Master of Science Tropical Hydrogeology and Environmental Engineering

Module Handbook

TECHNISCHE UNIVERSITÄT DARMSTADT

Contents

Abbreviations

WiSe	Winter semester
SoSe	Summer semester
CP	ECTS credits
SWS	Credit hours per week (*Semesterwochenstunden*)
VL	Lecture
VÜ	Lecture and exercise
PR	Practical training
EK	Excursion, field trip
SE	Seminar
PS	Project seminar
FP	Examination (*Fachprüfung*)
SL	Course achievement (*Studienleistung*)

Module name CM1 Semiarid Field Hydrogeology					
Module no. 11-02-3431	**Credits** 6 CP	**Workload** 180 h	**Self study** 90 h	**Duration** 1 semester	**Cycle** Yearly in the WiSe
Language of instruction English			**Person responsible for the module** Schüth		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Field Trip to a Semiarid Region	6 CP	EK	6

2 Course contents

Excursion to a semiarid area to study urban and rural water supply, irrigation, well types, regional groundwater balance and flow, water reservoirs, water quality, fossil waters, salt water intrusion, salinization, protection against soil erosion, river erosion during high floods, desertification.

3 Qualification and learning goals

Field work is an essential part of geoscientific work. In this module the students develop an understanding of how problems in geosciences and related scientific areas are practically solved in semi-arid countries where water resources are scarce. The students acquire theoretical and practical knowledge of geoscientific fundamentals and methods with focus on water and environmental management. They acquire skills to understand regional and global water and environmental problems - which often require interdisciplinary cooperation - and to develop approaches to solve them. As a usually multinational group during the field trip the students improve their intercultural competence. They also improve other soft skills such as team working skills and communication skills.

4 Prerequisites for attending

none

5 Type of exam

Report (SL)

6 Criteria for obtaining the credits

Participation in the field trip and acceptance of report by the course supervisor

7 Grading

Not graded (*bestanden/nicht bestanden*)

8 Curricula where the module is used

M.Sc. TropHEE:
Compulsory Modules

9 Literature

Dependent of destination of field trip

10 Comments

Module name CM2 Scientific Methods					
Module no. 11-02-3402	**Credits** 6 CP	**Workload** 180 h	**Self study** 150 h	**Duration** 1 semester	**Cycle** Yearly in the SoSe
Language of instruction English			**Person responsible for the module** Hinderer (Dean of Study Affairs)		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Project Seminar	6 CP	PS	2

2 Course contents

Questions and problems related to geosciences, water management and environmental technologies are addressed in small student teams, if possible in cooperation with students from other departments or course programmes. The results of the teamwork are compiled into a written report and are presented in the seminar. Presentation of the results may include both talks and posters.

3 Qualification and learning goals

The students will be able to employ team-oriented and interdisciplinary approaches for solving questions and problems related to geosciences, water management and environmental technologies, against the background of geological and technical factors as well as infrastructural and ecological/economical conditions. The students will be able to describe and present the results of their work in a scientifically adequate form (presentation skills).

4 Prerequisites for attending

none

5 Type of exam

Written report, seminar presentation, poster presentation, or other adequate form of representation of the work outcome, as agreed with the supervisor at the start of the term (SL). The supervisor(s) issue(s) an overall grade covering all course achievements which will be the grade for the module.

6 Criteria for obtaining the credits

Participation in the seminar and passing the exam

7 Grading

Graded (*Standardbewertungssystem*)

8 Curricula where the module is used

M.Sc. TropHEE:
Compulsory Modules

9 Literature

Dependent of contents to be addressed in the seminar

10 Comments

Module name CM3 Scientific Training					
Module no. 11-02-3403	**Credits** 12 CP	**Workload** 360 h	**Self study** 360 h	**Duration** 1 semester	**Cycle** Yearly in the WiSe
Language of instruction English			**Person responsible for the module** Hinderer (Dean of Study Affairs)		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Scientific training / internship	12 CP	PR	-

2 Course contents

The Scientific Training is a form of independent study, specially conceived for this study program. During this part of the program students will put into practice special geoscientific methods such as terrain analysis and mapping, chemical analyses and the collection and interpretation of external data to investigate a specific topic. The Scientific Training may take place at the Institute of Applied Geosciences of TU Darmstadt, at other scientific institutions, or in the industry. It may, in circumstances, be carried out directly in a semiarid or tropical region, e.g. in the home country of the student. The results are summarised in a final report and presented in a seminar.

3 Qualification and learning goals

The Scientific Training allows the student to study a given scientific subject by means of practical laboratory and/or field methods at a high level of independency. It is a step towards disciplinary specialisation, usually in the forerun of the Master Thesis. The student improves his methodical knowledge and skills and is enabled to assess and use different technical and/or analytical methods, including data evaluation. The student acquires skills to understand scientific problems in the field of water and environment and to develop approaches to solve them.

4 Prerequisites for attending

none

5 Type of exam

Written report and oral presentation (SL)

6 Criteria for obtaining the credits

Acceptance of report and presentation by the supervisor

7 Grading

Report graded by the supervisor (*Standardbewertungssystem*), oral presentation not graded

8 Curricula where the module is used

M.Sc. TropHEE:
Compulsory Modules

9 Literature

Dependent of contents to be addressed in the Scientific Training

10 Comments

Module name BM1 Fundamentals of Geosciences					
Module no. 11-02-3421	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1 semester	**Cycle** Yearly in the WiSe
Language of instruction English			**Person responsible for the module** Hinderer (Dean of Study Affairs)		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Geological Methods	3 CP	VÜ	2
2	Practical Mineralogy and Petrology	3 CP	VÜ	2

2 Course contents

Geological Methods: Geological mapping, structural field measurements, section drawing, stereographic projection, soil and rock description, drawing of stratigraphic sections.

Practical Mineralogy and Petrology: Crystallography, crystal morphology, basics of mineralogy, rock forming minerals and how to identify them. Introduction to magmatic and metamorphic petrology. Textural and structural characteristics of magmatic and metamorphic rocks. Metamorphic pathways.

3 Qualification and learning goals

The courses of this module aim at bringing the students - who often have different academic backgrounds - to an equal level of fundamental geological and mineralogical knowledge. The students improve or refresh their previous knowledge of geological basics and methodical skills, and of mineralogical basics. The students acquire methodical skills on how to identify important rock forming minerals and rocks in the field and by laboratory methods.

4 Prerequisites for attending

none

5 Type of exam

Written (90 min.) or oral exam (45 min.) (FP)

6 Criteria for obtaining the credits

Passing the exam

7 Grading

Graded (*Standardbewertungssystem*)

8 Curricula where the module is used

M.Sc. TropHEE:
Basic Modules

9 Literature

McCann, T. (Ed., 2008): The Geology of Central Europe.- 2 Vols.; London (Geological Society).

Maltman, A. (1990): Geological maps - an introduction.- New York (Wiley & Sons).

Bloss, F.D. (1994): Crystallography and Crystal Chemistry - An Introduction.- The Minera-

	logical Society of America, Washington D.C., USA; ISBN 0-939950-37-5. Nesse, W.D. (2000): Introduction to Mineralogy.- Oxford University Press; ISBN 13-978-0-19-510691-6.
10	**Comments**

Module name BM2 Hydrogeology					
Module no. 11-02-3406	**Credits** 6 CP	**Workload** 180 h	**Self study** 75 h	**Duration** 1 semester	**Cycle** Yearly in the WiSe
Language of instruction English			**Person responsible for the module** Schüth		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Hydrogeology	4 CP	VÜ	3
2	Hydrogeological Field Trips	2 CP	EK	2

2 Course contents

Hydrogeology: Water cycle, precipitation, evapotranspiration, runoff, atmospheric and riverine recharge, groundwater balance, methods for data regionalization, Darcy-flow basics and limits, steady state and transient flow, hydraulic potential, aquifer parameters, leakage, radial flow and pumping tests, regional groundwater flow, transport equation, diffusion and dispersion, retardation, groundwater chemistry.

Hydrogeological Field Trips: Day trips to places of hydrogeological interest including water works, waste water treatment plants, contaminated sites, landfill sites etc.

3 Qualification and learning goals

The students acquire fundamental knowledge of the hydrological cycle, groundwater hydraulics and chemistry with respect to various climatic zones, and the capability to apply related quantitative methods to actual hydrogeological problems. They acquire skills to understand local, regional and global water and environmental problems, and to develop approaches and solve them using hydrogeological methods. As a usually multinational group, during the field trips the students improve their intercultural competence. They also improve other soft skills such as team working skills and communication skills.

4 Prerequisites for attending

none

5 Type of exam

Hydrogeology: written or oral exam (FP); Hydrogeological Field Trips: participation (SL)

6 Criteria for obtaining the credits

Passing the exam and participation in the field trips

7 Grading

Hydrogeology: graded exam (*Standardbewertungssystem*) = total grade for the module; Hydrogeological Field Trips: participation only, no grading (*bestanden/nicht bestanden*)

8	**Curricula where the module is used** M.Sc. TropHEE: Basic Modules
9	**Literature** Domenico, P.A. & Schwartz, F.W. (1998): Physical and Chemical Hydrogeology.- 2nd ed., 506 p.; New York (Wiley & Sons). Fetter, C.W. (2000): Applied Hydrogeology.- London. Deutsch, W.J. (2003): Groundwater Geochemistry.- Boca Raton. Kurseman, G.P. & De Ridder, N.A. (1991): Analysis and Evaluation of Pumping Test Data.- ILRI. Fetter, C.W. (1999): Contaminant Hydrogeology.- 500 p.; New Jersey (Prentice Hall). Grathwohl, P. (1998): Diffusion in Natural Porous Media.- Boston.
10	**Comments**

Module name
BM3 Hydrochemistry and Physical Hydrogeology

Module no.	Credits	Workload	Self study	Duration	Cycle
11-02-3422	6 CP	180 h	120 h	1 semester	Yearly in the WiSe

Language of instruction	Person responsible for the module
English	Schüth

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Hydrochemistry	3 CP	VL	2
2	Physical Hydrogeology	3 CP	VL	2

2 Course contents

Hydrochemistry: Ionic species in groundwater; ion balance; activity; solubility product; dissolution of gases in waters; the carbonate system; redox reactions; classification of waters; water chemistry and geological formations; evolution of water chemistry; presention and interpretation of groundwater analyses; Schoeller and Piper diagram; hydrochemical calculations using PHREEQC.

Physical Hydrogeology: Factors and processes influencing the quantity and quality of water discussion all compartments of the hydrosphere, such as atmospheric water (rain, snow, hail), river water, lake water and their interactions; vulnerability of groundwater, water protection; case studies and methods are presented which give hints on how to evaluate and deal with groundwater vulnerability.

3 Qualification and learning goals

The students understand the chemical processes occurring in groundwater and are enabled to interpret and present groundwater chemistry data. They understand that water, particularly groundwater, is a vulnerable resource and acquire in-depth on the factors and processes governing groundwater vulnerability.

4	**Prerequisites for attending** none
5	**Type of exam** Written or oral exam (FP)
6	**Criteria for obtaining the credits** Passing the exam
7	**Grading** Graded (*Standardbewertungssystem*)
8	**Curricula where the module is used** M.Sc. TropHEE: Basic Modules
9	**Literature** Deutsch, W.J. (2003): Groundwater Geochemistry.- Boca Raton. Domenico, P.A. & Schwartz, F.W. (1998): Physical and Chemical Hydrogeology.- 2nd ed., 506 p.; New York (Wiley & Sons). Fetter, C.W. (1999): Contaminant Hydrogeology.- 500 p.; New Jersey (Prentice Hall). Stumm, W. & Morgan, J.J. (1995): Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters.- John Wiley & Sons.
10	**Comments**

Module name BM4 Geoinformation Systems					
Module no. 11-02-3408	**Credits** 6 CP	**Workload** 180 h	**Self study** 90 h	**Duration** 2 semesters	**Cycle** Yearly
Language of instruction English			**Person responsible for the module** Lehné		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Geoinformation Systems I (GIS I)	3 CP	VL + PR	3
2	Geoinformation Systems II (GIS II)	3 CP	VL + PR	3

2 Course contents

GIS I (Techniques): Concepts of Geoinformation Systems, special features of Geoinformation Systems, software components of ArcGIS, data types, georeferencing, editing and manipulating spatial data, spatial queries, interpolation techniques, thematic mapping and map layout, use of ArcGIS extensions (Spatial Analyst, 3D Anaylst).

	GIS II (Case Studies): In-depth knowledge of the most relevant functions of the ArcGIS software, and their application in GIS-based spatial decision support systems and GIS-based geostatistical analyses using exemplary data sets: - File Geodatabase - Database structures - Spatial Analyst - 3D Analyst - Geostatistical Analyst - spatial decision support systems - layout aspects (coordinate systems) - automation of workflows, model builder, batch processing annotation - Web publishing with the ArcGIS Publisher & ArcReader
3	**Qualification and learning goals** The students understand the concepts and theory of Geoinformation Systems and are enabled to apply them on an advanced level - beyond the basic functions - for processing complex geoscientific questions and problems. The courses, especially when dealing with case studies, include significant practical training which enables the students to improve soft skills such as organisational skills, team working skills, and presentation skills.
4	**Prerequisites for attending** none
5	**Type of exam** Written or oral exam (FP)
6	**Criteria for obtaining the credits** Passing the exam
7	**Grading** Graded (*Standardbewertungssystem*)
8	**Curricula where the module is used** M.Sc. TropHEE: Basic Modules
9	**Literature** Environmental Research Systems Institute Inc. (2002): ArcGIS manuals.- ESRI, Redlands, California. Greene, R.W. (2000): GIS in Public Policy - Using Geographic Information for More Effective Government.- 100 p.; Redlands, CA. (ESRI Press). Maidment, D.R. (ed., 2002): Arc Hydro - GIS for Water Resources. - 203 p.; Redlands, CA (ESRI Press). www.esri.com
10	**Comments**

Module name SM1 Hydraulic Engineering					
Module no. 11-02-3418	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1 semester	**Cycle** Yearly in the WiSe
Language of instruction English			**Person responsible for the module** Schüth		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Well Construction	3 CP	VÜ	2
2	Water Supply Systems	3 CP	VL	2

2 Course contents

Well Construction: Well borings, well materials, installation of casings and screens, pumps, well development, well aging and regeneration.

Water Supply Systems: Water consumption, water resources, water works, water treatment, artificial groundwater recharge, groundwater extraction, case studies.

3 Qualification and learning goals

The students acquire fundamental knowledge of design and construction of wells and water plants in rural and urban areas. The students are enabled to develop concepts for water supply systems from production to treatment and purification.

4 Prerequisites for attending

none

5 Type of exam

Written or oral exam (FP)

6 Criteria for obtaining the credits

Passing the exam

7 Grading

Graded (*Standardbewertungssystem*)

8 Curricula where the module is used

M.Sc. TropHEE:
Special Modules

9 Literature

Balke, K.-D. (2000): Grundwassererschließung.- Berlin.

Fletcher, G.D. (1987): Groundwater and Wells.- 2nd ed., 1089 p.; St. Paul, Minnesota (Johnson Filtration Systems Inc.).

Misstear, B., Banks, D. & Clark, L. (2006): Water Wells and Boreholes.- 498 p.; Chichester (Wiley & Sons).

Tholen, M. (1997): Arbeitshilfen für den Brunnenbau.- Köln.

10 Comments

Module name SM2 Hydrogeological Methods					
Module no. 11-02-3417	**Credits** 6 CP	**Workload** 180 h	**Self study** 75 h	**Duration** 2 semesters	**Cycle** Yearly
Language of instruction English			**Person responsible for the module** Schüth		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Water Analysis	3 CP	VL + PR	3
2	Hydrogeological Field Course	3 CP	PR	4

2 Course contents

Water Analysis: Surface water sampling in the field, determination of field parameters, quantitative analysis of major anions and cations as well as organic compounds in the laboratory (IC, AAS), calculation of ion balance, evaluation of plausibility and quality of water analyses, typing due to classification schemes.

Hydrogeological Field Course: Small borings via direct push methods, description of recovered soil samples/soil profiles, installation of piezometers, levelling of piezometers, groundwater sampling, field parameters, pumping tests, measurement of piezometric heads, generation of ground water isoline plots.

3 Qualification and learning goals

The module is a combination of field and laboratory work. Students acquire methodical skills to use standard laboratory equipment to analyse water samples and to evaluate the results. The students are enabled to apply basic field techniques to characterize groundwater levels, groundwater flow fields, and to characterize aquifers in terms of hydraulic properties. Through the hands-on field and laboratory work they gain soft skills such as organizational skills, team working skills, communication skills, and data presentation skills.

4 Prerequisites for attending

none

5 Type of exam

Water Analysis: written report on the laboratory work (SL); Hydrogeological Field Course: written report on the field work (SL)

6 Criteria for obtaining the credits

Acceptance of report by the course supervisor(s)

7 Grading

Water Analysis: graded (*Standardbewertungssystem*); Hydrogeological Field Course: graded (*Standardbewertungssystem*); total module grade weighted by CP shares of the two courses

8 Curricula where the module is used

M.Sc. TropHEE:
Special Modules

9 Literature

	Nollet, L.M.L. (2007): Handbook of Water Analyses.- 784 p., CRC Press Int. Brassington, F.C. (2006): Field Hydrogeology.- 276 p.; John Wiley & Sons.
10	**Comments**

Module name SM3 Soil and Unsaturated Zone					
Module no. 11-02-3410	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 2 semesters	**Cycle** Yearly
Language of instruction English			**Person responsible for the module** Hinderer		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Soil Erosion and Protection	3 CP	VL + SE	2
2	Unsaturated Zone Processes/ Groundwater Recharge	3 CP	VÜ	2

2 Course contents

Soil erosion and protection: Sensitivity of soils against man-made impacts, land use practice and soil degradation, measures against soil degradation (e.g. agricultural techniques), controlling factors of erosion, field measurement of erosion, models for the quantification of soil erosion, sediment storage and sediment yield of rivers; practical aspects of groundwater and soil protection.

Unsaturated Zone Processes/Groundwater Recharge: Water content, soil water retention curves, flow in unsaturated media, soil water budget, infiltration, drainage and redistribution, deep percolation diffusive and localized groundwater recharge, vadose zone monitoring, tracer techniques, laboratory methods and field methods.

3 Qualification and learning goals

The students are sensibilised for the protective function of soils and their vulnerability. They understand the characteristics of soil and the unsaturated zone as a key factor for water distribution/percolation in the unsaturated zone and for groundwater recharge. The students acquire knowledge on soil erosion and related problems as well as measures for counteraction worldwide, with special emphasis on their home country. In the seminar they foster their presentation skills.

4 Prerequisites for attending

none

5 Type of exam

Soil Erosion and Protection: presentation with short written summary (SL); Unsaturated Zone Processes: written or oral exam (FP)

6 Criteria for obtaining the credits

Acceptance of presentation and written summary by the course supervisor; passing of the exam

7	**Grading** Soil Erosion and Protection: graded (*Standardbewertungssystem*); Unsaturated Zone Processes: graded (*Standardbewertungssystem*); total module grade weighted by CP shares of the two courses
8	**Curricula where the module is used** M.Sc. TropHEE: Special Modules
9	**Literature** Sumner, M.E. (2000): Handbook of Soil Science.- Boca Raton. Fanning, O.S. (1989): Soil - Morphology, Genesis and Classification.- New York. Deckers, J.A. (1998): World Reference Base for Soil Resources: Introduction.- Leuven. Fitzpatrick, E.A. (1986): An Introduction to Soil Science.- Harlow. Morgan, R.P.C. (1995): Soil erosion and conservation. 2nd edition. Longman, 198 p. Paton, T.R. (1995): Soils: A New Global View.- London. Stephens, D.B. (1995): Vadose Zone Hydrology.- 347 p. CRC Press Inc. Tindal, J.A. & Kunkel, J.R. (1998): Unsaturated Zone Hydrology for Scientists and Engineers.- 624 p. Pretence Hall. White, R.E. (1987): Introduction to the Principles and Practice of Soil Science.- Oxford.
10	**Comments**

Module name SM4 Hydrogeochemistry					
Module no. 11-02-2223	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1 semester	**Cycle** Yearly in the SoSe
Language of instruction English			**Person responsible for the module** Schüth		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Contaminant Hydrogeochemistry	6 CP	VÜ	4

2 Course contents

Organic contaminants: occurrence and classification in soil and groundwater; physico-chemical parameters; distribution equilibria (Henry, Kow, Kd, Koc concepts); sorption isotherms; sorption kinetics; diffusion; contaminant transport in groundwater; non-aqueous phase liquids; inorganic contaminants: occurrence and classification in soil and groundwater; speciation, complex formation, stability diagrams; mobility; background values.

3	**Qualification and learning goals** The students acquire in-depth knowledge on the behaviour of contaminants in different environmental compartments, how to assess and evaluate environmental contaminations, and how to remove or reduce such contaminations. In particular the students are enabled to evaluate the behaviour of inorganic and organic contaminants in groundwater as well as their transformation processes, and can conclude on appropriate site investigation and remediation methods.
4	**Prerequisites for attending** none
5	**Type of exam** Written or oral exam
6	**Criteria for obtaining the credits** Passing of the exam (FP)
7	**Grading** Graded (*Standardbewertungssystem*)
8	**Curricula where the module is used** M.Sc. TropHEE: Special Modules M.Sc. Angewandte Geowissenschaften: Vertiefungsrichtung "Angewandte Geologie": Vertiefungsspezifischer Wahlpflichtbereich, 2. Fachsemester Vertiefungsrichtung "Umweltgeochemie": Kernbereich, 2. Fachsemester
9	**Literature** Schwarzenbach, R.P., Gschwend, P. & Imboden, D.M. (1996): Environmental organic chemistry.- Wiley, VCH. Domenico, P.A. & Schwartz, F.W. (1998): Physical and Chemical Hydrogeology.- 2nd ed., 506 p.; New York (Wiley & Sons). Fetter, C.W. (1999): Contaminant Hydrogeology.- 500 S.; New Jersey (Prentice Hall). Appelo, C.A.J. & Postma, D. (2005): Geochemistry, Groundwater and Pollution.- Taylor and Francis. Stumm, W. & Morgan, J.J. (1995): Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters.- John Wiley & Sons.
10	**Comments**

Module name SM5 Hydrogeology of Semiarid Areas					
Module no. 11-02-3412	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1 semester	**Cycle** Yearly in the SoSe
Language of instruction English			**Person responsible for the module** Schüth		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Salinization of Groundwaters	3 CP	VL	2
2	Fossil Groundwater Systems	3 CP	VL	2

2 Course contents

Salinization of Groundwaters: Salinization sources, natural saline groundwater and its hydrochemistry, sea-water intrusion, density driven flow, agricultural sources, case studies for coastal aquifers and agricultural salinization, soil salinization, preventive action against salinization.

Fossil Groundwater Systems: Worldwide distribution of fossil groundwater, characterization and quality of fossil groundwater, radioactivity, palaeoclimate, dating techniques, sedimentology of regional aquifer systems, management of fossil groundwater resources, groundwater overexploitation and groundwater mining, trans-boundary conflicts, case studies.

3 Qualification and learning goals

The students understand the causes of groundwater and soil salinization processes and to evaluate counter measures. They acquire knowledge on the particularities of fossil groundwater resources and the implications of their use. They become aware of problems related to trans-boundary groundwater systems which challenge both, large-scale management practices and international cooperation.

4 Prerequisites for attending

none

5 Type of exam

Written or oral exam (FP)

6 Criteria for obtaining the credits

Passing of the exam

7 Grading

Graded (*Standardbewertungssystem*)

8 Curricula where the module is used

M.Sc. TropHEE:
Special Modules

9 Literature

Bear, J., Cheng, A., Sorek, S., Ouazar, D. & Herrera, I. (eds., 2010): Seawater Intrusion in Coastal Aquifers Concepts, Methods and Practices.- 640 p.: Springer.

10 Comments

Module name SM6 Aquifer Sedimentology					
Module no. 11-02-3411	**Credits** 6 CP	**Workload** 180 h	**Self study** 90 h	**Duration** 1 semester	**Cycle** Yearly in the SoSe
Language of instruction English			**Person responsible for the module** Hinderer		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Sedimentary Basins	3 CP	VL	2
2	Field Course Sedimentology	3 CP	PR	4

2 Course contents

Sedimentary Basins: Types of sedimentary basins in plate tectonic context, methods of basin analysis, evolution of major basin types, petroleum and groundwater resources, case studies.

Field Course Sedimentology: Logging and mapping of sedimentary rocks in outcrops, measurements of gamma-ray and magnetic susceptibility, sampling, thin section analysis, porosity and permeability measurements in the lab.

3 Qualification and learning goals

The students acquire in-depth knowledge on the formation of sedimentary basins including petrological methods for the investigation of sedimentary rocks, to foster their understanding of the significance of such structures for important geo-resources such as groundwater, hydrocarbons, or geothermal energy. A field course supplements the lecture to train the students on practical methods and to deepen their understanding of the outcrop-analog approach. As a usually multinational group during the field course the students improve their intercultural competence. They also gain other soft skills such as organisational skills, team working skills, communication skills, and data presentation skills.

4 Prerequisites for attending

none

5 Type of exam

Sedimentary Basins: written or oral exam (FP); Field Course Sedimentology: written report on the field work (SL)

6 Criteria for obtaining the credits

Passing of the exam; acceptance of the report by the course supervisor

7 Grading

Sedimentary Basins: graded (*Standardbewertungssystem*); Field Course Sedimentology: graded (*Standardbewertungssystem*); total module grade weighted by CP shares of the two courses

8 Curricula where the module is used

M.Sc. TropHEE:
Special Modules

9 Literature

Allen, P.A. & Allen, J.R. (2005): Basin Analysis - Principles and applications.- 2nd edtion,

	560 p.; London (Blackwell). Allen, P.A. (1997): Earth surface processes.- 416 p., London (Blackwell). Einsele, G. (2000): Sedimentary Basins.- 792 p.; Springer. Miall, A.D. (2000): Principles of Sedimentary Basin Analysis.- Heidelberg (Springer). Nichols, G. (2009): Sedimentology and Stratigraphy.- 2nd edition, 432 p.; London (Wiley-Blackwell).
10	**Comments**

Module name SM7 Geophysical Methods					
Module no. 11-02-3413	**Credits** 6 CP	**Workload** 180 h	**Self study** 105 h	**Duration** 1 semester	**Cycle** Yearly in the SoSe
Language of instruction English			**Person responsible for the module** Hinderer		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Geophysical Field Methods	3 CP	VL + PR	3
2	Ground Penetrating Radar (GPR)	3 CP	PR	2

2 Course contents

Geophysical Field Methods: Introduction into various methods of applied engineering geophysics: seismics, geoelectrics, electromagnetics, ground penetrating radar, geomagnetics.

Ground Penetrating Radar (GPR): Practical, advanced application of a GPR system including processing and geological interpretation of data. 3D surveys, CMP analysis (velocity-depth profiles), monitoring, and local moisture sounding.

3 Qualification and learning goals

In the two field courses, the students are enabled to understand and use the most important geophysical field methods, including their data evaluation, and also acquire knowledge and methodic skills on the near-surface method of Ground Penetrating Radar (GPR). As a usually multinational group during the field course the students improve their intercultural competence. They also gain other soft skills such as organisational skills, team working skills, communication skills, and data presentation skills.

4 Prerequisites for attending

none

5 Type of exam

Geophysical Field Methods: written report on the field work (SL); Ground Penetrating Radar (GPR): written report on the field work (SL)

6	**Criteria for obtaining the credits** Acceptance of the reports by the course supervisor
7	**Grading** Geophysical Field Methods: graded (*Standardbewertungssystem*); Ground Penetrating Radar (GPR): graded (*Standardbewertungssystem*); total module grade weighted by CP shares of the two courses
8	**Curricula where the module is used** M.Sc. TropHEE: Special Modules
9	**Literature** Telford, W.M. (1990): Applied Geophysics.- Cambridge.
10	**Comments**

Module name SM8 Groundwater Modelling					
Module no. 11-02-3415	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 2 semesters	**Cycle** Yearly
Language of instruction English			**Person responsible for the module** Schüth		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Groundwater Modelling I	3 CP	VÜ	2
2	Groundwater Modelling II	3 CP	VÜ	2

2	**Course contents** Application of groundwater models; basic concepts of groundwater flow; analytical flow models; numerical flow models; finite difference models, finite element models; explicit/implicit solution of the flow equation; a complete groundwater flow model; 2D/3D flow modelling; computer exercises based on Modflow; case studies, model setup and model calibration; sensitivity analyses.
3	**Qualification and learning goals** The students are enabled to understand the basic concepts of groundwater flow modelling and to choose appropriate models for a variety of flow problems. They are enabled to use a commercial groundwater flow modelling software package (Modflow) and to evaluate the prospects and limitations of using this type of modelling software. Through the hands-on training they gain soft skills such as team working skills, communication skills, and data presentation skills.
4	**Prerequisites for attending** none
5	**Type of exam** Written or oral exam (FP)

6	**Criteria for obtaining the credits** Passing of the exam
7	**Grading** Graded (*Standardbewertungssystem*)
8	**Curricula where the module is used** M.Sc. TropHEE: Special Modules
9	**Literature** Anderson, M.P. (1992): Applied Groundwater Modeling.- San Diego. Chiang, W.-H. (1998): Aquifer Simulation Model for Windows.- Berlin. Chiang, W.-H. (2001): 3D-Groundwater Modeling with PMWIN.- Berlin. Rausch, R. (2004): Introduction to Groundwater Transport Modeling.- Berlin.
10	**Comments**

Module name SM9 Water Management					
Module no. 11-02-3419	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 2 semesters	**Cycle** Yearly
Language of instruction English			**Person responsible for the module** Schüth		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Integrated Water Resources Management (IWRM)	3 CP	VL	2
2	Water Treatment	3 CP	VL	2

2 Course contents

Integrated Water Resources Management: Objectives of sustainable water management, legal, financial and ecological aspects, fundamentals of sustainability assessment; determination of actual regional water yield through data analysis and hydrologic modelling; overview of consumptive and non consumptive, conflicting and complementary users, estimation of actual water demand; conjunctive use and management of water resources, overview of technical elements (dams and related plants, canals, dikes, etc.) of integrated water resources management; simulation and optimisation techniques for integrated water resources management, participatory decision support systems; case studies.

Water Treatment: Chemical/nonchemical disinfection (ozonation, chlorination, UV light), coagulation/flocculation (theory, selection of coagulants, practice), sedimentation (Stoke's law, critical settling velocity, practice), filtration (slow sand filtration, rapid filtration), membrane processes, sorption (GAC, PAC).

3	**Qualification and learning goals** The students understand the interplay of hydrogeological parameters on a watershed scale and the role of different stakeholders in managing watersheds. The students understand the fundamentals of water treatment processes and develop methodical skills to select water treatment technologies based on water quality requirements.
4	**Prerequisites for attending** none
5	**Type of exam** Written or oral exam (FP)
6	**Criteria for obtaining the credits** Passing of the exam
7	**Grading** Graded (*Standardbewertungssystem*)
8	**Curricula where the module is used** M.Sc. TropHEE: Special Modules
9	**Literature** Heathcote, I.W. (2009): Integrated Watershed Management: Principles and Practise.- 464 p.; John Wiley and Sons. MWH (2005): Water Treatment - Principles and Design.- 2nd edition, 1968 p.; Weinheim (Wiley-VCH).
10	**Comments**

Module name SM10 Clay Mineralogy					
Module no. 11-02-2238	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 2 semesters	**Cycle** Yearly
Language of instruction English			**Person responsible for the module** Ferreiro Mählmann		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Clay Mineralogy	3 CP	VL	2
2	Applied Clay Mineralogy	3 CP	VL	2

2 Course contents

Systematic of clay minerals, clay mineral diagenesis, structure transformations, ion exchange, clay mineral occurrences; technical/industrial use, scientific importance in different fields of geosciences, use in exploration techniques (hydrocarbons and geothermal energy).

3	**Qualification and learning goals** The students gain a sound understanding of the specific role of clays and clay minerals in different fields of geosciences and their use in geotechnical and environmental engineering.
4	**Prerequisites for attending** none
5	**Type of exam** Written or oral exam (FP)
6	**Criteria for obtaining the credits** Passing of the exam
7	**Grading** Graded (*Standardbewertungssystem*)
8	**Curricula where the module is used** M.Sc. TropHEE: Special Modules
9	**Literature** Velde, B. (1992): Introduction to Clay Minerals.- 159 p.; Chappman & Hall. Velde, B. (1995): Origin and Mineralogy of Clays. Clays and the Environment.- 356 p.; Springer. Rule, A.C. & Guggenheim, S. (2002): Teaching Clay Science.- CMS Workshop Lectures, 11, 223 p.; The Clay Minerals Society, Aurora, CO.
10	**Comments**

Module name SM11 Geoenvironmental Engineering					
Module no. 11-02-3420	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1 semester	**Cycle** Yearly in the WiSe
Language of instruction English			**Person responsible for the module** Schüth		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Contaminated Sites	3 CP	VL	2
2	Waste Disposal	3 CP	VL	2

2 Course contents

Principles of environment related civil and underground construction and engineering, in situ facilities, waste disposal covers and liners, treatment technologies, in situ methods, theory of mass and flow transport, behaviour of contaminants, properties of waste, contaminated soil and rock, groundwater rehabilitation technologies.

3	**Qualification and learning goals** The students are enabled to understand the environmental threats caused by contaminated land and the challenges of a sustainable, safe waste disposal, and to understand the possibilities but also limitations of modern engineering technologies used in these fields. The students acquire fundamental up-to-date knowledge of methods and designs related to the investigation, monitoring, encapsulation and remediation of contaminated sites and municipal landfills.
4	**Prerequisites for attending** none
5	**Type of exam** Written or oral exam (FP)
6	**Criteria for obtaining the credits** Passing of the exam
7	**Grading** Graded (*Standardbewertungssystem*)
8	**Curricula where the module is used** M.Sc. TropHEE: Special Modules
9	**Literature** Fetter, C.W. (1999): Contaminant Hydrogeology.- 2nd Ed., 500 p.; Prentice-Hall. Kuo, J. (1998): Practical Design Calculations for Groundwater and Soil Remediation.- 263 p.; Lewis Publishers, Boca Raton. Huang, P.M. & Iskandar, I.K. (eds., 2000): Soils and Groundwater Pollution and Remediation - Asia, Africa, and Oceania.- 386 p.; Lewis Publishers, Boca Raton. Reddi, L.N. & Inyang, H.I. (2000): Geoenvironmental Engineering, Principles and Applications.- 492 p.; Marcel Dekker Inc. Sharma, H.D. & Reddy, K.R. (2004): Geoenvironmental Engineering. Site Remediation, Waste Containment, and Emerging Waste Management Technologies.- 968 p.; John Wiley & Sons.
10	**Comments**

Module name SM12 Isotope and Tracer Techniques					
Module no. 11-02-3414	**Credits** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1 semester	**Cycle** Yearly in the WiSe
Language of instruction English			**Person responsible for the module** Schüth		

1	**Course(s)**				
	Course no.	**Course title**	**Workload (CP)**	**Teaching method**	**SWS**
	1	Isotope Hydrology and Dating	3 CP	VÜ	2
	2	Tracer Techniques	3 CP	VÜ	2
2	**Course contents** Isotope Hydrology and Dating: Natural and artificial isotopes, stable isotopes, radiogenic isotopes, groundwater dating techniques. Tracer Techniques: Types of tracers, application of artificial tracers in field tests, analysis of tracer breakthrough curves, tracer mixing models.				
3	**Qualification and learning goals** The students have in-depth knowledge on isotopes and tracer methods and their use in solving hydrological and hydrogeological questions. They are also able to assess results acquired by these methods for their plausibility, reproducibility and error margins. Through the hands-on exercises they gain soft skills such as team working skills, communication skills, and data presentation skills.				
4	**Prerequisites for attending** none				
5	**Type of exam** Written or oral exam (FP)				
6	**Criteria for obtaining the credits** Passing of the exam				
7	**Grading** Graded (*Standardbewertungssystem*)				
8	**Curricula where the module is used** M.Sc. TropHEE: Special Modules				
9	**Literature** Fritz, P. (1080): Handbook of Environmental Isotope Geochemistry.- New York. Käss, W. (1998) Tracing Technique in Geohydrology.- Balkema, Rotterdam.				
10	**Comments**				

Module name SM13 Remote Sensing and Statistics					
Module no. 11-02-3414	**Credits** 6 CP	**Workload** 180 h	**Self study** 105 h	**Duration** 1 semester	**Cycle** Yearly in the WiSe
Language of instruction English			**Person responsible for the module** Hinderer		

<table>
<tr><td>1</td><td colspan="5">Course(s)</td></tr>
<tr><td></td><td>Course no.</td><td>Course title</td><td>Workload (CP)</td><td>Teaching method</td><td>SWS</td></tr>
<tr><td></td><td>1</td><td>Remote Sensing in Geology</td><td>3 CP</td><td>VÜ</td><td>3</td></tr>
<tr><td></td><td>2</td><td>Statistics</td><td>3 CP</td><td>VÜ</td><td>2</td></tr>
<tr><td>2</td><td colspan="5">Course contents
Remote Sensing in Geology: Introduction to remote sensing techniques. Exercises with aerial photographs within a stereoscopic model by drawing and interpreting valley systems and geology; determination of quantitative data (e.g. difference in elevation, thickness of bed and strike and slip).

Statistics: Introduction on statistical methods; data presentation; elementary statistics, e.g. t-tests, F-tests, chi-square tests, analysis of variance, non-parametric tests; analysis of multivariate data, e.g. cluster analysis, PCA, CA, DCA; time series analysis, e.g. analysis of stationary and non-stationary data; PC-based exercises.</td></tr>
<tr><td>3</td><td colspan="5">Qualification and learning goals
The students have in-depth knowledge on isotopes and tracer methods and their use in solving hydrological and hydrogeological questions. They are also able to assess results acquired by these methods for their plausibility, reproducibility and error margins. Through the hands-on exercises they gain soft skills such as team working skills, communication skills, and data presentation skills.</td></tr>
<tr><td>4</td><td colspan="5">Prerequisites for attending
none</td></tr>
<tr><td>5</td><td colspan="5">Type of exam
Written or oral exam (FP)</td></tr>
<tr><td>6</td><td colspan="5">Criteria for obtaining the credits
Passing of the exam</td></tr>
<tr><td>7</td><td colspan="5">Grading
Graded (Standardbewertungssystem)</td></tr>
<tr><td>8</td><td colspan="5">Curricula where the module is used
M.Sc. TropHEE:
Special Modules</td></tr>
<tr><td>9</td><td colspan="5">Literature
Drury, S.A. (1997): Image Interpretation in Geology.- 2nd ed., 283 p.; Allen & Unwin, London.

Miller, V.C. & Miller, F. (1961): Photogeology.- 248 p., McGraw-Hill, New York.

Ray, R.G. (1960): Aerial photographs in geologic interpretation and mapping.- Prof. Paper U.S. Geol. Survey, 373: 230 p., Washington.

Chilès, J.-P. & Delfiner, P. (1999): Geostatistics.- 720 p.; New York (Wiley & Sons).

Davis, J.C. (2003): Statistics and Data Analysis in Geology.- 638 p.; New York (Wiley & Sons).

Isaaks, E.H. (1989): Applied Geostatistics.- New York.

Goovaerts, P. (1999): Geostatistics for Natural Resources Evaluation.- Oxford.</td></tr>
</table>

	Townend, J. (2002): Practical statistics for environmental and biological scientists.- 276 p.; New York (Wiley & Sons). Webster, R. & Oliver M.A. (2007): Geostatistics for Environmental Scientists.- 336 p.; New York (Wiley & Sons).
10	**Comments**

Module name Master Thesis					
Module no. 11-02-5001	**Credits** 30 CP	**Workload** 900 h	**Self study** 900 h	**Duration** 1 semester	**Cycle** Every semester
Language of instruction English			**Person responsible for the module** Hinderer (Dean of Study Affairs)		

1 Course(s)

Course no.	Course title	Workload (CP)	Teaching method	SWS
1	Master Thesis	30 CP	Thesis	-

2 Course contents

In the Master thesis, students apply and intensify their knowledge and skills acquired in the preceding courses. Under individual guidance, students will actively, and with increasing independence, work on a specific problem which is part of a scientific research project. The topic of the Master Thesis will usually be defined by the supervisor in response to a suggestion by the candidate. The topic will usually reflect the chosen specialisation of the student as documented by the choice of elective modules.

3 Qualification and learning goals

The students acquire in-depth knowledge on a specific, usually research-oriented topic in the field of geosciences, especially in the field of water-related issues and/or environmental management and engineering. They are able to apply knowledge and methodical skills acquired during participation in the TropHEE programme in order to independently work on given scientific questions, recognise new problems, find new solutions, and discover the limits of knowledge pertaining to a specific research area. The students are able to document, present and discuss the scientific results of their work and their evaluation in a coherent and scientifically adequate form.

4 Prerequisites for attending

Formal preconditions as laid out in the examination regulations

5 Type of exam

Written thesis set up in accordance with the examination regulations (*Ausführungs-bestimmungen*)

6 Criteria for obtaining the credits

Acceptance of the thesis by the supervisors

7	**Grading** Graded (*Standardbewertungssystem*)
8	**Curricula where the module is used** M.Sc. TropHEE: Master Thesis
9	**Literature** Dependent of contents to be addressed in the thesis
10	**Comments**