



Universiteit Utrecht



MASTER'S PROGRAMME

# Hydrology

GRADUATE SCHOOL OF GEOSCIENCES

Realise your master plan.

**Are you interested in studying the water cycle? Do you want to learn about the processes relating to groundwater and surface water? Do you want to know how polluted soil and groundwater can be remediated? Do you want to work on solutions to the world's shortage of clean drinking water? Do you want to help solve global problems concerning overabundance, scarcity or quality of water?**

**Sign up for the Master's Programme Hydrology at Utrecht University! This programme is rooted in top class research groups, which together cover a wide range of disciplines in the area of hydrology. We will provide you with a firm fundamental basis and you will learn how to use this knowledge during your own independent research project.**

### **What is Hydrology about?**

Hydrology is the study of the water cycle, i.e., how water evaporates from sea and land, where and how much returns to the earth's surface as precipitation, how much is stored in soils and aquifers, and how water travels through rivers and underground to the seas and oceans. Hydrologists help solve local and global problems related to the overabundance, scarcity, or quality of water. They do so using their understanding of various physical, chemical, and biological processes in the water cycle and soil-water system.

### **Two tracks: Environmental Hydrogeology and Earth Surface Hydrology**

Within this Utrecht University programme, you can choose from two tracks: Environmental Hydrogeology and Earth Surface Hydrology. The track **Environmental Hydrogeology**

focuses on the environmental issues relating to hydrologic processes in the subsurface. You will learn to understand, quantify and model the transport in porous media. Possible research subjects are: groundwater flow and exploration, transport of dissolved material in the subsurface, pollution and remediation of soil and groundwater, the storage of thermal energy in aquifers or the invasion of seawater in groundwater systems in coastal areas.

The track **Earth Surface Hydrology** is concerned with the study of hydrological processes near and on the earth's surface. In this programme you will learn to understand and model the flow of water. Possible research subjects are: flow of water in basins and rivers, surface runoff, modelling and prediction of erosion and landslides, the relation between water flow and climate change, the impact of human activity on the hydrological cycle and the relation between soil moisture and ecosystems.

### **Your research challenge**

It could be your job to find answers to these questions:

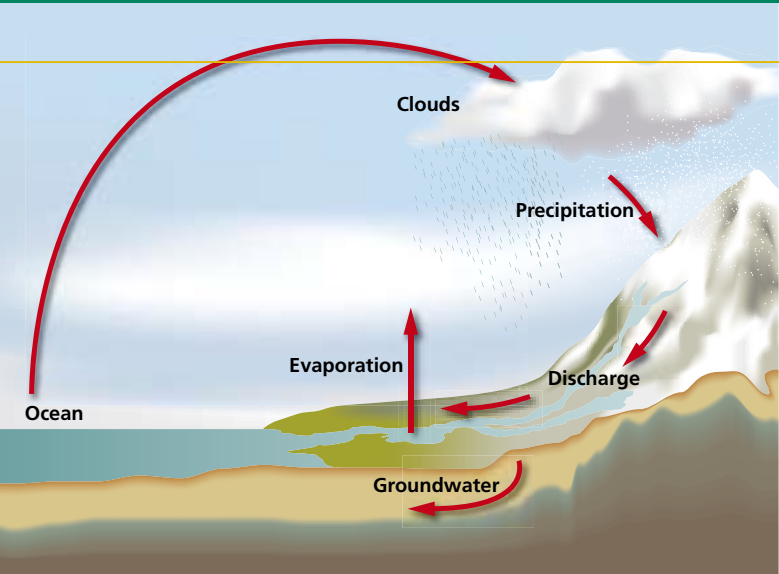
- If the climate changes, what types of water management will enable us to cope with larger floods?
- How can we remove viruses from groundwater?
- How can we understand desertification and erosion?
- How can we model/predict natural attenuation of organic contaminant plumes in groundwater?
- If the population continues to grow, will we still have enough water left for everyone?
- How can we design systems for storage of thermal energy (heat/cold) in the subsurface?

### **Utrecht University**

Located in the centre of the Netherlands, Utrecht University is one of Europe's leading universities, recognised internationally for its high-quality, innovative approach to both research and teaching. It is a world-class environment for MSc students. Utrecht University is proud of its high international ranking (e.g. Shanghai list) and offers the broadest spectrum of disciplines available in the Netherlands. Each year about 2,000 students from all over the world come to study at Utrecht University. For ambitious students seeking new challenges in an international environment, the MSc programme offers a tremendous array of opportunities. If you decide to come to Utrecht to do a Master's programme, you will be able to enjoy a lively city as well as the scientific atmosphere at our campus 'De Uithof'. The campus features modern architecture, a large library, beautiful Botanical Gardens and the Olympus sports centre. Students greatly appreciate the student flats, shops, restaurant and three bars.

### **City of Utrecht**

Utrecht is a dynamic city in the centre of the Netherlands. One sixth of its 300,000 inhabitants are students, making it a real university town. In the historic centre you will find excellent museums in a setting of picturesque courtyards, restaurants and delightful little shops. Much of the city's mediaeval atmosphere can still be felt today in the layout of its streets and alleyways. In the summer, you can enjoy a drink or meal at one of the many pavement cafés along the streets and canals. The city of Utrecht is also known for its festivals and cultural programmes. Many large and small theatre groups present plays, operas, dance performances, musicals and cabarets. Utrecht also has many trendy clubs where you can hear the latest hits and see the trendiest fashions. There is large variety of student unions that cater to all types of students. All this makes the city of Utrecht a very attractive place for many people, including graduate students. So, why not earn your degree in this pleasant and picturesque university town in the Netherlands?



- How can we effectively use flood and drought forecasts to help water authorities and farmers?
- What are efficient methods to minimise seawater intrusion in coastal areas?
- How do ecosystems and the hydrological cycle interact, and how does this affect climate change?
- What are the long-term effects of CO<sub>2</sub> storage in geological formations?

**Why Utrecht?**

**A wide spectrum of disciplines**

What makes Hydrology at Utrecht University unique is that students are exposed to a wide spectrum of disciplines within Hydrology and Earth Sciences in general. Within the

Earth Sciences groups, there are links between hydrology and geology, geophysics, geochemistry, physical geography and remote sensing. You can choose from a variety of combinations of the offered courses and research subjects.

The Utrecht campus is a major Earth-Sciences hub, both at national and European levels. The Utrecht Centre of Geosciences (UCG) is an alliance consisting of the Earth-Sciences groups of the Faculties of Geosciences, Physics (Meteorology/Oceanography) and Biology (Biogeology) and their on-campus neighbour TNO Built Environment and Geosciences - National Geological Survey.

Another very important feature of the Hydrology programme in Utrecht is the combination of theoretical studies, laboratory experiments and fieldwork. Our first-rate laboratory facilities are a valuable asset in this regard.

The staff are part of an extensive national and international network, from which students undoubtedly benefit. Students are able to participate in courses, research or traineeships abroad.

For those who are interested in stochastic hydrology, it is interesting to note that Utrecht University is the only place in the Netherlands where this subject is taught in such a comprehensive form. You will learn to observe the huge variations in time and space found in the water cycle and how to deal with the uncertainty that results from these variations.

**Barbara Snacken, Master's student Hydrology**



'I'm involved in a research project on a new promising technique.'

The Master's programme Hydrology particularly interested me because water is currently a hot topic (climate change, depletion of groundwater resources, groundwater pollution) and it will be even more important in the future. I took both tracks (Earth Surface Hydrology and Environmental Hydrogeology) and specialised in environmental hydrogeology. My Master's research was about mechanical well clogging in extraction wells. Any

type of extraction well (oil, water) will experience production loss due to well clogging. I tried to come up with a model for the physical processes that play an important role. When you know about the processes, you can predict how long a well will work at its full potential. Currently I am doing an internship in the United States at the Colorado School of Mines. I'm involved in a research project on a new promising technique, with which remediation of difficult to reach dense chlorinated contaminants could be

effective and financially attractive. This is a great experience: not only do I get to work in a research facility but it is also great to live abroad for six months, meet new people, get to know a new culture, and explore America's exciting national parks. When I return to the Netherlands I hope to find a job in a groundwater (remediation) company, where I can put my knowledge into practice.

# Study programme

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**Hydrology is a two-year Master's programme that is taught in English. It consists of courses and research, totalling 120 European Credit Points (in the European Credit Transfer System ECTS). The programme comprises one year of course modules, six months of independent research culminating in a Master's thesis and a six-month traineeship. The table below lists all the hydrology courses to be taken in the first year. These courses are 7.5 ECTS each. Students should take at least 60 ECTS of courses in the first year and are required to choose five out of the eight hydrology courses offered. The first two courses (Land Surface Hydrology and Principles of Groundwater Flow) are compulsory. Apart from the requirement to choose five of the eight courses, students are free to put together their own study programme. There are, however, two distinct study tracks.**

## **Earth Surface Hydrology track**

Students who take the track Earth Surface Hydrology will learn in greater detail about hydrological processes on the surface and in the shallow subsurface. Apart from the compulsory courses Land Surface Hydrology and Principles of Groundwater Flow, they will take courses about unsaturated zone hydrology, stochastic hydrology and the relation between hydrology, climate change and fluvial systems. Additional courses outside the hydrology curriculum can be taken such as: Remote Sensing, Spatial Analysis with GIS, Land Degradation and Catchment Modelling, Fluid Mechanics, Coastal and River Management, Dynamic Meteorology, Turbulent mixing and Boundary Layers. Naturally, the Master's research projects will be related to earth surface hydrology.



## **Environmental Hydrogeology track**

Students who attend the track Environmental Hydrogeology will study subsurface flow and transport processes. Apart from the compulsory courses Land Surface Hydrology and Principles of Groundwater Flow, they will take courses related to subsurface transport phenomena, environmental hydrogeology (comprising multi-phase flow and remediation techniques), reactive transport modelling, unsaturated zone hydrology, stochastic hydrology, and the relation between hydrology, climate changes and fluvial systems. Due to the highly interdisciplinary nature of the Environmental Hydrogeology track, a variety of courses can be taken from the curriculum of related disciplines like geochemistry,

**You are required to choose five of the following eight courses in the first year:**

### **Earth Surface Hydrology**

- GEO4-4404 Land surface hydrology
- GEO4-1434 Principles of groundwater flow
- GEO4-4417 Unsaturated zone hydrology
- GEO4-4420 Stochastic hydrology
- GEO4-4423 Hydrology, climate change and fluvial systems

### **Environmental Hydrogeology**

- GEO4-4404 Land surface hydrology
- GEO4-1434 Principles of groundwater flow
- GEO4-1433 Hydrogeological transport phenomena
- GEO4-1432 Environmental Hydrogeology
- GEO4-1421 Reactive transport in the hydrosphere\*

\* Not mandatory, but does count toward the 'five-out-of-eight' requirement for Hydrology, track Environmental Hydrogeology.



geophysics, geology, and mathematics. For each student, a tailor-made study programme will be designed, in line with the individual skills and interests of the student.

**Master’s thesis and traineeship**

Your Master’s thesis and traineeship will probably be the most important part of your studies and the key to your future career. During the project, you will gain specialist knowledge of a particular field of research within Hydro(geo)logy. Your research may comprise fieldwork, laboratory work and/or theoretical modelling. It is also possible to conduct (part of) the research at a university or research institute abroad. The traineeship can be spent in a variety of ways, in the Netherlands or abroad. Students may work at consultancy agencies, (national) research institutes, governmental agencies, water boards or at other universities.



**What can you expect?**

The academic year is divided into four semesters. You will take two courses per semester (7.5 ECTS). These two courses will account for approximately 16 lecture or contact hours a week. You will be also expected to spend around 24 hours a week on individual study or projects together with fellow students.

During this MSc programme you will frequently be asked to analyse recent scientific articles and write scientific essays. You will be assessed continuously during the courses, on basis of your preparation of essays, homework, presentations, input during workshop discussions and research plans. In addition, oral or written exams are part of the assessment procedure.

**Marc Bierkens, Professor Earth Surface Hydrology at the Faculty of Geosciences**



**‘Research is done in collaboration with geologists, physical geographers, biologists, environmental scientists and meteorologists’**

My research group focuses on the relationship between water and climate, water and ecology and water quality. These are the more fundamental research subjects. But I also work on applied research subjects like the development of a system that can help forecast the hydrological conditions in a certain area.

At Utrecht University hydrological research is done amidst the highest concentration of earth scientists in the Netherlands.

This enables the research to be done in collaboration with geologists, physical geographers, biologists, environmental scientists and meteorologists.

Besides the coaching of PhD-students and staff, I am involved in coaching and teaching students during their master’s thesis. Most students are very motivated and curious. Having students from all over the world makes for an international atmosphere.

In 1988, during my MSc-studies I left for California in the USA to do hydrological research for a year. During this year I really got addicted to doing research! After having worked for several research institutes and consultancy agencies, I was appointed professor in 2002.

# Examples of research projects

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## Interaction between hydrology and ecosystem dynamics

If natural terrestrial ecosystems are to be managed successfully, an understanding is needed of the interaction between vegetation patterns and environmental factors such as climate, soil and water. Therefore this project focuses on modelling the interaction between vegetation dynamics (growth rate, death and establishment of plant species) and the variation of groundwater levels and soil moisture content.



During fieldwork in the Bialowiecki National Park in Poland, near the Belarusian border, soil samples were collected and groundwater levels and soil moisture content were measured. The vegetation was also mapped. All these data were used as in a hydrology-vegetation model that analyses the importance of competition for limiting resources such as water, nutrients and light, as well as the effect of climate change on the ecosystem.

## Mixing of miscible fluids in porous media

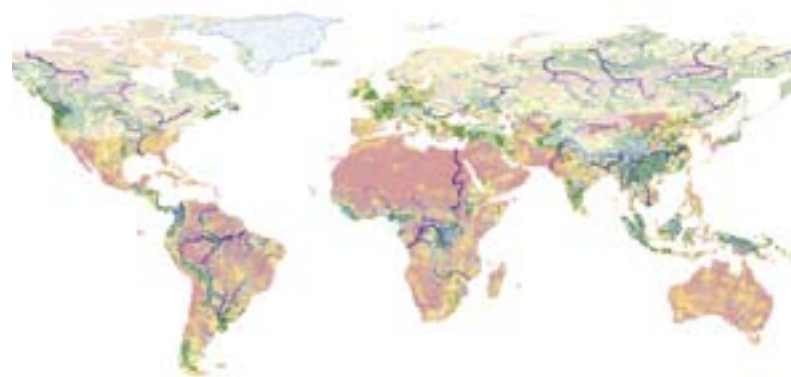
It is extremely important to have a good and fundamental understanding of mixing processes in groundwater. Mixing processes play a significant role in (bio)remediation techniques for contaminated soil and groundwater, in seawater



intrusion processes, and in the highly saline groundwater in the vicinity of subsurface salt domes. In particular, when the mixing fluids have a different specific weight, and moreover, if the geological formations are heterogeneous, interesting phenomena can be observed. These phenomena cannot be modelled using the standard classical theories for mixing fluids in porous media. To develop an adequate new theory to model these phenomena, experimental and theoretical research is being conducted by students of the environmental hydrogeology group, in close collaboration with scientists from Kazan State University in Russia.

## Understanding the global water cycle

When considering climate change, knowing the behaviour of water on land is of crucial importance. For instance, the moisture content of the soil determines whether a heat wave can persist. It also affects the growth of vegetation and thus the amount of CO<sub>2</sub> that is taken up by the land, which in turn has consequences for the greenhouse effect. If the runoff from the Siberian rivers into the Arctic sea changes, this could have an effect on ice-coverage and ocean circulation. To investigate the interactions between climate and the water cycle a computer model was built that can simulate the global water cycle. The model is also very useful for analysing how climate change and population growth could affect the amount of drinking water and water available for agriculture.



River discharge, snow pack and soil moisture on a global scale.

## Biodegradation of dissolved organic contaminants

PCE is a widespread and highly toxic organic contaminant, which belongs to the group of oil-like substances that have a higher density than groundwater. If there is a PCE spill at the ground surface, gravity causes it to penetrate the subsurface. The solubility of PCE in groundwater is very low. Nevertheless low concentrations of the toxic PCE compounds dissolved in groundwater present a serious environmental threat. One of the potential remediation techniques is biodegradation



under natural conditions. It is of particular interest to show that PCE can be biodegraded in the vicinity of the spill location, i.e. where pure, undissolved PCE is still present in the groundwater. Preliminary laboratory experiments have shown that this is indeed the case.

## Career prospects

Hydrology prepares you for a career in academic research, industry or at government organisations in the Netherlands or abroad. It is expected that the severity and complexity of water-related problems will only increase in the future, as the population continues to grow and floods and droughts occur in response to climate change. Furthermore, the water cycle is crucial to environmental pollution and ecology. To meet these challenges many hydrologists are needed now and will be in the future. Major employment sectors include the drinking water industry, river management, resource exploration and production, environmental monitoring and protection (large research institutes and consultancies), geotechnical engineering and waste management.

## Examples of companies and institutes

**Government organisations:** Water boards, Rijkswaterstaat (Dutch Directorate of Public Works and Water Management), VROM (Ministry of Housing, Spatial Planning and the Environment).

**Industry and consultancy:** TAUW, Groundwater Technology, Witteveen & Bos, IF-Technology, Royal Haskoning, Shell, NAM, TTE, DHV, and a variety of drinking water supply companies, like Oasen, WML, Vitens, and Evides.

**National research institutes:** TNO Built Environment and Geosciences, RIVM (National Institute for Public Health and the Environment), GeoDelft, KIWA Water Research, Delft Hydraulics.

Ruud Schotting, Professor Quantitative Water Management at the Faculty of Geosciences

‘Water is a beautiful substance; you can even build a carrier on it!’

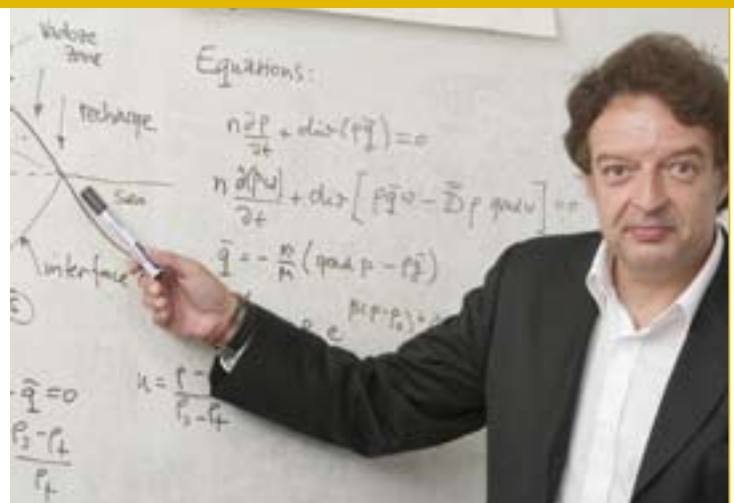
I studied applied physics, and my first, quite unexpected encounter with water was in the early eighties. At GeoDelft, I had to contribute to a project relating to the design of the storm-surge barrier in the Oosterschelde estuary. A few years later I started working on the type of water that is invisible most of the time, but nevertheless indispensable for society: groundwater.

When, in the late seventies, several cases of severe soil and groundwater pollution were discovered in the Netherlands, GeoDelft was motivated to start a new research department to study subsurface transport

processes. Again, this was an exciting time for me.

My academic career and scientific adventures in hydro(geo)logy basically didn't start until 1998, when I got a PhD degree in modelling fresh and salt groundwater. The

nice thing about hydro(geo)logy is that on the one-hand you are dealing with advanced and interesting science, while on the other, the subject is highly relevant to society. Worldwide, the demand for skilled



water professionals is growing rapidly. Water is a beautiful substance; you can even build a carrier on it!

**Type of Master:** Research  
**Language:** English  
**Duration:** 2 years (full-time only)  
**Start:** 1 September or 1 February (enrolment in September is recommended)  
**ECTS:** 120  
**Degree:** Master of Science  
**Registration name:** Earth Sciences  
**Registration code:** 66985  
(You will need to use this name and code when applying for this programme.)

## Entrance requirements

### University bachelors

Applicants should hold at least a BSc in a relevant subject (e.g. Earth Sciences, Natural Sciences, Physical Geography, Civil Engineering, Applied Mathematics) or a BSc from University College Utrecht.

### Dutch HBO bachelors

Applicants should have a sufficient background in physics and mathematics. Those holding the following degrees should meet this requirement:

- Aquatic Ecotechnology, Civil Engineering, Chemical Technology, Applied Physics, Coastal and Oceanic Studies, Land and Water Management, Environmental Technology, Environmental Sciences
- Other comparable programmes

You may be eligible for admission if you have a degree other than the ones mentioned above. Your application will be evaluated on an individual basis. You may be able to compensate any deficiencies in your previous education by taking one or more Bachelor's modules prior to, or at the start of, the Master's programme. Your English must be of academic standard. For more details on language requirements, visit: [www.uu.nl/internationalmasters](http://www.uu.nl/internationalmasters).

## Application and admission

See:

- [www.uu.nl/masters](http://www.uu.nl/masters) (Dutch students)
- [www.uu.nl/internationalmasters](http://www.uu.nl/internationalmasters) (foreign students)

You can also download the application forms and instructions from these sites.

## Tuition fees

The annual tuition fee for Dutch students and for students from other EEU (European Economic Area) countries is 1538 euros. For students of non-EEU countries, the tuition fee for this programme is 10,000 euros.

## Scholarships

Special scholarships are offered for outstanding students enrolled in the Master's Programme Hydrology:

- TNO scholarship
- Utrecht Excellence Scholarships
- System Earth Modelling scholarship

Check [www.uu.nl/internationalmasters](http://www.uu.nl/internationalmasters) >> Finance for more information about our scholarships. Visit [www.uu.nl/financial-assistance](http://www.uu.nl/financial-assistance) for more information on financial matters in general.

## Utrecht Feel at Home Service

To emphasise Utrecht's international orientation, the University offers the unique 'Utrecht Feel at Home Service', which guarantees accommodation for foreign students and offers support for visa applications and financial assistance, amongst many other things.

## Master's Programmes offered by the Utrecht Graduate School of Geosciences

**Earth Sciences:** Biogeology, Geochemistry, Geology, Geophysics, Hydrology, Physical Geography, System Earth Modelling (Prestige Master)

**Innovation and Environmental Sciences:** Science and Innovation Management, Sustainable Development

**Human Geography and Urban and Regional Planning:** Economische Geografie\*, Geografie en Communicatie\*, Geographical Information Management & Applications, International Development Studies, Human Geography and Planning, Planologie\*, Regionale Geografie\*, Urban Geography\*\*

\* offered in Dutch, \*\* offered in Dutch and English

## Further information

### Hydrology

Check out the programme's website at:

- [www.uu.nl/internationalmasters](http://www.uu.nl/internationalmasters) >> Master's programmes

If you have any additional questions after consulting our websites, please contact us at [mscinfo@geo.uu.nl](mailto:mscinfo@geo.uu.nl) or phone +31 (0) 30 253 51 16.

### Practical information on Utrecht University

- [www.uu.nl/masters](http://www.uu.nl/masters) or
- [www.uu.nl/internationalmasters](http://www.uu.nl/internationalmasters)

### Frequently asked questions

- [www.qdesk.uu.nl](http://www.qdesk.uu.nl) or
- [www.qdesk.uu.nl/english](http://www.qdesk.uu.nl/english)