Co-funded by the
Erasmus+ Programme
of the European Union

EU HEIs WM
LABORATORY EQUIPMENT LISTS

University of Nis

Strengthening of master curricula in water resources management
for the Western Balkans HEIs and stakeholders

Project number: 597888-EPP-1-2018-1-RS-EPPKA2-CBHE-JP

www.swarm.ni.ac.rs

PROJECT INFO

Project title	Strengthening of master curricula in water resources management for the Western Balkans HEIs and stakeholders
Project acronym	SWARM
Project reference number	597888-EPP-1-2018-1-RS-EPPKA2-CBHE-JP
Funding scheme	Erasmus+ Capacity building in the field of higher education
Web address	www.swarm.ni.ac.rs
Coordination institution	University of Nis
Project duration	15 November 2018 – 14 November 2021

DOCUMENT CONTROL SHEET

Work package	WP1 Analysis of water resources management in the Western Balkan region
Ref. no and title of activity	WP1.4 Identification of needed laboratory resources in WB HEIs and alignment with formed EU HEIs WRM laboratory equipment list
Title of deliverable	EU HEIs WM laboratory equipment list
Lead institution	BOKU
Author(s)	Kurt Glock, Michael Tritthart, Zakhar Maletskyi, Elisabeth Sundheim, Maria Manuela Portela, Rodrigo Proenca de Oliveira, Barbara Karleuša, Nevena Dragičević, Elpida Kolokytha, Petar Filkov
Document status	Final
Document version and date	V03 07.03.2019
Dissemination level	Regional, International

VERSIONING AND CONTRIBUTION HISTORY

Version	Date	Revision description	Partner responsible
v.01	05.02.2019	Document created	BOKU, NMBU, UNIRIFCE, UACEG, UL, AUTh
v.02	22.02.2019	Revision	BOKU
v.03	07.03.2019	Final	BOKU

Contents

1 Introduction

The education of students in the field of water resources management requires – besides theoretical lectures – practical exercises in laboratories to strengthen the knowledge on hydraulic fundamentals and interrelationships. Examples of necessary equipment and tools for laboratories are presented in the following chapters stated below:

- Fundamental fluid mechanics and hydraulics
- Groundwater flow and soil physics
- Water sanitation and treatment
- Hydrology
- Software used in water resources management

According to the introduced tools WB partner HEIs will identify their needed resources and prepare lists of laboratory equipment, software and literature.

2 Fundamental fluid mechanics and hydraulics

Fluid mechanics deal with physical principles of fluids and the forces on them and can be divided into fluid statics and fluid dynamics. Focusing on incompressible fluids (e.g. water) it is generally denoted as hydrostatics and hydrodynamics. Due to the fact that the analytical description of hydromechanic processes is not always possible, empirical approaches have been established leading to the term of hydraulics.

2.1 Fluid properties and hydrostatics

Practical exercises on basic principles of fluid mechanics should include the determination of fluid properties (e.g. density, specific gravity, viscosity, etc.), the investigation of the effects of static pressure, the operation and application of pressure gauges and manometers as well as the investigation of the buoyancy force and stability of floating bodies.

Teaching equipment covering the mentioned requirements are e.g. “F9092 Fluid Properties & Hydrostatics Bench – Issue 14” (Armfield, 2019) and “HM 115 Hydrostatics trainer” (Gunt, 2019) and are depicted in Figure 1. Independent of the company the modular design of the teaching equipment allows for a continuous upgrade.

a)


b)


Figure 1: Fluid properties and hydrostatics – Teaching equipment a) F9092 Armfield b) HM 115 Gunt

2.2 Fluid dynamics

In the course of practical exercises on fluid dynamics the Bernoulli´s principle, the momentum equation and the Reynolds experiment should be presented.

The mentioned principles can be presented during experiments for example using the "F1-series" (Armfield, 2019) or the "HM 150-series" of Gunt (2019). Figure 2 shows the module "F1-15 Bernoulli´s Theorem Demonstration – Issue 19" and the module "HM 150.18 Osborne Reynolds experiment", depicted exemplarily for this practical exercise. It is recalled that independent of the company the base module is a necessary requirement for all teaching tools.

a) 

b) 

Figure 2: Fluid dynamics – Teaching equipment a) F1-15 Armfield b) HM 150.18 Gunt

2.3 Open channel flow

Basic principles of open channel flow including the understanding of sub- and supercritical flows, the enforcement of a hydraulic jump, the usage of hydraulic structures for flow control, the implementation of weirs and the application of Manning´s formula should be highlighted in this practical exercise.

Teaching equipment covering the mentioned requirements are for instance "C4MKII Multi-Purpose Teaching Flume - Issue 2" (Armflied, 2019) and "HM 160 Experimental flume" (Gunt, 2019), which are depicted in Figure 3.


a)

b)

Figure 3: Open channel flow – Teaching equipment a) C4MKII Armfield b) HM 160 Gunt

2.4 Flow in pipes

In the course of practical exercises dealing with flow in pipes including pressure losses, shut-off devices and piping elements should be presented.

The mentioned principles can be discussed during experiments using for instance “HM 150.11 Losses in a pipe system” of Gunt (2019), which is depicted in Figure 4. It is recalled that the base module is a prerequisite of the teaching tool.

Figure 4: Flow in pipes – Teaching equipment HM 150.11 Gunt

2.5 Additional topics

Topics, which might be interesting for additional exercises and which require additional teaching equipment are listed below.

- Pump and turbine tests
- Naval Architecture
- Wave Generator
- Sediment transport facilities

2.6 Measuring instruments

Measuring instruments are partially integrated in the above-mentioned equipment. Moreover, Table 1 presents an exemplary list of devices which can additionally be used for determining further parameters during the experiments as well as during monitoring tasks at a river site.

Table 1: Hydraulics measuring instruments

Device	Information	Measured parameter
FlowSens	SEBA Hydrometrie https://www.seba-hydrometrie.com/?L=1	Discharge
M1 Mini current meter	SEBA Hydrometrie https://www.seba-hydrometrie.com/?L=1 (Counting device required)	Discharge
Teledyne RD Instruments RiverPro ADCP	SEBA Hydrometrie https://www.seba-hydrometrie.com/?L=1 (Miniboat required)	Discharge

3 Water sanitation and treatment

Depending on the quality of water different processes are necessary to consider in the scope of water sanitation as well as water treatment. The broad range of operation units needed for removing substances can be classified in mechanical, biological and physical/chemical processes.

3.1 Mechanical processes

The most common mechanical methods are flotation, sedimentation and filtration, which are all used for removing solid particles.

Practical exercises dealing with mechanical methods should include the treatment with dissolved air flotation (e.g.: CE 587 (Gunt, 2019), Figure 5a), the separation in sedimentation tanks (e.g.: W7MkII (Armfield, 2019)) and the treatment using depth filtration (e.g.: EFLPC (Edibon, 2019), Figure 5b).

a) 

b) 

Figure 5: Mechanical processes – Teaching equipment a) CE 587 Gunt b) EFLPC Edibon

3.2 Biological processes

In general biological processes are used to degrade dissolved organic substances and are classified into anaerobic and aerobic processes, whereby the aerobic processes are grouped in biofilms and activated sludge methods.

The mentioned principles can be presented during experiments using for instance “CE 705 Activated sludge process” of Gunt (2019), which is depicted in Figure 6a, or using the simplified system “W11 Aerobic Digester Issue 7”, which is offered by Armfield (2019) (Figure 6b).

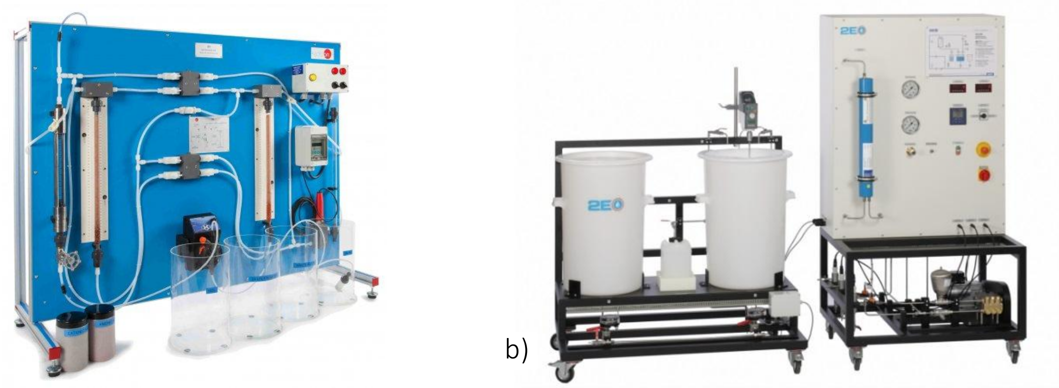
a) b)

Figure 6: Biological processes – Teaching equipment a) CE 705 Gunt b) W11 Armfield

3.3 Physical/chemical processes

The removal of dissolved inorganic and non-biodegradable substances in water is done by physical and chemical processes including adsorption, membrane separation processes, ion exchange, flocculation as well as chemical oxidation.

Teaching equipment covering the mentioned processes are provided by Armfield (2019), Gunt (2019) and Edibon (2019). Figure 7 exemplary depicts the operation unit “EII Ion Exchange Unit” (Edibon, 2019) and “CE 530 Reverse osmosis” (Gunt, 2019).



a) b)

Figure 7: Physical/chemical processes – Teaching equipment a) EII Edibon b) CE 530 Gunt

3.4 Integrated solutions

Due to the fact that water usually contains several substances with different properties, a single process is not sufficient to remove all of them. Therefore water treatment plants are commonly designed in several stages.

So-called multistage water treatment plants including several mentioned processes are offered by Gunt (2019). Independent of the multistage approach, a self-made combination of several processes in practical exercises is also possible using the appropriate toolkits.

3.5 Drinking water

A pilot plant for drinking water including a reverse osmoses membrane is depicted in Figure 8, which is offered by J&F water treatment (2019). A wide range of different membrane units is also provided by Convergence (2019).

Figure 8: Drinking water – Ecosoft commercial reverse osmosis system MO 6500

3.6 Measuring instruments

Measuring instruments are partially integrated in the above-mentioned equipment. Moreover, Table 2 presents a list of devices which can additionally be used for determining further parameters during the experiments as well as during monitoring tasks at a water sanitation or treatment plant. The use of these devices was reported by NMBU.

Table 2: Water sanitation and treatment measuring instruments

Device	Information	Measured parameter
2100N	Hach Lange https://at.hach.com/trubungsmessgerate/2100q-portables-trubungsmessgerat/family?productCategoryId=25046168552	Turbidity
8800 ICP-QQQ	Agilent https://www.agilent.com/en/products/icp-ms/icp-ms-systems/8800-triple-quadrupole-icp-ms	Nearly all elements in periodic table but no speciation, i.e. It can't distinguish between As(3) and As(5)
Conductivity meters	WTW	Conductivity and salinity

	https://www.wtw.com/en/products/product-catalog/lab-products/conductivity/portable-meters.html	
DR3900	Hach Lange https://de.hach.com/dr3900-spektralphotometer-mit-rfid-technologie/product?id=23358295122	COD-Cr (Dichromate method) Chemical oxygen demand
Easychem plus	Systea http://www.systea.it/index.php?lang=en	NH4, NO2, NO3, PO4, Tot-Nitrogen, total-Phosphorous etc. Wet chemistry parameters by Spectrophotmetric determination and it is also possible to set up new methods
Fluorometer 10-AU	Turner designs https://www.turnerdesigns.com/10au-field-laboratory-fluorometer	Fluorescence
IDEXX tests	IDEXX https://www.idexx.co.uk/en-gb/water/products/	E-coli, Colilert, Enterolert etc. Bacteria
LE 14/11 Muffle furnace	Nabertherm https://www.labunlimited.com/s/ALL/4AJ-9764541/Nabertherm-Compact-Muffle-Furnaces-LE-14-11-B150-LE140K1BN	TOC-LOI Total organic carbon - Loss of ignition method
Microscopes, imagine center	NMBU https://www.nmbu.no/en/services/centers/imaging-centre/equipment	Overview of possible microscopes
Model PCA	Micrometrix https://micrometrix.com/index.php/particle-charge-analyzer-model-pca/	Particle charges
Oxitop	WTW https://www.wtw.com/en/products/product-categories/benchtop-meters/oxitopr-measuring-systems/oxitopr-is.html	BOD (Biological oxygen demand)
PeCOD	Mantech https://mantech-inc.com/analysis-systems/chemical-oxygen-demand/	COD (Pecod method) Chemical oxygen demand
pH meters	WTW/VWR https://www.wtw.com/de/produkte/produktklassen/labormessgeraete/inolabr-labormessgeraete/inolabr-ph-7110.html	pH
QuickCODlab	LAR https://www.lar.com/products/cod-analysis/cod-analyzer-quickcodlab.html	TOD (Total oxygen demand)
Skalar San++	Skalar https://www.skalar.com/analyzers/automated-wet-chemistry-analyzers/	Chemistry Analyzer
Titrator	Metler Toledo https://www.mt.com/at/de/home/products/	Titration unit that can be connected to micrometrix

	Laboratory_Analytics_Browse/Product_Family_Browse_titrators_main.html	PCA
Zetasizer nano Z	Malvern https://www.malvernpanalytical.com/en/products/product-range/zetasizer-range/zetasizer-nano-range/zetasizer-nano-z	Zetapotential
Zetasizer WT	Malvern https://www.malvernpanalytical.com/en/products/product-range/zetasizer-range/zetasizer-wt	Zetapotential

4 Groundwater flow and soil physics

The definition of groundwater flow is given by the flow, which has infiltrated into the ground and is transported through an aquifer. The flow is strongly influenced by the surrounding soil, which requires a particular coverage of this issue.

4.1 Groundwater flow

Practical exercises on groundwater flow should include the determination of the groundwater level, the adjustment of the groundwater level via wells, the measurement of flow in excavation pits and the analysis of concentric loads on the substrate.

The mentioned principles can be presented during experiments using for instance "HM 167 Groundwater flow" of Gunt (2019), which is depicted in Figure 9.

Figure 9: Groundwater flow – Teaching equipment HM 167 Gunt

4.2 Seepage flow

The demonstration of seepage and groundwater flow is possible through the visualization of streamlines using injections of contrast mediums.

Teaching equipment ("HM 169 Visualization of seepage flows") covering the mentioned processes are provided by Gunt (2019) and are depicted in Figure 10.

Figure 10: Seepage flow – Teaching equipment HM 169 Gunt

4.3 Soil physics

Practical exercises on the determination of soil physics broaden the horizon of upcoming water resource managers. In cooperation with soil scientists, geotechnicians or geologists the courses might be offered including the determination of grain size distributions, soil densities and hydraulic conductivities.

4.4 Measuring instruments

Measuring instruments are partially integrated in the above-mentioned equipment. Moreover, Table 3 presents an exemplary list of devices, which can additionally be used for determining further parameters during the experiments as well as during monitoring tasks in the field.

Table 3: Groundwater flow and soil physics measuring instruments

Device	Information	Measured parameter
Double ring infiltrometer	UGT https://www.ugt-online.de/en/products/soil-science/conductivity/doppelringinfiltrometer/	Water infiltration
Permeameter	Eijkelkamp https://en.eijkelkamp.com/products/laboratory-equipment/	Permeability factor (k-factor)
Lysimeter	UGT https://www.ugt-online.de/en/products/lysimeter-technology/	Water balance (e.g. evapotranspiration)
Soil sample ring sets	UGT https://www.ugt-online.de/en/products/soil-science/soil-sampling/stechzylinder-entnahme-set/	Soil physics in undisturbed soil samples
Tensiometer	UGT https://www.ugt-	Water tension

	online.de/en/products/soil-science/tensiometers/	
UMP-2, SMT-100, TRIME-PICO, etc.	UGT https://www.ugt-online.de/en/products/soil-science/soil-moisture/	Soil moisture, soil temperature and conductivity

5 Hydrology

Hydrological processes effected by rainfall of varying duration and including seepage flow as well as runoff in rivers should be highlighted in subject-related practical exercises. Additionally, mass transport at hillside locations as well as in rivers can also be considered.

5.1 Studies in hydrology

Surface and groundwater flows are strongly related to rainfall and infiltration processes. Unique operation units are designed to investigate the impact of rainfall and infiltration on the earth surface.

The aforementioned principles can be presented during experiments using for instance “HM 145 Advanced hydrological investigations” of Gunt (2019), which is depicted in Figure 11a, or using the simplified system “FEL3 Rainfall Simulator - Issue 1”, which is offered by Armfield (2019) (Figure 11b).

a) 

b) 

Figure 11: Studies in hydrology – Teaching equipment a) HM 145 Gunt b) FEL3 Armfield

5.2 Sediment transport

Sediment transport in rivers is becoming increasingly important in the course of water resource management. Therefore the sediment-related processes should be investigated in the course of practical exercises.

Teaching equipment covering the mentioned requirements are “CAS Sediment Transport Demonstration Channel” (Edibon, 2019) and “HM 140 Open-channel sediment transport” (Gunt, 2019), which are depicted in Figure 12.

a)  b) 

Figure 12: Sediment transport – Teaching equipment a) CAS Edibon b) HM 140 Gunt

5.3 Measuring instruments

Instruments needed for hydrological investigations are also used in related research fields (hydraulics, groundwater flows, etc.) and are listed in the respective chapters. Moreover, Table 4 presents an exemplary list of devices which can additionally be used for determining further parameters during the experiments as well as during monitoring tasks in the field. The main focus is given to instruments measuring meteorological parameters, which are the basis for hydrological processes.

Table 4: Hydrology measuring instruments

Device	Information	Measured parameter
Air analysis	UGT https://www.ugt-online.de/en/products/meteorology/air-analysis/	Air constituents
Radiation	UGT https://www.ugt-online.de/en/products/meteorology/radiation-sensors/	Radiant flux density
Rain gauges	UGT https://www.ugt-online.de/en/products/meteorology/rain-gauges/	Amount of rain
Temperature and moisture sensors	UGT https://www.ugt-online.de/en/products/meteorology/temperature-and-moisture-sensors/	Air temperature, soil temperature and moisture, humidity
Weather station UGT	UGT https://www.ugt-online.de/en/products/meteorology/weather-station/wetterstation-ugt/	No measurement, station including data logger for connecting different sensors
Wind and baro transmitters	UGT https://www.ugt-online.de/en/products/meteorology/wind-and-baro-transmitters/	Wind direction and speed

6 Software used in water resources management

The application of software is becoming increasingly important in water resources management. An overview of well-known products in different fields is given in the forthcoming sub-chapters.

6.1 Hydraulics and hydrodynamics

In general, hydraulic and hydrodynamic simulations are grouped into piping system calculations and free surface simulations, which are additionally classified into 1D-, 2D- and 3D-numerical models. Table 5 gives an overview of different software products. Simulation exercises using piping system calculations and 1D (and 2D) free surface calculations are usually considered appropriate for master students.

Table 5: Hydraulics simulation software

Software products	Information
Piping system calculation	
AFT Fathom	Applied Flow Technology https://www.aft.com/products
EPANET	Environmental Protection Agency https://www.epa.gov/water-research/epanet
Fluidflow	Flite Software NI Ltd http://fluidflowinfo.com/products/incompressible-flow/
Pipe Flow Software	Pipe Flow Software https://www.pipeflow.com/
Free surface calculation	
HEC-RAS (1D)	US Army Corps of Engineers https://www.hec.usace.army.mil/software/hec-ras/
MIKE 11 (1D)	DHI Water and Environment https://www.mikepoweredbydhi.com/products/mike-11
WASPI (1D)	Hydroconsult https://www.hydroconsult.net/software/waspi-sms-tools-1/
CCHE2D-Flow (2D)	National Center for Computational Hydroscience and Engineering https://www.ncche.olemiss.edu/cche2d-flw-model/
FLO-2D (2D)	FLO-2D Software https://www.flo-2d.com/
Hydro_As-2D/SMS (2D)	Hydrotec, Dr. Nujic / Scientific Software Group https://www.hydrotec.de/software/hydro-as-2d/ https://www.hydrotec.de/software/support/downloads/sms-downloads/
MIKE FLOOD (2D)	DHI Water and Environment https://www.mikepoweredbydhi.com/products/mike-flood
TELEMAC-2D (2D)	Laboratoire d'Hydraulique of EDF http://www.opentelemac.org/index.php/presentation?id=17
ANSYS Fluent (3D)	ANSYS Inc. https://www.ansys.com/products/fluids/ansys-fluent

Delft3D (3D)	Deltares https://oss.deltares.nl/web/delft3d
FLOW-3D (3D)	Flow Science Inc. https://www.flow3d.com/
RSim-3D (3D)	Dr. Tritthart (2005) http://www.wau.boku.ac.at/en/iwa/
TELEMAC-3D (3D)	Laboratoire d'Hydraulique of EDF http://www.opentelemac.org/index.php/presentation?id=18

6.2 Hydrology

Conceptual models are used for investigating the hydrological balance in entire river basins. Less attention is paid to physical characteristics of rivers (e.g. flow velocities, water depths, etc.) than on changes of long-term time series (e.g. run-off, etc.) and reservoir storages based on changes in the environment (e.g. climate, agriculture, etc.).

Table 6: Hydrology software

Software products	Information
Hydrology	
COSERO	Eder et al. (2005)
HBV	SMHI Swedish Meteorological and Hydrological Institute https://www.smhi.se/en/research/research-departments/hydrology/hbv-1.90007
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System https://www.hec.usace.army.mil/software/hec-hms/
HSPF	Environmental Protection Agency https://www.epa.gov/ceam/hydrological-simulation-program-fortran-hspf
HYSIM	Water Resource Associates https://www.watres.com/software/HYSIM/
LARSIM	LARSIM-Entwicklergemeinschaft http://www.larsim.info/das-modell/
MIKE SHE	DHI Water and Environment https://www.mikepoweredbydhi.com/products/mike-she
WaSiM	HSC J. Schulla http://www.wasim.ch/en/index.html

6.3 Decision making

Frequently used products for integrated water resources management are decision support systems (DSS) using a wide range of information building as fundamental basis for any kind of decision. A conceptual overview of a decision support system is depicted in Figure 13.

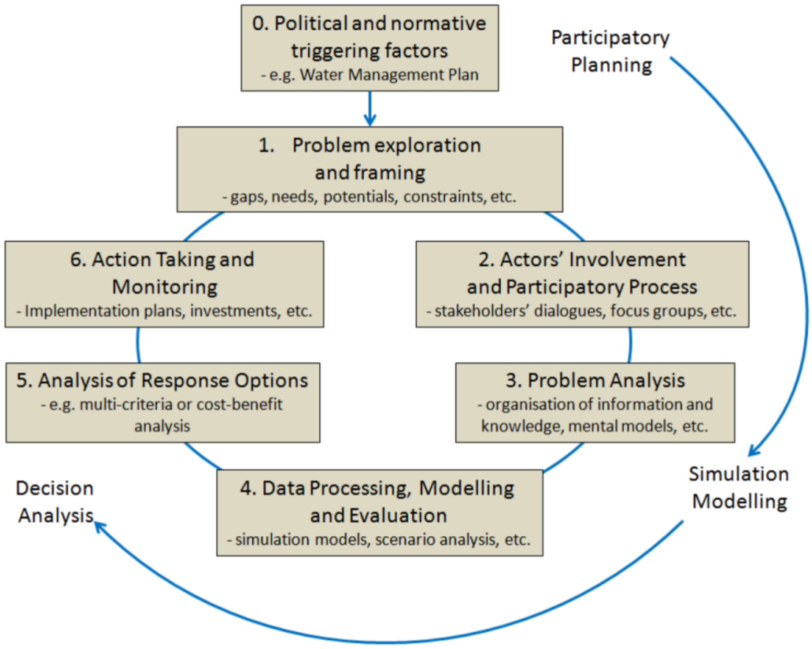


Figure 13: Decision support system (Giupponi & Sgobbi, 2013)

An overview of examples of existing products is given in Table 7.

Table 7: DSS software

Software products	Information
Decision Support System	
MIKE OPERATIONS	DHI Water and Environment https://www.mikepoweredbydhi.com/areas-of-application/mike-operations
Nile DSS	Georgakakos (2007)
WEAP	Stockholm Environment Institute's U.S. Center https://www.weap21.org/index.asp?NewLang=EN

6.4 Sediment transport

Simulation of sediment transport in rivers is becoming increasingly important in the course of water resources management. However, the application of sediment transport models is currently still mostly restricted to scientific applications and environments. A number of the hydrodynamics models listed in section xx feature also sediment transport modules which can be activated on demand. Moreover, there are tailor-made sediment transport and morphodynamics models, which are exemplarily presented in Table 8.

Table 8: Sediment transport software

Software products	Information
Sediment transport	
D-Morphology	Deltares https://www.deltares.nl/en/software/module/d-morphology/
HEC-RAS (1D)	US Army Corps of Engineers https://www.hec.usace.army.mil/software/hec-ras/
HYDRO_FT-2D	Hydrotec https://www.hydrotec.de/software/hydro-as-2d/hydro_ft-2d-transportprozesse/
iSed	Tritthart et al. (2011) http://www.wau.boku.ac.at/en/iwa/

6.5 Water treatment

Mechanical, chemical, physical and biological processes in water treatment are considered in simulations of water treatment plants. The use of the following software products enables the prediction of changes in the treatment process due to various external influences (e.g. increased organic or hydraulic loading, changes in process management, failure of machines, etc.).

Table 9: Water treatment software

Software products	Information
Water treatment	
AqMB	AqMB Pty Ltd. https://aqmb.net/
ASIM	Eawag aquatic research https://www.eawag.ch/en/department/eng/software/
GPS-X	Hydromantis ESS, Inc. http://www.hydromantis.com/GPSX.html
SIMBA#	inCTRL Solutions https://www.inctrl.ca/software/simba/
WEST	DHI Water and Environment https://www.mikepoweredbydhi.com/products/west
STOAT	http://www.wrcplc.co.uk/ps-stoat

7 Conclusions

The present study includes a comprehensive overview of equipment and software used in practical exercises in the field of water resources management. These exercises are a fundamental basis within higher education in the aforementioned discipline to strengthen the knowledge of hydraulic fundamentals and interrelationships.

Some equipment sets introduced in this report are based on modules, which can be expanded as required. This structure allows a cost-efficient acquisition as well as a demand-oriented adjustment of the exercises.

Instruments used for monitoring data related to water resource management (e.g. devices for measuring flow velocities, water depths, pH-values, oxygen concentration, etc.) are briefly introduced.

It is noted that software products used in water resource management might need commercial licenses, which are often reduced in price for educational purposes. A possible interface to common software products (e.g. ArcGIS, AutoCAD, etc.) should be considered when acquiring new software products.

8 References

Armfield (2019). http://discoverarmfield.com/en (Call 01.2019).

Convergence (2019). https://www.con-vergence.com/ (Call 03.2019)

Edibon (2019). http://www.edibon.com/en/ (Call 01.2019).

Georgakakos, A. P. (2007). Decision support systems for integrated water resources management with an application to the Nile basin (pp. 99-116). Elsevier: Amsterdam, The Netherlands.

Giupponi, C., & Sgobbi, A. (2013). Decision support systems for water resources management in developing countries: Learning from experiences in Africa. Water, 5(2), 798-818.

Gunt (2019). https://www.gunt.de/en/ (Call 01.2019).

J&F water treatment (2019). http://jandfwatertreatment.ie/ (Call 01.2019).

Tritthart, M. (2005). Three-dimensional numerical modelling of turbulent river flow using polyhedral finite volumes. Wien. Mitt. Wasser-Abwasser-Gewässer, 193, 1–179.

Tritthart, M.; Schober, B.; Habersack, H. (2011). Non-uniformity and layering in sediment transport modelling 1: Flume simulations. J. Hydraul. Res., 49, 325–334.

Eder, G., Fuchs, M., Nachtnebel, H. P., and Loibl, W. (2005). Semidistributed modelling of the monthly water balance in an alpine catchment, Hydrol. Process., 19, 2339–2360, 2005.