Faculty of Environmental Sciences

Final State Examinations for Master **Programmes** – Thematic Areas

Environmental Modelling

2023

The final state exam consists 4 exams of different fields. There are three compulsory exams – **Hydraulic and Hydrological Modelling, Groundwater Modelling and Transport of Contaminants in Atmosphere**. The last one can be chosen from **Hydrodynamics of Porous Media or Modelling in Soil Science or Physical – Chemical Aspects of Processes in Environment.**

HYDRAULIC AND HYDROLOGICAL MODELLING

1. Hydrological models, their classification, basic principles of hydrological systems, uncertainty of hydrological modeling

2. Calibration and validation of hydrological models

3. Calibration and validation statistics, AME, ME, NS, RMSE, MSE, NS, persistency index etc.

4. Black models, linear model for runoff forecasting, AR model for runoff forecasting, parameter estimation

5. Neural network models for forecasting of hydrological time series, parameter estimation, ANN architecture

6. Grey box models, linear reservoir, nonlinear reservoir, Q-S relationship, finite difference method for descrition of mass balance of reservoir oriented models

7. Lumped grey box models for the description of water balance: PDM model, HBV model, Bilan model

8. White box models their principles, hillslope overland flow models, St equations for overland flow models, finite difference methods

9. Optimization algorithms for calibration of hydrological models

10. Event based rainfall runoff models, components, effective rainfall, baseflow separation methods

11. Unit hydrograph theory, basic principles of unit hydrograph theory, S curve, type of unit hydrographs

12. Nash model of unit hydrograph, Diskin cascade, Clark unit hydrograph model

13. Linear time invariant transfer function model, izochron model, ordinary least squares and the estimation of discrete form of unit hydrograph, TA curve histogram of isochrones

Literature:

ABBOTT M., MINNS A. 1998 : Computational Hydraulics. Aldershot.

VEN TE CHOW ET AL. 1988 : Applied hydrology. McGraw-Hill.

SHAW, M.,E.: Hydrology in Practice. Routledge, 2004, s 569, ISBN 0-7487-4448-7.

GROUNDWATER HYDRAULICS MODELLING

1. Properties of fluids

2. Hydrostatics. Pressure and hydrostatic forces.

3. Hydrodynamics. Flow regimes. Basic equations.

4. Fundamentals of aquifer hydraulics, effective stress, compressibility and elasticity.

5. Basic equations. Darcy´s law.. Limitations of the Darcian approach.

6. Properties of aquifers,(porosity, storativity,………etc). Dupuits assumptions.

7. Multi-layered aquifer system. Seepage. Flow nets.

8. Steady and unsteady flow to wells – confined and unconfined aquifers.

9. Pumping and recovery tests – evaluation.

10. Image well theory.

11. Well flow near aquifer boundaries, multiple well problems.

12. Real wells. Wellbore storage, skin effect. Evaluation of well cleanning.

Literature:

BEAR, J., VERRUIJT, A.,1992 Modeling Groundwater Flow and Pollutin.D. Reidel Publ. Comp.Dordrecht.

CHARBENEAU, R., J.,2006 Groundwater Hydraulics and Pollutant Transport. Waveland Pres, INC.

FREEZE, R. ALLEN AND CHERRY, JOHN A.,1979 Groundwater. Englewood Cliffs, NJ Prentice Hall Inc.

VERRUIJT, A.,1979 Theory of Groundwater Flow. MacMillan. London.

TRANSPORT OF CONTAMINANTS IN ATMOSPHERE

1. Gaussian plume model and its principled limits

2. Justification of moment equations for flow field (compressibility and incompressibility versions), transport theorem

3. Reynolds averaging, derivation of Reynolds equations and Reynolds tensors of turbulent fluctuations

4. Turbulence closure problem, the structure of moment equations for time derivative of Reynolds tensors (Keller - Friedman equations)

5. Boussinesq hypothesis, approximate models for turbulence in the atmosphere and order of this models

6. Principle of control volumes numerical method

7. Local discretization of moment equations, coordinates transformation

8. Principle of pressure correction in numerical calculation of flow field

Literature:

ALLERO, D., 2007 Fundamentals of Air Pollution. Academic Press. pp. 968

WARK, K., WARNER, C.F., WAYNE, T.D., 1997 Air Pollution Its Origin and Control, Prentice Hall, pp. 919.

VACH, M. Transport of Contaminants in Atmosphere. Learning text, FES CULS in Prague

HYDRODYNAMICS OF POROUS MEDIA

1. Application of differential calculus in hydrology. Relationship between rainfall and rainfall intensity, thermal expansion of liquids including water anomaly in density x temperature relationship. Compressibility of liquids, including the importance of the modulus of elasticity. Determination of the volume of a retention basin from a time series of flow rates.

2. Heat conduction. Fourier's law, temperature gradient, heat. Dirichlet and Neumann boundary condition for heat conduction. Material parameters for the heat conduction equation.

3. Darcy's law, pressure head and hydraulic head. Hydraulic conductivity, units. Experimental determination of hydraulic conductivity by single cylinder test. Difference between hydraulic conductivity and permeability.

4. Unsaturated soil environment. Moisture content of porous media and its moisture limits. Soil moisture retention curve, its relationship with statistical pore size distribution. Capillary barrier.

5. Darcy-Buckingham law, Richards equation. Types of boundary conditions for the Richards equation, specific boundary conditions of the free drainage and ejection surface type.

Literature:

KURAZ, M., BLOECHER, J. R.: Hydrodynamics in porous media -- seminar, CULS lecture notes, Prague 2017, online: http://drutes.org/documents/seminar.pdf

KURAZ, M., BLOECHER, J. R.: Hydrodynamics in porous media, CULS lecture notes, Prague 2017, online: http://drutes.org/documents/lectures.pdf

MODELLING IN SOIL SCIENCE

1. Methods applicable for soil porous systems description, pore-system models, capillary models and their application.

2. Equation describing transient water flow in soils, soil hydraulic properties and their determination.

3. Pedotransfer functions for soil hydraulic properties estimation.

4. Equation describing gas transport in soils, basic properties describing gas behavior in soil and their determination.

5. Equation describing heat transport in soils, soil thermal properties and their determination.

6. Convective-dispersion equation for description of conservative solute transport in soils, hydrodynamic dispersion coefficient and its determination.

7. Methods applicable for description of non-conservative solute transport in soils.

8. Equilibrium solute adsorption onto soil particles, adsorption isotherms.

9. Equation describing reaction rate, reaction order, half-life.

10. Multiphase transport definition, methods for description of multiphase transport, basic characteristics.

11. Inverse modeling and its application for soil properties determination.

Literature:

DANE, J.H., TOPP, G.C. (eds). 2003. Methods of soil analysis, Part 4 - Physical methods. SSSA. Madison. USA. ISBN 0-89118-841-X.

KODEŠOVÁ, R. 2020. Modeling in soil science, Lectures and Project Assignments.

NIELSEN, D.R., WENDROTH, O. 2003. Spatial and temporal statistics. Catena Verlag GMBH. Germany. ISBN 3-923381-46-8.

SCHAAP, M.G., LEIJ, F.J., VAN GENUCHTEN, M.TH. 1999. A bootrstrap-neural network approach. University of California. Riverside. 1237

ŠIMŮNEK, J., ŠEJNA, M., VAN GENUCHTEN, M. TH. 2005. The HYDRUS-1D. IGWMC-TPS-53. International Ground Water Modeling Center. Colorado.

VAN GENUCHTEN M.TH., LEI F.J., YATES S.R. 1991. The RETC code. EPA/6000/2-91-065. US EPA.

PHYSICAL – CHEMICAL ASPECTS OF PROCESSES IN ENVIRONMENT

1. The second theorem of thermodynamics, the concept of entropy and its derivation

2. The third theorem of thermodynamics, the principle of adiabatic demagnetization

3. Gibbs energy - definitions, relations Gibbs energy with equilibrium constant of chemical reactions

4. Kinetics processes of the first to n-th order, solutions of simple ODE by separation of variables

5. Kinetics of simultaneous processes, solutions of ODE for the subsequential processes and similar type of equations.

6. Formulation of systems of ODE (dynamical systems) for more complex kinetic schemes

7. Euler methods for numerical solution of ODE and systems of ODE

8. Runge-Kutta numerical methods for ODE solution – only basic principle, an indication of the deriving of second order scheme.

9. Definition of PDR, Galerkin approximation method

10. Principle of finite elements method

Literature:

MOORE W. J. : Physical Chemistry (5th Edition). Prentice-Hall, 1999

VACH M. : Physical - Chemical Aspects of Processes in Environment, Study text, ULS Prague