management principles
- 2.10 Major environment policies related to fish diversity conservation and water resources development in Nepal

3 Socio-economic Aspects [5 hours]

- 3.1 Social and cultural aspects of river
- 3.2 Water use rights, rights of indigenous fisher community
- 3.3 Livelihood of local and indigenous fisher community
- 3.4 Impacts of water resource development on fisher community
- 3.5 Ecology and society
- 3.6 Roles of communities in riverine fish conservation
- 3.7 Gender roles in fish conservation

4 Fish Ecology [15 hours]

- 4.1 Fish Biology: Physiology and anatomy
- 4.2 Fish Habitat
- 4.3 Riverine fish and distribution in Nepal
- 4.4 Fish behavior and migration in Himalayan rivers
- 4.5 Fish yield estimation
- 4.6 Ecosystem dynamics

5 Planning, Design, Operation and Maintenance of Fish Passage [24 hours]

- 5.1 Hydraulics and sedimentation phenomena at head works
- 5.2 Types and components of fish passage
- 5.3 Planning on location and layout of fish passage
- 5.4 Data requirements for design of fish passage
- 5.5 Design of upstream fish passage facilities
- 5.6 Design of downstream fish passage facilities
- 5.7 Other fish passage technologies
- 5.8 Construction methods and materials
- 5.9 Operation, monitoring and maintenance of fish passage facilities

6 Experimental Practices and Modeling Concepts in Fish Passage [8 hours]

- 6.1 Study of fish behavior in laboratory
- 6.2 Study of fish behavior in field, based on eco-hydraulics approach
- 6.3 Modelling practices for a section of fish passage
- 6.4 Modelling practices for fish passage entrance and outlets

Assignments/Tutorials

- 1. Fish yield estimation
- 2. Planning and layout of fish passage
- 3. Hydrological data analysis and design flow estimation
- 4. Design of pool and weir type fish passage
- 5. Design of vertical slot fish passage
- 6. Design of Denil fish passage
- 7. Calculation of passage efficiency

Individual assignment on literature review of relevant topics and case studies on fish passage, prepare a brief report and a presentation from the learning. The paper for the review will be assigned by the lecturer.

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	3	3
2	5	5
3	5	5
4	15	15
5	24	24
6	8	8
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Clay, C. H. (2017). Design of fishways and other fish facilities. CRC Press. <https://doi.org/10.1201/9781315141046>
2. FAO. (2002). Fish passes: Design, dimensions, and monitoring. Rome: FAO. Retrieved from <http://www.fao.org/3/y4454e/y4454e00.htm>
3. Katopodis, C. (1992). Introduction to fishway design. Fishways. Retrieved from <http://www.wra.gov.tw/public/attachment/41110254871.pdf>
4. Schwevers, U., & Adam, B. (2020). Fish protection technologies and fish ways for downstream migration. Cham: Springer International Publishing. <https://doi.org/10.1007/978-3-030-19242-6>
5. Shrestha, T. K. (2008). Ichthyology of Nepal: A study of fishes of the Himalayan waters.
6. Vigneux, E., & Larinier, M. (Eds.). (2002). Fishways: Biological basis, design criteria, and monitoring. Bulletin Francais de la Pêche et de la Pisciculture, 364(Supplement).
7. Handouts, research papers, and e-resources.