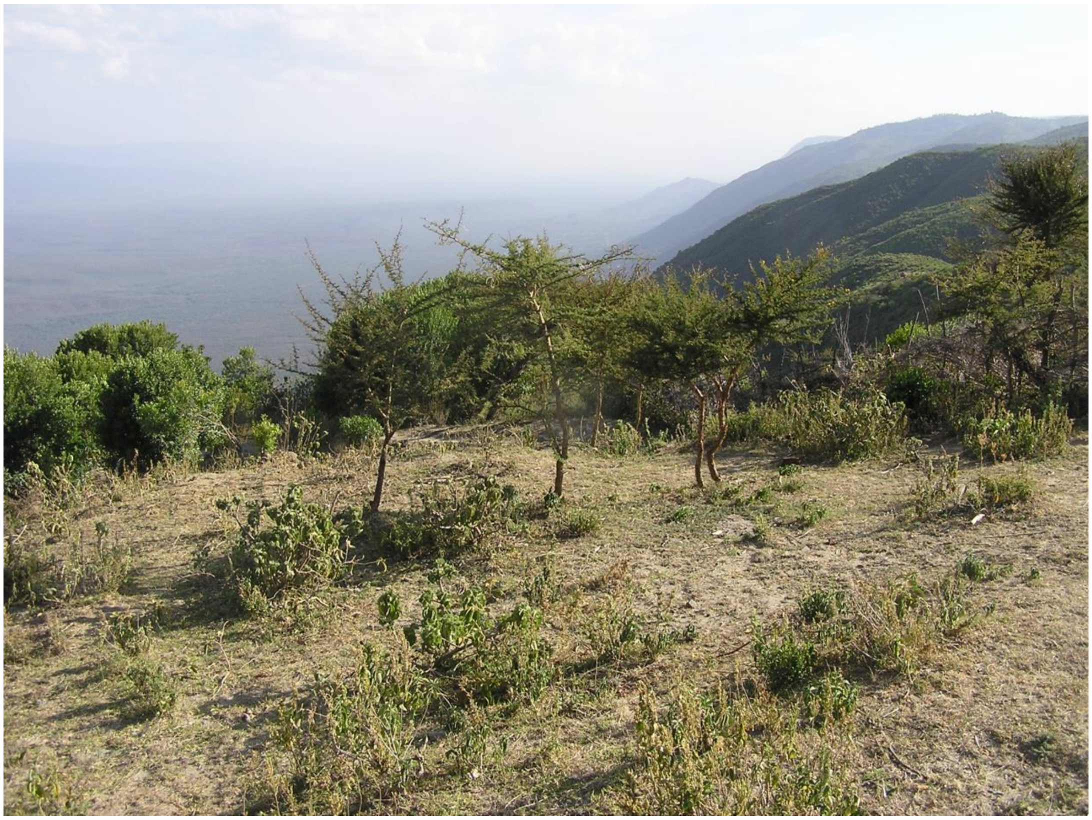
Expansion of Practical University Programs in Hydrogeology and Water Resources Management In Africa

A Case for Support



UniWater Education Limited

October 2017

Can you imagine a world where …..

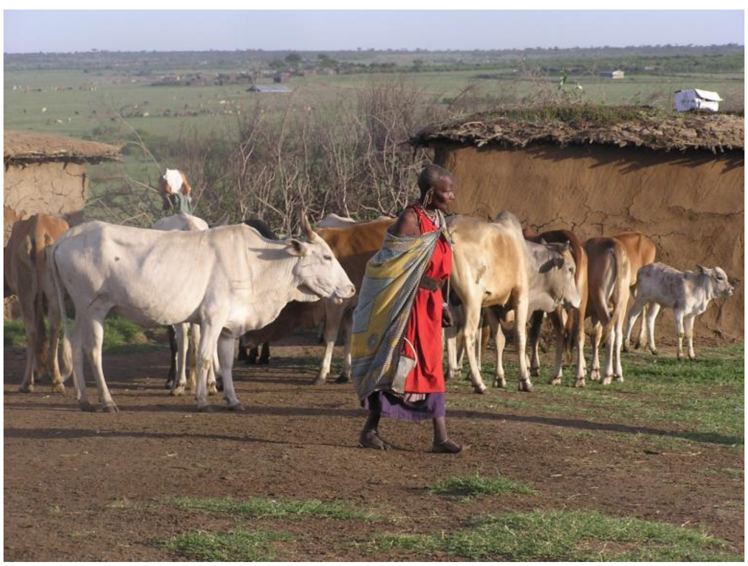
- *safe water is easily accessible for all people for domestic purposes*
- *industry uses fresh water responsibly and where the environment is not harmed*
- *the water sector is operated by professionals who have been educated in-country*
- *stewards of the environment are nationals*
- *reliance on foreign aid is minimized or eliminated, and*
- *children and women fill their days going to school or engaging in productive activities, rather than filling*
- *water jugs many kilometres from their homes?*

........we can

Introduction

Every day the media describes in detail how the World Water Crisis impacts millions of people and the environment as a whole. The western world is flush with NGOs who pull at our heartstrings by showing us the many children who will die today due to a lack of adequate drinking water, while asking for donations. Unfortunately, what isn't widely known is that people in developing nations suffer because of poorly installed water wells that go dry, or as a result of no maintenance being done on the water systems. This world doesn't need more NGOs, or more money. What it could use most is having people with technical expertise that ensures that

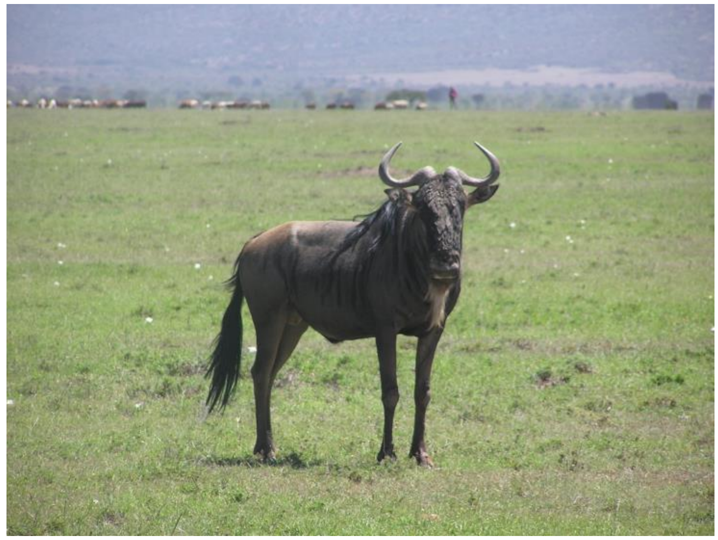
> ...wells are properly placed and designed to maximize the amount of water that can be extracted from the ground,
>
> ...aquifers are properly managed so they are able to continue to produce water into the future,
>
> ...water systems are adequately maintained so they operate for decades instead of months, and
>
> ...ecosystems are protected for the use and enjoyment of future generations.



Unfortunately, while North America enjoys the benefits of having more than 4,000 technical specialists and professionals per million people, these numbers drop to 35 per million people in sub-Sahara African nations (The African Capacity Building Foundation). This lack of specialists is seen as being a factor in stunting the economic growth of these countries now and far into the future.

Based on extrapolation of data presented in "An Avoidable Crisis – WASH Human Resource Capacity Gaps in 15 Developing Economies" (International Water Association, 2014), UniWater estimates there is a need for 60,000 water professionals now, if the Sustainable Development Goals are to be achieved by 2030.

The lack of local groundwater specialists plays a role in how aid programs are supported by foreign NGOs. The role of hydrogeologists (technical experts in groundwater systems) is largely underutilized by NGOs due to the perceived added costs that it involves (http://www.rwsn.ch/documentation/skatdocumentation.2011-12-21.2247027239/file). Unfortunately, when cost and short-term water supply are the sole determinants of the success of a project, the long-term sustainability of the resource may be compromised. Having more professionals available in country would ensure the security of aquifers and ecosystems are preserved, the quality of water projects would soar, and the suffering of many people would end.



Program Description

UniWater Education Limited (UniWater) is preparing an education program that is focused on applied hydrogeology, in particular Water Resources for Developing Nations. It is a one or two year, masters' level post-graduate program. An outline of the program is described in Attachment A. A similar program had been taught at the University of London (UCL) in England for more than 35 years. The unfortunate aspect of the UCL program though was that students needed to leave their home countries in order to study. Many of these students did not relish the idea of returning to the poverty of their home country after having a taste of western life. This is the innovative aspect of what UniWater is doing – we are taking the program to established sub-Sahara African universities in order to educate Africans in their home countries. As a result of not having to leave their families to gain their education, we expect graduates will remain there after graduating to help solve local water issues. Also, the cost of educating one candidate out-of-country can now be spent on educating many more people in-country instead.

Our goal is to get as many programs started as quickly as possible, to make the biggest impact.

The curriculum is modular in format, and consists of a core program in hydrogeology (approximately 60%), hydrology (approximately 10%) and water supply (approximately 30%). See Appendix A for a detailed program description. This core program is the basis of each UniWater program, which the host university is expected to customize according to local needs, environmental issues and experience of the existing faculty. The host university is allowed to pick and choose which aspects they wish to focus on, and as a result, each program will be individualized. In this manner, each host university will 'own' the program and will be the certificate-granting authority. As time progresses, more modules will be added to the UniWater program thus offering more flexibility for the host university to diversify from their competitor universities. The fact that the UniWater program contains aspects of both the science of groundwater and surface water flow, plus the social aspects related to water supply and distribution makes it unusual. However, the aspect that sets it apart from other hydrogeology programs that currently exist in Africa is its strength in the *practical application* of skills learned by students.

The pinnacle of this program is the field school. It is a two-week program that teaches students how to put theory into practise. Many programs existing in Africa today only teach the academic aspects related to this science, which is good for conducting research, but it does not prepare students for working in the water sector after graduating. As a result, many graduates are unable to get employment.

To qualify, a hosting university needs to have high quality math and science departments, and it needs demonstrate its desire to see this program initiated. So far, we have received responses from fourteen universities that wish to run this program, and another eighteen universities who are interested in partnering with them as mentors to ensure the longevity of the program.

In addition, we work with the host universities to bring industry professionals into the classroom, develop the idea of internships or workterms in industry, and to use real projects in the classroom for students to 'learn by doing' at the same time as offering technical expertise to the project.

The Current Situation

Currently we are working with five universities in Ethiopia (2), Kenya, Tanzania and Nigeria. Each are at various stages of gaining University Senate Committee approval to offer the program. However, Sokoine University of Agriculture (SUA) in Morogoro, Tanzania has been granted approval, but has not been able to start classes. Due to a lack of scholarships for the students. The university requires a minimum of 5 students to commence the program, each requiring USD 5,000/year for two years. Corporations in the area are more supportive of other water programs at neighbouring universities that are established, albeit theoretical and not practical.

Our solution is to support SUA, and indeed, all of our partnering universities, to develop the field school first and use it as a beacon for drawing students to the university.

It is expected that students enrolled in the field school would be accommodated together in a housing complex where they could work collaboratively and share experiences, developing relationships that would extend into their professions. Participating professionals would mix with students, sharing life experiences in the working world, and allowing possible employment opportunities to emerge.

If the field school is established before students are admitted into the MSc program, participants could be solicited from working professionals who lack field experience, or students who are attending a neighbouring university that lacks a field component in their program. In fact, the host university could set up an arrangement with their competitors to hold their field school for them, customized to their needs. In this way, many more people would be trained in the field methods that are missing today in university programs and working professionals. The field school could be operating for an extended period, and could be a source of income to the host university.

Anticipated Impact of MSc Program

After graduating, it is anticipated that graduates will be qualified to work in industry, government, consulting, community-based organizations, NGOs or research. Partnerships formed between the north-south universities will transfer learning between the learning institutes and would encourage the exchange of students and faculty into the future. Graduates involved in research would further enhance the scientific base of the host country to contribute to finding future solutions to the water crisis. The quality of water projects will improve, and rural water systems will be completed for less cost, and more projects will be completed. The quality of the infrastructure will improve and the sustainability of aquifers and surface water will increase. In time, reliance on foreign-based NGOs will diminish, and a culture of self reliance will ensue.

Anticipated Funding

Our proposed budget for the 2017/2018 calendar years, and annual expected budgets for successive years are provided in Appendix B. For 2017/2018, our total budget is $192,000.

At the present time, UniWater is looking for funding partners who would be able to assist us with getting the first field school operational at Sokoine University of Agriculture in Tanzania. **The cost for this is $50,000**. In exchange for provision of funds, funding partners will be showcased on program materials at the university, and will earn a prominent place on UniWater's website.

Closing

This program is aimed at assisting Africans to help themselves, to solve the challenges related to water supply, use and protection in the future in Africa. If you are interested in helping to facilitate this, please contact Laurra Olmsted at lolmsted@uniwaterd.org .

Appendix A

Proposed Master of Science Program in Hydrogeology and Water Resources Management

1. INTRODUCTION

1.1 Overview

Groundwater forms the most important source of water supply in the urban, peri-urban and rural areas of most sub-Sahara African (SSA) countries, thereby driving a country's socio-economic development. However, because it is below the earth surface and is not visible, groundwater flow and occurrence is poorly understood by most non-technical people. As a consequence, groundwater has not been developed to its full potential as a source of high quality water. In some locations, rapid expansion of urban areas has occurred resulting in an increased risk to groundwater quality in areas of recharge.. Climate change in the past several decades has resulted in unpredictable rainfall events which can affect groundwater recharge quality and quantity as well as control of surface water. This creates enormous challenges, and poses threats to groundwaterthat may negatively affect continued provision of adequate and safe potable water in the future. Therefore, UniWater Education Limited (UniWater) is developing a generic M.Sc./PGDip programme in Hydrogeology and Water Resources Management to provide advanced training of professionals in hydrogeology to promote the sustainable use of groundwater for today's water needs and to protect the resource for the future.

The proposed programme curriculum will include the following aspects of water resources:

- technical hydrogeology, hydrology and hydrochemistry;
- social community water supply;
- integrated water resources management (IWRM); and
- governance.

The intent is to encourage development of the program at numerous host universities in Sub-Saharan Africa to increase the number of training programmes offered in-country to African nationals. The programme will be applicable to both an MSc level degree which consists of course work plus a research project, or as a diploma which would be earned with only the course work component. It is expected that each host university will customize the programme to fit their format and requirements. The first programme is planned to commence in September 2014 at two to four host universities. Based on the response experienced by prospective host universities, it is anticipated that three new programs will be initiated each successive year after 2014 for at least 5 years. The initial programme will consist of only 'core courses', but as time allows, elective courses will be added as selected by the host university based on local issues and faculty expertise. The content of the core courses will also be updated periodically by UniWater with new technologies and developments. Any updates will be available to the host universities.

An important aspect of the UniWater program is the connection to a mentoring university. At this time, the University of Toronto Scarborough in Canada is the mentoring university for the pilot program. As the number of programs increases, partnerships with other mentoring universities will be formed as required. It is desired that eventually African universities will fill the role of mentors.

The students at the mentoring university will conduct an annual fundraiser to raise proceeds in support of scholarships at the host university.

1.2 Aims of the Programme

The programme emphasizes scientific facts, social and economic values and ethics that are essential in developing the sustainable use of groundwater. The program intends:

- To create and improve awareness of the occurrence of groundwater.
- To improve the level of understanding of the integration between surface water and groundwater to more effectively develop, utilize and manage the resource.
- To work with water supply agencies in improving access to safe drinking water for all people in the country, regardless of where they live and independent of their social-economic status.
- Encourage the employment of more technical specialists in the water sector.

1.3 Target Group

The program is targeted at persons interested or working in water and water-related agencies including river basin organizations and catchment management authorities, who manage both groundwater and surface water; water management authorities; water utility organisations; environmental and natural resources sectors; NGOs; and consultants working in the water sector.

1.4 Admission Criteria

Applicants shall be eligible for registration in the Master's degree in Hydrogeology and Water Resources Management if he/she has: A bachelor degree (with a minimum of second class or its equivalent) in Geology, Hydrogeology or Geography from a recognised institution or any other related field, e.g. Civil Engineering, Environmental Engineering, or Environmental Sciences (with 'A' level Mathematics/Geography). In cases, where the applicant does not have the above qualifications, the publication of a research article in a peer reviewed journal on any topic in this field, and/or relevant work experience exceeding five years, may be considered with letters of recommendation from his/her agencies.

1.5 Duration

The program could be offered on a full time basis for a maximum of two academic years, and will consist of the following:

- Course work in the first year (First academic year-8 months), and
- An independent research project (Second academic year- extends 8 to 12 months),
- Candidates who complete only the course work (First academic year) would be eligible for the award of a Postgraduate Diploma in water resources.

1.6 Mode of Delivery

Each course is structured on a modular basis where students take classes over two semesters. Each module is assigned credit hours. The mode of delivery will be through lectures, practicals, self study and independent research. The Research Project will be undertaken independently with individual supervision by a faculty member or any practising hydrogeologist with an MSc or more advanced degree.

1.7 Structure of the Programme

The structure of the core programme is as given below:

Semester	Course code	Course title	Credit unit
First	GLG 651	Groundwater and its Occurrence	3
	GLG 661	Borehole siting, drilling and completion	3
	GLG 671	Groundwater Flow in Aquifers	3
	GLG 681	Groundwater Chemistry and Pollution	3
Second	GLG 652	Integrated Water Resource Management	3
	GLG 662	Groundwater Modelling	3
	GLG 672	Research Methodology	3
	GLG 682	Field School	3
Third	GLG 600	Research Project	6

1.8 Financial Considerations

Funding to create the programme curriculum has been generously provided by Grand Challenges Canada, a program created by the Government of Canada to provide ***Bold Ideas with Big Impact***™ *in global health.*

The intent is to provide the program curriculum at no charge to approved host universities that meet the following requirements:

- Currently have an accredited undergraduate science-based program with higher-level mathematics;
- Currently have, or will have by the beginning of the program, sufficient staff to teach the curriculum, with at least one PhD level professor who specializes in Hydrogeology in a senior position on the faculty team.
- Have sufficient classroom and laboratory space for instruction purposes.
- Have access to computers for the computer modelling module, and books for reference purposes.

It is necessary for the host university to provide the staff, equipment and physical space to present this program. It will also be the responsibility of the prospective host university to fulfill all senate requirements to ensure this programme is accredited by the university.

While funding has not yet been secured beyond development of the curriculum, UniWater is confident that additional funding will be secured by partnerships with corporations or government programs to proliferate the initial program to successive host universities beyond 2014.

2. Module Details

2.1 GLG 651 - Groundwater and Its Occurrence

Rationale

The student will learn the concepts of geology and the occurrence of groundwater – specifics of hydrogeology and the language of hydrogeologists.

Learning Objectives

Upon Completion of the module participants will be able to….

1. Understand how/where water exists on earth and beneath the ground surface.
2. Demonstrate an understanding of the dynamics of surface water and groundwater flow
3. Become familiar with the language used by hydrogeologists and the tools used to communicate technical information.

Teaching Methods

Two one-hour lectures per week, plus one three-hour practical per week.

Topics and Learning Activities

A. Geological Environments

An introduction to igneous, sedimentary and metamorphic rocks, geologic structures; weathering processes, soil formation processes and constituents; aspects of soil mineralogy, physics and chemistry.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- identification of igneous, sedimentary and metamorphic rocks (1, 2, 3)
- Geology of Africa, Regional Geology of host country (4)
- Hydrogeologic/geologic map reading and development of cross sections (5)

Field trip

- Examination of regional aquifers in outcrops, if possible. Identification of springs

B. Water in Our World

The hydrologic cycle; the potential use of groundwater vs surface water; regional vs local flow (Toth model); geothermal springs; the water budget.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Examination of the use of groundwater globally (6)
- The water budget (7)
- Climate change impacts (8)

Field trip

- Basin-wide water balance
- Toth flow model
- Effects of climate change

C. Introduction to Hydrogeology

Aquifers and aquitards; nature of head; Darcy's law; porosity, hydraulic conductivity/permeability (field vs lab measurements); groundwater flow towards a well; isotropic and anisotropic aquifers; homogeneous and heterogeneous aquifers; estimation of hydraulic conductivity from particle size distribution; field tests for permeability (pumping tests); use and construction of flow nets.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Understanding of Darcy's law, velocity of groundwater flow (9)
- Field and lab hydraulic conductivity measurements, using slug tests, sieve analysis, permeameter tests (10)
- Flow to a well using analog models (electricity) (11)
- Flow to a well in a homogeneous and heterogeneous aquifer (tank test) (12)
- Flow net construction (13)

Lecturing Material

MOOC lectures from UNESCO-IHE

Texts

Handouts

Powerpoint presentations

Assessment

Assignments 30%

Field trip 10%

Written exam (closed book) – 60%

Hours Allocation

UniWater Education Groundwater and its Occurrence – GLG 651

Nr	Topic	Lecture	Practicals	Fieldtrip	Self study	Contact hrs	Load hrs	Lecturer
	Geological Environments	6	15	4	20	25	45	
	Water in Our World	8	9	4	20	21	41	
	Introduction to Hydrogeology	10	15		20	25	45	
	Total	24	39	8	60	71	131	

2.2 GLG 661 - Borehole Siting, Drilling and Completion

Rationale

Exploration for and development of an invisible commodity is difficult. Therefore, it is important that the development of drilling programmes is consistent with sustainable use of the resource. It is critical that boreholes are drilled in a manner to optimize the resource and that wells are installed properly to ensure maximum water supply. Borehole geophysics will also be taught to provide tools on strata interpretation and screen placement. Well development, maintenance and rehabilitation will provide tools for extending the life of a well.

Learning Objectives

Upon Completion of the module participants will be able to….

1. Assess and survey an area in need of a water well
2. Determine the appropriate drilling location, drilling method, collect available information for planning the drilling program.
3. Prepare an effective drilling contract, be knowledgeable of how to hire and supervise a drilling contractor.
4. Know what information to record and how to keep proper records of the drilling process and well completions.
5. Know how to construct a water well, maintain it, and rehabilitate an ineffective well.

Teaching Methods

Two one-hour lectures per week, plus one three-hour practical per week.

Topics and Learning Activities

A. Groundwater Exploration

The use of geological information and geophysics (remote sensing, airborne and surface methods) to delineate the best drilling locations.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Remote sensing, airborne geophysics (EM, LandSAT) (1)
- Electrical Resistivity (2)
- Seismic (3)
- Gravity (4)
- Magnetic (5)
- Tomography (6)

B. Borehole Drilling

Methods and optimum geologic environments for use of manual methods, low cost mechanized methods (cable tool) and high cost mechanized methods (rotary, auger, percussion).

Learning Activities

Formal lectures

C. Well Completions and Development

The purpose of each well component, selection of appropriate materials (casing, screen, gravel pack, grout/seal, apron). Use of piezometers/monitoring wells. Purpose of pack development, Rehabilitation methods (symptions, physical methods, acidification, shock chlorination).

Learning Activities

Formal lectures

Laboratory practicals (the number in parentheses refer to the practical number)

- Well design (7)

D. Borehole Geophysics

Use of caliper, temperature, conductivity, spontaneous potential, resistivity, natural gamma, neutron, CCTV

Learning Activities

Formal lectures

Laboratory practicals

- Geologic correlation using borehole geophysics and geology (8, 9)

E. Pumping Equipment

Selection of appropriate pumping equipment (size, material, water storage considerations, hand pumps, maintenance, electrical considerations).

Learning Activities

Formal lectures

Laboratory practicals (the number in parentheses refers to the practical number)

- Selection of pumping equipment (10)

Lecturing Material

Texts

Handouts

Powerpoint presentations

Assessment

Assignments 30%

Written exam (open and closed book) – 70%

Hours Allocation

UniWater Education Borehole Siting, Drilling and Completion – GLG 661

Nr	Topic	Lecture	Practicals	Fieldtrip	Self study	Contact hrs	Load hrs	Lecturer
	Groundwater Exploration	6	18		20	24	44	
	Borehole Drilling	3			5	3	8	
	Well Completions	2	3		10	5	15	
	Borehole Geophysics	8	6		15	14	29	
	Pumping Equipment	2	3		10	5	15	
	Total	21	30		60	51	111	

2.3 GLG 671 – Groundwater Flow in Aquifers

Rationale

This course intends to create an understanding of how water flows in the subsurface. The course teaches the principles of conducting a pumping test to assess the potential for water supply, as well as assess the ability of the well(s) to deliver the volume of water desired in a given time.

Learning Objectives

Upon Completion of the module participants will be able to….

1. Demonstrate an understanding of how water flows in the subsurface
2. Plan and execute a pumping test program, analyze the results for sustainable pumping of the aquifer, and present the information in 'layman's terms'.

Teaching Methods

Two one-hour lectures per week, plus one three-hour practical per week.

Topics and Learning Activities

A. Theory of Groundwater Flow in Confined, Leaky and Unconfined Aquifers

Radial flow to wells, definition of terms (porosity, T, Sx, S, Sy, leakage factor), Confined aquifers (Theim for steady state, Theis and Jacob for transient flow), Leaky aquifers (Walton for steady state, Hantush-Jacob for transient) and Unconfined (Thiem-Dupuit for steady state, Neuman for transient). Effects of boundaries. Step tests. Well fields. Slug tests.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Confined aquifers (Theim, Theis and Jacob) (1, 2)
- Leaky aquifers (Walton and Hantush-Jacob) (3, 4)
- Unconfined (Thiem-Dupuit and Neuman) (5, 6)
- Boundaries (7)
- Step Tests (8)

B. Practical Use of Pumping Tests

Planning, data collection, filtering and analysis of data, recommendations based on results.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Well field (9)
- Field trip planning (10)
- Field trip data analysis (11)
- Field trip results presentation (12)

Field trip

- Conduct a pumping test in real-time, analyze data and present results and recommendations to class/community/client (pump calibration, step test, 24 hr pumping test, 24 hr recovery)

Lecturing Material

Texts – Freeze and Cherrry (1979), Kruseman and deRidder (1991)

Handouts

Powerpoint presentations

Assessment

Assignments 45%

Field trip 25%

Written exam (closed book) – 30%

Hours Allocation

UniWater Education Groundwater Flow in Aquifers – GLG 671

Nr	Topic	Lecture	Practicals	Fieldtrip	Self study	Contact hrs	Load hrs	Lecturer
	Theory of GW Flow	18	24		24	42	66	
	Practical Use of Pumping Tests	6	12	36	0	30	54	
	Total	24	36	36	24	72	120	

GLG 681 – Groundwater Chemistry and Pollution

Rationale

Living in today's world means that there is the potential for groundwater contamination. By knowing these hazards, groundwater can be protected from degradation. However, it is important to also understand how chemical interaction of water flowing within rocks in the subsurface may concentrate some chemical parameters in the water. Such chemical variations in groundwater can be used as a tool for understanding its flow paths in the subsurface.

Learning Objectives

Upon Completion of the module participants will be able to….

1. Understand groundwater chemistry and what affects it, both naturally and anthropogenic sources.
2. Determine whether a source of water is potable, or suitable for agricultural purposes.
3. Be able to ascertain whether contaminated water is a result of natural processes or contamination.
4. Be aware of remedial measures that can be used to deal with contaminated groundwater.

Teaching Methods

Two one hour lectures per week and one three-hour practical per week.

Topics and Learning Activities

A. The Chemistry of Water

An introduction to hydrochemistry, how water is analyzed in a laboratory, the influences of sampling techniques, data presentation methods, natural processes that influence the chemistry in various locations, and the use of isotopes for groundwater dating and characterization.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Analyzing water samples using field methods, mass spectrometer, atomic absorption (1)
- Assessing data quality (2)
- Data presentation methods – manually (3)
- Data presentation using software (4)
- Regional data review (5)
- Isotopes (6)

B. Pollution

The impact of man on water quality, sources of pollution. Behaviour of organic and inorganic contamination. Sampling protocols for contaminant studies. Saline intrusion. Effects of Oil and Gas exploration/production, mining. The use and development of groundwater protection zones.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Saline intrusion (7)
- Oil and Gas exploration contaminant assessment (8)
- Oil and Gas operation contaminant assessment (9)
- Mining assessment (10)

Field trip

- Day trip to an oil and gas drill site to identify sources of impacts, then to a production facility to identify sources of contamination there.
- Day trip to a mining operation to identify sources of contamination or other impacts related to this industry that could ultimately impact water source and quality.

C. Groundwater Remediation Techniques

Attenuation Processes (sorption; filtration; microbiological degradation; dilution); Pump and Treat Methods (setting goals; system design; containment and capture techniques; pumping considerations; groundwater treatment methods); isolation of contaminant (capping, barrier walls, funnel and gate); Water treatment options for domestic supplies (point of use biosand filters, reverse osmosis, boiling, ceramic filters, chlorination, charred corn stalks).

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Remediation of organic compounds (11)
- Remediation of inorganic compounds (12)
- Treatment of domestic water supplies (13)

Lecturing Material

Texts

Handouts

Powerpoint presentations

Assessment

Assignments 30%

Field trip participation 10%

Written exam (closed book) – 60%

Hours Allocation

UniWater Education Groundwater Chemistry and Pollution – GLG 681

Nr	Topic	Lecture	Lab work	Fieldtrip	Self study	Contact hrs	Load hrs	Lecturer
	The Chemistry of Water	9	18		9	27	36	
	Pollution	9	12	16	9	37	46	
	GW Remediation Techniques	6	9		6	15	21	
	Total	24	39	16	24	79	103	

2.4 GLG 652 – Integrated Water Resource Management

Rationale

This course examines how groundwater and surface water need to be managed as one resource to ensure there is water for future generations. The effect of groundwater on manmade structures, and vice versa, will be examined in a bid to avoid detrimental interactions. Furthermore, getting community buy-in to a project is critical to long-term sustainability. Sources of water for domestic supply in addition to groundwater will be examined for their application to improving access to safe drinking water. Other social aspects related to the delivery of water in communities will be examined, including funding of water projects, working with NGOs and CBOs, the role of government, and capacity building in non-technical aspects (ie the nine aspects of the RWSN manual drilling capacity building project) that will raise the ability of the entire water sector to fill the needs now and in the future.

Learning Objectives

Upon Completion of the module participants will be able to….

1. Work with community groups and other stakeholders to work towards finding sustainable solutions to domestic or agricultural water supply problems.

2. Be able to present technical information in a format that everyone is able to understand.
3. Evaluate all sources of available water for use.
4. Be knowledgeable of all aspects that go into capacity building in the water sector.
5. Understand the role of government in protection of groundwater.

Teaching Methods

Two one hour lectures per week and one three-hour practical per week.

Topics and Learning Activities

A. The Role of Government

Collection, storage and retrieval of groundwater and hydrologic data. The use of computer models for resource management and presentation of information. Basin studies, 'safe' yield, monitoring and protection mechanisms. The use of CBOs for public engagement. Conflict management and economics aspects of water management will be addressed. Transboundary water resource management instruments. Enabling partnerships.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Database management (1)
- Basin analyses (2)

Field trip

- Tour of Ministry of Water

B. Integrated Use of Water

Rainwater harvesting, dew collection, storm-water collection, water reuse, artificial recharge, water storage and delivery.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Evaluation of various sources of water for a community (3)
- Solutions for Communities using water storage and distribution systems (4)

C. Climate Change Indicators

Examine trends over the last century/decade locally and identify indicators to monitor for future climate change impacts. Evaluate how groundwater is impacted, and how groundwater can be used to mitigate the impacts of climate change by managing its storage, recharge, changes in quality and demand.

Learning Activities

Formal lectures

Laboratory practicals

- Small group discussions to find solutions and monitoring options (5, 6).

D. Building Capacity in the Water Sector

Using the RWSN 9-stage programme for capacity building in the manual drilling sector, students will learn how capacity building is created.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Identify where manual drilling is appropriate (7)
- Setting up a manual drilling industry (8)
- On-going activity for manual drilling (9)

Lecturing Material

RWSN manual drilling programme.

Texts

Handouts

Powerpoint presentations

Assessment

Assignments 35%

Field trip 5%

Written exam (closed book) – 60%

Hours Allocation

UniWater Education Integrated Water Resource Management – GLG 652

Nr	Topic	Lecture	Practicals	Fieldtrip	Self study	Contact hrs	Load hrs	Lecturer
	The Role of Government	5	6	4	12	15	27	
	Integrated Use of Water	5	6		12	11	23	
	Climate Change Indicators	4	6		20	10	30	
	Building Capacity in the Water Sector	6	9		8	15	23	
	Total	20	27	4	52	51	103	

2.5 GLG 662 – Groundwater Modelling

Rationale

Mathematical models in groundwater flow and contaminant transport are increasingly used to provide answers to hydrogeologic questions that arise at hazardous waste sites. While mathematical procedures in some models may be highly complex, and must be understood by the modeller to produce a useful simulation, the goal of modelling implied in this course is to provide an approximation of a site specific situation. Therefore, a qualified professional with a background in hydrogeology and experience in groundwater modelling will be best suited to determine whether a simulation is reasonable, and to present recommendations based on a modelling study.

Learning Objectives

Upon Completion of the module participants will be able to….

1. Build a simple computer flow model and understand how each parameter affects the outcome of the results.
2. Understand how model calibration and sensitivity analyses impact the quality of the model.
3. Critically assess a model generated by someone else for usefulness in mimicking groundwater flow.

Teaching Methods

One hour lecture per week and two three-hour practicals per week.

Topics and Learning Activities

A. Introduction to Flow Models

Introduction to groundwater flow models, the types (finite difference and finite element) and descriptions (2 and 3-dimensions), purposes and process of building a model (conceptual model, grid development, calibration and sensitivity analyses, predictive uses); governing equations and numerical methods.

Learning Activities

Formal lectures

Laboratory practicals (the number in parentheses refers to the practical number)

- Examination of various flow models (1)

B. Building a Model

Conceptual model, grid design, assigning parameters, data needs and assignment, kriging, boundaries, sources and sinks, solute transport.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Building a flow model based on a real project (2 to 7)
- Presentation to the class (8 to 10))

Lecturing Material

Texts

Handouts

Powerpoint presentations

Assessment

Assignments 70%

Written exam (closed book) – 30%

Hours Allocation

UniWater Education Groundwater Modelling – GLG 662

Nr	Topic	Lecture	Practicals	Fieldtrip	Self study	Contact hrs	Load hrs	Lecturer
	Introduction Flow Models	3	3			6	6	
	Building a Model	9	57			66	66	
	Total	10	60			72	72	

2.6 GLG 672 – Research Methodology

Rationale

In order to conduct research that is justified and provides results that can be replicated or verified, research methods need to be consistent in technique.

Learning Objectives

Upon Completion of the module participants will be able to….

1. To formulate a problem and develop techniques for finding solutions to it.
2. Use literature to determine what research has been already done.
3. Develop a methodology for the research.
4. Present a research proposal.

Teaching Methods

One hour lecture per week and two three-hour practicals per week.

Topics and Learning Activities

A. Introduction to Research

The role of research in social, science and business. The steps taken to identify and formulate a research problem, development of questions, formulation of hypotheses, and literature review. Sampling techniques (theory, types, steps, error, sample size, advantages and limitations). Data for research (primary data, collection methods, schedule, pretest, pilot study, case studies, secondary data, limitations and cautions). Processing data (checking, editing, coding, transcriptions, tabulations, analyses).

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Development of a thesis project (1 to 5)

B. Scientific Report Writing and Presentations

The principles of presentation of data and interpretation of results, including formats, pagination, use of quotations, footnotes, abbreviations, tables and figures, referencing, documentations, appendices, indexing, presentations.

Learning Activities

Formal lectures

Laboratory practicals (the numbers in parentheses refer to the practical number)

- Evaluation of various examples (6, 7)
- Preparation of a thesis proposal (8)
- Presentation of the thesis proposal to the class (9, 10)

Lecturing Material

Texts

Handouts

Powerpoint presentations

Assessment
Assignments 70%
Written exam (closed book) – 30%

Hours Allocation

UniWater Education Research Methodology – GLG 672

Nr	Topic	Lecture	Practicals	Fieldtrip	Self study	Contact hrs	Load hrs	Lecturer
	Introduction to Research	5	30		15	25	50	
	Scientific Report Writing and Presentations	5	30		5	25	40	
	Total	10	60		20	50	90	

2.7 Field School

Rationale

Hands-on learning is often the most practical. This **two** week-long field school will attempt to transform academic lessons into a real-life context of how they are conducted.

Learning Objectives

Upon Completion of the module participants will be able to….
Conduct all field aspects of a professional hydrogeologist, including

- Surveying community needs and communicating effectively with the public
- Demonstrate an understanding of how geophysical surveys are conducted, and what the responses indicate.
- Survey physical locations of boreholes and other features.
- Supervise effectively drilling activities.

- Design and conduct aquifer pumping tests for assessing aquifer properties.
- Conduct contaminant assessments.
- Install and develop an effective borehole.

The communities selected will understand that they will benefit from working with the students on this project, but that it is a learning experience. The activities will be overseen by qualified people, and the drilling will be conducted by experienced drillers. Funding for these projects will need to be supplied by NGOs, such as UNICEF, or other interested parties.

Teaching Methods

10 days of hands-on instruction in a field setting, supplemented with classroom instruction as necessary.

Topics and Learning Activities

A. Community Needs Assessment (Day 1)

Working with a CBO to assess the needs of a community and develop an action plan and budget.

Learning Activities

- In groups of 3 to 4, work with CBO to assess current situation and work to develop possible solutions. Present findings to class and ask for feedback.

B. Geophysical Surveys (Days 2 and 3)

Plan and conduct geophysical surveys to assist in understanding the subsurface and selection of drilling location.

Learning Activities

- In groups of 4, decide which geophysical surveys to conduct, plan them out, conduct the surveys and analyze the results.
- Conduct spatial location surveys/GPS of local features.

C. Drilling (Days 4 and 5)

Review of drilling contract, supervision of drilling crew, logging of samples

Learning Activities

- In groups of 2 or 3, discuss existing contract, supervise all aspects of the drilling process, record progress and log samples. Decide when to stop drilling.

D. Well Installation and Development (Days 6 and 7)

Decide where and how to install the screen and gravel pack. Monitor installation, record notes. Develop gravel pack to remove fines.

Learning Activities

In groups of 2 or 3, supervise installation of screen and pack; development of well screen/pack, install seal and apron

E. Well testing (Days 8 and 9)

Conduct pumping tests to determine aquifer parameters.

Learning Activities

After allowing a well to recover to static levels, conduct pumping tests (pump calibration, step drawdown and constant rate tests) using any other neighbouring wells as observation wells, to determine the efficiency of the well, the safe pumping rate, depth of the pump, and the location of any boundaries. Determine whether the aquifer is unconfined, confined, or semi-confined. Use pumping test data as well as recovery data. Assess chemistry data for any changes during the test. Monitor barometric fluctuations, tidal influences (if applicable), and any uses of groundwater during the test.

F. Presentations (Day 10)

Compile all information and present it in 'layman's terms' to the people of the community.

Learning Activities

- Compilation of all technical information into a comprehensive technical report.
- Translate the results of the report into layman's terms, and prepare a presentation.
- Present the results to the class for feedback, make adjustments as necessary.
- Present the results to the community.

Assessment

Active participation in Field School 100%

Hours Allocation

UniWater Education Field School – GLG 682

Nr	Topic	Lecture	Practicals	Fieldtrip	Self study	Contact hrs	Load hrs	Lecturer
	Community Needs Assessment			8		8	8	
	Geophysical Surveys			16		16	16	
	Drilling			16		16	16	
	Well Installation and Development			16		16	16	
	Well Testing			16		16	16	
	Presentations			8	16	8	24	
	Total			80	16	80	96	

2.9 GLG 600 - Dissertation

Rationale

Working in the real world will have challenges that aren't taught in a classroom. This project will include aspects of analyzing what the issue is and how to determine a way to solve the problem.

Learning Objectives

For students to learn how to solve problems without the structured classroom activities.

Teaching Methods

Each student will have an advisor for assistance, but the work will be conducted independently.

Topics and Learning Activities

Project definition will be developed with the guidance of the advisor and will be approved before initial research is commenced. Wherever possible, real problems relating to increasing access to potable water supply will be encouraged.

Assessment

Continuous Assessment 50%
Final Examination 50%

3. Summary of Core Course Programme Hours

Course	Lecture Hrs	Practicals Hrs	Field Trips	Self Study	Contact Hrs	Load Hrs	Av Hr/wk Contact Hrs	Total Av Hr/wk
				Semester 1				
GLG 651	24	39	8	60	71	131		
GLG 661	21	30		60	51	11		
GLG 671	24	36	36	24	72	120		
GLG 681	24	39	16	24	79	103		
Total	**93**	**144**	**60**	**168**	**273**	**465**	**22.75**	**38.75**

Semester 2

GLG 652	20	27	4	52	51	103		
GLG 662	10	60			72	72		
GLG 672	10	60		20	50	90		
GLG 682			80	16	80	96		
Total	**40**	**147**	**84**	**88**	**253**	**361**	**25.3**	**36.1**

Note: Semester 1 consists of 12 weeks of classes, while Semester 2 consists of 10 weeks of classes for GLG 652, 662 and 672, followed by a 2 week field school (GLG 682). Exams can be scheduled at the end of Semester 1 (optional) and at the end of Semester 2, either before or after the field school (GLG 682).

4. Recommended Readings

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McClay, K. R. (1991). The Mapping of Geological Structures. Wiley

MacDonald, A., Davies, J., Calow, R. and Chilton, J. (2005) Developing Groundwater: A Guide for Rural Water Supply. Practical Action

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Ranjit Kumar (2005); Research Methodology: A Step-by-Step Guide for Beginners. Second edition, SAGE Publishers Ltd

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Rushton, KR (2003). Groundwater Hydrology, Conceptual and Computational Models. Wiley, 416 pp.

Schneider, S. (2011) Water Supply Well Guidelines for Use in Developing Countries. Second Edition.

Schnieders, J (2003) Chemical Cleaning, Disinfection & Decontamination of Water Wells, First Edition, Johnsons Screens Inc.

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Telford, W. M., Geldart, L. P., Sheriff, R. E. (1990). Applied Geophysics. Second Edition, Cambridge University Press.

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Willis Weight (2008). Hydrogeology Field Manual. Second Edition, McGraw-Hill Professional.

Younger, P. (2006) Groundwater in the Environment: An Introduction. First Edition Wiley-Blackwell

5. CLOSING

For further information please contact Laurra Olmsted, Executive Director, UniWater Education Limited at lolmsted@uniwatered.org

Attachment C
Collaborating Organizations

Current Partnerships
Sokoine University of Agriculture, Tanzania
University of Nairobi, Kenya
University of Calabar, Nigeria
Bahir Dar University, Ethiopia
Hawassa University, Institute of Technology, Ethiopia

Potential Future Hosting Universities
University of KwaZulu-Natal, South Africa
University of Development Studies, Ghana
North-West University, South Africa
University of Mines & Technology, Ghana
University of Dodoma, Tanzania
Kigali Institute of Science and Technology
University of Malawi
University of Zimbabwe
Ahmadu Bello University, Nigeria
Kwame Nkrumah University of Science and Technology

Mentoring Universities (with established programs)
University of Toronto, Scarborough Campus, Canada
University of Dar es Salaam, Tanzania
Ibn Tofail University, Morocco
University of Pretoria, South Africa
INRGREF Tunisia
University of Namibia
Cadi Ayyad University, Morocco
Hawassa University, Ethiopia
University of Khartoum, Sudan
University of the Free State, South Africa
University College London, UK
Kigali Institute of Science and Technology, Rwanda
Oregon State University, USA
University of Addis Ababa, Ethiopia

Mentoring Universities (with established programs), cont'd
Austin College University
University of Glamorgan, Wales
University of Strathclyde, Scotland
University of Witwatersrand, South Africa
Federal University of Technology, Nigeria
Université Cheikh Anta Diop, Senegal
Botswana International University of Science & Technology
Autonomous University of Mexico

Other Collaborating Organizations
United Nations University Institute for Water, Environment and Health
Groundwater Relief
Groundwater Solutions for Policy and Practice
Africa Groundwater Network
International Association of Hydrogeologists
Burdon Groundwater Network
Ministry of Water and Environment, Uganda
Mundell & Associates, USA
Hydrogeologists Without Borders
Groundwater Science, USA
O'Brien & Gere Consultants, USA
Sorensen Groundwater Consulting, USA
CAP-NET
Rural Water Supply Network
Centre for Affordable Water and Sanitation Technologies
National Groundwater Association
Global Water Partnership
GW-Mate
CHR Water Consultants (Namibia)
WaterCan

Past Funding Partners
Grand Challenges Canada – Stars in Global Health
Golder Associates Ltd

Appendix B
Budget

Budget Item	*Required Funds 2017/2018*	*Required Funds Annually (2019+)*
Field School Establishment Working with host universities to develop program, engage instructors, deliver training, set up contracts with equipment providers, advertise programs	$50,000 (first university)	$60,000 (3 universities per year)
Curricula Development Including lectures, updates, review	$50,000	$50,000
Program Promotion Including symposia presentations, meeting with African Ministers of Water/Environment, Funders, networking with potential host/mentoring universities	$50,000	$50,000
Resource Support to Host Universities Including shareholder meetings, field/laboratory equipment, books, computers as needed	$25,000	$100,000
Administrative (10%) Office expenses	$17,000	$26,000
Total	**$192,000**	**286,000**