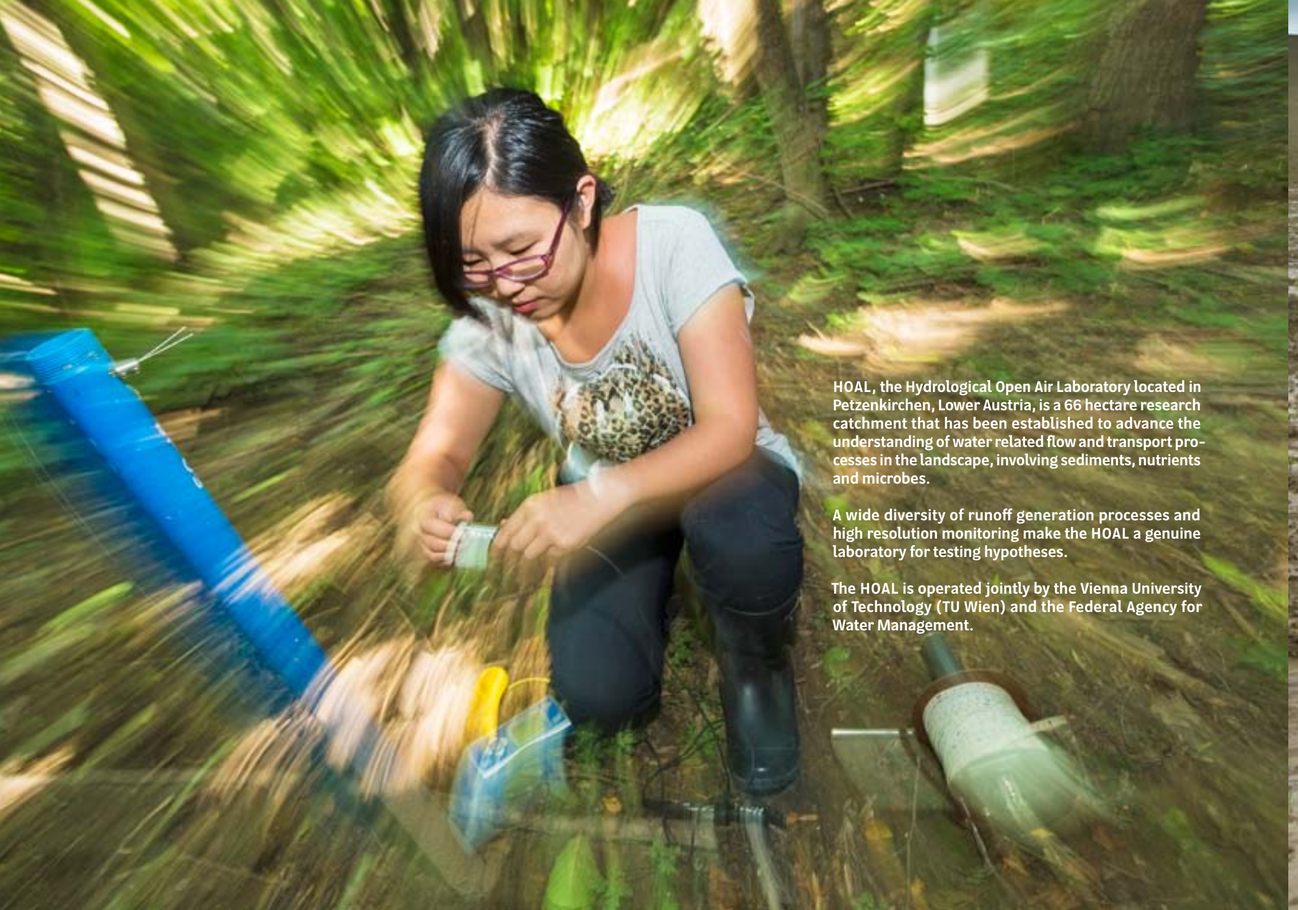


HOAL, the Hydrological Open Air Laboratory located in Petzenkirchen, Lower Austria, is a 66 hectare research catchment that has been established to advance the understanding of water related flow and transport processes in the landscape, involving sediments, nutrients and microbes.

A wide diversity of runoff generation processes and high resolution monitoring make the HOAL a genuine laboratory for testing hypotheses.

The HOAL is operated jointly by the Vienna University of Technology (TU Wien) and the Federal Agency for Water Management.

HOAL

The Hydrological Open Air Laboratory Petzenkirchen

TU WIEN

BAW

MINISTERIUM FÜR EIN LEBENSWERTES ÖSTERREICH

BUNDESAMT FÜR WASSERWIRTSCHAFT

HOAL, the Hydrological Open Air Laboratory in Petzenkirchen, Lower Austria, is a 66 hectare research catchment that has been established to advance the understanding of water related flow and transport processes in the landscape, involving sediments, nutrients and microbes.

The overarching science questions have guided site selection, identification of dissertation topics and the base monitoring. The specific hypotheses have guided the dedicated monitoring and sampling, individual experiments, and repeated experiments with controlled boundary conditions.

The HOAL catchment is ideally suited for researching water flow and transport processes, because it features a range of different runoff generation processes (surface runoff, springs, tile drains, wetlands) and it is convenient from a logistic point of view as all instruments can be connected to the power grid and a high speed glassfibre Local Area Network. This makes the HOAL a genuine laboratory where hypotheses can be tested, either by controlled experiments or by contrasting sub-regions of different characteristics.

The diversity in flow and transport processes also ensures that the HOAL is representative of a range of catchments around the world and the specific process findings from the HOAL are applicable to a variety of catchment settings.

Cutting edge research, interdisciplinary collaboration, networking within the science community and beyond, and provision of long-term experimental infrastructure are the cornerstones of the HOAL programme, which is becoming a hub for hosting guest scientists, through a closely knit network with other academic institutions and observatories.

The HOAL is operated jointly by the Vienna University of Technology (TU Wien) and the Federal Agency for Water Management of the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW). More than 20 researchers and experts explore science questions in the HOAL under the guidance of Günter Blöschl and Peter Strauss.

Peter Strauss, Head of the Institute for Land and Water Management Research, Federal Agency for Water Management of the BMLFUW.

Günter Blöschl, Head of the Centre for Water Resource Systems (CWRS) and the Institute of Hydraulic Engineering and Water Resources Management of the TU Wien.

» Water related flow and transport processes involving sediments, nutrients and microbes are explored in the Hydrological Open Air Laboratory (HOAL) in Petzenkirchen, Lower Austria.

HOAL, the Hydrological Open Air Laboratory, Petzenkirchen, is situated in the western part of Lower Austria (48° 9' N, 15° 9' E), some 100 km west of Vienna. Elevations range from 268 to 323 m a.s.l. The subsurface consists of Tertiary sediments of the Molasse zone and fractured siltstone. Soils include Cambisols and Planosols with medium to poor infiltration capacities.

The climate is humid with mean annual temperatures around 10 °C, precipitation around 800 mm/yr and runoff around 200 mm/yr (equivalent to 4 l/s at the 66 hectare catchment outlet).

As many of the overarching science questions are related to erosion and nutrients, it is an advantage that most of the catchment is used for agricultural purposes where sediment and nutrient fluxes tend to be bigger than for forested or urban settings. The crops include winter wheat and maize. Manure and fertilizer application are accurately known from farmers' book keeping which are useful for estimating nutrient and faecal pollution inputs.

There is a strong human footprint in the catchment which adds richness to the research.

» The HOAL is a 66 hectare agricultural catchment some 100 km west of Vienna in the Alpine Foreland of Lower Austria. The climate is humid, Cambisols and Planosols prevail.






A wide range of runoff generation mechanisms occurs in the HOAL which makes it a genuine laboratory where hypotheses of flow and transport can be tested, either by controlled experiments or by contrasting sub-regions of different characteristics. This diversity also ensures that the HOAL is representative of a range of catchments around the world.

Due to shallow, low permeable soils, the concave part of the catchment was tile drained in the 1950s in an effort to reduce water logging. Two tile drain systems do not dry out during the year while two are ephemeral.

There are two clearly visible springs that directly discharge into the stream draining the HOAL. The water from one of them originates from a fractured siltstone aquifer with distinct hydrologic and chemical characteristics while another spring has more shallow water contributions.

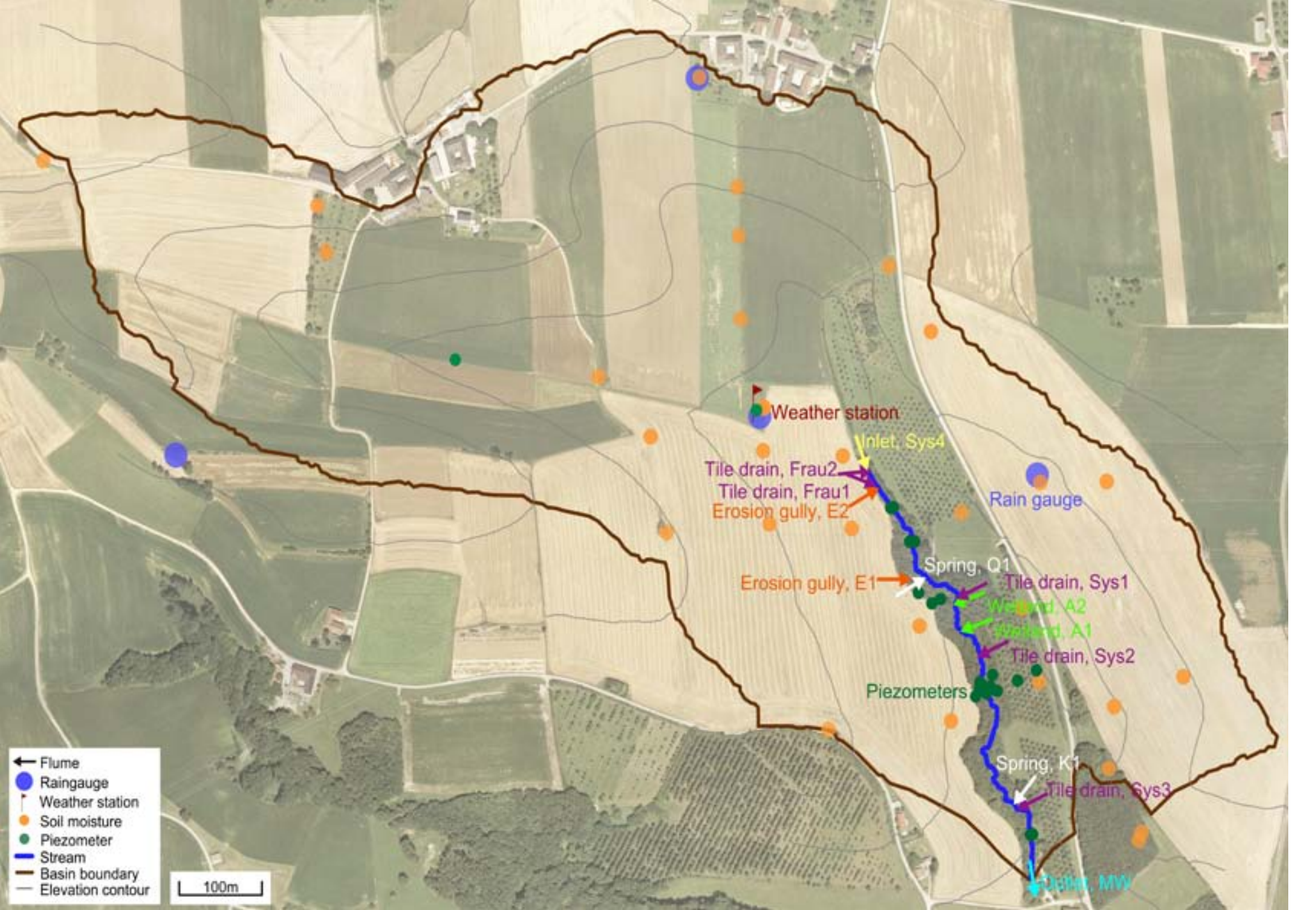
In the south-eastern part of the catchment is a small wetland close to the stream which permanently seeps into the stream. The wetland is fed by springs at its upper part and usually responds very quickly to all types of rainfall due to its high saturation state.

During high intensity thunderstorms in summer and spring, infiltration excess overland flow tends to occur with a very substantial, fast contribution from the tile drainage system.

During major storms, saturation overland flow occurs across the fields (mainly in the depression areas) which enters the stream at three locations. In winter rain-on-snow runoff may occur as saturation overland flow during large events which causes gully erosion.

The main runoff generation mechanism in winter is through lateral subsurface pathways (shallow subsurface preferential flowpaths, drainage pipes). Even minor events will lead to a significant increase of stream flow due to high soil moisture during the winter. After freezing periods, when the soil is still frozen, infiltration excess overland flow may occur.

» The HOAL is special due to its many different runoff generation processes, including infiltration excess overland flow, saturation excess runoff from wetlands, tile drainage flow and groundwater discharge from springs.



Some of the most interesting science questions of water flow and transport processes require long term observations with high temporal and spatial resolution. A nested monitoring approach was therefore adopted for the HOAL consisting of base monitoring, dedicated monitoring and sampling, and individual experiments, involving more than 300 sensors with a typical resolution of 1 minute.

A substantial number of high resolution raingauges and stream gauges were chosen as the base monitoring setup. Basic chemical and physical parameters are monitored by online sensors and regular grab sampling. A weather station was set up to monitor the energy fluxes at the land-atmosphere interface. Spatial sampling to characterise the catchment include Lidar for high definition topography, soil mapping and sampling.

As part of the dedicated monitoring and sampling strategy, a soil moisture network within the catchment and three eddy correlation stations were set up. Faecal indicators and water quality characteristics are monitored to understand the dynamics of faecal contamination and nutrient fluxes.

Field campaigns are being conducted over limited periods of time to obtain more in-depth understanding of the processes at the field scale. Examples include tracer tests in the stream to elucidate stream aquifer interactions and a field campaign dedicated to measuring transpiration and bare soil evaporation separately. A small number of experiments are conducted with controlled boundary conditions such as resuspension experiments in the stream.

The HOAL is located within walking distance of the premises of the Institute for Land and Water Management Research which vastly facilitates the day-to-day maintenance of the instruments and experimental setups. Most instruments have been connected to the power grid and to a high speed glassfibre Local Area Network which further assists data management, remote monitoring of the functioning of the instruments and the short term planning of experiments.

» A total of more than 300 sensors have been installed in the HOAL, in addition to sampling, experiments and surveys, to allow high resolution (1 minute) monitoring with much spatial detail.






One of the hallmarks of the HOAL observatory is its ability for fostering cooperation across the disciplinary boundaries which allows doctoral students to address more complex science questions than is possible through individual dissertations. The main strategy for achieving this consists of organising the research through joint groups and joint research questions.

A number of doctoral students currently address, e.g., research questions related to space time patterns of flow paths and evaporation. Atmospheric scientist Patrick Hogan is investigating the soil moisture and land use controls on spatial evaporation patterns within the catchment. One specific hypothesis Patrick Hogan is testing is that the relative importance of soil moisture controls exceeds that of topographic controls at all times of the year. As evaporation is an important flux in the HOAL it will directly affect soil moisture (of interest to remote sensing specialist Mariette Vreugdenhil) and indirectly affect the flow paths (of interest to hydrogeologist Michael Exner-Kittridge who deals with nutrient fluxes).

Structural engineer Abbas Kazemi Amiri is taking advantage of the eddy correlation systems and conducts measurements of the dynamic wind loading of the mast structure to understand the interactions of water resource structures with wind, and specifically the role of fatigue. Conversely, Patrick Hogan can make use of the expertise and research progress of other students by testing the spatial distribution of evaporation obtained by his eddy-correlation instrumentation against observed runoff volumes in different parts of the catchment.

Hydrologist Rasmiaditya Silasari's thesis quantifies the spatial organization of the flow patterns. One specific hypothesis she is testing is that spatial connectivity is a major determinant of the flow rates and flow dynamics. The numerical hydrological simulations she conducts for testing her hypotheses are directly relevant to Mariette Vreugdenhil for interpreting spatial soil moisture.

» The cooperation of researchers across disciplinary boundaries within the HOAL allows them to address more complex science questions than is possible through individual studies.

Understanding runoff generation mechanisms is very important for better estimating floods that may occur in small catchments, in particular if one is interested in extrapolating from small to large floods and to changed environmental conditions. Researchers in the HOAL are investigating flood generation aided by the diversity of runoff generation processes such as surface runoff, springs, tile drains and wetlands.

Saturation patterns within the catchment are monitored using video cameras to understand the space-time patterns and connectivity of surface flow. This is complementary to the soil moisture network by providing better spatial resolution.

The images allow the assessment of the role of surface ponding, micro-topography and the spatial organisation of surface flow within the catchment. They are used for validating theories of flow connectivity and distributed hydrological models, and assist in understanding water quality and sediment transport processes in the HOAL.

>> The spatial organisation of surface runoff within the catchment is monitored and used for testing flow connectivity theories, to assist in understanding flood generation processes.

Knowledge about the sources of sediments is very relevant for managing contaminants such as phosphorus and for controlling soil loss from agricultural landscapes. During infiltration excess overland flow events in the HOAL, sheet, rill and gully erosion may occur on the fields that are poorly covered by crops, but sedimentation immediately occurs when the sediment laden water enters a field with better cover.

Turbidity is monitored at various locations in the HOAL along with autosamplers to be able to calibrate the sediment-turbidity relationships for each event separately. Aerial photographs are taken to identify erosion patterns and calculate eroded soil volumes after erosive rainfall events.

To understand sediment deposition and resuspension in the stream, repeated resuspension experiments were conducted, where sediment-free water was pumped into the source of the stream and flow rates, sediment and solute concentrations as well as grain size distributions were measured. The experiments are complemented by numerical modelling.

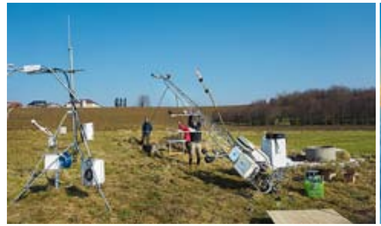
» Sediment monitoring, experimentation and modelling are conducted to understand the sources and pathways of sediments in the landscape.

Evaporation may vary significantly over short distances and it is interesting to understanding its controls at various space-time scales.

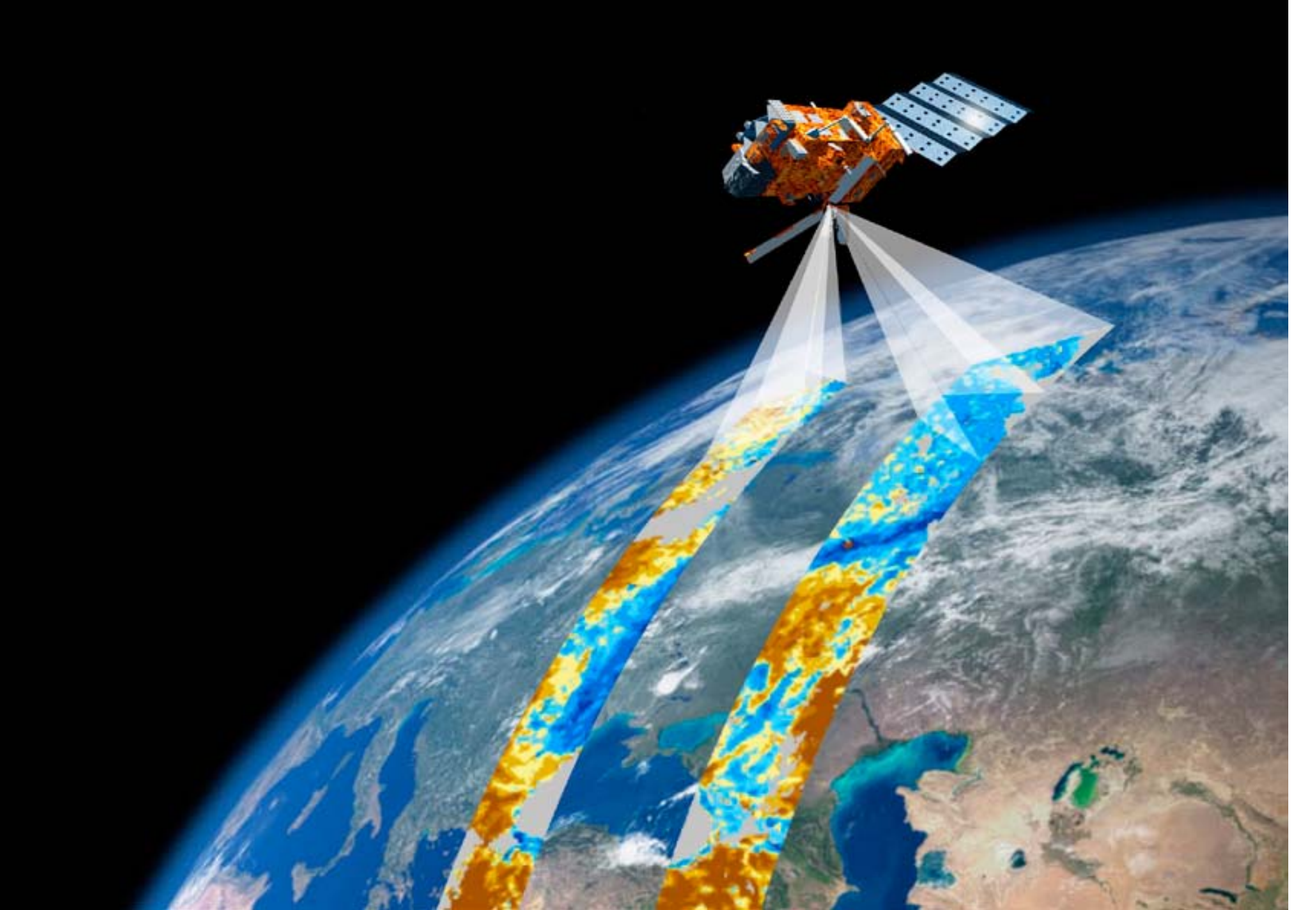
Three eddy correlation stations were set up in the HOAL. One set of instruments has been set up at the weather station location. Additionally, two mobile stations are deployed based on a site rotation plan to optimise the locations for each sensor relating to the factors of interest; topography, soil type and moisture and vegetation. Scintillometer measurements of aggregated fluxes over a line of about 150 m are made for comparison to obtain momentum flux, sensible heat flux and information on the turbulent parameters of the air.

The data are compared with numerical simulations of the atmospheric processes to ascertain that the controls identified are generalisable to other land surface conditions.

Field campaigns dedicated to measuring transpiration and bare soil evaporation separately in a field of maize shed light on the role of vegetation in total catchment evaporation.



» Eddy correlation measurements are conducted at a number of locations in the HOAL to understand the spatial evaporation patterns and test numerical models.



SCIENCE QUESTIONS – HOW CAN SMALL SCALE SOIL MOISTURE VARIABILITY BE RELATED TO THE RESPONSE OF SATELLITE SENSORS?

Understanding the controls of spatial soil moisture patterns in small catchments is essential for upscaling soil moisture from point to catchment scales as needed for drought predictions. The relative importance of the factors driving the spatial distribution of soil moisture will change during the season, e.g. topography may control the soil moisture distribution during wet periods, and vegetation and soil properties may be more dominant during dry conditions, which will affect the way satellite sensors see the soil moisture.

A soil moisture network of more than 30 stations within the catchment was set up that uses wireless transmission technology. Time Domain Transmission sensors are used which measure the dielectric conductivity from the propagation velocity of an electromagnetic wave.

Scaling analyses are conducted to relate the soil moisture variability to a larger landscape context. There is a close interaction with the transpiration and flood generation analyses.

» A wireless soil moisture network has been installed to understand the controls of how satellite sensors see small scale soil moisture variability.

Much of the pollution in the landscape moves in the subsurface. The timing and location of pollution transport is driven by the groundwater dynamics. Groundwater levels and chemical characteristics are monitored at numerous locations within the HOAL.

A number of geophysical surveys are being conducted to improve the delineation of hydrogeological heterogeneities and processes in the subsurface. The techniques include ground penetrating radar, induced polarization and low-induction number electromagnetic induction methods. The information on the subsurface so obtained is combined with numerical flow and transport models.

To understand the stream-aquifer interactions several tracer tests were performed. These tests allowed the estimation of stream bank fluxes. Infrared cameras are used to identify hotspots of groundwater recharge into the stream. Mass balances over sections of the stream are used to determine the role of near-stream riparian trees on the daily fluctuations of the stream flow during low flow conditions.

» Geophysical surveys, tracer tests and groundwater monitoring and modelling are conducted to understand the timing and location of pollution transport in the subsurface.

There is a delicate balance between the application of phosphorus and nitrogen as a fertiliser to agricultural land and their harmful effects on surface and subsurface waters. Cost-effective mitigation measures need to target the sources and flow paths that conduct the bulk of the load.

Multiple flow paths (e.g. overland flow, macropore flow, matrix flow, tile drainage) of these substances are studied in the HOAL. A water quality monitoring network was installed. While the high sediment concentrations in the HOAL facilitate the sediment process analyses, they complicate the monitoring of water quality parameters, as they tend to clog sensors. A new device was developed, termed Water Monitoring Enclosure, that allows in-situ monitoring of water quality parameters for highly dynamic, sediment laden streams.

Autosampling and grab sampling is performed at regular intervals, and analysed for a range of parameters including stable isotopes. Mixing analyses, assisted by tracer tests, have identified the main sources and flow paths in the landscape.

» A water quality monitoring network provides data to understand the main sources and flow paths of phosphorus and nitrogen in the landscape.

Microbial water safety management can be enhanced by real time detection of faecal pollution from enzymatic activity. Such measurements will also shed light on microbial transport processes at the catchment scale.

The HOAL is an ideal test bed for such automated measuring devices due to its highly dynamic runoff, sediment concentrations and bacterial contamination from manure.

Four enzymatic analysers with two different designs have been set up at the catchment outlet. The devices sample stream water at intervals of 1 or 3 hours. The results for different setups are compared with laboratory analyses in order to optimise the strengths of the instruments in a real time mode.

Interpretation of the faecal indicators in the context of physical and chemical parameters for events with contrasting characteristics (e.g. fast and short response times, dry and wet antecedent soil moisture) sheds light on microbial pollution processes. Manure events and the fate of faecal pollution can be identified from the time dynamics of the indicator.

» Four enzymatic analysers have been installed for stream water sampling and the set up is optimised for a real time mode.

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Hydrology and water resources management

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Structural mechanics

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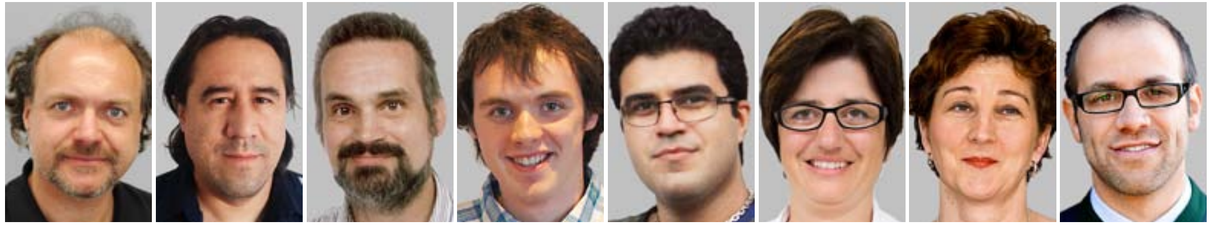
Hydrology, Erosion processes and sediment transport

Michael Exner-Kittridge
Water quality, Nitrogen sources and pathways



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Remote sensing

Prof. Matthias Zessner
Water quality

A highly motivated team of scientists is conducting research in the HOAL, including Alfred Paul Blaschke[abh], Günter Blöschl[ab], Martine Broer[a], Christian Bucher[ac], Gemma Carr[a], Xiaofei Chen[a], Alexander Eder[ad], Michael Exner-Kittridge[ae], Andreas Farnleitner[afh], Adrian Flores-Orozco[g], Peter Haas[ab], Patrick Hogan[a], Abbas Kazemi Amiri[a], Markus Oismüller[ad], Juraj Parajka[ab], Rasmiaditya Silasari[a], Philipp Stadler[ae], Peter Strauss[d], Mariette Vreugdenhil[a], Wolfgang Wagner[ag], Matthias Zessner[ae]

These are supported by a group of support staff including Ulrike Gobec[d], Peter Haas[b], Lukas Kornfeind[e], Carmen Krammer[d], Monika Kumpan[d], Lukas Nemeth[e], Gertrud Neumeister[b], Matthias Oismüller[bd], Ernis Saracevic[e], Günther Schmid[d], Andreas Winkelbauer[e]. A range of collaborations with both national and international research institutes and agencies are under way, including the Austrian Institute of Technology, the International Atomic Energy Agency, and the Helmholtz Centre for Environmental Research. The HOAL programme is becoming a hub for hosting guest scientists, through a closely knit network with other academic institutions and observatories.

The Laboratory and the research are supported by the TU Wien, the Federal Agency for Water Management, the Austrian Science Fund (FWF) through the Vienna Doctoral Programme on Water Resource Systems, and a number of research projects. The HOAL team would like to thank all funders.

FWF Der Wissenschaftsfonds

Vienna Doctoral Programme on Water Resource Systems

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» A highly motivated team of scientists is conducting research in the HOAL, assisted by a group of support staff. The HOAL programme is becoming a hub for collaborations on water research.

Observatories in other geoscience disciplines, such as astronomy and meteorology, require relatively modest space on the land. In contrast, hydrology is about water and matter fluxes at the landscape scale, so the requirements regarding space are invariably more extensive.

Arrangements have therefore been made with the land owners of the HOAL involving permissions to use their land, the exchange of information on agricultural management practices and, where applicable, changes to these practices.

Any maintenance or experimentation activities in the field are planned in agreement with the land owners. There is an annual open day where the doctoral students explain their recent research to the local community.

The HOAL Team appreciates the helpful cooperation of the land owners.

» The HOAL Team would like to thank the land owners for their helpful cooperation and their support of the HOAL research.

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