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LETTER

Post-Brexit implications for transboundary groundwater management along the Northern Ireland and the Republic of Ireland border

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There are multiple transboundary groundwater bodies shared between Northern Ireland and the Republic of Ireland that are currently managed jointly through the EU Water Framework Directive. In 2016 the United Kingdom voted to leave the European Union and consequently, there are uncertainties regarding the future status of groundwater management between Northern Ireland and the Republic of Ireland in regards to future UK environmental policy. This paper explores the post 'Brexit' transboundary groundwater implications, if a transboundary groundwater agreement is required between Northern Ireland and the Republic of Ireland, and, should it transpire, what form should it take.

Introduction

Transboundary aquifers are bodies of groundwater that are shared between two or more countries such that groundwater moves across political borders of countries (Wada and Heinrich 2013). There are currently around 608 transboundary aquifers identified across the world (IGRAC and UNESCO-IHP 2015). This precious and vulnerable resource requires joint and conjunctive management between riparian states (Fraser *et al* 2018). It is well known that transboundary groundwater is an area of international law that has been underrepresented (Matsumoto 2002). There is a high disparity between the number of transboundary aquifers and groundwater bodies identified globally (608) and the number of ratified international treaties that are in place to govern them (6), which include 4 full agreements and 2 memorandums of understanding (Burchi 2018). International groundwater law can be considered to be in a juvenile state but has begun to evolve. A recent push toward transboundary water management has come in the form of the sustainable development goals (SDG), for which transboundary cooperation is necessary (McCracken and Meyer 2018).

The European Union (EU) has been progressive in its effort to regulate and manage transboundary resources. Within the EU Water Framework Directive (WFD) (2000) (European Commission 2015, European Commission 2000), member states are asked to align their water policies with EU standards and manage resources in a cooperative manner. However, on the 26th March 2016, the United Kingdom (UK) voted to leave the EU (referred to hereafter as Brexit). The lead-up to Brexit has resulted in uncertainties regarding the future status, and implications, of the UK's environmental policy.

This paper explores the need for an international agreement governing the management of transboundary groundwater resources shared between Northern Ireland and the Republic of Ireland to negate negative Brexit policy impacts. This article first reviews the setting of the Republic of Ireland–Northern Ireland border, focusing on issues that may pose a threat to transboundary water resources in the region. Secondly, it considers the implications that Brexit may have upon future environmental legislation in Northern Ireland and makes a case for a transboundary water agreement between the two countries. Finally, we present a review of two international groundwater

agreements with consideration to their development, and the lessons that can be applied to this case study.

Study area

Ireland is found in the Atlantic Ocean to the west of Great Britain. It is the third largest island in Europe and encompasses an area of 84 421 km² (William 2009). Within, it is home to the countries of the Republic of Ireland and Northern Ireland, the latter being a devolved nation of the United Kingdom.

Northern Ireland's constitutional status

Devolution for Northern Ireland was established under The Belfast Agreement, also known as the Good Friday Agreement, and was signed on 10 April 1998. Under the Agreement, the UK Parliament transferred legislative and executive powers over most local affairs to the Northern Ireland Assembly and Executive Committee—including environmental legislative control (Northern Ireland Assembly 2019). Since this agreement, constitutional and political development has progressed including formulation and implementation of environmental legislative controls.

Geology and hydrogeology

The geology of the Republic of Ireland is varied. Limestones take up approximately half of the land surface on the island with the remainder being composed of a mixture of sandstones, metamorphic and basement rocks (Williams 1970, Gunn 2000, Geological Society of Ireland 2004). A significant percentage of the limestone, ~75%, is karstified and as such the geology is classified by distinctive terrains that have formed as a result of dissolution the rock. Karst is a type of geology which is characterized by distinctive flow characteristics and landforms as a result of exceedingly high bedrock solubility and fracture driven, secondary porosity, including caves and smaller conduits. This type of terrain is typically found in limestones that are all easily dissolved by water (Hiscock 2009). Importantly, the tendency for karst aquifer systems to be relatively pervious, with interconnected underground channel and cave networks, means that groundwater quality or quantity impacts at one location can be transmitted relatively rapidly to adjacent locations on a regional scale (kilometers). This increases the potential for cross-boundary effects.

Alongside limestones and karst, the island of Ireland exhibits sandstones and basement lithologies alongside superficial deposits such as clay, gravel and outwash sands from past glaciation periods (British Geological Survey and Department of the Environment for Northern Ireland 1994).

Transboundary aquifers

There are a total of 34 transboundary aquifers shared between Northern Ireland and the Republic of Ireland;

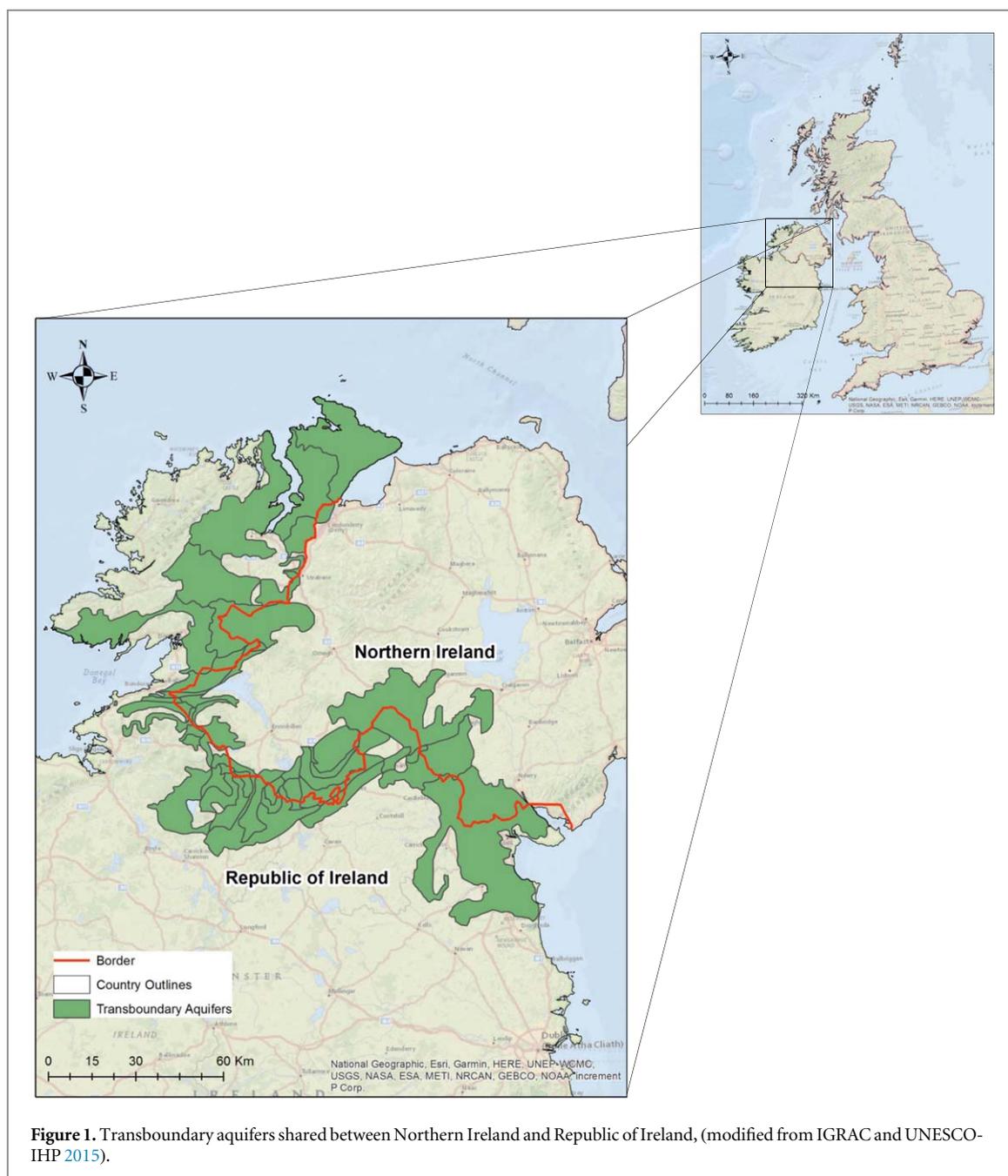
composed of karstic, sandstone, superficial deposits and basement lithologies (figure 1). These were delineated following the methodology outlined in Geological Survey of Ireland (2003) which involved a literature review of the geologies of both countries with 1130 distinct formations then grouped into 'rock unit groups' (RUGs). Major aquifers were then designated on the basis of these RUGs with the agency with the largest area of aquifer in its respective country taking the lead on the description of the ground-water body.

The transboundary aquifers shared between Northern Ireland and the Republic of Ireland are composed of intrusive igneous, Silurian, Ordovician and Precambrian basement lithologies, which provide some shallow groundwater through shallow cracks and joints opened by weathering; Viséan Sandstones that are locally important aquifers that transfers water through intergranular flow; Limestones and karstic aquifers in which flow is primarily in fissures and other discontinuities; and finally superficial deposits such as clay, gravel and outwash sands that are also highly productive but shallow (British Geological Survey and Department of the Environment for Northern Ireland 1994).

Groundwater use within Northern Ireland is currently limited due to the country's abundant surface water resources. With the majority of the area supplied by piped network coverage, groundwater abstraction is often limited to private borehole supplies or occasional public supply (6% of the 740 million litres currently used on a daily basis) (Mitchell 2004, Masterson *et al* 2008). In contrast, The Republic of Ireland uses groundwater resources more heavily than Northern Ireland. This is due to a combination of the Republic of Ireland having more plentiful groundwater resources which contribute to approximately 25% of national drinking water (Daly and Warren 1998) and Northern Ireland having a considerably higher rate of piped network water coverage (99% in Northern Ireland versus 87.5% in Republic of Ireland) (McKibbin 2010). For both countries, groundwater is also an important contribution to sustaining river flows through baseflow (Mitchell 2004).

Success of the WFD

EU membership has been instrumental in driving environmental policy in the UK and Republic of Ireland (Burns *et al* 2018). In 2000, the EU WFD was published and entered into force due to increasing demand for cleaner and more sustainable rivers, aquifers, lakes and beaches. Its main purpose was to set objectives for the protection of water bodies for the future (European Commission 2015). The WFD promotes an integrated water resource management approach. It calls for all member states to take responsibility for their inland and coastal water bodies



achieving a ‘good status’ or better (DAERA 2019). To achieve this, member states must establish integrated basin level water management and publication of river basin management plans that set out a management agenda for six-year time frame cycles (2009–2015, 2016–2021 and 2022–2027) (DAERA, 2019, European Commission 2015, Daly *et al* 2016). These plans outline the approach each member state will take to ensure each water body reaches good status in terms of both water quality and quantity (European Commission 2015).

Furthermore, the EU has pushed for clear environmental definitions in discourse and principles. One such example is the ‘Polluter Pays Principle’ which was introduced in the Treaty on the Functioning of the EU under article 191 (European Union 2012) and was

codified in the 2004/35/CE EU Directive on Environmental Liability with the Regard to the Prevention and Remedying of Environmental Damage (European Commission 2004). A further requirement of these EU Directives is that member states must translate this approach into national legislation and policy. To comply with this, Northern Ireland introduced The Environmental Liability (Prevention and Remediation) Regulations (Northern Ireland) 2009 (Northern Ireland Assembly 2009) and the Republic of Ireland introduced the European Communities (Environmental Liability) Regulations (2008) (Government of Ireland 2008).

Article 5 of the WFD required member states to also characterize all aquifers within respective River Basin Districts. This included identification of their

extent, location and all influencing pressures and risks that are relevant to them. In the River Basin Management Plan for the Republic of Ireland (2018–2021) there is explicit mention of cooperation regarding transboundary waters (section 10.5) with the Neagh Bann International River Basin District specifically having 35 shared water bodies, 5 groundwater, and the North Western International River Basin District having 85 shared water bodies, 29 groundwater shared with Northern Ireland (North-Western International River Basin District 2009). To meet the WFD requirements for these, intergovernmental ministerial coordination was required, alongside the development of working groups with representatives from both states and the establishment of joint technical groups (Government of Ireland 2018). An example of this is the three jointly established International River Basin Districts shared between Northern Ireland and the Republic of Ireland, each with its own International River Basin District Management Plan (DAERA 2008a).

The main International River Basin Districts are thus the Neagh Bann District, the North Western Basin District, and the Shannon Basin District. A small portion of the Shannon Basin District is within Northern Ireland, and in consultation with the Republic of Ireland, the management plan was drafted by the Republic of Ireland (DAERA 2008b). The other two International River Basin Districts are jointly managed between the two member states and are coordinated through the North–South WFD Coordination Group (DAERA 2008a).

The Neagh Bann international river basin district spans 6000 km² in Northern Ireland and 2000 km² within Ireland (DAERA 2008b). The North Western International River Basin District spans 7400 km² in Ireland and 4900 km² in Northern Ireland (DAERA 2008a). The North Western and The Neagh Bann International River Basin District Management Plans are composed of four components; a joint document focusing on the cooperation of the status of the shared waters and future shared environmental objectives; draft plan summary documents detailing specific information on the assessments and proposals for status, objectives and measures for each part of the international river basin; an electronic information system that provides data on individual water bodies; and background documents such as technical studies that provide details of monitoring programs and classification of waters (DAERA 2008a).

All groundwater bodies shared between the two countries across the International River Basin Districts are at a good status and the overall provision is protection of this status (DAERA 2008a). Through examples like this, it is observed that EU membership has provided a platform for a shared agenda through the WFD and has allowed for transboundary cooperation (Burns *et al* 2018).

Supporting the river basin district management programs is the CARE (Catchment Actions for Resilient Eco-systems) project. Funded by the EU, its aim is to improve the quality of transboundary river basins across the Finn, Blackwater and Arney catchments (Geological Society of Ireland 2019). Although international groundwater is at a good status under the WFD, other aquifers in the island of Ireland are not at the same standard. The WFD is working to address these issues but disruptions to the progress being made by Brexit and potential changes in environmental legislation could be detrimental.

Alongside the groundwater bodies within the international basins shared between Northern Ireland and the Republic of Ireland, the two countries also share many international rivers. In total, there are 26 rivers shared within the Neagh Bann District and 51 within the North Western Basin District. As of 2009, in the Neagh Bann District only 30.8% of the rivers were ‘good status’. In the North Western Basin District, it was even lower at 23.5%. These figures may have changed since but no reports have been discoverable on the status of international surface waters from 2009 onwards. Within the River Basin Management Plan for Ireland 2018–2020, there have been three key areas identified for cross-border cooperation. These include 21 water bodies ‘At Risk’ and 12 water bodies ‘Under Review’ (Government of Ireland 2018).

The main limitations on the progress of the surface waters to good status include agriculture, domestic waste-water treatment systems, urban waste-water, urban runoff and historically polluted sites (Government of Ireland 2018). Progress will need to be made in this area as continued poor status could impact groundwater through hydrological connections and compromise their good status. Despite this, the WFD has still been instrumental in developing the environmental policy within Northern Ireland and the rest of the UK for the better.

Key transboundary groundwater concerns

In discussing the potential need for a transboundary management agreement between the two countries, it is important first to understand the key potential threats to groundwater in the region that the WFD has been aiming to address.

Vulnerability of Karstic aquifers

It is well established that karst systems do not follow conventional Darcian flow in these aquifers, or beneath river basins. As such, one of the most significant challenges in the management of groundwater systems in karst derives from the variability of flow characteristics both spatially and temporally, and the resulting challenges in quantifying their extent or even delineating a true boundary (Bonacci 2008). The nature of karstic systems is such that surface water and

groundwater interacts closely, and any actions on overlying surface waters may result in a rapid and unpredictable result in impacts to water quality or quantity in the subsurface system (Moe *et al* 2016). Without an in-depth understanding of the true nature of the aquifer, there can be no guarantee of protection of the environment, local receptors or itself (McConvey 2015). The use of karst water recourses therefore needs to be understood effectively and safeguarded as populations become more reliant on them for water supply (Bonacci 2008). This is especially important given that the 2030 SDGs, with Ireland and the UK as signatories, are designed to focus on local impacts. Here in particular SDG6 requires transboundary management to the benefit of local populations.

History of waste disposal

Before implementation of the WFD, the Republic of Ireland disposed of commercial and industrial waste in landfill sites rather than managing it in cooperation with the environment (Fagan 2010). Illegal waste disposal is a well-known issue in Northern Ireland that has arisen due to historically weak enforcement of environmental regulations (Brennan 2016). This combined with the costs of waste disposal in the Republic of Ireland resulted in a black market for illegal waste trade and disposal. Examples of potential waste issues include fuel laundering, liquid sheep dip (used to rid sheep of external parasites) disposal, illegal landfill sites and illegal waste disposal on unlicensed land (Stevenson 2008). Fuel laundering is the process of taking red diesel (diesel with dyes added and sold for agricultural purposes, and which has lower excise duty), and stripping of this dye using a combination of harmful solvents and an absorbing material. This process is inefficient and results in hazardous waste to the makeshift environments in which it is carried out (Grant Thornton UK LLP, 2013). Historically fuel laundering has been carried out using simple ingredients, such as cat litter, to absorb dyes, achieving an illicit but profitable result. Fuel laundering has been especially common along the border as a result of fuel price discrepancy and the comparative remoteness of the region. It is a well-known issue, with HM Revenue and Customs having dismantled 38 laundering sites in Northern Ireland in 2013, resulting in the seizure of 574 238 l of fuel; an operation that would be unlikely to have occurred without the increased environmental regulations enforced by EU legislation (Cross Border Organized Crime 2014). One less known issue is the fact that disposal of the waste created from the laundering process carries high environmental risks. These wastes are 'illegally deposited' in small volumes in wooded areas or along roadsides. It is likely that pollutants will leech into the subsurface and be carried in runoff into groundwater and watercourses harming the environment, ecology and biology of these regions (Donnelly 2015). Migration of petroleum hydrocarbons such as

benzene, a carcinogen, is a further pollution risk from illegal operations regarding diesel laundering and illicit fuel activities. The risk of spillage of the actual fuel when transporting (or working) is high in the makeshift operations, carries the contamination risk of NAPL migration into the subsurface and groundwater, particularly in areas with Karstic aquifers. Although the WFD has made considerable progress in reducing water contamination from illegal waste disposal, there is always a difficulty in controlling illegal activity and changes in future environmental legislation post-Brexit could create environmental ambiguities that could be taken advantage of.

Agricultural contamination

Agriculture is a major industry across the island of Ireland (Richards *et al* 2009). However, it has significant impacts for surface and groundwater contamination (Schulte *et al* 2006). This is particularly common in rural areas where crop and livestock farming is prevalent (EHS 2000 in Wang and Yang 2008) and nitrate and phosphate are regularly utilized in chemical fertilizers, soiled waters and slurries. Impacts on water resources include chemical pollution and microbial contamination but most commonly eutrophication of water from nutrient enrichment (Musolff 2009, Richards *et al* 2009). Historically, surface water and groundwater has been widely contaminated by these activities (Aggelopoulos and Tsakiroglou 2009, Nziguheba and Smolders 2008, Rahn *et al* 2010, Strebel and Böttcher 1989 in Barrett *et al* 2013). Examples of specific industry established contamination include the Upper Bann Catchment in Northern Ireland where up to 11% of the basin exhibits a high risk of nitrate contamination (Wang and Yang 2008), phosphorus contamination in the North West of Ireland (Schulte *et al* 2006), and in nitrate contamination in rivers in the south east of the Republic of Ireland (Richards *et al* 2009).

The reduction of diffuse nutrient emission to waters to control eutrophication of rivers, lakes, estuaries and near coastal waters has improved under the WFD. There are still improvements to be made, particularly to surface waters that may be connected to internationally shared groundwater (Richards *et al* 2009). Any groundwater contamination on one side of an International River Basin can cause negative impacts for the neighboring country due to the nature of groundwater flow systems transferring water from one part of an aquifer to another.

Surface water contamination

In areas where surface waters are hydraulically linked to groundwater, any contamination of surface water can impact connected aquifers. As previously discussed, the surface waters shared between Northern Ireland and the Republic of Ireland are not at as good a status as the groundwater's. This poses a risk to the

status of groundwater in these international basins, particularly if environmental regulations over the status of surface waters were to change post-Brexit. Furthermore, any future contamination of surface water supplies may push either country to utilizing their groundwater more, resulting in increased abstraction that could become unsustainable. This could cause cross-border conflict over groundwater availability and access.

Increased pressure for groundwater abstraction

As it stands, Northern Ireland and the Republic of Ireland do not abstract large quantities of groundwater from their aquifers. Climate change is starting to increase stresses upon water resources in these traditionally water rich regions as global temperatures rise. The IPCC has reported changing precipitation patterns and extremes across the globe (Bates *et al* 2008). The island of Ireland is not immune to this. Studies across the island of Ireland indicated a trend of higher river flows in the winter and spring, alongside lower river flows in the late summer and autumn (Cunnane and Regan 1994, Charlton and Moore 2003, Murphy and Charlton 2006, Steele-Dunne *et al* 2008 in Hall and Murphy 2010, Arnell 2006). On top of this, global temperatures are also rising; with a 1.25 to 1.5°C increase in mean monthly temperatures predicted for 2021–2060 in the Republic of Ireland (McGrath *et al* 2005 in Brady and Gray 2010). Increasing temperatures and sporadic rainfall can contribute to increased water stress. In time of water stress, the countries within Ireland may look to their groundwater supplies for greater security.

Many regions on the island of Ireland are also now facing the problem of water demand exceeding supply due to population growth (Forfás 2008 in Brady and Gray 2010). Consequently, this increase in population will lead to an increase in demand for public and private water supplies (Hall and Murphy 2010). Public supplies may look to groundwater to support this increase in demand. If they do so, it is essential this is done under consultation with neighboring countries in order to prevent cross border conflict due to over abstraction and the consequences that may come with this.

The changing political agenda

The consequences of Brexit for environmental law within Northern Ireland are uncertain and therefore are considered broadly herein. The United Kingdom's decision to exit the EU put into effect article 50 of the Lisbon Treaty. This triggered a two-year negotiation process for a member state to leave the EU, after which a framework for future relations with the EU must be decided (European Union 2007). As the UK's environmental policy has until now transcribed EU law, the decision to leave the EU has resulted in an increasing

level of ambiguity for future environmental legislative instruments, a challenge facing environmental, and more specifically to this case, water legislation and policy across the Northern Ireland–Republic of Ireland border.

Early in January 2020, the UK government voted through a withdrawal bill that agrees the terms of the UK's departure from the EU. The future relationship with the EU will not include a single market or customs union. This alignment removes the UK's obligation to adhere to strict EU directives and regulatory targets, leaving the UK Government free to legislate as it sees fit. The UK officially left the EU on the 31st January 2020 and when it did, EU environmental legislation was incorporated into UK law. (UK Government 2017). The withdrawal agreement now gives the UK the power to amend or change any law as it sees fit moving forward and omits a legally-binding clause committing the UK to not reduce green protections after Brexit. This suggests that the government's intention moving forward is to amend environmental legislation post-Brexit and not uphold the WFD. This could ultimately lead to a relaxation of environmental standards (Cave 2016).

The Northern Ireland Assembly and Executive Committee has devolved power from the UK government over environmental legislation (Northern Ireland Assembly 2019). It will therefore be up to Northern Ireland how they decide to move forward with environmental regulation within the country; to uphold the WFD and deal with potential cross-border discrepancies as EU legislations changes (which Northern Ireland would have no say in), or, develop and implement new environment regulations and move away from the WFD. Currently, Northern Ireland has no official position on post-Brexit environmental governance, but stakeholders have proposed that considering Northern Ireland's weak past of environmental governance and its politically instable past, the county may benefit from taking a lead from the UK government's position, which is to pass its own new environmental legislation (Burns *et al* 2018).

When Northern Ireland and the Republic of Ireland signed the Belfast Agreement the two countries established the North–South Ministerial Council. Its purpose is to foster cooperation between Northern Ireland and the Republic of Ireland through data exchange, joint consultations and cooperative action over the 6 areas it covers, the environment being one (Brennan and Dobbs 2019). The Northern Ireland Assembly has experienced multiple periods of suspension, with the latest lasting three years and ending in January 2020 (Northern Ireland Assembly, 2020). Consequently, the North–South Ministerial Council has also been suspended numerous times resulting in a lack of environmental policy development and environmental governance reform during these periods (Brennan *et al* 2019).

Moving forward post Brexit, if the Northern Ireland Assembly chooses to move away from the

WFD amid potential cross-border discrepancies from evolving EU legislation, the government could look to international law for guidance over how to continue managing their transboundary groundwater resources with the Republic of Ireland. This could be discussed and agreed upon through the North–South Ministerial Councils mechanisms. This could be in the form of an international transboundary water agreement between the two countries. What form this would take must be carefully considered.

Lessons from current transboundary cooperation

For countries out-with the EU and thus the WFD scope, international water law provides an overarching framework to address issues that arise when implementing effective integrated water resource management of transboundary surface water and groundwater resources. There are two legal instruments if countries wish to foster a transboundary groundwater agreement. The Convention on the Law of the Non-Navigational Uses of International Watercourses (UNWC) (United Nations 2014) is the most recent ratified legal instrument that addresses transboundary watercourses. This convention applies to all international watercourses and their waters, and specifically to this case, to transboundary groundwater aquifers that are hydraulically connected to surface waters (Article 2). The convention is based on the concept of ‘equal and reasonable utilization’ thus entitling watercourse states to equal rights to the utilization of the watercourse (Article 5). Under the convention, states are also required to not cause significant harm to the watercourse (Article 7). States are also obliged to share data relevant to the watercourse regularly with each other (Article 9) to preserve dependant ecosystems of the watercourse (Article 20) and manage pollution and/or contamination (Article 21) (United Nations 2014).

The Watercourse Convention is however not a complete inclusive representation of the status of groundwater within international law. The convention was never created with the purpose of covering all aspects of groundwater international law within its scope. Subsequently, its criteria as to whether a transboundary aquifer is within its scope is strict (Eckstein 2007). For example, aquifers that are not hydraulically connected to surface water systems but which may still transmit water across international boundaries are not under the Watercourse Convention (Rieu-Clarke *et al* 2013). Non-renewable groundwater sources and aquifers that are not connected internationally through surface waters or river basins are not considered to be part of this convention (Eckstein 2007). The Watercourse Convention does not have a standard definition of what constitutes a transboundary aquifer alongside suggested criteria for the

management of these resources. These are considerable limitations of this convention. For the karstic aquifers within the Republic of Ireland and Northern Ireland, the Watercourse Convention would be applicable as karstic aquifers are inherently connected to surface water systems. However, there are other transboundary aquifers that are not karstic between the two countries and thus potentially not connected to surface water systems. These aquifers would not be protected under the Watercourse Convention. Subsequently, an agreement based on the Watercourse Convention would only cover some of the transboundary aquifers within the island of Ireland, and leave other aquifers potentially vulnerable.

An alternative to the Watercourse Convention is the UN Draft Articles on the Law of Transboundary Aquifers (United Nations 2008). The UN Draft articles on the Law of Transboundary Aquifers were published in 2008 after a brief 6 year development initiated in 2002 by the UN International Law Commission but have not yet been ratified. These articles aim to account for situations where the UNWC is not appropriate for developing transboundary groundwater agreements (Sanchez *et al* 2016). This set of draft articles differs to the Watercourse Convention in that they focus only on groundwater/groundwater systems (Article 2a). For an aquifer to fall under the governance of the draft articles, it must cross a political border or have a hydrological connection within another country/state (thus the draft articles extend to all surface waters connected to transboundary aquifer). The draft articles are intended to provide guidance to member states when the Watercourse Convention does not. The articles focus on the use of transboundary aquifers/aquifer systems and other activities that may impact said aquifers/aquifer systems and encourage measures to protect and manage them (United Nations 2008). The articles promote equitable and reasonable use (Article 4), regular exchange of data (Article 8), the identification of recharge and discharge zones (Article 11) alongside cooperative system monitoring (Article 13) and implementation of measures to do no significant harm (Article 12). The definition of the term ‘aquifer’ within the articles is unique and was seen as a compromise between policy makers and scientists. Traditionally, an aquifer is a geological unit with the ability to store and transmit water. However, the articles consider the aquifer as both the geological unit and the water that is stored within it. Under this definition, a portion of the aquifer today may not be part of the aquifer tomorrow as groundwater are often in constant flux. This definition may cause issues when member states try to define the physical extent of the transboundary aquifer they wish to manage (Eckstein 2007).

Although the draft articles have been annexed to a UN General Assembly Resolution, they, as of yet, have only assisted in the development of one international agreement regarding the shared management, equitable use and development of transboundary aquifers

(The Guarani Aquifer Agreement) (Sindico *et al* 2018). The draft articles can also only provide direction for member states and, consequently, only holds legal obligation if all involved states agree to use them.

The Watercourse Convention and the Draft Articles differ to the WFD in multiple ways. Firstly, implementation of the WFD into domestic law is a legal requirement as a member state of the EU. The Watercourse Convention and the Draft Articles do not hold this weight as they are optional legal frameworks that countries can opt in to if they wish. Without the WFD in place, member states have no obligation to cooperate over their shared resources. Secondly, the WFD is applicable across all member states borders, whereas the Draft Articles and Watercourse Convention are meant for a single water body/system agreement. These differences make the WFD one of the most progressive instruments globally that addresses transboundary water management.

Outside of the WFD, there are only 4 full transboundary groundwater agreements currently in place internationally: The Genevise Aquifer Agreement (France and Switzerland) (1977 and 2007); the Regional Strategic Action Plan on the Nubian Sandstone Aquifer (Chad, Egypt, Libya and Sudan) (1992 and 2000); the Guarani Aquifer Agreement (Argentina, Brazil, Paraguay and Uruguay) (2010) and the Al-Sag/Al Disi Aquifer Agreement (Jordan and Saudi Arabia) (2015). Additionally, there are two memorandum of understanding: The North West Sahara Aquifer System (Algeria, Libya and Tunisia) (2002–2008) and the Iullemeden Aquifer System (Mali, Niger and Nigeria) (2009) (Burchi 2018). For the Northern Ireland-Republic of Ireland case study, the Genevise and Guarani Aquifer Agreements are the most relevant.

The Genevise Aquifer agreement

The Genevise Aquifer agreement can be seen as a positive example of transboundary water cooperation between an EU member state (France) and a non-EU member state (the Canton of Geneva in Switzerland). This sets a precedent for potential EU/non-EU groundwater relations by illustrating that a groundwater agreement can be developed and maintained successfully without full EU status and could be used as a model for Northern Ireland and the Republic of Ireland groundwater relations if the UK decides to no longer follow the requirements of the WFD.

The Genevise aquifer supplies water to approximately 700 000 people in Geneva, Switzerland and communities across the border in Haute-Savoie, France. In the 1960/70s groundwater levels in the aquifer dropped significantly due to over abstraction, considered a result of poor coordination between stakeholders (de los Cobos 2018). The decision was made to channel water from the aquifer recharge zone, the Arve River, and using land drains recharge water directly into the aquifer.

An agreement was reached between the Canton of Geneva (Switzerland) and the Department of Haute-Savoie (France) to last for 30 years and signed on 19/June/1978. This has since been superseded by a 'convention on the protection, utilization, recharge and control of the Franco-Swiss Genevise aquifer' that came into force on 01/January/2008. Both the 1978 and 2008 conventions require an international commission who oversee all actions that impact upon both states. The commission sets out a yearly utilization program which considers the needs of all users and outlines any measures required to mitigate any pollution events (Quevauviller *et al* 2009). Meetings of the commission are held bi-annually and alternate between France and Switzerland with the head of each respective delegation taking the lead in their own country. This has worked to avoid conflict and the agreement and commission is seen as a globally successful example of successful transboundary water cooperation.

One successful aspect of the Genevise aquifer agreement is the focus upon local management in its structure, which is topically very relevant to recently agreed SDG goals, targets and indicators. Both sides of the agreement were developed by local authorities and as such the agreement was entirely focused to the specific needs in a local context. The region has also set up a transboundary water community committee to further enhance cooperation and has been strengthened by a memorandum of understanding regarding cross border water cooperation signed on 12/December/12 (de los Cobos 2018).

The Genevise Aquifer Agreement is primarily an agreement on the abstraction of groundwater resources for public supply (de los Cobos 2018). However, after the Fukushima accident and an extreme drought in the region in 2011, the committee also implemented measures to prevent all risks of pollution (and water scarcity) to the transboundary basin (de los Cobos 2015, 2018). Similar pollution prevention measures could be adopted in the Northern Ireland- Republic of Ireland case study.

Although it does not entirely apply, it could be seen that the international cooperation displayed between the canton of Geneva and France is a model example for the case of Northern Ireland and the Republic of Ireland. It is important to emphasize that Switzerland is not an EU member state and as such is not bound to the requirements of the WFD. For the case of the post-Brexit UK, and any change to environmental legislation that no longer fully follows the WFD, this case provides evidence that international water relations can be sustained with one side being a WFD member and the other not and that pollution control can be part of a working agreement.

The Guarani aquifer agreement

The Guarani Aquifer System is one of the world's largest freshwater reserves and encapsulates an area of 1100 000 km² in South America. The system is shared

between Argentina, Brazil, Paraguay and Uruguay (Foster *et al* 2009). In 1979, Argentina, Brazil and Paraguay signed an agreement regarding the use and protection of the Parana River, a major resource for all three states. This reduced tension in the region that had resulted from conflicting interests on the river, and signifies a high potential for international cooperation between the states. More recently, representatives from Argentina, Brazil, Paraguay and Uruguay met in 2003 with to develop the legal framework for the protection, use and management of the Guarani aquifer. During this period of development, 2003–2009, the Guarani Aquifer System Project (GASP) was negotiated between all four states and numerous NGOs.

The Guarani Aquifer agreement was the first transboundary groundwater agreement developed since the UN Draft articles on the Law of Transboundary Aquifers were published in 2008. This agreement is unique as it was developed to actively prevent issues of groundwater depletion, pollution, and resulting conflict, rather than act as a reactive measure as demonstrated in the Genevese example. This is seen to be a key facet of the draft articles with ‘development, utilization, conservation, management and protection of groundwater resources’ as one of the key principles included (United Nations 2008). Furthermore, there was a push to involve all levels of stakeholders in the agreement. Although national and international players carry the most power, practical decision making, implementation and any institutional changes on a day to day basis come from the local scale with any agreement directly impacting upon them the most (Green 2010). This awareness of the different levels of stakeholders involved, alongside a high level of data exchange cooperation within the project both directly contributed to the successful development of the Guarani Aquifer Agreement (Villar and Riberio 2011). Specific articles within the agreement that could be applicable to the Northern Ireland-Republic of Ireland case study are Article (3): that parties will use the water resource in a reasonable and sustainable manner, not causing significant harm, Article (4): that parties promote the conservation of the environment, and article (14): that parties will cooperate in the identification of at risk areas, specifically ones that require treatment.

This agreement is an example of the challenges encountered when developing a transboundary groundwater agreement. This agreement is vast in its scope and took over 16 years (2002–2018) to be ratified due to a myriad of complications including disagreements on dispute settlement provisions in 2005 which halted talks until 2010 (Sindico *et al* 2018). Argentina and Uruguay ratified in 2012, Brazil in May 2017 and finally Paraguay in April 2018, bringing the agreement into force (Villar 2018).

Theoretically an agreement between Northern Ireland and the Republic of Ireland should be more simple to develop and ratify than that for the Guarani

Aquifer due to the smaller number of stakeholders and current political oversight. However, the two countries have a long history of strained relations. As a result, a full international groundwater agreement should during development emphasize the involvement of local stakeholders as was the case for the development of the Guarani agreement. Not only does this approach align with the SDG ethos, but it is likely the most valuable lesson from these two agreements that can be applied to the Republic of Ireland–Northern Ireland case study.

Moving forward with transboundary aquifer management

Transboundary aquifer protection is often limited to single system agreements within international law and it tend to be very difficult to achieve due to conflicts in interest from participating countries (Eckstein 2007). In this case, the loss of the WFD would result in a loss of transboundary cooperation over 34 groundwater bodies spanning 3 international river basins. No international transboundary agreement has accounted for multiple aquifers across multiple river basins in this way.

An agreement and management plan that replaces the WFD would need to span across all international river basins shared between the two countries encompassing all 34 aquifers. Alternatively, and more realistically, joint consultation and more in depth aquifer assessments could identify key aquifers that may be at the greatest risk post-WFD that separate agreements could address. Any future management strategy that aimed to manage and protect these key ‘at risk’ transboundary aquifers would need to take into consideration the local realities of the karstic aquifers and the specific contamination threats posed to them.

A management strategy governed by an international agreement may wish to adopt 4 main components. Firstly, a management strategy will need to focus on the continuation of the ‘good status’ of the transboundary groundwater bodies. This will involve sustainable and equitable use of the groundwater whilst ensuring strict pollution control to protect the vulnerable karstic aquifers. Data should be regularly shared between the two countries, and a comprehensive cooperative monitoring system implemented. Secondly, the management strategy will have to be at multiple scales; from the River Basin District level down to stakeholder/community level (Daly *et al* 2016). At the Basin District level, catchment management must be led by national environmental agencies. However local stakeholders like the communities residing close to the border can take the lead in developing and executing management practices (Daly *et al* 2016). Another important aspect to consider, particularly moving forward, is the SDG agenda. Target 6.5.2 of the SDG’s calls for integrated water resources management with transboundary cooperation where

appropriate (UN Water 2017). The nature of integrated water resource management demands for both surface and groundwater to be considered in a holistic management approach and therefore the shared transboundary groundwater bodies between Northern Ireland and the Republic of Ireland will need to be managed in conjunction with surface water systems.

Conclusions

Following Brexit, the nature of its outcome will direct environmental legislative changes in the region. Multiple transboundary water issues between Northern Ireland and the Republic of Ireland have been highlighted including the vulnerability of karstic aquifers and contamination risks through waste disposal and agricultural activities emphasized. These pose threats to water sustainability and quality. Protection of these aquifer's post Brexit through transboundary management will be vital. This is especially important due to the relatively pervious nature of karst groundwater systems as any adverse effects can be transmitted long distances in a relatively quickly manner, making cross-boundary cause-and-effect circumstances more likely.

Northern Ireland has two environmental legislative options moving forward post-Brexit; to uphold the WFD and amend national legislation as and when EU legislation is updated to avoid cross-border environmental discrepancies arising between Northern Ireland and the Republic of Ireland; or to replace the WFD with new domestic environmental legislation. The second option would require an international agreement between Northern Ireland and the Republic of Ireland to ensure no negative impacts to transboundary groundwater resources. Any agreement between the two countries might enshrine lessons learned from both the Guarani and Genevese Aquifer Agreement alongside principles from the UN Draft Articles on the Law of Transboundary Aquifers, such as equitable and reasonable use (Article 4), regular exchange of data and information (Article 8), and protection, reduction and control of pollution (Article 12) (United Nations 2008). A lack of an agreement could lead to mismanagement of the resource. This impacts not only drinking water supply, the environment and transboundary water quality, but also the SDGs targets and its interlinkages such as the water-energy-food nexus (Ziv *et al* 2018). Alongside this agreement, strict new national environment regulations would need to be imposed to replace those lost from the EU.

Moving forward, conducting a transboundary diagnostic analysis along with border of Northern Ireland–Republic of Ireland border is advisable. The analysis should include quantification of all environmental issues involving water, and results might focus on both economic and environmental impacts. This wider focus would provide an indication of the needs of both states in

terms of international groundwater relations and could assist in identifying 'at risk' aquifers that may require future cross border agreements to manage them. A review of identified transboundary groundwater bodies and consideration made to the hydrogeological potential of identified units would serve as a starting point. With subsequent focus upon convergence points such as springs or rivers and divergence points such as watershed divides in a catchment would be useful to give an indication of the actual potential for groundwater flow, including direction of flow, across the border.

The applicability of the results from this study are limited by the unique nature of Brexit and resulting unknown future for international groundwater relations in the region. However, if any other EU member states also wish to leave the EU the recommendations for future practice regarding international groundwater, and any other relevant environmental legislations, would become directly applicable.

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Data availability statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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