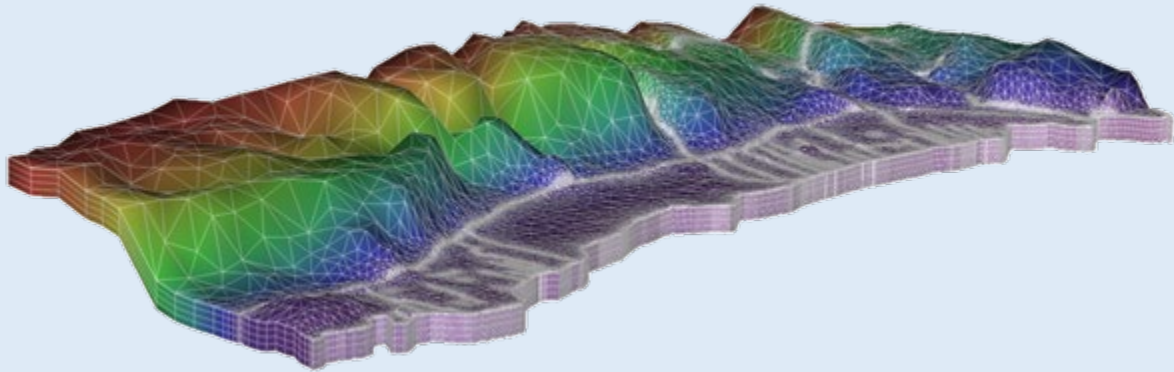


MSc Thesis ideas' catalogue 2026

Specialekatalog



Water Resources' MSc Thesis ideas contained in this catalogue

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1. Fluoride release and transport in alluvial aquifers in the arid regions of Kenya

Groundwater fluoride (F^-) concentrations exceeding the WHO recommended drinking water guideline of 1.5 mg/L are one of the major hazards to drinking water safety in Kenya. High groundwater F^- is associated with water-rock interactions, geothermal mixing, and shifting calcite and fluorite equilibria due to saline intrusion or evaporation-induced increase in salinity and pH. Climate change and unsustainable groundwater abstraction may further increase groundwater salinity and thus exacerbate F^- release from the sediments. Despite the complexity of the involved processes, and high spatial variability of groundwater F^- concentrations, partially controlled by salinity, the isolated effect of each of the F^- controlling processes have rarely been properly constrained in previous studies. The aim of this study is to explore and advance conceptual models of F^- cycling in aquifers in Turkana County, Kenya based on conceptual groundwater system models developed under the project REACH at the University of Nairobi.

Objectives:

- To conduct a literature review on F^- cycling in arid regions.
- To prepare maps of groundwater F^- and other relevant constituents in the study area.
- To conduct PhreeqC speciation calculations to derive mineral saturation indices.
- To integrate information from REACH project and national databases into a conceptual F^- cycling model.
- To set up a hydrogeochemical model of F^- release and transport in the alluvial aquifers of Turkana County, Kenya.

The activities are related to an ongoing project awarded by the Danida Fellowship Centre on behalf of the Ministry of Foreign Affairs of Denmark. The thesis will be co-supervised by the researchers at the University of Nairobi and Geological Survey of Denmark and Greenland (GEUS). The master student will have an office space at the Geochemistry Department, GEUS.

Contact persons: Søren Jessen (sj@ign.ku.dk), Daniel Olago (dolago@uonbi.ac.ke), Jolanta Kazmierczak (jka@geus.dk)

2. Eksperimentel test af CO₂ fangst i basalt

Lagring af CO₂ i formationer af frisk og porøs basalt har vist sig at være en effektiv måde at lagre flere tusinde ton CO₂/år i form af sekundær kalcit (e.g., Snæbjörnsdóttir et al., 2020). Lagringen foregår som et resultat af opløsning af basalt i kulsyre, og opløseligheden kan dermed bruges som indikator for lagringseffektivitet.

Dette speciale vil teste opløseligheden af tre typer basalt ved temperatur- og tryktilstande som kan forventes at findes i undergrunden relevante for potentiel CO₂ fangst i Grønland, Færøerne og Danmark. Resultaterne vil kombineres med en geokemisk model af systemet til bedst mulig evaluering af potentialet for CO₂ fangst i et komplet system. Specialet vil derfor inkludere laboratoriarbejde med anvendelse af et højtryk og -temperatur autoklave-system med mulighed for anvendelse af en bred vifte af klassiske geologiske instrumenter såsom XRD, SEM-AQM og ICP-OES.

Forsøgene vil udføres i et samarbejde mellem GEUS (Geokemisk afdeling samt afdeling for Kortlægning og Mineralske råstoffer), IGN og Ministeriet for mineralressourcer i Grønland (MMR), hvoraf laboratoriarbejdet vil fordeles over GEUS og IGN-faciliteter.

Contact persons: Knud Dideriksen (kdi@geus.dk), Nynke Keulen (ntk@geus.dk) eller Maja B. Rasmussen (mr@ign.ku.dk).

3. UAS and Satellite Hydrometry

KU-IGN is coordinating a large EU Horizon project on Uncrewed Airborne Systems (UAS) and Satellite Hydrometry (<https://uawos.dtu.dk/>). In this project we develop new contactless airborne monitoring technology to survey water surface elevation and water surface slope in rivers, riverbed geometry and river flow velocity/discharge. We combine airborne datasets with satellite EO data, specifically from the SWOT and ICESat-2 missions to parameterize, calibrate and validate river models in poorly instrumented and remote regions. Within the UAWOS framework, there are multiple opportunities for MSc thesis projects. Depending on the student's interest, projects can focus on airborne data acquisition and processing (potentially including field work in one of the UAWOS field sites, <https://uawos.dtu.dk/demonstration-cases>), river modelling in Mike+ or similar hydraulic modeling software, and inland water satellite earth observation using [SWOT](#) and [ICESat-2](#) datasets.



UAWOS water penetrating radar drone payload

Objectives:

- Estimating river discharge from contactless airborne datasets of water surface elevation, riverbed geometry and surface water velocity
- Hydraulic modeling of rivers using airborne and satellite hydrometric datasets
- Developing rating curves for poorly monitored and remote river reaches
- Improving flood risk assessment models and flood forecasting systems with airborne and satellite EO inland water datasets

Contact persons: Peter Bauer-Gottwein (pbg@ign.ku.dk), Zhen Zhou (zhezh@dtu.dk).

4. Hydrogeologisk model for Storkøbenhavn

Geo har en meget detaljeret geologisk model (hydrostratigrafiske model) for Storkøbenhavn i 25×25 meter grid, som løbende bliver opdateret efterhånden som ny viden kommer til fra f.eks. anlægsprojekter og vandressourceopgaver. Der er både en 'voxel'-model og en 'lag'-model. Modellen kan ses i GeoAtlasLive og den geologiske modellering foregår løbende i GeoScene3D.

Hovedformålet med projektet er at udbygge den hydrostratigrafiske model til en hydrogeologisk model via en række delopgaver og derefter anvende modellen til en konkret opgave. Fokus kan enten være på det primære magasin (kalk) eller på terrænnært grundvand.

Det aftales nærmere hvilke(n) delopgave(r), som der skal lægges mest vægt på, baseret på den studerendes ønsker. Der er også muligt at selv være med til at samle data ind i felten.

Formål:

- Dataindsamling fra forskellige kilder og kvaliteter
- Evt. Logstratigrafiske analyse
- Evt. Geostatistik analyse
- Evt. Geologisk modellering GeoScene3D
- Numerisk modellering i MIKE SHE, FEFLOW eller MODFLOW

Contact persons: Flemming D. Christensen (Geo, fdc@geo.dk) og Søren Jessen (sj@ign.ku.dk)

5. Borehole condition assessment (two separate topics possible)

Geophysical methods and level-determined sampling in fully screened groundwater wells

The condition of a borehole is paramount with respect to the yield of an abstraction well, mixture of natural water chemistry and risk of contamination.

5.1 Geophysical logs of abstraction wells for water works

Geophysical methods can check on newly drilled boreholes ensure that the design and specification criteria have been met as required. The methods can also check the quality of existing boreholes and the sealing between the casing and the formation. If the sealing is deficient, there is a risk for a contamination of the aquifers due to flow along the outside of the casing through the different geological layers.

The task is to further develop and optimize the use of geophysical logs for quality check of boreholes and based on logs create a geological interpretation to localize flowpaths.

Geo utilises a combination of down-hole video cameras and various geophysical techniques to provide a cost effective solution to borehole evaluation. In this project, you get to experience geophysical logging with Geo, and you get in-depth knowledge of the different logs used, while you help develop and test new logging products.

5.2 Method for water level sampling in abstraction wells for water works

Sampling water from several depth specific intervals along a groundwater well screen enable owners to reconstruct wells, e.g., to avoid water from polluted strata to enter the well. In this project, you'll learn the aspects of depth specific sampling. You'll apply and compare the method termed the Dual Pumping Technique (DPT) for level determined sampling in open groundwater wells with the Separation Pumping Technique (SPT) and multilevel well (MLW) well sampling techniques, or other techniques:

- Dual Pumping Technique (DPT)
- Heat Pulse -Separation Pumping Technique (SPT)
- Discreet Packer Pump Sampling
- Low-Flow (Minimal Drawdown) Sampling.
- Other types of water level sampling in abstraction wells

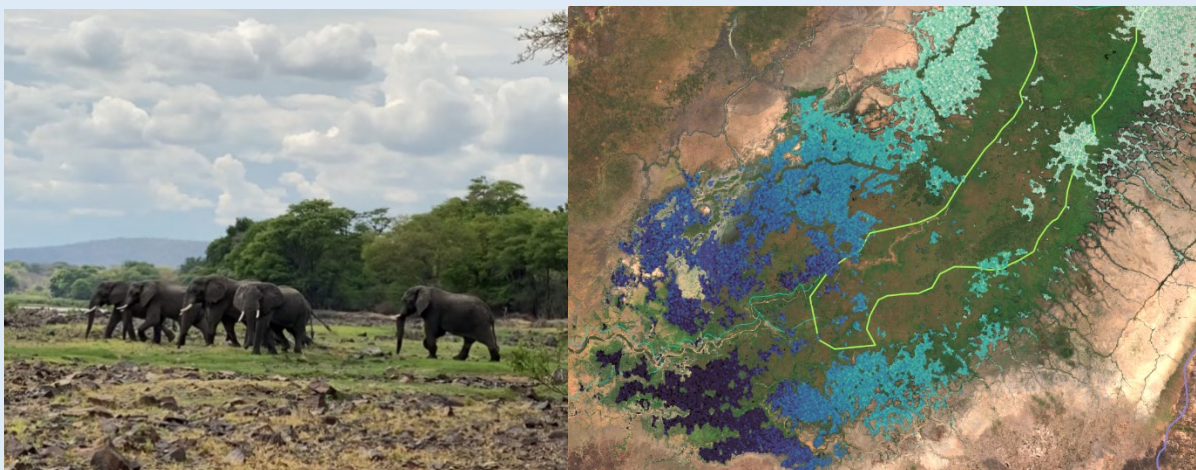
Objectives:

- Field work and compare different methods for depth specific sampling.
- Use flow log results to compute pollutant concentrations of water entering different depth intervals.
- Compare computed results to observations and, if possible, derive uncertainty.
- Possibility for geostatistical analysis.
- Possibility for modelling with e.g. MIKE SHE, FEFLOW, MODFLOW, PHAST or other models.
- Possibility of constructing radial model for efficient geochemical modelling of water quality in production wells.

Contact persons: Jesper Lind (Geo, jel@geo.dk) og Søren Jessen (sj@ign.ku.dk)

6. Integrated hydrological modelling and monitoring of the Usangu Wetlands, Tanzania

KU-IGN hosts the Global Wetland Center project (<https://globalwetlandcenter.ku.dk/>). This project aims to develop new observation and modeling technology to simulate and quantitatively estimate wetland greenhouse gas emissions and understand wetlands' greenhouse gas budgets from local to global scale. One of the field sites of the project are the [Usangu Wetlands](#) in Tanzania. For this wetland, we are developing an integrated hydrological model in Mike SHE, simulating inflow, outflow, evapotranspiration, flooding and subsurface flow processes. We aim to couple the integrated hydrological model with a vegetation and biogeochemical process model to estimate the greenhouse gas emissions from the wetland and explore their dependence on key hydrological variables such as depth to water table. Due to limited availability of on ground measurements, satellite remote sensing data will be used for model calibration and as inputs into machine learning methods.



Left: Herd of elephants roaming in Usangu Wetlands. Right: Surface water from the SWOT pixel cloud product over the western Usangu wetlands. The green line indicates the boundaries for the Ihefu swamp at the center of the wetlands.

Objectives:

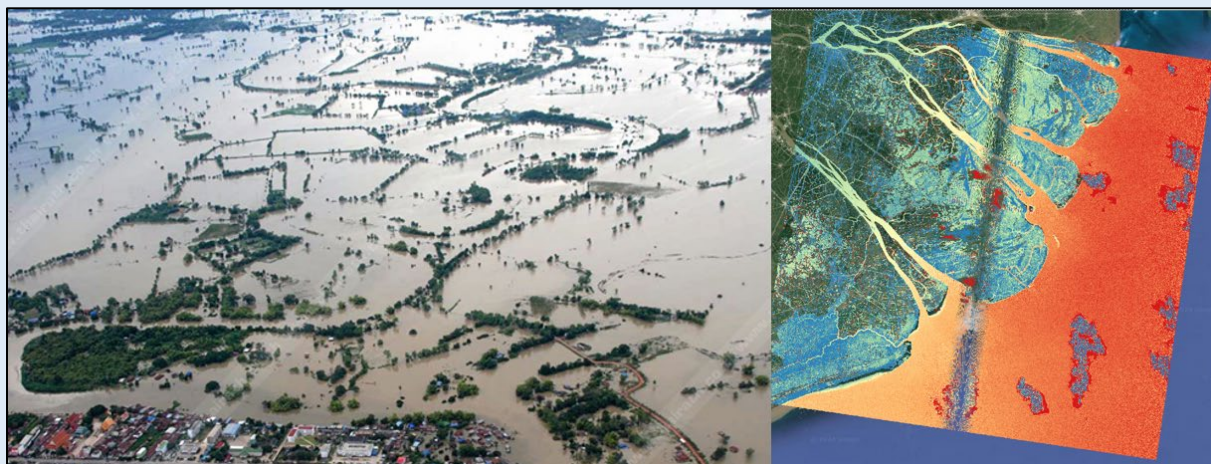
- Set up, parameterize and calibrate an integrated hydrological model of the Usangu Wetlands, using all available in-situ observations as well as satellite earth observations from multiple missions, including [SWOT](#) and [ICESat-2](#).

- Develop and implement a model for wetland greenhouse gas emissions as dependent on key variables simulated by the integrated hydrological model, using Mike Ecolab or similar generic modeling software.
- Develop data-driven surrogate modeling approaches for efficient and global-scale assessment of wetland greenhouse gas balances, based on satellite earth observation and insights from detailed integrated hydrological modeling.

Contact persons: Sarah Franze (safr@dhigroup.com), Peter Bauer-Gottwein (pbg@ign.ku.dk).

7. Modelling and monitoring of compound flooding in deltas and estuaries using satellite earth observation

Recent satellite earth observation missions such as [SWOT](#) and [ICESat-2](#) datasets provide continuous water surface elevation datasets across the river-coast-ocean interface in estuaries and river deltas for the first time. Such datasets are extremely valuable for the calibration and validation of integrated hydrodynamic models used to simulate compound flooding events, when flooding is caused by a combination of high river flows, storm surges in the ocean and extreme local precipitation. Low lying deltas, such as the Mekong River delta, are particularly exposed to compound flooding events, events that are expected to be more frequent and harmful with future climate change and sea level rise. At KU-IGN, we explore and exploit the value of these datasets using the Mekong River delta in Vietnam as a case study. This work is funded by an industrial postdoc project carried out in collaboration with DHL.



Left: Flooding over the Mekong Delta on 2011 (source <https://floodlist.com/asia>). Right: SWOT water surface elevation and extent raster product.

Objectives:

- Develop an integrated river-coastal hydrodynamic model in Mike Flood
- Compare model outputs to spatio-temporally distributed water surface elevation datasets from SWOT and ICESat-2
- Calibrate and adjust the model to improve the match between simulated and observed water surface elevation in the inland water and coastal domains
- Use the model to simulate the impact of compound flooding events
- Simulate how future climate change scenarios and sea level rise will affect compound flooding events
- Explore strategies and modeling workflows for efficient transfer to other sites

Contact persons: Monica Coppo Frías (mcf@ign.ku.dk), Peter Bauer-Gottwein (pbg@ign.ku.dk).

8. Terrænnært grundvand og sætnings-risici

Den nye lovgivning fra 1. juli 2025 pålægger kommuner at udlægge indsatsområder i spildevandsplaner fra 1. juli 2027. Landets Forsyninger er forpligtet til at etablere afværgeforanstaltninger – dvs. grundvandssænkende foranstaltninger. Sænkning af et grundvandsspejl kan, under de rettet geologiske betingelser, medføre at terrænet synker, dvs. sætter sig, hvilket er af stor betydning for byggerier og eksisterende bygninger. Et væsentligt element i prioriteringen bliver de samfundsøkonomiske aspekter.

Hovedformålet med dette projekt er at udvikle en model for vurdering af potentielle geotekniske sætnings-risici baseret på eksisterende data. Her skal bl.a. Geos landsdækkende database for boredata, øvre vandspejl og sætningsgivende øvre jordlag inddrages. Endvidere skal jordartskort, bygningsmasse og InSAR-vertikal-bevægelser og evt. andre tilgængelige data inddrages i modellen.

Det aftales nærmere hvilke(n) delopgave(r), som der skal lægges mest vægt på baseret på den studerendes ønsker. Der er også muligt at selv være med til at samle data ind i felten i et testområde, såfremt der er et passende projekt i perioden.

Objektives/Formål:

- Dataindsamling og sammenstilling fra forskellig kilder
- Udvikling af model
- Afprøvning i testområde med en forsyning/Kommune
- Evt. Machine Learning

Contact persons: Nina Søager (Geo, nis@geo.dk) og Søren Jessen (sj@ign.ku.dk)

9. Can we use water isotopes to derive groundwater age?

Objectives:

- Analyse the literature for similar studies.
- Extend the national precipitation network to obtain the first impression of the national variation in the isotope composition of the precipitation.
- Extend the coupling between isotope data and data from the GRUMO wells.
- Extract probable groundwater ages from the DK-model.
- Evaluate the potential of using water isotopes for age estimates of groundwater in a warming (or cooling) world.

Groundwater is derived from rainwater. The isotope signal (the ratio between heavy and light water molecules) of rainwater is a function of the temperature in the cloud where the rain is formed. Global warming leads to an increase in the temperature, implying that the increasing temperature will lead to a change in isotope signal in the groundwater. This means that we may be able to use the water isotope signal of the groundwater to estimate when the infiltration of the water now pumped from a well took place. The isotope signal was measured for all of the GRUMO wells during 2022-25 (GRUMO is the national groundwater monitoring program). For some of these wells the year of infiltration has been determined using $3\text{H}/3\text{He}$, giving a possibility of making a direct comparison!

In other places a more qualitative comparison can be made based on the depth of the groundwater, possibly supported by data from the “DK-model” of the Danish hydrological system or perhaps other models made in relation to the groundwater resource management of the water works. A nationwide monitoring of the precipitation has slowly started, this should give us an idea of the national variation. At the moment the GRUMO samples from 2022-25 have been measured – but the 2025 data still need

to be combined with 2022-24 data to enable associating the isotope data with existing data of especially the measured groundwater age and the ages extracted from the “DK-model”. In addition there is a partial dataset of GRUMO wells from some years ago (Sascha Müller).

Contact persons: Søren Jessen (sj@ign.ku.dk) and Rasmus Jakobsen (GEUS, raj@geus.dk).

10. Global river hydrologic and hydraulic modelling using satellite earth observation

From recent satellite earth observation missions such as [SWOT](#) and [ICESat-2](#), we now get water surface elevation at ca 10m spatial resolution for any larger river of the world (wider than ca 20m) and at relatively high temporal resolution (5-15 acquisitions per month, depending on where we are on the planet). Moreover, from ICESat-2 or local LiDAR DEMs we can extract the unsubmerged cross section shapes for all rivers. What we still miss for a complete hydraulic characterization of world rivers are (a) submerged cross section shape, (b) hydraulic roughness, (c) runoff, (d) information on river and reservoir regulation. In many parts of the world, it is reasonable to assume that hydraulic roughness and cross section shape are stable in time. For 1D hydraulic/hydrodynamic models, one can lump them into a conveyance curve (as explained in <https://doi.org/10.5194/hess-25-6359-2021>) and parameterize the curve in terms of a zero-conveyance elevation and one or two shape parameters. This work is funded by an industrial PhD project carried out in collaboration with DHI.



Left: Satellite tracks at low flow (yellow) and full flow (green) conditions. The high flow can be seen in the top of the river bend, with a satellite image from a different day. Right: Estimated river channels from the low flow (top) and full flow (bottom) satellite pass.

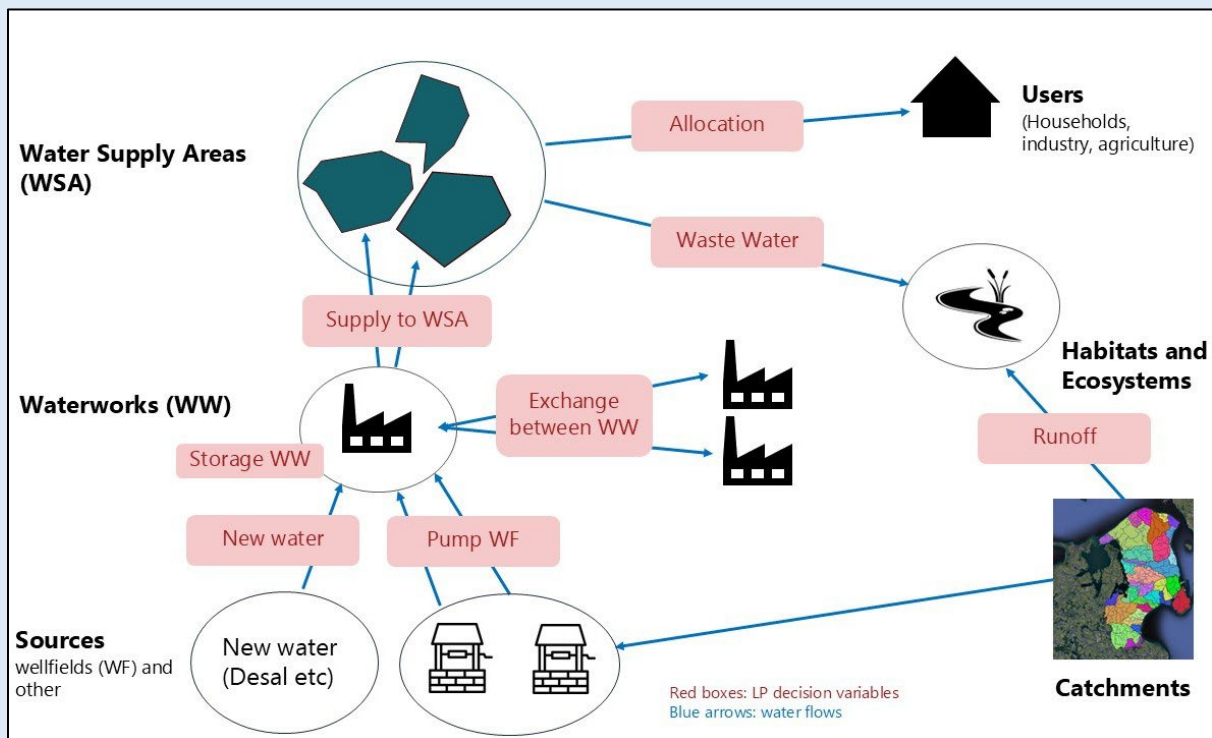
Objectives:

- Develop, test, and apply workflows for automatic extraction of river cross section geometry from ICESat-2 and local LiDAR DEM datasets.
- Develop, test and apply workflows for extraction of WSE datasets from SWOT for any river and for comparison of SWOT data with river modeling results.
- Develop an inverse modeling framework to jointly estimate rainfall-runoff model parameters and conveyance curve parameters along the river.
- Apply developed workflows and modeling concepts to selected world rivers

Contact persons: Aske Folkmann Musaeus (afm@ign.ku.dk) and Peter Bauer-Gottwein (pbg@ign.ku.dk).

11. Water Supply Security in Denmark to 2050

The 2022 agreement on green hydrogen will increase water demand in DK by ca. 5% in 2030. Water demand in other sectors will grow too (industrial expansion, population growth in cities, irrigation demands). At the same time, groundwater resources are already regionally overused, future groundwater availability is uncertain, and wellfields are vulnerable to pollution. There is a need to quantitatively analyze supply-side and demand-side solutions and to develop a holistic framework to evaluate portfolios of investments and policy changes that can ensure water supply security in Denmark to 2050. This project will develop a new integrated water supply and use decision support framework, combining the National Hydrological Model, models of the water supply infrastructure, and models of water users. The framework will be used by the water utilities and the municipalities to plan and quantitatively analyze the performance, reliability and robustness of various demand-side and supply-side investments and policy changes to determine optimal and climate-robust policy portfolios that will ensure Denmark's water supply security to 2050.



Conceptual model of the groundwater and water supply management problem

Objectives:

- Develop industrial, domestic and agricultural water demand scenarios to 2050
- Develop spatio-temporally explicit supply models (quantity-cost) for new water sources (desalination, reclaimed wastewater, treated groundwater).
- Develop coupled optimization modeling framework linking GEUS' national hydrological model, models of non-groundwater sources, models of the water supply infrastructure (wellfields-waterworks-water supply areas), and water use models.
- Evaluated and benchmarked present value, reliability, robustness, and other relevant performance criteria for multiple portfolios of infrastructure investment and policies that ensure secure water supply to 2050.

Contact persons: Peter Bauer-Gottwein (pbg@ign.ku.dk).

12. Tracing intrusion and freshening from groundwater chemistry patterns in coastal aquifers

The process of cation exchange in coastal aquifers gives rise to characteristic hydrochemical 'signatures' of the groundwater that reveal the direction of groundwater movement. For example, intrusion of Na-Cl seawater into a fresh aquifer with a Ca-HCO₃ type groundwater results in a Ca-Cl₂ water type. And during freshening, the flushing of a saline aquifer by fresh Ca-HCO₃ water forms a Na-HCO₃ water type. These effects are typically visible when data are plotted in Piper diagrams and Stiff diagrams, which are commonly used by the industry in hydrological investigations. However, the cation exchange processes are non-linear and the salt-freshwater interface may move forth and back. The net result is, that the hydrochemical 'signatures' may become blurred or masked. The aim of the proposed project is to unmask these patterns, via reactive transport modeling of cation exchange during repeated (modelled) intrusion and freshening. The results of conceptual model cases will be compared to hydrochemical data from the SaltCoast projects activities at Rømø and Brede Stream estuary/delta in south-western Denmark.

Objectives:

- Collect estuary/delta sediment and depth-matched water samples.
- Measure in the laboratory the amounts of exchangeable cations, and the cation exchange coefficients to be used in the modelling.
- Setup a 1D model to derive the hydrochemical 'signatures' arising from single and repeated events of intrusion and freshening.
- Develop an automated plotting scheme of the 1D-model result into e.g. Piper diagrams in Python.
- Conceptualize the findings in order to broaden the applicability thereof by industry users.

Contact person: Søren Jessen (sj@ign.ku.dk)

13. Iron oxidation kinetics at the iron oxide surface

Iron oxidation is immensely important geological and geochemical process that has been studied widely. Yet, there is still rooms for more studies. This laboratory and PHREEQC modelling study will determine the kinetics of the oxidation of ferrous iron in the presence of the surface of different iron oxide:

Objectives:

- Review the literature – part of it; there are tons of literature on iron oxides.
- Make and freeze-dry a suite of different iron oxides in the laboratory (e.g. goethite, hematite and ferrihydrite).
- Measure the specific surface area of the iron oxides and determine their type using XRD. Perhaps do some SEM imaging.
- Make oxygenated suspensions of each iron oxide and add an initial concentration of ferrous iron. Monitor the Fe(II) concentrations using ferrozine. Filter out and dry the product.
- Measure the specific surface area of the product and do XRD analysis to document if mineral phase changes have occurred.
- Set up a PHREEQC model to simulate iron oxidation kinetics. Do the rates per m² of iron oxide surface depend on the type of iron oxide? If so, the iron oxidation is intimately linked to the chemistry at the surface.
- Conceptualize the findings in an scientific article-like document.

Contact person: Søren Jessen (sj@ign.ku.dk)

14. Collaboration with the consulting companies Niras, Rambøll, Geo, COWI, DHI, or others.

Consulting companies are often left with ideas for further investigations when their consulting projects end, which often occur when the funding is used. Interesting MSc projects can be formulated on this basis and the companies are often very interested in pursuing and providing support to these projects.

The project ideas vary all the time and therefore one of us can make contact to companies and arrange meetings to discuss options.

Contact persons: Majken Zibar (mcl@ign.ku.dk), Peter Bauer-Gottwein (pbg@ign.ku.dk), Karsten Høgh Jensen (khj@ign.ku.dk) and Søren Jessen (sj@ign.ku.dk).

15. Exploring the effects of extreme climate events on deep groundwater reservoirs through hydrological modelling

With a changing climate, more frequent weather extremes, such as heavy rainfall, flooding, and droughts are to be expected. Denmark experienced a severe drought in the summer of 2018, while the winter of 2023/2024 had record breaking amounts of precipitation. During the recent years, Greater Copenhagen Utility (HOFOR) has observed decreasing groundwater levels in some of the catchments where groundwater is abstracted. Consequently, there is a need to investigate the effects of extreme climate events and changes in rainfall patterns on the deep groundwater resources. The aim is to enhance our understanding and knowledge of what the potential impact of the dry summer of 2018 and wet winter of 2023 on the deep groundwater reservoir is. The project furthermore aims to provide an understanding of whether the wet winter of 2023 can compensate for the dry summer of 2018.

The project will be based on an existing MIKE SHE model to simulate various model scenarios for some of HOFORs catchment areas by using available climate data, hydrological data, and groundwater level data. The MSc thesis will be executed in collaboration with HOFOR and consist of the following:

Objectives

- Setup of a hydrological model in MIKE SHE.
- Validation of the model using a comprehensive time series dataset of groundwater levels and river discharge.
- Selection and assessment of which extreme climate scenarios to simulate.
- Scenario simulation of extreme weather conditions.
- Analysis of how climatic parameters affect the deep limestone groundwater reservoir.
- Optionally, geological fault lines and their impact on groundwater resources may be analyzed.

Contact persons: Karsten Høgh Jensen (khi@ign.ku.dk), Kristian Bitsch (HOFOR, krbi@hofor.dk) and Lena Ali (HOFOR, lenali@hofor.dk)

16. Hydrological modelling of nutrient-poor peatlands: Bøllemosen

The Bøllemosen bog, located 16 km north of Copenhagen, is encircled by forest and therefore generally nutrient poor. However, there are recent indications of deterioration of its ecological state which call for restorative actions. The bog has been previously biologically characterized, and, regarding nutrient loading, it is clear that the bog receives some nutrients by atmospheric deposition. However, little remains known about the hydrology and hydrogeochemistry of the bog, which may largely control the

ecological state of the habitat. Therefore, in the proposed project, the influence of nutrient input from hydrological pathways will be addressed, in an assessment of the hydrogeology of Bøllemosen. Bøllemosen bog is one of 261 protected EU habitats in Denmark. Danish authorities therefore are responsible for securing or improving its ecological state.

Objectives

- Conduct a literature search to find existing (historical) hydrogeological data regarding Bøllemosen.
- Monitor a network of piezometers (existing + possibly new) and a rain gauge with respect to hydraulic head and water chemistry and stable isotopes of water.
- Conduct geophysical investigations in conjuncture with hand drillings and borehole information from existing borehole and create a conceptual hydrogeological model.
- Monitor the hydrology of surface hydrological features such as ditches, ponds, etc.
- Integrate the information with existing data to create a conceptual hydrogeological model and a water balance for Bøllemosen.
- Setup a numerical distributed hydrogeological model for Bøllemosen.

Contact persons: Majken Zibar (mcl@ign.ku.dk) and Søren Jessen (sj@ign.ku.dk)

17. Locating tile drains in agricultural fields using gamma-ray soil sensing

Tile drains are used extensively in clayey agricultural soils to ensure optimal soil moisture conditions for maximum crop productivity. By installing tile drains, excess soil water can be removed by maintaining the groundwater table below the root zone. In Denmark, the use of artificial drainage of agricultural soils employing tiles started around the 1850s and today approximately half of all agricultural fields are drained by tiles or pipes. Unfortunately, the exact layout of the drainage system is not always known and may be important if the system has deteriorated and needs to be repaired. Also, in numerical assessment of water resources, identifying drain locations can help achieve more representative water balance estimates. To obtain this information, conventional methods such as tile probes or trenching equipment, can be used. However, these are costly and invasive procedures which may cause damage to the drainage system.

Gamma-ray soil sensing is a method that records the natural emission of gamma radiation from the soil produced by the decay of Potassium-40, Uranium-238 and Thorium-232. The recorded gamma radiation depends mainly on the type of soil, as clay minerals contain higher concentrations of these radioactive nuclides. However, water in the soil also affects the measured gamma radiation as the gamma rays are attenuated by the water and thereby reduce the signal from the soil. A non-invasive estimation of soil moisture can therefore be deduced from measurements of gamma radiation.

This project aims to evaluate the use of gamma radiation maps to locate the drainage system of one or several agricultural fields with known drainage layouts (such as the PLAP-fields managed by GEUS). By collecting spatial gamma radiation during and after a rainfall event the drains can be delineated as the largest soil moisture change should be found directly above and in close vicinity to the drain pipes.

Contact persons: Mie Andreasen (GEUS, ma@geus.dk), Sachin Karan (GEUS, saka@geus.dk) and Majken Looms Zibar (mcl@ign.ku.dk)

18. Hydrological modelling for sustainable groundwater management in South Africa

Semi-arid regions are dominated by highly irregular precipitation patterns, which strongly influence the hydrological cycle and water resources availability. Large temporal and spatial variations in

precipitation causes large variability in runoff and groundwater recharge. Because of its climatic characteristics the Hout/Sand river catchment in the Limpopo province of South Africa is prone to droughts, and combined with irrigation for intensive agriculture, a growing population and climate change the region is facing severe water challenges. In order to identify sustainable groundwater management scenarios a better understanding of the hydrological processes is required, in particular the replenishment of groundwater.

Several projects can be developed in relation to an on-going Danida funded project in South Africa:

- 1) Further development and calibration of the MIKE SHE model for the study area using both traditional data in the form of river discharge and groundwater levels and remote sensing data such as soil moisture, evapotranspiration and flooding extent. Since the rainfall-runoff relationships are complicated and partially unknown new conceptualizations need to be tested as well as alternative targets for calibration.
- 2) Replenishment of groundwater can occur as diffuse or focused recharge. Diffuse recharge is recharge that is distributed over the catchment in response to precipitation and in semi-arid areas it often occurs as episodic events. Focused recharge occurs from rivers and managed recharge from e.g. farms and varies significantly in space and time. The two recharge components and their mutual significance at catchment scale should be analyzed using the MIKE SHE model in combination with historical data on groundwater levels as well as data currently collected from two field infrastructures established in the study area.
- 3) Development of an alternative modelling framework for the study catchment based on MODFLOW-6 incorporated in the GMS system.
- 4) Analysis of impact of climate change on the hydrological components and on groundwater use and management.
- 5) Downscaling of the hydrological model simulations to community and farm scale using machine learning techniques to help improving groundwater management at smaller scales.
- 6) Analysis of reactive transport of a managed recharge site using geochemical modelling.

If relevant, the project can partly cover travel expenses to South Africa.

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19. Can soil moisture be used as a predictor of droughts and flashfloods?

In Denmark, the higher temperatures caused by the changing climate will affect the seasonal precipitation patterns. We can both expect wetter winters and longer and more severe periods of drought during the growing season. The wetter winters may cause high soil moisture levels in the upper soil layers. When the soil becomes saturated additional rainfall may not infiltrate fast enough and the excess water will produce increased quick flow with risk of flooding both locally and at downstream locations. Droughts during the growing season may in turn result in loss of agricultural yield but can also adversely affect natural ecosystems or cause damage to infrastructure (e.g., damage on buildings due to subsidence). In the recent years, both droughts (summers 2018 and 2023) and flashflood events (winters 2019/2020 and 2023/2024) have been recorded with large economic consequences to follow.

Soil moisture data has been collected at six agricultural sites across Denmark since 2000 by GEUS and at three field sites in Skjern characterized by different land covers (agricultural field, heathland and coniferous forest) since 2013/2014 by UCPH. These sites represent different weather regimes and soil types. This project will use data from these sites to investigate whether recorded soil moisture can be used as a predictor of drought and flash floods. The analysis will be data-driven, and will exploit

additional data such as regional information of crop yield, floods, and satellite soil moisture data from SMAP.

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20. Groundwater parks: Modelling the transition from highly intense agriculture to nature

To protect the drinking water resource in Denmark several groundwater parks are being planned in Denmark. The parks are located in groundwater recharge zones, and generally involve farmland being taken out of practice and converted to nature, such as wetlands, forests and open meadows. The concept is that nitrate and pesticide application will be reduced or removed from the recharge that replenishes the drinking water reserve. Further benefits such as biodiversity, recreational areas and climate adaptation are also a part of the transition. In an ongoing project in Denmark's largest abstraction site, Holmehave, on Funen, we combine well-established and new techniques for monitoring the effect of the upcoming extensive land conversion. The project involves several collaborations with the water utility company and the municipalities. However, to upscale and project the impacts of the conversion, hydrological modelling is needed to track shifts in the hydrological system as the natural landscape grows and to quantify impacts on the groundwater resource. An MSc project can contain some of the elements below or combinations of these:

Ideas/content

- Fieldwork: Setup and analysis of a hydrological monitoring network with new innovative measuring equipment.
- Modelling: Detailed hydrological modelling of the area, before and after the transition, including setup and calibration.
- Modelling: Modelling of energy fluxes, with a focus on the change in evapotranspiration from agriculture to forest.
- Modelling: Analyzing future hydrology under climate change and more extensive land use conversion.

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21. Data-driven estimation of groundwater recharge

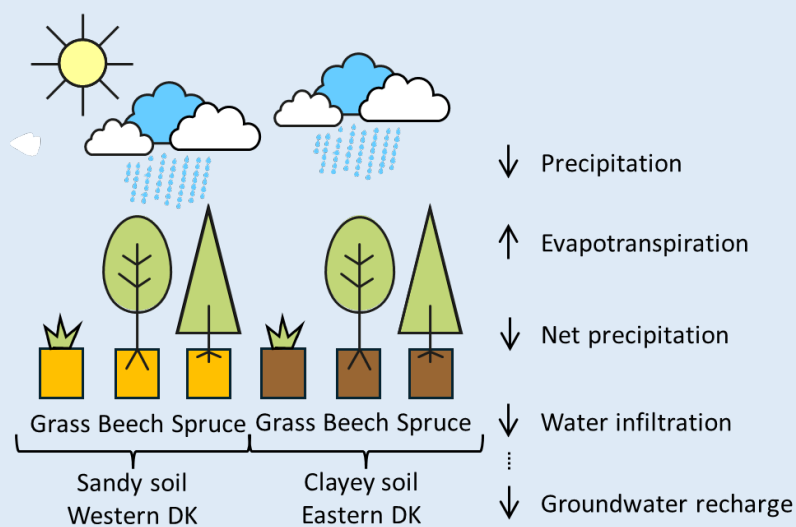
In Denmark, 100% of all drinking water is extracted from the groundwater resources. In order to sustainably use this resource, i.e. avoid a lowering of the groundwater table and maintaining the required inflow of groundwater to streams and lakes to ensure these ecosystems, it is necessary to quantify the amount and timing of water recharging the groundwater each year. Unfortunately, groundwater recharge is difficult to measure directly. Instead, this important water flux is typically estimated using hydrological models or by rearranging the water balance equation and using best-estimates of the other water fluxes, i.e.:

Recharge = Precipitation – (Evapotranspiration + Overlandflow + Interflow + Storage change).

This project will explore the possibilities of using time-series of river discharge to estimate land-cover dependent groundwater recharge in the Ahlergaard catchment. The first step is to perform a hydrograph separation to remove the amount of river discharge that cannot be assumed to originate from groundwater recharge. Then a multi-station approach will be used to estimate the land-cover dependent recharge of the dominating land cover types in the area, i.e. agriculture, heathland, and forest. Finally, the estimates of recharge will be compared with modelling results from the DK-model and measurements of recharge below an agricultural field within the catchment.

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22. Groundwater recharge below different land cover types



Since the 1990's, planting forest has become a common water management practice. The change of agricultural land to forest (i.e., afforestation) is used to secure the quality of the underlying groundwater resource by discontinuing the addition of nutrients, pesticides, and PFAS at the surface. In 2020, forest formed 14.7% of the total land cover in Denmark. It is a political goal that by the end of the 21st century, 20-25% of the country should be covered by forest. With increased afforestation, it is important to understand how different land cover types affect the water balance at the surface, and ultimately the groundwater recharge.

In this project 1D hydrological models (MIKE SHE using the SWAT module) will be setup for a unique field location close to Hillerød, i.e. the Frederiksborg ICP forest site. At this site, three different land cover types, i.e. open grassland, deciduous forest, coniferous forest, exist within 200 m of each other. Due to the close proximity, the external forcing of the system and the local geology are expected to be the same. Measurements of local throughfall, soil moisture, groundwater table are available at the three sites and will be used to calibrate the hydrological models to obtain estimates of groundwater recharge.

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23. Hydrological modelling of a study catchment in Uganda

A new research project funded by Danida will be launched in 2025 in which four Ugandan partners and three Danish partners are involved. One of the activities will involve development and calibration of an integrated hydrological model of the Enyau River study catchment using the Soil and Water Assessment Tool (SWAT). This open-source modelling platform is considered as one of the most versatile hydrological models in terms of functionality, applicability and implementation and has been extensively used worldwide for semi-arid regions to assess water resources, nutrient dynamics and sediment transport to analyze the impact of water and agricultural management practices, soil conservation, land use and climate change.

Objectives

- Collection of in-situ, satellite retrieval and global database data
- Conceptualization of hydrological model in the SWAT modelling platform
- Calibration of the hydrological model against collected data using state-of-the-art optimization techniques
- Analysis of water resources dynamics
- Retrieving an ensemble of climate projections from the latest generation of global and regional climate models, bias correcting and downscaling
- Applying the model to quantify the impact of projected anthropogenic and climate changes on water resources and agricultural production

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24. Your project?

Please remember that the above MSc Thesis ideas *are only ideas*. You are always welcome to bring your own ideas to the table, and to discuss with us in order to develop the project that suits you best.

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