IQUA

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Editor: Susann Stolze

1. Editor's Note

Dear IQUA members,

Welcome to IQUA newsletter No. 65.

I am delighted to present the latest issue of the IQUA newsletter to you, which features a range of exciting contributions from members of our society. This includes a report on the virtual IQUA Autumn Symposium 2020 as well as several abstracts presented at the meeting. The newsletter also reports on the 2020 IQUA Autumn Field Meeting to West Cork and several ongoing research projects in Ireland. As the Quaternary community mourns the passing of Eric Grimm, the newsletter features an obituary for this exceptional and internationally renowned scientist.

This is the first newsletter that I have compiled for IQUA as editor. I have taken over the role from Martha Coleman who has served in this position over the past two years.

I would like to thank all who contributed to this edition.

Kind regards,

Susann Stolze, CSM, Colorado, February 2021
(sstolze@mines.edu)

2. Cúpla Focal

[lit.] A couple of words ... from the President

As we approach the end of a surreal year of working under restrictions, I find it astonishing to think that it's only been twelve months since Graeme Swindles and I were discussing which venue in Queen's would be best for the IQUA 2020 Spring meeting. That meeting was the first of IQUA's annual events to fall victim to the COVID lockdown, though a very minor setback compared to what many families, workers, business owners and healthcare professionals have had to endure over the ensuing months. By summer, we didn't need a neuropsychological study to tell us that many of us were also suffering from Zoom fatigue (not helped by the proliferation of contingency planning meetings – or was that just Queen's?!). But by winter, we also learnt that we could successfully pull off a virtual meeting, namely the Autumn Symposium on "Carbon Sequestration" organised by Graeme Swindles and Catherine Dalton, and ably assisted by the two new IQUA postgrad reps, Adrienne Foreman and Ryan Smazal.

The Committee, newly elected at the AGM which eventually took place via Zoom in June, has not been idle. Following on from the great success of hosting INQUA 2019 (aren't we glad it wasn't last year – be grateful for small blessings!), we're keen to ensure the Irish Quaternary community remains vibrant, that we continue to inspire and support the next generation of investigators, and that our work is recognised on the international stage. We're presently finalising some initiatives put forward by the Committee and the membership so watch this space! Mark Coughlan, Treasurer, has also spearheaded the launch of Corporate Membership to help foster engaged research with relevant public and private organisations. More details in the Newsletter…

Fuelled by the success of the Virtual Autumn Symposium, we will have a Virtual Spring Meeting (and our second Virtual AGM) in April, with the hopes of picking up that conversation about the Queen's venue again next year. It's too soon at this stage to say what will await us in the summer or autumn, but we nurture a hope of being able to meet in person, even if under the cover of a mask or two, or whatever else is required, some time in the near future. I predict a theme on past pandemics, their causes and impacts, will be waiting to surface when we come out the other side. Any takers?

Gill Plunkett, IQUA President

3. IQUA Committee (2021)

President: Gill Plunkett, Queen's University Belfast
Secretary: Graeme Swindles, Queen's University Belfast
Treasurer: Mark Coughlan, iCRAG
Postgraduate Rep: Adrienne Foreman, NUI Galway; Ryan Smazal, Dundalk Institute of Technology
Webmaster: Benjamin Thébaudeau, Trinity College Dublin
Publications Officer: Mark Coughlan, University College Dublin
Newsletter Editor: Susann Stolze, CSM, Colorado
General Members: Sara Benetti, University of Ulster; Gordon Bromley, NUI Galway; Kieran Craven, Maynooth University, GSI; Catherine Dalton, Mary Immaculate College, University of Limerick; Gayle McGlynn, Trinity College Dublin; Chris Randolph, retired archaeologist; Sam Roberson, British Geological Survey, Belfast

4. New Corporate Membership

Marc Coughlan, iCRAG, e-mail: mark.coughlan@icrag-centre.org

In January 2021, IQUA launched its Corporate Membership scheme. The purpose of this scheme is to encourage wider interest in the Quaternary and to increase awareness amongst the general public and within industries connected with Quaternary studies of the activities of IQUA. Members of the scheme can avail of discounted field guides and complimentary passes to IQUA field trips and symposia.

We are delighted to welcome Arup Ireland, the Geological Survey of Ireland and UCD School of Archaeology as our newest corporate members and wish to thank them for their support. Anyone interested in joining the scheme can contact our Treasurer, Mark Coughlan.

5. IQUA Autumn Symposium 2020

The IQUA Autumn Symposium on ***Carbon Sequestration*** was held as a zoom meeting on November 27th, 2020.

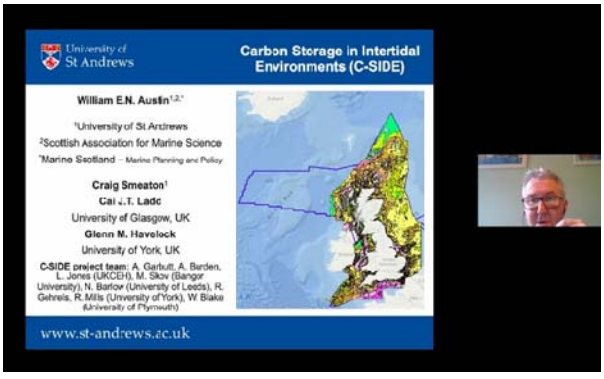
Symposium Report

Ryan Smazal, Dundalk Institute of Technology, e-mail: d00242675@student.dkit.ie

This past November was the IQUA Autumn Symposium, with the main topic of discussion being Carbon Sequestration. While the traditional opportunity to meet in person was dearly missed, being able to reconnect with colleagues, old and new, was absolutely appreciated by presenters and guests alike.

After a welcome by IQUA president Gill Plunkett and introduction by Graeme Swindles, who chaired the morning session, talks got under way. The morning session featured William Austin as the keynote speaker, discussing the C-SIDE (Carbon Storage in Intertidal Environments) project. The true diversity of carbon sequestration projects was on full display in the morning session as presenters discussed sequestration in environments including seas, peatlands, wetlands, and catchment systems.

After a virtual lunch break, the afternoon session, which was chaired by Catherine Dalton, kicked off. Afternoon talks captured the attention of upwards of 55 participants, intrigued by talks discussing sequestrations in deltas, peatlands, bogs, and seas. An underlying theme found throughout the symposium was the importance of using and understanding the natural environment for carbon sequestration method. The 2020 symposium was closed by the afternoon chair with resounding success on the day, which will surely be a sign of more excellent talks to come.



Keynote speaker William Austin gives his presentation on the C-SIDE project.

Symposium Abstracts

Keynote: Carbon Storage in Intertidal Environments (C-SIDE)

William E.N. Austin (corresponding author)[1,2,*], Craig Smeaton[1], Cai J.T. Ladd[3], Glenn M. Havelock[4], C-SIDE project team

[1]School of Geography and Sustainable Development, University of St Andrews, UK
[2]Scottish Association for Marine Science, Oban, UK
[3]School of Geographical and Earth Sciences, University of Glasgow, UK
[4]Department of Environment and Geography, University of York, UK
*e-mail: wena@st-andrews.ac.uk

GHG emissions and removals resulting from changes in saltmarsh management can be included in national emission accounting under the Land Use, Land Use Change and Forestry (LULUCF) sector. However, they are not included in the UK GHG inventory (GHGI) at this time. The LULUCF sector is currently the only sector of the national GHGI that is a net sink, with scope to offset emissions in other sectors. The IPCC's 2013 Wetland Supplement (IPCC, 2014) to the 2006 IPCC guidelines details expanded guidelines for the quantification and accounting of GHG emissions and removals associated with the management of different wetland types, including drainage and rewetting of tidal marsh (Chapter 4). The UK has elected wetland drainage and rewetting for the second commitment period of the Kyoto Protocol, and using the IPCC Wetland Supplement will report emissions from peatlands in its national inventory by 2022 at the latest under the obligations of the UN Framework Convention on Climate Change (UNFCCC). This also has significance for commitments to the Paris Agreement and the national requirements of the UK's Climate Change Act. Inclusion of saltmarshes in the UK GHGI would provide an important first step necessary to account for, protect, and restore these long-term carbon stores, realising their potential for climate change mitigation. Here, we report on the progress of the NERC-funded C-SIDE project to assess the carbon stocks in UK saltmarsh habitats.

Put a lid on it: Quaternary sediments and CCS in the North Sea

Andrew M. W. Newton

School of Natural and Built Environment, Queen's University Belfast, UK
e-mail: a.newton@qub.ac.uk

It is unlikely that emission reductions alone will be sufficient for meeting national targets. This will require the removal of CO_2 either directly from the air or when the hydrocarbon source is initially extracted. Carbon capture and storage (CCS) provides a mechanism for this and involves the geological storage of CO_2 in either former hydrocarbon reservoirs or underground aquifers beneath the Earth's surface. The prolific history of oil and gas exploration in the North Sea means that there are many storage sites that could potentially be suitable for upscaling CCS. The Quaternary sediments in the North Sea measure up to 1 km thick and represent a significant part, or indeed all, of the overburden above some potential CO_2 storage sites. Thus, understanding the nature of the Quaternary record in the North Sea is important for identifying potential pathways of fluid migration that might reduce the efficacy of CCS reservoir targets. The work presented here uses a multi-proxy dataset from the North Sea that investigates the Quaternary geological record in order to: 1) unravel what insights this record provides for long-term climate reconstruction in northwest Europe; and 2) the potential implications of this climate record for the efficacy of CCS in areas of the North Sea where the overburden seal is largely comprised of Quaternary sediments.

Divergent responses of permafrost peatlands to recent climate change

Thomas G. Sim (corresponding author)[1,*], Graeme T. Swindles[2,3], Paul J. Morris[1], Andy J. Baird[1], Claire L. Cooper[4], Angela V. Gallego-Sala[5], Dan J. Charman[5], Thomas P. Roland[5], Werner Borken[6], Donal J. Mullan[2], Marco A. Aquino-López[7], Mariusz Gałka[8]

[1]School of Geography, University of Leeds, Leeds, UK,
[2]Geography, School of Natural and Built Environment, Queen's University Belfast, Belfast, UK
[3]Ottawa-Carleton Geoscience Centre and Department of Earth Sciences, Carleton University, Ottawa, Ontario, Canada
[4]School of Geography, University of Lincoln, UK
[5]Geography, College of Life and Environmental Sciences, University of Exeter, Exeter, UK
[6]Soil Ecology, University of Bayreuth, Bayreuth, Center of Ecology and Environmental Research (BayCEER), Dr.-Hans-Frisch-Str. 1-3, 95448 Bayreuth, Germany
[7]Arts and Humanities Institute, Maynooth University, Maynooth, Co. Kildare, Ireland
[8]University of Lodz, Faculty of Biology and Environmental Protection, Department of Geobotany and Plant Ecology, 12/16 Banacha Str., Łódź, Poland
*email: gy12tgs@leeds.ac.uk

Permafrost peatlands are found in high-latitude regions and store globally-important amounts of soil organic carbon. These regions are warming at over

twice the global average rate, causing permafrost thaw and exposing previously inert carbon to decomposition and emission to the atmosphere as greenhouse gases. However, it is unclear how peatland hydrological behaviour, vegetation structure, and carbon balance, and the linkages between them, will respond to permafrost thaw in a warming climate. Here, we show that permafrost peatlands follow divergent ecohydrological trajectories in response to recent climate change within the same rapidly warming region (northern Sweden). Whether a site becomes wetter or drier depends on local factors and the autogenic response of individual peatlands. We find that bryophyte-dominated vegetation demonstrates resistance, and in some cases resilience, to climatic and hydrological shifts. Drying at four sites is clearly associated with reduced carbon sequestration, while no clear relationship at wetting sites is observed. We highlight the complex dynamics of permafrost peatlands and warn against an overly-simple approach when considering their ecohydrological trajectories and role as C sinks under a warming climate.

Blue Carbon Ireland – Quantifying carbon stocks and sequestration rates in coastal wetlands

Grace Cott (corresponding author), Shannon Burke, Sadhbh McCarrick, Elke Eichelmann,

School of Biology and Environmental Science, University College Dublin

Coastal wetlands play a disproportionally large role in the global carbon cycle due to their high primary productivity and unique ability to trap sediments. The carbon stored in vegetated coastal wetlands (including saltmarshes and seagrass beds) has been termed 'blue carbon'. In addition to carbon storage, coastal wetlands provide numerous services such as coastal protection from storm-surge and sea-level rise. There is a striking dearth of knowledge on the dynamics of blue carbon habitats in Ireland and their potentially significant carbon stocks have not been included in Ireland's National Inventory Reports to the UNFCCC. This project aims to quantify carbon stocks and sequestration rates in coastal wetlands and determine factors that lead to carbon preservation. A study of North Bull Island saltmarsh, Co. Dublin has shown the average carbon stock of these wetland soils is 883±400 Mg C ha^{-1} which is over three times the global average per hectare for saltmarsh soils. The carbon density values of North Bull Island saltmarsh are comparable to carbon densities of low-lying blanket bogs. Including above and belowground vegetation, the total carbon stock of this wetland is 107,784±785 Mg C. If this wetland were to be degraded through drainage or restriction of tides it would result in the release of 395,567±2,697 Mg CO_2 into the atmosphere. These results highlight the important role that coastal wetlands play in climate mitigation.

Land use may influence the composition and biodegradability of dissolved organic carbon in carbon-rich catchment drainage

Ying Zheng (corresponding author) [1], Susan Waldron[1], Hugh Flowers[2]

[1]School of Geographical and Earth Sciences, University of Glasgow, Glasgow, UK
[2]School of Chemistry, University of Glasgow, Glasgow, UK

The terrestrial flux of dissolved organic carbon (DOC) is the largest transfer of reduced C from land to aquatic systems. Land use is suggested to influence the concentration and composition of fluvial DOC. However, little is known about whether this propagates through to affect in-stream DOC reprocessing.

In this study, we examined water from a 5.7 km^2 peaty headwater catchment in Scotland to explore how aquatic DOC composition is affected by wind farm-related land uses, and how DOC biodegradation may be influenced by its composition. The one-year monthly water monitoring showed that DOC in the felled sub-catchment had greater concentration, but was less humified (smaller SUVA410, larger E2/E4) than the other one dominated by wind turbines. This may be due to younger DOC from the breakdown of residual branches in felled catchment, or more humification in soils in the wind farm areas.

We further incubated the stream water from these sub-catchments in dark to explore DOC biodegradability. Only 2.9–12.1% (0.60–2.74 mg/l C) of DOC was biodegraded over 21 days, less than many other studies. Weekly UV-visible measurements and fluorescence excitation-emission matrices with parallel factor analysis (PARAFAC) revealed that protein-like florescence component C6 changed actively with biodegradable DOC (BDOC) removal. The initial SUVA254, SUVA410, C6, and concentrations of SRP and TON were good as single predictors for BDOC loss. SUVAs and C6 likely reflected the loss of refractory/labile DOC pools. Spatially, larger BDOC loss was found in the wind turbine-dominated sub-catchment, in late winter and summer, which may be because of greater nutrient concentrations, less DOC aromaticity and more labile DOM material. However, although little DOC was lost (≤12.1%), the C loss was comparable to other

research if normalised for the length of incubation, which suggests that intra-site, other factors influence the capacity for DOC degradation.

This research indicates the composition of soil-derived DOC in freshwater can vary over space and time and in response to land use. In turn this inherited composition can affect the cycling of DOC in aquatic continuum, which potentially impacts C loss from freshwater to atmosphere and export to oceans.

Defining peatland zones using self-organising map clustering on airborne radiometric data and OS digital elevation model

David O'Leary (corresponding author)[1,*], Stephen Monteverde[2], Oisín Callery[1], Mark Healy[2], Colin Brown[1], Eve Daly[1]

[1]Earth and Ocean Sciences and Ryan Institute, College of Science and Engineering, National University of Ireland, Galway, Galway, Ireland
[2]Civil Engineering and Ryan Institute, College of Science and Engineering, National University of Ireland, Galway, Galway, Ireland
[*]e-mail: d.oleary1@nuigalway.ie

Peatlands are becoming recognized as important carbon sequestration centres. Through restoration projects of industrial drained peatlands in which the water table is raised, they may become carbon neutral or possibly carbon negative. Restoration projects require a knowledge of intra-peat variation across potentially large spatial areas. The integration of multidimensional geophysical tools, digital elevation models, and satellite remote sensing products, combined with modern data analytical techniques, may provide a rapid means of accessing variations in intra-peat variation of either thickness or water content over such scales. In this study, an airborne radiometric survey, being flown nationally over the Republic of Ireland, combined with a digital elevation model, is used to delineate areas within an industrial raised peatland where peat thickness is consistent. Radiometric data are particularly suited to peat studies as they are sensitive to water content and peat thickness and require relatively little expert knowledge to utilise. Peat, as a mostly organic material, acts as a low signal environment where variations in the signal are linked to intra-peat variation of thickness and/or water content. This study uses an unsupervised machine learning, self-organizing map clustering methodology to group the study site into three zones interpreted as 1) the edge of the bog where peat layer is thinning or there is influence on the radiometric signal from non-peat soils outside of the bog, 2) the normal peat conditions where thickness and saturation appear as a relative constant in the radiometric response, and 3) areas where the peat is either thinner or drier. A ground geophysical survey was conducted to verify this interpretation. The delineation of such spatial variations in the radiometric response could aid any restoration project in the initial stages or act as a baseline study to monitor changes to the peatland during and after a restoration project is complete.

Estimating allochthonous coastal carbon burial in the western Ganges-Brahmaputra delta over the last 5,000 years

Rory P. Flood (corresponding author)[1,*], M. Georgina Milne[2], Graeme T. Swindles, [1,3], Iestyn D. Barr[4], Julian D. Orford[1]

[1]Geography, School of Natural and Built Environment, Queen's University Belfast, UK
[2]School of Geography, University of Leeds, UK
[3]Ottawa-Carleton Geoscience Centre and Department of Earth Sciences, Carleton University, Ottawa, Ontario, Canada
[4]Geography and Environmental Management, School of Science and the Environment, Manchester Metropolitan University, Manchester, UK

The Ganges-Brahmaputra (G-B) fluvial system drains the Himalayas and is one of the largest sources of terrestrial biospheric carbon to the ocean. It represents a major continental reservoir of CO_2, as allochthonous carbon is captured from the c. 1–2 billion tons of sediment supplied each year. In this study, the geochemical and grain-size properties of sediments from the western G-B delta are used to investigate variations in, and controls on, allochthonous coastal carbon capture (burial) over the past 5,000 years. Our main findings are: (1) Beta regression of aluminium and silica ratio data is a robust method of estimating allochthonous total organic carbon in sediment from the G-B delta; (2) the estimated rate of sediment deposition over last 5,000 years is between 1.0 and 2.5 mm yr^{-1}, although uncertainty surrounds the reworked origins of these sediments; and (3) temporal variation in the rate of allochthonous total organic carbon accumulation through the last 5,000 years is generated by variability in the prevailing sedimentary depositional processes. The delivery and burial of estimated allochthonous total organic carbon is predicated on the continual supply of sediment to the G-B delta, which future management strategies may need to consider given changing rates of deposition.

Modelling organic carbon accumulation rates and residence times for a Welsh ombrotrophic peatland

Luke Andrews (corresponding author)[1,*], Richard Payne[1], Nancy Dise[2], James Rowson[3], Simon Caporn[4], Roland Gehrels[1], Maria Gehrels[1], Ed Garrett[1]

[1]Department of Environment and Geography, University of York, UK
[2]UK Centre for Ecology & Hydrology, UK
[3]Department of Geography and Geology, Edge Hill University, UK
[4]John Dalton Building, Manchester Metropolitan University, UK
[*]e-mail: LOA504@YORK.AC.UK

Northern peatlands store vast quantities of organic carbon (C) which have accumulated over millennia, due to rates of C sequestration exceeding decomposition. The importance of these terrestrial C sinks for climate change mitigation depends upon the Carbon Accumulation Rate (CAR) and the differing residence times of C within the aerobic acrotelm and anaerobic catotelm. Variations in CAR may be compared with proxy-based palaeo-hydroclimatic reconstructions, providing an insight as to how these ecosystems will respond to future climate change.

A number of different methods have been used to quantify CAR in peatlands. Long term Apparent Rates of Carbon Accumulation (LARCA) are based upon the dry bulk density, carbon content, and age of the deepest peat at a site. Recent Apparent Rates of Carbon Accumulation (RERCA) are based on a column section between the surface and a given dated horizon (or horizons) within a surface core. These differ from the actual net rate of carbon accumulation however, as these methods do not account for the relatively rapid loss of C in the acrotelm and the slow but persistent loss of C occurring in the catotelm.

Here, three approaches to quantifying C accumulation are used to understand the C dynamics for Cors Fochno, a coastal lowland raised bog in Ceredigion, Wales. LARCA, a Bayesian age-depth model based RERCA and the novel application of a two-pool model of CAR are estimated for the site and compared with palaeo-vegetation and fire history reconstructions. We demonstrate that both age-depth models and LARCA provide reasonable CAR estimates.

Increased macro-charcoal deposition and increases in bulk density associated with fire events artificially inflate CAR. Mean RERCA values for the past c. 1500 years were 19.5% higher than the mean average LARCA estimated from three cores from the site. Using a two-pool model in tandem with an age-depth model yielded reasonable but lower CAR estimates with lower estimate uncertainty (20.4±2.8 g OC m^{-2} yr^{-1}). In addition, the two-pool model provided useful peat C diagnostics, including organic C inputs, decay rates and C transit times. C inputs were estimated to be 138.5±39.8 g OC m^{-2} yr^{-1}. Decay rates within fast cycling C pools were 99.8% faster than slow cycling C pools. Fast-cycling C was estimated to transit the soil system in 23–43 years, compared to 4705–87,032 years for slower cycling C. Rates of C accumulation in fast cycling pools were 82.2% greater than for slow cycling pools (74.3±25.1 g OC m^{-2} yr^{-1} and 13.2±0.9 g OC m^{-2} yr^{-1}, respectively).

We conclude that each estimate provides a valuable insight regarding the C dynamics across different timescales. With traditional age-depth based techniques, the relationship between CAR and climate was obscured by the effect of burning or other disturbances, as well as by incomplete decomposition of labile material within the surficial peat. Two-pool model techniques may be used to develop robust CAR estimates with smaller estimation uncertainties than traditional methods. These also quantify and account for differences in CAR, decomposition rates and C transit times between the fast and slow cycling C pools. However other sources of uncertainty within CAR estimations remain, e.g., chronological uncertainty and the effects of fire.

Assessing the impact of inter-annual climatic variability on rates of net ecosystem carbon dioxide exchange at Clara bog

Matthew Saunders (corresponding author) [1,*], Ruchita Ingle[1], [2]Shane Regan

[1]School of Natural Sciences, Trinity College Dublin, Ireland
[2]National Parks and Wildlife Service, Ireland
[*]e-mail: saundem@tcd.ie

Peatland ecosystems are integral to the mitigation of climate change as they represent significant terrestrial carbon sinks. In Ireland, peatlands cover ~20% of the land area but hold up to 75% of the soil organic carbon stock, however, many of these ecosystems (~85% of the total area) have been degraded due to anthropogenic activities such as agriculture, forestry, and extraction. Furthermore, the carbon stocks that remain in these systems are vulnerable to inter-annual variation in climate, such as changes in precipitation and temperature, which can alter the hydrological status of these systems leading to changes in key biogeochemical processes and carbon and greenhouse gas exchange. During 2018, exceptional drought and heatwave conditions were reported across Northwestern Europe, where reductions in precipitation coupled with elevated temperatures were observed. These conditions were also observed in Ireland where, for example,

precipitation received at the Clara bog research platform in 2018 was reduced by 213 mm relative to the preceding 10-year average and was 301 mm lower than precipitation received in 2019. These differences in precipitation altered the hydrological dynamics of this ecosystem resulting in changes in water table height and rates of carbon dioxide uptake and release. In this paper, we investigate the impacts of these environmental conditions on gross primary productivity and ecosystem respiration and report on the vulnerability and resilience of these ecosystems to act as a net carbon sink during periods of exceptional inter-annual climatic variability.

Investigation of the CO_2 storage potential of the Celtic Sea Basins

Pablo Rodríguez Salgado (corresponding author)[*], John J. Walsh, Conrad Childs, Tom Manzocchi

Irish Centre for Research in Applied Geosciences (iCRAG), School of Earth Sciences, University College Dublin, Ireland
Fault Analysis Group, School of Earth Sciences, University College Dublin, Ireland
[*]e-mail: pablo.rodriguez-salgado@icrag-centre.org

Carbon Capture and Storage (CCS) is considered a key technology to mitigate climate change during the current energy transition. CCS technology can capture CO_2 emissions derived from large point sources and sequester it underground in porous geological formations. Ireland has vast offshore basins with great potential for CO_2 storage which could therefore contribute to the energy transition and the achievement of EU carbon reduction targets. This study aims to identify potential sites for CO_2 storage in the Cretaceous succession of the North Celtic Sea Basin by taking advantage of Ireland's legacy hydrocarbon exploration database. The main research questions are: What are the characteristic properties of reservoir rocks and seals and their spatial distribution? How do the different families of faults affect the seal rock integrity? Which faults are most susceptible to reactivation during CO_2 injection? Where are the most promising sites for CO_2 injection and storage? What volumes of CO_2 can potentially be stored at these sites? To answer these questions, multiple observations from individual boreholes including pressure tests, oil and gas show distribution, core and fluid sample analyses and stress indicators are combined with the existing regional-scale mapping of faults and key horizons to reduce the main uncertainties relating to i) the nature and spatial distributions of reservoir and seal rock formations, ii) the distribution and characteristics of faults and iii) estimates of potential CO_2 storage volumes. This project represents a detailed study of the geological storage potential in the North Celtic Sea Basin and it is expected to become a reference for future storage project development.

Monitoring groundwater depths, pH, and redox potential and GHG modelling of a cutover blanket peatland in Galway, Ireland

Amey S. Tilak (corresponding author)[1,*], Seamus Hoyne[1], Jasper van Belle[2]

[1]Research and Development Unit (RDI), Limerick Institute of Technology (LIT), Moylish, Limerick, Ireland,
[2]University of Applied Sciences, Van Hall Larenstein, Leeuwarden, Netherlands
[*]e-mail: amey.tilak@lit.ie

The Irish partners in Limerick Institute of Technology (LIT) working with EU INTERREG Carbon Connects Peatland Project for reducing high carbon footprint of drained peatlands in North-West Europe using sustainable bio-based business models for farmers on their rewetted peatlands. The LIT in collaboration with private landowner and Freshwater Pearl Mussel (PMP) are monitoring the carbon sequestration potential of 9 ha cutover blanket peatland in Galway, Ireland. The monitoring conducted in two phases: pre-rewetting (May–October 2020) and post-rewetting (November 2020 – December 2021). The groundwater levels, pH, and redox potential monitored daily at different spatial locations using data loggers and vegetation survey conducted. The carbon in peat and water also measured in pre-rewetting period. The groundwater levels, vegetation types along with land management factors utilized for modelling GHGs using "Site Emissions Tool" developed by VHL, Netherlands. The pre-rewetting monitoring results showed that groundwater levels, pH, and redox potential varied from 2.5 cm to 23 cm, 3.86 to 6 and -131 mV to +403 mV, respectively. The SET results showed that the "Global Warming Potential (GMP) of the cut-over blanket peatland was +5.11 t CO_2 equivalent per hectare per year". The SET tool will quantify carbon gain or losses using pre and post-rewetting data, i.e., groundwater levels, vegetation types, and land management factors.

The role of salt in long-term carbon storage offshore Ireland

Conor O'Sullivan (corresponding author)[1, 2,*], Conrad Childs[1, 2], John J. Walsh[1, 2], Muhammad M. Saqab[3], Patrick Shannon[4]

[1]Irish Centre for Research in Applied Geoscience (iCRAG), School of Earth Sciences, University College Dublin, Ireland
[2]Fault Analysis Group, School of Earth Sciences, University College Dublin, Ireland,
[3]Norwegian Geotechnical Institute, 40 St. Georges Terrace, Perth, WA 6000, Australia

[4]School of Earth Sciences, University College Dublin, Ireland
*e-mail: conor.osullivan@icrag-centre.org

Carbon dioxide (CO_2) is one of the most abundant greenhouse gases emitted by human activity, making the capture and storage of CO_2 essential in mitigating global climate change. Removing CO_2 from the atmosphere and storing it for geological periods (10,000+ years) can have a meaningful and positive impact on reducing the effects of climate change and offsetting the CO_2 emitted during the societal transition from hydrocarbons to renewable energy. Therefore, identifying sites with geological characteristics suitable for the long-term storage of CO_2 becomes increasingly important, in particular the identification and mapping of regional seals which will impede the vertical migration of injected CO_2 back to the shallow subsurface and atmosphere. The physical properties of salt (NaCl) make it an ideal seal; salt is a crystalline solid with very low permeability and porosity and behaves like a fluid over geological timescales, making it less susceptible to fracture and leakage relative to other seals such as mudstones. The deformation of salt layers during the evolution of sedimentary basins can also play a role in the formation of structures suitable for CO_2 storage. This study uses a variety of legacy and modern datasets collected for hydrocarbon exploration, primarily borehole and seismic reflection data, to map the distribution and composition of salt within the Slyne Basin, offshore north-western Ireland. Two salt-prone layers are identified, the Late Permian-aged Zechstein Group and the Late Triassic-aged Uilleann Halite Member. These salt layers are already proven to be effective regional seals, with the Uilleann Halite Member acting as a seal for the Corrib gas field and the Corrib North gas discovery. Understanding the distribution of salt within the Slyne Basin will aid in the identification of suitable sites for the long-term storage of CO_2 and provides paleogeographic context for Permian and Triassic salt in other basins offshore Ireland.

6. IQUA Autumn Field Meeting 2020

IQUA Field Trip to West Cork

Robin Lewando, independent researcher located in West Cork, e-mail: robinlewando@hotmail.com

The first area to be visited on this field trip is the location of initial and ongoing research (described later), Three Lakes, a 2 km stretch of 3 lakes and surrounding bog which lie east-west halfway between Dunmanway and Drimoleague.

From the eastern end, following the course of the old railway line back into Clashnacrona gorge, it was clear that even prior to the construction of the railway in the early 1860's the outlet from the lakes draining through the gorge ran through a channel in the rocks. These were blasted and levelled to create a bed for the railway and a deeper channel for the water. The old land surface can be seen 3 to 4 m above, on top of the exposed rock faces – we can only guess at the original course of the drainage, when this was a meltwater channel; but the 1st edition OS map (c. 1840) shows that it was not so different from the present course. The presence of bedrock here in the gorge, at several metres above the lake and bog level, is possibly the result of the narrowing of the valley to this point, lifting the ice and reducing the gouging effect that scoured out the basin in which Three Lakes now lies. This created the rock lip that subsequently held back drainage.

Further up the road from the old level crossing (where the still extant gates being metal box section, not wood as was to be expected, was puzzled over) and on to a rise, a good view was obtained of the eastern end of the Three Lakes valley just by the outlet. Low mounds were seen to represent a slump fan probably of former glacial debris, possibly having blocked the drainage, some of which might well have been washed down through the gorge as some level was overtopped. The local farmer passed, stopped, and added to the story by mentioning that the land surface here had been cleared of former “bog”; and solved the query of the level-crossing gates, which he had made as replicas of the wooden originals.

The mound at the middle lake, looking east towards the gorge.

A brief discussion of the problems with mapping and how GSI software can be used. In this case a map of the field trip area was assembled using public domain data from GSI as well as satellite data for digital surface models. But topography remains a problem due to the varying accuracy levels of the satellite data, which is reflected through the contour algorithms used.

Moving into the area by the middle lake, looking at the slopes of Killaveenoge to the south, extensive evidence of sediment movement and slumping between minor drainage channels could be seen, and the possibility of lateral moraines along the hillside now covered in forestry and scrub was discussed. Standing on the mound surrounded by bog, this was compared to the form of a beaded esker type morphology, although we cannot be sure whether this is a rock or sediment mound; and also a similarity to the Tullahedy mound, albeit rather smaller.

The mound at the middle lake looking west.

A six metre core has been extracted from the bog near to the old railway line and away from the lake - 5.8 m of organic sediment followed by a rapid transition to pale grey silt or gyttja. The bottom part of the core – still in the process of being analysed – is very high in diatom frustules, with many sponge spicules, suggesting the open water of a lake, probably coinciding with the more rapid rate of deposition, until that part of the lake was infilled by vegetation and became bog. More information will result as analysis of the samples continues. Radiocarbon ages for the organic parts of the core are 1417±25 at 1.0 m; 8868±43 at 2.9 m; 10026±49 at 5.8 m; giving dates of deposition in calibrated years as AD 597-659, 8223–7830 BC; 9808–9359 BC, respectively. These are whole peat dates, so probably represent younger ages than peat-fraction dating would give. These three radiocarbon dates were generously funded by IQUA through the Bill Watts Chrono Award 2018.

Gouge coring at the edge of the middle lake, nearer the valley bottom, also showed 5.9 m of organic sediment underlain by pale grey silt. The question arose as to whether further organic sediment may lie under a layer of silt; and how much silt is lying in the base of the valley. Further coring and dating is desirable, and it was proposed that obtaining a piston corer and taking a sample from the middle lake would be an ideal progression.

The mound here in the valley being compared to Tullahedy suggests that it may have been an attractive and secure site for an early settlement, although it is probably too small for a permanent settlement. It clearly represents what would have been an easily defended site, in a valley bottom surrounded by bog. Field walking when the pasture is ploughed and reseeded might turn up some finds. A depression in the side of the mound is reminiscent of similar depressions elsewhere which have been interpreted as caused by melting of buried ice blocks.

Moving on to the westward end of the top lake to the watershed between the three lakes with eastward flowing drainage, and the Kilnahera bog that drains to the river Rua flowing west. The watershed is only about 10 m above the lake level and 200 m from the top lake. A good view was also obtained from here of the main inflowing stream from the northern hillslopes into the middle lake. Research at the Three Lakes site was instigated whilst studying with the Archaeology Department of UCC, as an investigation into relationships between the pollen record and activity related to the surrounding ringforts, of which there are several on the valley sides. Although extending the research, as an independent researcher to incorporate the full time scale covered by the sediment at the site, research and analysis of the archaeology at this site is also ongoing.

The next site to be visited was down the Ruagagh valley, a river that flows westwards alongside the road from Three Lakes to Drimoleague, parallel to and north of the Rua. About 2.5 km from Drimoleague there is a glacial mound that is currently being dug for gravel. Alongside the track crossing the field leading to the extraction pit some exposed soil and upper level subsoil in the side of the track was seen. Solifluction and slumping features, possibly even ice wedge traces, were apparent with a variety of fine sands and silt with sorted gravel lay-

ers. The main pit has a high back wall of about 8 m which is largely discoloured through weathering and organic growth, and is composed of a thick sequence of bedded silts and sands, with apparent block faulting and folding. There was also a clear discontinuity in particle size and structure with the cross-bedded sands and gravels, visible in the edge of the main pit exposure. The back wall was clearly recognised as lake bed deposits of fine sand, even in this incongruous position, and has been well used by sand martins. Soft sediment deformation was apparent, but whether as a result of transport of the sediment, or movement due to melting, is unclear.

The gravel extraction is from the 'tail' of the mound pointing down valley, and the sediment was interpreted as a fluvial deposit of a high energy channel, or maybe delta. Layering and sorting was apparent in these gravels and sands. Again, minor glaciotectonic deformation was visible. The area where the two deposits meet is not visible, being covered by mounds of extracted sediment. It was a point of discussion as to how a lakebed deposit of this depth, and a low energy environment, should be in a prominent position in the valley floor, right next to the gravels and sands of the high energy deposit. Possibly a block of lakebed sediment was transported by ice and dumped here. This was agreed to be a site of great interest, enlightening as to local postglacial conditions, and worthy of further investigation. More mounds further down the Ruagagh valley were seen, both from here, and as we drove along the road skirting the north side of the valley.

The fine sediment in the backwall at the gravel pit.

Next stop was Barr na Carraige, Top of the Rock, north of Drimoleague, from where a stunning view, despite the weather closing in, of the hills and intervening landscape to the north, was obtained. Nowen Hill (535 m), Dereenacrinnig (509 m) and Mullaghmesha (494 m) from east to west were all clearly visible as well as lower hills further west toward Bantry. The full nature of the landscape was clear to see. The Ilen valley meltwater channel lies directly below Barr na Carraige.

From here the route passed the confluence of the Clodagh and Ilen rivers at Ahanafunshion and up the hillside to Leitry cross, turned east and then after a few km turned south to come down overlooking the upper Clodagh valley. A couple of stops on this narrow road enabled good views down into the valley of many small glacial mounds, suggestive of deposition under receding and thinning ice. Despite the regional movement of ice from the north to the south, and out into Bantry bay, and over the coast to the west, these mounds have a distinct alignment, illustrating how, on a more local and intimate scale, ice movement often harmonised with the topography. There were final musings on the nature of an early postglacial landscape bare of vegetation being so mobile and subject to change and modification; and how it has since become covered with vegetation, which with a reduced precipitation has resulted in a far more stable landscape in which features of more than 10,000 years in age can still be seen and studied.

At this point it was nearly half past five, the weather was worsening and we called it a day. The loop south was not explored and must wait for another day. Although the number of attendees was severely reduced due to COVID-19 restrictions, this was a most enjoyable field trip, and has provided further inspiration and ideas, and opened up new areas of investigation for the research. Many thanks to those who did attend and for making the afternoon so stimulating. There are many glacial deposits and features across lowland West Cork with plenty of scope for further trips.

Many thanks also to Robert Beamish, landowner at Three Lakes, and to Wesley and David O'Driscol, landowners at the gravel pit, for so readily allowing access to their land and being both interested and understanding.

The field trip members at the gravel pit.

7. Ongoing Research Projects

Photogrammetric survey data is helpful in identifying surface features too small to be resolved by standard mapping surveys

Robin Lewando, independent researcher located in West Cork, e-mail: robinlewando@hotmail.com

A set of data was obtained recently from an aerial photogrammetric survey of a small (1 km^2) area in West Cork. The data from the digital surface model (DSM) was based on a 1 m grid and detected elevation variations of centimetre scale.

Also available from the same company was a digital terrain model (DTM) based on a 5 m grid. The DTM is produced by processing the DSM and removing those features that are non-terrain, such as trees, hedgerows, buildings. The algorithms used are probably based on ascertaining large changes in elevation, such as will be found with buildings and trees as against the background terrain elevation; changes within the 1 m grid that are greater than would be expected in the normal topography of the land surface. As a result of the processing to produce the DTM, the scaling of the survey data is increased to the 5 m grid.

The use of GIS software is necessary to make the data of either the DSM or DTM visually useful. The data is single band, i.e. monochromatic, as opposed to a lot of satellite imagery which is composed of three bands which often represent the RGB regions of the visible spectrum, but may also represent regions outside the visible spectrum. Commercially available satellite imagery is not currently produced at such small scale as 1 m grid.

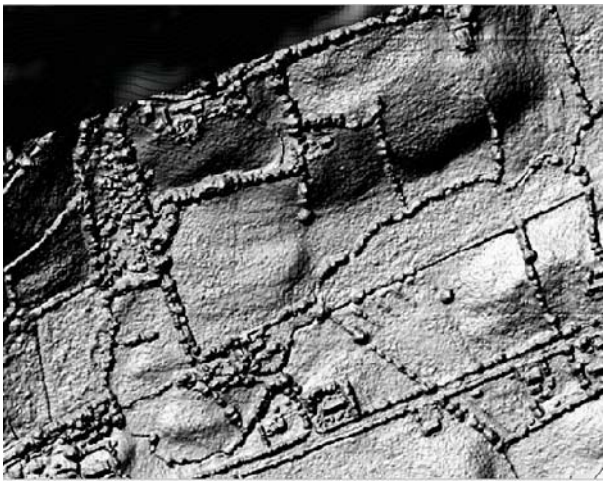
The monochromatic property of the survey data makes visualisation a simple matter of light and dark shading dependent upon the elevation value of each cell. The GIS can be used to generate contours or hillshading from the elevation data, both of which have strong visual impact. The results from applying these algorithms to the data are self evident and visually striking. It is also possible to change the scaling vertically, a practice often employed in geology and geography, to accentuate features. By applying a 5x vertical scaling, surface features of low elevation become more obvious.

The survey data obtained was of the western end of the Ruagagh river valley just to the east of Drimoleague in West Cork. This area is the site of a mound of glacial sediment that is currently being extracted. A visit to this mound revealed that the fine grained sediment is possibly lakebed glacial sediment. Thus it was decided to obtain imagery of the rest of the valley in which it is known are several more mounds of various sizes and heights. The intention was to gain an idea of the distribution and alignment of the sediment deposits with a view to site visits and sampling of those areas deemed to be of interest.

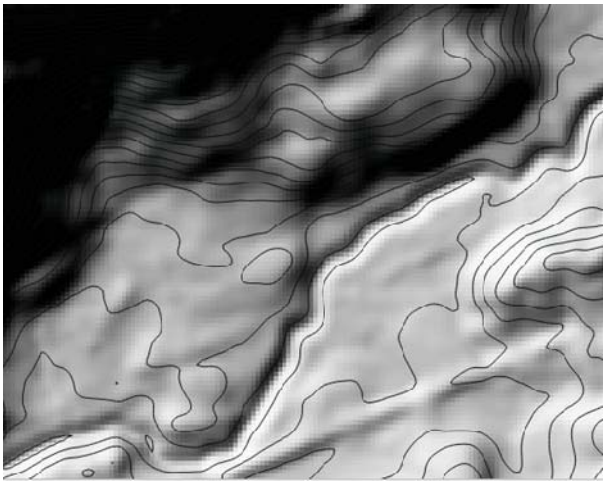
The purpose of this article is to demonstrate just one feature that was discovered as a result of viewing the DSM image data. When the hillshading algorithm with a 5x vertical scaling was applied to the survey data, an area of hillside on the northern side of the river had the appearance of a slump of material off the hillside into the valley. The course of the river appears to have been changed by the slumped material. Viewing the area on OSI.ie shows that the river's course has not changed since the 1837 first edition OS survey. This is the site of Dromdaleague House and property. Further investigation, including visiting the site, has yet to take place – hampered somewhat by COVID19 restrictions.

Finally, comparison of the DSM with the DTM for the same area illustrates how the production of the DTM clearly involves loss of definition. However, the production of contours does demonstrate that the DTM appears to enable reasonably accurate topography imaging. The areas that benefit most from removal of surface features are woodland, and extensive areas of made up ground, such as roadways with buildings alongside. Lidar surveys may be more productive in woodland areas due to some of the projected light bouncing back from the ground surface under the trees. The cost of survey data is high – one square kilometre costs about €100 for

each of the DTM and DSM. The survey company generously provided the DTM for comparison free of charge.



The area of possibly slumped hillside as seen in the hillshade of the DSM. Vertical exaggeration of 5x. Republic of Ireland DTM, DSM - © Bluesky International Ltd.



The area of possibly slumped hillside as seen in the hillshade of the DTM. Contours at 2 m. Vertical exaggeration of 5x. Republic of Ireland DTM, DSM - © Bluesky International Ltd.

How far inland did the Irish Sea Ice penetrate?

Michael E. Philcox, Geology Department, Trinity College Dublin, e-mail: mphilcox@tcd.ie

This 4-m boulder of Leinster granite (Fig.1) was unearthed from a diamict (till?) at the bottom of a thick pile of gravel and sand (Fig. 2) in the Blessington Delta complex (ING approx. N968163), more specifically from Pit 14 in the NW Zone (Philcox, 2019). The gravels are composed mainly of limestone clasts; the underlying bedrock is Silurian greywacke. The nearest limestone outcrop is >10 km to the west. The nearest in situ granite is c. 5 km to the east. The simplest interpretation is that a local mountain ice cap carried the granite westward prior to the eastward movement of limestone-bearing Midland ice during the Last Glacial Maximum (LGM). Maybe so, but an alternative should be considered.

Figure 1. Granite boulder, moved out of the way.

Figure 2. Silurian greywacke bedrock, overlain above gently right-dipping erosion surface by Quaternary gravels. Boulder came from diamict at base of gravels on the right.

While Midland ice converged on the Leinster Mountains from the NW, Irish Sea ice covered coastal areas from the NE and advanced some way along the northern end of the mountain front. It deposited marine shells at the north-western corner of the mountains near Brittas at an altitude of 290 m (Farrington, 1942) before the arrival there of Midland ice. It is assumed that further westward movement was blocked by Midland ice, but how far west is not known. Is it possible that the granite boulders in the Naas-Kildare area and in the Blessington gravels came from the north end of the pluton rather than more directly from further south? Is the geochemistry or mineralogy of the pluton known in sufficient detail to enable us to answer this?

A related question concerns another minor component of the Blessington gravels, namely a rock closely resembling (superficially at least) Lambay Porphyry. Again, the simplest interpretation is that this came from somewhere in the Kildare Inlier, but perhaps the geochemistry of the porphyry can be definitely tied to Lambay Island. If so, it would strengthen the case for a much further inland penetration of Irish Sea Ice than is currently known.

On the other hand, if the simplest interpretations are substantiated, then the pre-LGM mountain ice cap appears to have been more formidable than the literature suggests.

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GSI's regional assessment of groundwater resources

Robbie Meehan, consultant Geologist, here representing Groundwater Section, Geological Survey Ireland, e-mail: antalamhireland@gmail.com

Katie Tedd, Groundwater Section, Geological Survey Ireland, Beggars Bush, Haddington Road, Dublin 4

Coran Kelly, Tobin Consulting Engineers, Block 10-4, Blanchardstown Corporate Park, Dublin 15

Introduction

It was only in the 1960s that laws affording some level of protection to the rights of persons or companies abstracting groundwater came into being across the developed world (Younger, 2007). These regulations generally involved some form of permit, whereby an onus was placed on a new abstractor to satisfy a public authority that the new pumping operation would not adversely affect the continued availability of water to those abstracting in the vicinity.

The challenge of having good ecological status in our water bodies has been taken up in Ireland's endeavour to fulfil the requirements of the Water Framework Directive (European Union, 2000). An important component of this Directive is the assessment of the quantitative or volumetric status of our water bodies, which has been a significant driver in developing the water abstractions register (Government of Ireland, 2018) and the upcoming Water Environment (Abstractions) Bill which will outline how abstractions will be licensed.

It is within this developing regulatory framework that we can now better consider not only the role of groundwater, but also the details and logistics involved in how groundwater resources must be managed to meet both present day as well as future demands, without having a detrimental effect on ecosystems. In many respects the main objective of quantitative groundwater resource assessment can be summed up by the term "Safe Yield of an aquifer" (Wright, 1987; Zhou, 2009). The term 'Safe Yield' is the acceptable limit of annual abstraction from an aquifer. Originally it was taken as being equal to the annual recharge to the aquifer, but nowadays it is defined in a more subtle way as "the maximum annual yield from the aquifer which can be abstracted without adverse consequences" (Alley and Leake, 2004). Depletion of the resource is only one of the possible adverse consequences.

GSI's current groundwater resource potential assessment

Geological Survey Ireland (GSI)'s Groundwater Section has recently started to re-visit the regional assessment of potential groundwater resources in eastern Ireland. GSI is building upon previous regional assessments in the east of the country (e.g., EDA, 2008; An Foras Forbartha and GSI, 1981) and taking them a stage further by incorporating data that has become available since the above studies were completed. GSI is also using surface water catchments as the unit of assessment, which not only follows the principles of integrated catchment management but also enables more comprehensive water balance assessments to be undertaken as additional catchment-based quantitative data – surface water flows in particular – are based on the same study area. Such an assessment also allows a more thorough understanding of Irish groundwater and its contribution to surface water to be achieved, which will become increasingly important when considering the effects of climate change.

The initial project was developed from discussions with Irish Water regarding its water supply needs – including the emergency issues faced during the 2018 drought – and in considering their information gaps. The work is being conducted to identify potential areas for new groundwater supplies. Public water supplies are a specific focus of the project to provide scientifically-robust information to support Irish Water. One of the key elements to this holistic

approach has been close co-operation with the EPA, as providers of data and input into analyses.

The ultimate aim of this assessment will be to formulate a consistent and objective methodology to further assess groundwater resources on a regional basis in Ireland. Although there is already a good general understanding of regional resources in eastern Ireland from previous studies, this work will further develop and refine that knowledge and guide the relevant stakeholders to optimise groundwater resource management.

Data and methods employed in resource potential assessment

Within each catchment studied, surface water catchment boundaries are used to delimit the assessment unit (see Fig. 1).

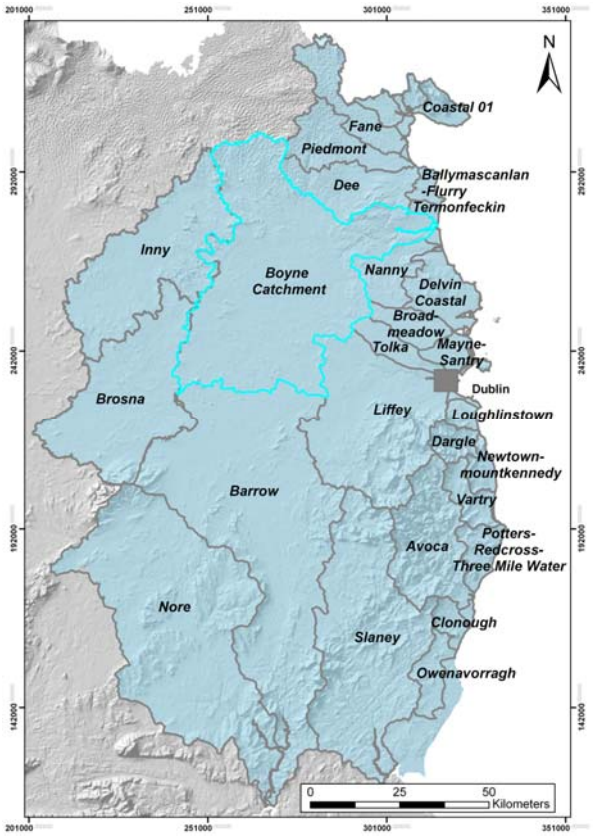

Figure 1. Catchments included in the east of Ireland study area, illustrating the situation of the Boyne as an example.

Within each assessment unit, the catchment is assessed in terms of its natural and anthropogenic setting, to form a conceptual model of the main drivers of hydrological and/or hydrogeological characteristics, flows and properties therein. Site specific data are then examined to ascertain if this matches the regional mapping concept. For example, the Dunshaughlin groundwater monitoring point at the southeastern end of the Boyne Catchment is located in Dinantian Upper Impure ('Calp') limestone bedrock, classified as a Locally Important, moderately productive, 'Lm' bedrock aquifer. Groundwater levels in the borehole have a relatively wide range (approximately 9 m, see Fig. 2).

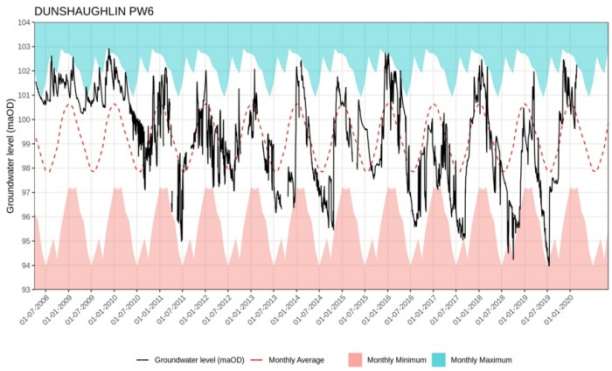

Figure 2. Groundwater levels at the Dunshaughlin Public Water supply borehole, at the southeastern edge of the Boyne Catchment.

Data from the regional and site specific assessments are then collated to develop conceptual models for sub-zones within the larger catchment region, with associated water balance calculations derived. The water balance calculations are holistic and consider groundwater as part of the entire catchment system. The sub-region conceptual models are then used to split the catchment up into similar hydrogeological zones. These zonations and the conceptual understanding of the catchment is then used to rank the different areas in the catchment in terms of groundwater resource potential. The water balance assessment is completed on the entire catchment to understand how water travels through it and how significant groundwater is within the catchment. The water balance consists of a calculation that accounts for all significant inputs and outputs of water to and from both surface water and groundwater systems in the catchment, and any interactions between these two systems.

The final portion of the study assesses potential constraints on future abstractions. An abstraction impact assessment is carried out, based on the Water Framework Directive's groundwater quantitative assessment, and a surface water capacity test is completed, based on EPA QUBE outputs. Other considerations taken into account include the presence and situation of protected areas within each

catchment, aspects related to groundwater vulnerability therein, and potential impacts on groundwater quality. An overview appraisal of the potential impacts of climate change is also incorporated.

As well as identifying areas with good groundwater resource potential for further, local scale investigation, these catchment-scale assessments also compile all data relevant to groundwater resources within that catchment into one place, develop hydrogeological conceptual models and water balances which will be of use to many separate and disparate stakeholders in the future, and, given that the studies are data-driven, identify obvious data gaps and areas for potential future research, assessment and monitoring.

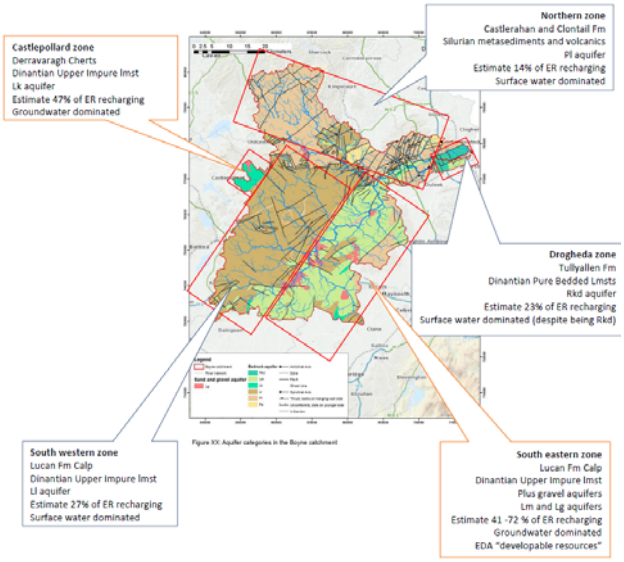

Figure 3. Hydrogeological conceptual model and resultant groundwater resource zonations for the Boyne catchment.

The current groundwater resources assessment work of Groundwater Section in GSI builds upon existing regional work and expertise but now also provides a consistent and objective methodology to assess groundwater resources on a regional and catchment basis. As well as this, the work identifies areas with good potential groundwater resources for further, local scale investigative study. Furthermore, though the 'top-down' study is at a regional scale, the methodology is quite powerful in terms of illustrating where there might be issues, even at a much more detailed, and local, scale.

As at start 2021, the project is about to conclude its desk study phase, which will inform hydrogeological field investigations at key sites, such as those expected to have good potential, or have shown conflicting sets of information at desk study stage. These site-scale investigations will be undertaken over the next year, and are aimed at quantifying resource characteristics. Once this has been completed and the catchment reports published, a project review will be undertaken to assess the prudence of rolling out the studies nationally.

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9. Upcoming Events

IQUA Spring Symposium 2021

Adrienne Foreman, Palaeoenvironmental Research Unit, NUI Galway, e-mail: a.foreman1@nuigalway.ie

Our Spring Symposium has been scheduled for 16 April this year and will have no registration fee. The spring meeting usually has a focus on postgraduate researchers, so we encourage all PGRs with research to share to submit an abstract. We are happy, of course, to receive abstracts for any and all exciting Irish Quaternary research from established and other early career researchers as well. Please include a note with your abstract indicating if you are a postgrad.

Submit abstracts to iquaabstracts@gmail.com by 5 March 2021.

Looking forward to seeing what everyone is up to!

10. Obituaries

Eric C. Grimm (1951–2020)

On Sunday, November 15th, 2020, Dr. Eric C. Grimm, loving husband, father, and world-renowned scientist, passed away suddenly at the age of 69. Eric was born on August 20th, 1951 in Cincinnati, Ohio. He grew up in Rapid City, SD, exploring the geology and plant life of the Black Hills. He was fascinated with science, and was an insatiable reader. Eric received his Ph. D. in Ecology from the University of Minnesota in 1981.

Eric accepting his Distinguished AMQUA Career Award in Santa Fe, New Mexico, 2016.

In 1988, he moved to Springfield, IL and began his career at the Illinois State Museum as the Curator of Botany, rising to become the Director of Sciences in 2013. He helped lead the Landscape History Program, which contributed to the understanding of long-term changes in climate, landforms, ecosystems, and human-environment interactions and was the basis for the Museum's natural history hall.

Eric was committed to sharing scientific research with the public. He was a brilliant lecturer and excelled at explaining complex topics in a friendly and understandable way; his lectures on climate change always drew a crowd. He was internationally known and respected for his studies of fossil pollen (palynology) and research documenting long-term changes in vegetation and climate. He developed the North American Pollen Database, which was used to refine climate models to predict future climate change and to understand how species adapt to changing climates.

After his retirement from the Museum, he continued his robust research agenda and development of the Neotoma Paleoecology Database. He was deeply respected by his colleagues and beloved for his generosity in mentoring young scientists. Among his many honours, he was elected a Fellow of the American Association for the Advancement of Science in 2002, received the Outstanding Service

Award from the International Paleolimnology Association in 2012, and awarded the 2015 Distinguished Career Award by the American Quaternary Association.

He spent the past five years working from his home office in Jefferson, SD where he enjoyed tending to his vegetable garden, taking walks with Jane at the Adams Homestead and State Nature Preserve, and assisting with the care of his mother-in-law Pauline Allard. Eric loved spending time outdoors hiking, fishing, and skiing. His friends and family will fondly recall casual walks becoming guided nature tours, with Eric stopping to inspect leaf shapes and cheerily relating the scientific name of every tree and shrub.

This text is an excerpt of the obituary by Eric Grimm's wife Jane Anne Allard published online at https://www.legacy.com/obituaries/keloland/obituary.aspx?n=eric-grimm&pid=197110651&fhid=28599. Jane Anne Allard kindly gave permission to reproduce the text in the newsletter.

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The annual membership cost is: €20 waged; €10 students/ unwaged. IQUA offers a fast, safe, online payment system already familiar to many (PayPal) for joining IQUA or renewing your membership, and for purchasing past field guides (where available). PayPal allows you to pay securely with your credit/debit card via the IQUA website: http://www.iqua.ie/membership.html. If you do not have access to our online PayPal system, please complete the following form and send it with a cheque for the relevant annual subscription to the IQUA Treasurer Mark Coughlan at the address below. Cheques should be made payable to IQUA.

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O'Brien Centre for Science (East)
University College Dublin
Belfield
Dublin 4
Ireland

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