GeoNetZero Centre for Doctoral Training (CDT): Geoscience and its Role in the Low Carbon Energy Transition

(2022 start)

Project Title: The use of mineral-chemical stratigraphy to assess the environmental impact of sediment capture behind hydroelectric power plants

Host institution: Royal Holloway, University of London
Supervisor 1: Amy Gough
Supervisor 2: Domenico Chiarella

Project description (250 words max.):

Due to environmental concerns, there are no large-scale hydroelectric power plants planned for the UK. However, there is around 2.8 GW of capacity which would more than double the 2.4 GW of power currently generated. Assessment of the environmental impacts of hydroelectric schemes through high-resolution analysis of how damming affects sediment and water transfer, and subsequent mitigation of this through sustainable practices can make hydropower a reliable and cheap energy source.

As a result of these environmental concerns, most new dams are developed in lower income countries, making these the perfect location for studying the direct impacts. For example, the Citarum River of West Java, Indonesia has four hydroelectric dams along its course, producing 2.7 GW of power. As the geology feeding sediment into the river is well known, the long-term effects of damming on river pathways and sediment delivery can be studied. Water and sediment capture behind dams have implications for delta stability, water quality, food security, and aquaculture.

A mineral-chemical stratigraphy from before and after the Citarum River dams will be developed to quantify changes in sediment composition and generate a stratigraphic traverse to highlight predictability of these changes. 100 gravity-cored samples will be collected and analysed using Raman Spectroscopy and SEM-EDS to determine sediment composition and heavy mineral signatures. XRF will identify any agriculturally significant element depletion (full training in these techniques will be given). This high-resolution study into the effects of dam placement will develop a globally applicable methodology that will ensure sustainable hydroelectric dam development.

Stated link to the overarching theme of the CDT i.e. The Role of Geoscience in the Energy Transition and the challenge to meet the net zero emission targets (NOTE: In order to qualify for NEO Energy CDT funding, there must be an explicit link to the Energy Transition with a clear application to the UK's Continental Shelf (UKCS). For projects supported by 100% matched funding from your University, links to the broader Energy Transition remit are sufficient):

The UK Government's National Renewable Energy Action Plan led to the development of 40 – 50 MW of hydroelectric power between 2010 and 2020, despite there being a stated potential capacity of around 2.8 GW in the UK. One of the driving factors behind development of hydroelectric plants slowing since the 1960s and 1970s is the concern about the immediate effects on the environment. Understanding these possible effects, and thinking about mitigation techniques, can help sustainably install an increased capacity of hydropower schemes within the UK. Using an established case study, such as the dams on the Citarum River, can allow for historical changes to the river systems to be identified, and any negative effects to be considered. The model development from this will highlight these negative effects and allow for the development of a mitigation plan designed to sustainably re-start the development of hydroelectric plants in suitable sites around the UK. This

project is also globally applicable as ~ 2000 (reported) hydroelectric power plants are currently in development.

As we move into using an increasing amount of sustainable energy technology to reach our energy demands in the UK we have a responsibility to ensure that the negative impacts do not outweigh the positives, ultimately energy production should not come at the expense of the environment. This project ensures that increasing energy demands can be met in the UK by harnessing available hydropower in a sustainable way. A key reason that Indonesia has been chosen is that the impacts have been previously recorded in the region (e.g., Mekong Delta) but this study steps beyond that why investigating what sediments are trapped, the immediate effects (e.g., the depletion of fertility in delta soils) and how to mitigate for them is still understudied.

This project fits within the remit of the CDT subheading 'Environmental Impacts and Dependencies resulting from continued exploration and / or the deployment of low carbon technologies' by assessing the environmental impact of hydroelectric dam developments in order to find 1) a reproducible methodology to assess the impact of water and sediment capture behind dams on the environment (and local populations) downstream, and 2) provide a groundwork for identifying sustainable methods for placing hydroelectric dams to increase power generation from this relatively cheap and readily available source, with particular application towards future projects within the UK.

Details of mapping/fieldwork locations/data to be used by the project and confirmation of access to key data being secured (please attach map as an appendix if relevant):

Fieldwork will talk place along the course of the Citarum River, Java, Indonesia. Samples will be collected using a gravity corer to the depth of 1 m at regular intervals along the river, with additional samples being taken from the reservoirs behind the dams.

Ideally, two field seasons of 1-2 months will be completed within year 1 and year 2 of the project in the dry season between May and October to allow easier access to sandbars and exposed bedforms down the river. Local boats and a driver will be hired to support the fieldwork.

Data that are available: geological samples from the source area of the river to allow for a comparison between 'expected' sediment composition and 'actual' composition. Shuttle Radar Tomographic areal images are also available to allow for the present-day routing pathways of the river to be identified on ArcGIS. Should the fieldwork be delayed, these data provide a strong start to the project even without the new samples.

Plan B in the case that fieldwork remains inaccessible: We work closely with the Institute of Teknologi Bandung (ITB) and Dr Alfend Rudyawan of ITB is an external supervisor on this project. The source of the Citarum River is just to the west of Bandung. As part of our collaboration, we work closely with student counterparts, where they support our in-country research in return for a Scholarship to the Energy Geosciences MSc at Royal Holloway, University of London. Our current local Indonesian counterpart has 2.5 months left on his agreement, so if fieldwork for the PhD student is not possible, he will run the field campaign with the support of Dr Rudyawan, and then ship the samples back to Royal Holloway for analysis using DHL for safe and reliable shipping. Analysis is done at Royal Holloway due to access to in-house facilities.

As a final back up, it is possible that the mineral-chemical stratigraphy part of this project could be completed using the Rheidal Power Station of North Wales as a case study.

Outline of planned work schedule for the 4-year research period:

Month 1: In order to adhere to the dry season – fieldwork will commence straight away in October for 1 month if possible. Training will be provided on the job

Month 2 – 6: Training in laboratory skills (using samples), introduction to literature of research area, training in necessary computing skills

Month 6 – 12: Processing samples from first field season in the mineral separation laboratory at Royal Holloway, University of London

Month 12: Second field season to collect samples

Month 6 – 12: Alongside the sample processing, analysis of SRTM images to assess drainage pathways using ArcGIS and historical GoogleEarth Imagery

Month 13 – 19: Processing samples from the second field season in the mineral separation laboratory at Royal Holloway, University of London
Month 20 – 24: Compositional analysis of the sediments from separates focusing on optical analysis of the samples.

Month 24 – 36: Focus on analysis of the sediments – this time will be allocated to heavy mineral analysis using Raman Spectroscopy (at the University of Gottingen, Germany with training provided), SEM-EDS at Royal Holloway (training provided by Dr Amy Gough), and geochemistry using XRF facilities at Royal Holloway (training provided by Professor Matthew Thirlwall).

Month 36 – 42: Putting it all together: Modelling the mineral-chemical stratigraphy down the course of the Citarum River using a combination of heavy minerals (Raman Spectroscopy and SEM-EDS), light mineral sediment composition, and geochemistry.

Month 42 – 48: Final write up and editing of the thesis

Any Additional Research Costs (NOTE: **Each CDT studentship includes an individual Research Training and Support Grant (RTSG) budget of £20k for the full 4-year study period)**

£20 k is a suitable RTSG budget for this project, however, if any additional costs arise a £10 k pot has been allocated by the Southeast Asia Research Group at Royal Holloway, University of London to cover them.

PhD Proposal: GeoNetZero CDT (2022 start)

Supervisory arrangements and involvement of external partners (NOTE: Please indicate the area(s) of expertise covered by each supervisor. External collaboration is encouraged, but if proposed partner is not currently providing support to the CDT, please outline the extent of the partner's involvement with the project.)

First supervisor: Dr Amy Gough – expertise in the geology of SE Asia, sedimentary provenance, and fluvial sedimentology

Second supervisor: Dr Domenico Chiarella – expertise in sedimentology, particulary sedimentology of delta systems

Internal additional project support: Dr Max Webb – expertise in sedimentary geochemistry and the basement geology of SE Asia.

External supervisor: Dr Alfend Rudyawan (Institute of Teknologi Bandung) – expertise in the source geology surrounding Bandung that feeds into the Citarum River. Local knowledge and fieldwork support will be provided by Dr Rudyawan.

Likely graduate career routes:

Energy industry with hydroelectric companies, career in policy looking at development of hydroelectric dams, further research in postdocs.