Water Abstraction:

Interactions with the Water Framework Directive & Groundwater Directive and Implications for the Status of Ireland's Waters

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EXECUTIVE SUMMARY

The lack of coherent and comprehensive regulations on water abstraction in Ireland is in breach of the Water Framework Directive (WFD) and must be rectified to ensure compliance. New legislation must be enacted to ensure the responsibilities of the state are conducted.

The aim of this research project is to provide SWAN and member organisations with:

- An assessment of the impacts of abstraction on surface water, groundwater and groundwater-dependant terrestrial ecosystems;
- An overview of relevant policy and legislation pertaining to water abstraction in Ireland;
- A qualitative survey of relevant stakeholders to inform on abstraction management; and
- Recommendations for effective measures, under the WFD, to control abstractions.

Currently, the available information on water abstraction is not sufficient to accurately characterise its impacts in Ireland. The location of abstraction points and the volumes that are abstracted for the majority of abstraction points on both a total and temporal basis are unknown. This makes it impossible to accurately assess the impacts of abstraction on a local or regional scale. Any legislation that is enacted must address this data gap and provide accurate information on which sound management decisions can be based.

Impacts of Abstraction

Abstraction is the removal of water from surface water (rivers, lakes, canals, reservoirs) or from groundwater, either permanently or temporarily, and transported to the place of use. The impacts of abstraction are generally only experienced when localised discharge is lower than abstraction, yielding reduced baseflows in rivers, lakes and groundwater bodies. These reduced flow volumes (and related velocities) and lower flow levels will be particularly exacerbated during periods of natural low flow. Over-abstraction of water has the potential to impact on the hydrology, hydrogeology and ecology of water bodies. There are complex interactions between water abstraction and its aquatic environment and the impacts of these depend on a range of factors that include: the volume of water abstracted; the time and duration of abstraction and return to a water body; the hydrology and morphology of water bodies; and the degree of connectivity between different components of the hydrological cycle. This yields impacts that vary greatly both spatially and temporally.

Over-abstraction from surface waters can lower downstream water volumes, altering flow dynamics, changing channel morphology and impacting water quality (through changing temperature and increasing relative concentrations of dissolved and suspended matter). Similarly, over-abstraction from groundwater can result in lower groundwater levels, altering storage capacity and potentially impacting groundwater quality and groundwater-dependant terrestrial ecosystems (by reducing level and flow of connected groundwater bodies). These impacts would also have implications for connected surface water bodies. The ecology of freshwater environments can also be negatively impacted: macro-invertebrates, macrophytes, phytoplankton and fisheries are all at risk under changing flow regimes.

Water abstraction yielding a negative alteration of the biological, hydromorphological and chemical elements for status classification will result in the downgrading of a water body, resulting in a breach of the WFD. Abstraction controls are required where abstraction is assessed to pose a risk to any of these classifying elements which would result in the water body being classified either at less than good status, or (if within-status trends indicate) are "at risk" of deterioration to a lower status.

Policy and Legislation in Ireland

The WFD requires controls over the abstraction of fresh surface water and groundwater, as well as the impoundment of fresh surface water, including a register of water abstractions and a requirement of licensing for abstraction and impoundment. These controls must be periodically reviewed and, where necessary, updated. This is not being conducted in Ireland. There is currently no primary legislation surrounding water abstraction of groundwater or surface water. Only the Water Supplies Act 1942, Groundwater and Surface Water Regulations 2000-2006, European Communities (Birds and Natural Habitats) Regulations 2011 and Water Pollution Act 1977 specifically refer to abstraction and frequently only in a tangential manner with no comprehensive framework. While Member States are entitled to remove certain abstractions from both the Register and the licencing system if those abstractions have "*have no significant* *impact on water status"*, this latitude does not provide justification for the exclusion or non-implementation of a licencing regime *at all*. In 2015, a working group on abstraction was established and led by the Department of Housing, Planning, Community and Local Government's Water Policy Advisory Committee, though output from the working group and ministers has indicated that any licensing regime will focus only on the "*most significant volumes and pressures*" without imposing an "*unnecessary regulatory burden*". This would omit most abstractions from requiring licensing.

The existing register of abstractions in Ireland includes most public and group water schemes and licensed industrial schemes and provides an abstraction rate of 575,000 m^3/day. Since compilation of the original register, there have been no systemic updates or attempts to rectify data gaps identified since 2009, which include unregulated abstractions such as domestic wells and small private abstractions including golf courses, hotels, hospitals and schools, in addition to wells for agricultural use. Due to the data gaps, the register is almost certainly underestimating the total number of abstraction schemes or points across the country, and as a result, the total abstraction volumes is likely to be under-represented.

While the register was due to be updated in 2016, the updated register is not publicly available and appears to still rely on previous (incomplete) datasets. It is not apparent that the lacunae identified from previous iterations have been substantially addressed. The number of abstractions has increased only from approximately 2,000 to 2,600 with no evidence that this is a comprehensive overview of abstractions. Therefore, significant concerns remain around the quality and comprehensive nature of that data and it is difficult to have faith in the accuracy of the figure of 575,000 m^3 /da**y** as an estimate of the total abstraction volume across the country.

The lack of a strong regulatory regime in Ireland is particularly unsatisfactory when both Scotland and Northern Ireland have introduced comprehensive regulations to provide for requirements of the WFD in relation to water abstraction. The system in those jurisdictions have the great benefit of a single regulatory agency, web portals for applications, public accessibility to the information obtained and real enforcement powers in the event of default. These regimes offer a model around which public consultation could be quickly and easily launched in this country.

Abstraction in Ireland

The Irish River Basin District covers 70,237 km^2, subdivided into 46 catchments with 4,829 water bodies (including 3,192 rivers, 818 lakes, 195 transitional water bodies, 111 coastal and 513 groundwater bodies). To comply with the WFD, these water bodies must attain at least "good" classification status and are monitored at 3,191 river, 216 lake, 80 transitional, 43 coastal and 336 groundwater sites. In the most recent reporting period (2013-2015), 55% of monitored river water bodies and 46% of monitored lake sites attained at least "good" classification, though this is a 3% decline since 2007-2009. High status sites account for only 10% of water bodies (down from 13% in 2007-2009). 91% of groundwater bodies achieved "good" status; a decrease of 6% since the previous monitoring period (2007-2012). Of the characterised water bodies, 32% are designated as being at risk of not meeting WFD guidelines, with 25% requiring further review. It is not known how many of these are due to abstraction pressures. However, if water bodies are declining nationally for a number of reasons independent of abstraction, the impacts of abstraction will further compound the negative result.

Impacts of abstraction have been recorded in Ireland, but are not prevalent in the scientific literature. It is not known if this is due to a lack of impacts, or a lack of study into the impacts of abstraction. Recorded impacts include lower groundwater levels resulting in desiccation of wetlands and saltwater intrusion at coastal sites. Abstraction points can also provide conduits for pollution. Information on water abstraction in Ireland is far from complete with current databases of abstraction not containing the necessary data to fully assess impacts. In particular, comprehensive data on locations of abstraction points, and volumes abstracted are missing. Given that impacts of abstraction are localised and can take time to materialise, it is fundamental to our understanding of water abstraction pressures that these are known and assessed, particularly where there are impacts upon protected habitats and species. This is especially true with respect to any changes arising through projected climate change, which are expected to be spatially heterogeneous.

Stakeholder Survey

Twenty-five statutory and non-statutory stakeholders were contacted for this report and interviews were conducted with eleven of these. A number declined to participate, with a lack of knowledge on the water abstraction in question frequently cited as a reason for non-participation. Due to the relatively small total sample of respondents, inferences drawn from responses can only be indicative.

From all stakeholders that responded, a range of pressures were identified, including ecological impacts and shortcomings in governance. Respondents not immediately concerned with aquatic environments demonstrated low levels of awareness of the diverse and complex impacts of abstraction on aquatic environments and approached the issue with a focus on water supply for human consumption. There was a minority view among respondents that the regime should be “light” and limited; this was far outweighed by those that who saw future regulations as an important opportunity to collect detailed registration and monitoring data in order to gain a comprehensive picture of abstraction in Ireland, and to design a responsive, risk-based licensing system that would address retrospective assessment and mitigation and be integrated into forward planning.

There were universal concerns regarding a lack of political will to deliver a management regime, and a number of specific significant hurdles identified including cost, administrative burdens, the difficulties of implementing a flexible risk-based approach, and the need for education on the importance of aquatic resources.

Recommendations

The currently available data on the location, rate and duration of abstractions is inadequate and is preventing comprehensive studies on the impacts of water abstraction in Ireland. While the national risk of abstraction in Ireland is believed to be low, abstraction can be a significant risk on a local scale, with impacts capable of causing a downgrading in status classification of a given water body under the WFD. In Ireland, there are documented impacts of abstraction and these impacts are likely to grow in scale and extent as projected climate change takes effect, with repercussions for WFD classification.

To minimise the impacts of abstraction and to ensure compliance with the WFD, the three main requirements which must be fulfilled are as follows:

(i) Improved assessment of the impacts of abstraction in Ireland:

  a. Metering of all abstraction points; and
  b. Collation and study of abstraction data by various stakeholders.

(ii) Clear, consistent and strong legislation:

  a. Consolidation of surface water and groundwater regimes; and
  b. Establishment of a coherent national abstraction register.
     i. Introduced on a phased basis; and
     ii. All abstractions are included on a register which is publicly available.
  c. Establishment of a coherent licencing regime:
     i. Introduced on a phased basis;
     ii. All abstractions above a risk-based threshold value are licensed. This could begin at 10 m^3/day and change as more accurate information is acquired;
     iii. Abstractions below the risk-based threshold do not require licensing but must comply to general binding rules;
     iv. Proposed abstractions >100 m^3/day should be further reviewed by a competent agency;
     v. Licensing regime should be flexible to include abstraction points in vulnerable areas; and
     vi. Licensing authority has power to prescribe bespoke conditions in regions of significant concern.

(iii) Improved stakeholder engagement:

a. Initiation of information and awareness-raising campaign; and

b. Active engagement with stakeholder representative bodies.

Chapter 1: Introduction – Background and Objectives of Research Project

1.1 The Sustainable Water Network (SWAN)

The Sustainable Water Network (SWAN) is a collective of twenty-seven of Ireland's leading environmental groups working together to protect and enhance the country's aquatic resources, especially through the implementation of the Water Framework Directive (WFD), Groundwater Directive (GWD) and other water-related legislation. Members of SWAN include national and local non-Governmental organisations (NGOs) which have a wide range of specialist and locally detailed knowledge and expertise in all areas of Ireland's aquatic environment.

Member organisations of the SWAN collective work together at local, national and River Basin District level to ensure that all the requirements of the Water Framework Directive are fully implemented in the spirit as well as the letter of the law. As part of this strategy, SWAN aims to ensure that the country's River Basin Management Plans are implemented correctly, and that any shortcomings in these Plans are addressed during the consultation and implementation process of river basin planning.

An essential element of SWAN's work is participating in the national debate on the sustainable management of water resources and the aquatic environment with the support of evidence-based information, analysis, recommendations and international best practise examples. A key part of this work includes making submissions to Government Departments and Agencies, especially in response to public consultation requests. SWAN also works to raise public awareness of water issues, and has prepared and distributed a number of professionally produced and illustrated information leaflets various water-related topics.

SWAN has played a very active role in focusing attention on a wide range of water-related issues, and has campaigned for a much greater appreciation of the intrinsic value of Ireland's water resources, and for the need to protect these resources from a wide range of potentially damaging activities. As discussed in subsequent chapters, water abstraction has the potential to negatively impact the status of water bodies and there is a necessity for the Irish government to legislate for water abstraction under the requirements of the Water Framework Directive. To date, legislation in this country has been virtually non-existent, and the current necessity provides a unique opportunity to put systems in place to accurately measure and control the use of this vital natural resource.

These concerns have led SWAN to invite submissions for a research project on water abstractions; this report presents the results of the work undertaken by Rodinia Consulting (Kieran Craven), Envirologic (Colin O'Reilly), Adjust (Harriet Emerson), John Kenny, and Whitehill Environmental (Noreen McLoughlin), under the guidance of a Steering Group established by SWAN.

1.2 Research Methodology and Guiding Principles

The aim of this research project, as determined by SWAN, is to provide:

- An assessment of the impacts of abstraction on surface water, groundwater and GWDTEs;
- An overview of relevant policy and legislation pertaining to water abstraction in Ireland;
- A qualitative survey of relevant stakeholders to inform on abstraction management; and
- Recommendations for effective measures, under the WFD, to control abstractions.

The results of the research will therefore:

- Provide the necessary evidence-based information and analysis to inform SWAN submissions and communications with national government agencies and Departments, EU institutions and other stakeholders during formal and informal consultations on relevant policy development and implementation; and
- Inform and contribute to the policy and advocacy work of SWAN's member organisations in the public debate on water abstraction.

The most relevant principle guiding the current project is that all our conclusions and recommendations are, as far as practically possible, evidence-based and supported by, and draw on, peer-reviewed literature, case studies, and European and best practice; additionally, the recommendations should be applicable to the situation in Ireland.

To facilitate this, the following methodology was employed, consisting of separate but linked work packages, as follows:

(i) A wide-ranging review of the literature on water abstraction, including research reports, peer-reviewed literature, and studies conducted by international agencies, government agencies, environmental NGOs, and academic researchers to provide information on adverse impacts of water abstraction on the aquatic environment;

(ii) An examination of what policies and legislative controls are already in place, in Ireland and other relevant jurisdictions to address the impacts of water abstraction;

(iii) A consideration of the current situation in Ireland, including:

  (a) The currently available data on water abstraction in Ireland; and

  (b) Any recorded impacts of water abstraction on aquatic environments.

(iv) A survey of relevant stakeholders that included telephone conversations with key personnel;

(v) Formulation of conclusions, and submission of these conclusions and our draft recommendations to the Steering Group; and

(vi) Having obtained the observations of the Steering Group, we then prepared the final conclusions and recommendations, together with an executive summary or non-technical summary of the research report as a whole.

CHAPTER 2: WATER ABSTRACTION AND ITS ENVIRONMENTAL IMPLICATIONS FOR WATER RESOURCE MANAGEMENT

2.1 Introduction

Abstraction is the removal of water from surface water (rivers, lakes, canals, reservoirs) or from groundwater, either permanently or temporarily, and moved to the place of use[1]. Water abstraction is conducted by a wide variety of societal sectors including public bodies, energy producers, private industry, agriculture and individuals. Freshwater ecosystems depend on the adequate quantity, quality, timing, and temporal variability of flow[2]. Water abstraction has the potential to impact all these parameters. In 2015 the European Commission (EC)[3] officially identified over-abstraction as the second most common pressure (after pollution) on the ecological status of surface water bodies in the EU, affecting 8% of European rivers.

This chapter looks at the general impacts of water abstraction on water bodies. It begins with an overview of water abstraction, before completing a literature review of the impacts of abstraction on surface waters, groundwaters and GWDTEs.

[1] http://www.fao.org/nr/water/aquastat/data/glossary/search.html?termId=7584&submitBtn=s&cls=yes&lang=en

[2] Baron, J.S., Poff, N.L., Angermeier, P.L., Dahm, C.N., Gleick, P.H., Hairston, N.G., Jackson, R.B., Johnston, C.A., Richter, B.D., Steinman, A.D., 2002. Meeting ecological and societal needs for freshwater. *Ecological Applications* **12**, 1247–1260

[3] EC (2015b) Communication from the Commission to European Parliament and the Council: The Water Framework Directive and the Floods Directive: Action towards the 'good status' of EU water and to reduce flood risks. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015DC0120&from=EN on 7th May 2017.

This literature review was undertaken in order to summarise the current pressures and impacts (including the cumulative impacts) of surface and groundwater abstraction and their impacts on GWDTE. The main areas researched as part of this review included:

- The process of water abstraction;
- The Water Framework Directive, and its implications for water abstraction;
- An overview of the hydrology and ecology in surface waters that are affected by water abstraction along with mechanisms by which they are affected;
- An overview of how hydrogeology can be affected by water abstractions; and
- The potential impacts of projected climate change.

The abstraction of water from surface water bodies can have a multitude of impacts upon the morphological and chemical parameters of the water body. This in turn can lead to a series of impacts, both individual and cumulative, on the ecology of the water body. These impacts include:

- Hydrology and Hydrogeology:
    - Changes to surface water regimes
        - Hydrology
        - Morphology
        - Water quality
    - Changes to groundwater regimes
        - Storage and flow
        - Groundwater quality
        - GWDTE
- Ecology:
    - Changes in macro-invertebrate communities due to habitat loss or alteration;
    - Changes in macrophyte communities and a loss of species richness due to habitat loss and alteration in marginal areas;
    - Alterations in phytoplankton from a low-biomass diatom dominated community to a high-biomass, filamentous algae community; and

- Changes in the food supply and physical habitat requirements of fish, e.g., loss of gravel spawning beds.

2.2 Overview of Abstraction Process

2.2.1 Processes of Abstraction

Water can be abstracted from surface waters (rivers, lakes) or groundwater and the method of abstraction will vary based on the end use (which influences volume and quality required) and budget of the projected works. This can involve pumping, piping, diverting water into a reservoir, or sinking a borehole or well.

Surface water abstraction is usually taken directly from a point source (intake structure) below the surface of the water body. This can vary from an engineered structure (e.g. dam (Figure 2.1)) to a PVC pipe (e.g. household (Figure 2.2)). Direct intakes require a minimum depth of water year round to ensure a permanent water supply and may require the construction of a weir downstream to ensure sufficient depth is maintained. If used for drinking water, surface water generally requires treatment before being delivered to the user as it may be contaminated by faecal and organic material, along with having high turbidity[4]. Because rivers and lakes can provide large, consistent volumes of water, surface water is frequently used for large urban water supply systems.

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[4] World Health Organisaion Factsheet 2.7: Surface water abstraction. Available at: http://www.who.int/water_sanitation_health/sanitation-waste/fs2_7.pdf?ua=1. Accessed 25th May 2-17.

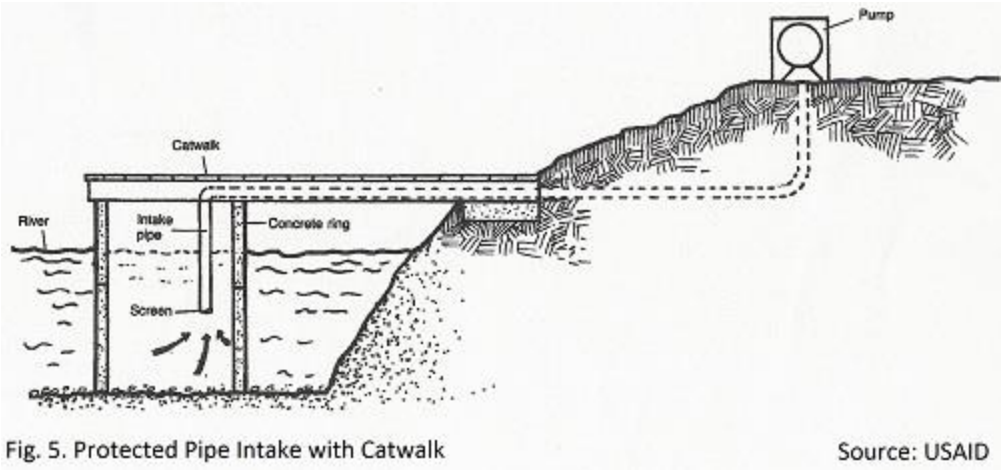

Figure 2.1: Schematic of surface water intake

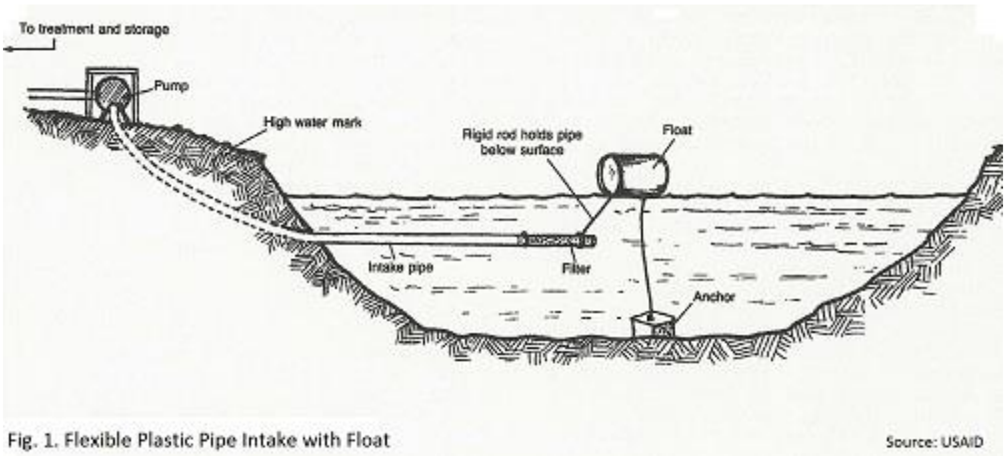

Figure 2.2: Schematic of low budget surface water intake

Groundwater abstraction can include pumping of groundwater from a well, pumping from natural springs, and engineering works where permanent cuts are made that result in a permanent lowering of the water table[5]. For groundwater well abstraction, a well is drilled to

[5] CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102

intercept the aquifer (i.e. below the water table). The land area that contributes recharge (i.e. rainfall) to the well or spring is referred to as the Zone of Contribution[6]. This terminology is distinct from the zone (or radius) of influence of the well which is the area where drawdown occurs due to pumping. In Ireland, most water wells installed in bedrock using an air-hammer rotary drilling rig[7]. Comprehensive guidelines concerning water well drilling in Ireland are provided by the IGI[8] and EPA[9] (see Figure 2.3) though there is currently no statutory or planning requirement to install production boreholes to these specifications.

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[6] Misstear B.D., Banks D. & Clark L. (2006) *Water Wells and Boreholes*. Wiley & Sons Ltd: Chichester, pp514.

[7] Institute of Geologists of Ireland: Guidelines for water well construction (2015). Available at: *igi.ie/assets/files/Water%20Well%20Guidelines/Guidelines.pdf.*

[8] IGI summary guidelines for water well construction (2015). Available at: *igi.ie/assets/files/Water%20Well%20Guidelines/Summary.pdf.*

[9] https://www.epa.ie/pubs/advice/drinkingwater/EPA_DrinkingWater_AdviceNoteNo14b_web.pdf.

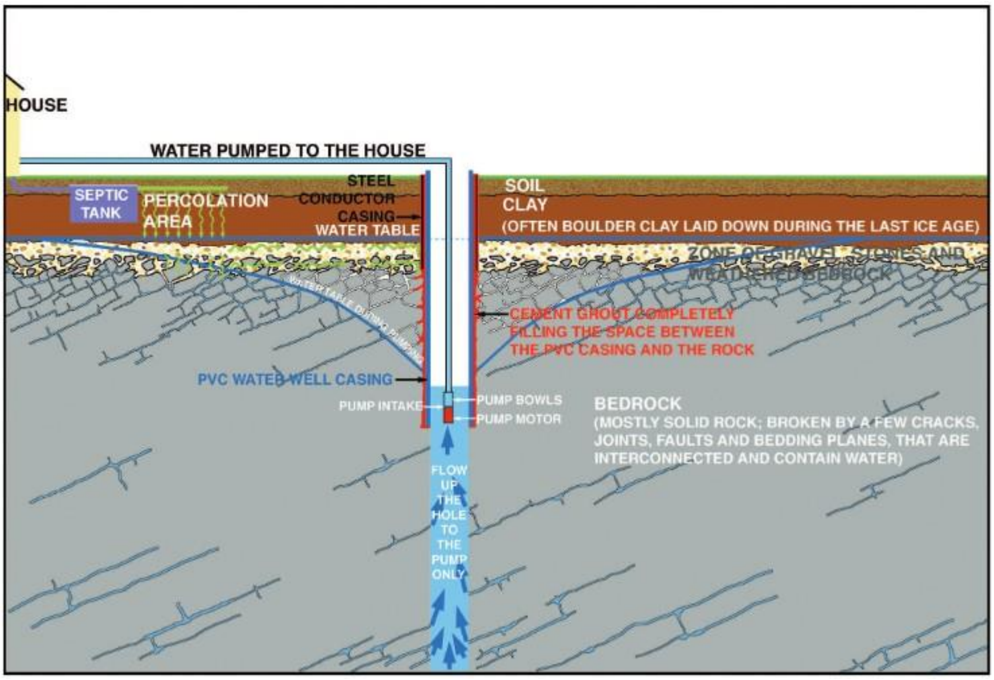

Figure 2.3: Recommended design of domestic borehole in Ireland[10]

2.2.2 Abstractors

Multiple sectors are involved in water abstraction and include:

- Energy production
- Agriculture
- Industry
- Public water supply
- Private water supply

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[10] Institute of Geologists of Ireland: Guidelines for water well construction (2015). Available at: *igi.ie/assets/files/Water%20Well%20Guidelines/Guidelines.pdf*. Figure 1

According to European Environment Agency (EEA)[11] water abstraction usage across EU member states is estimated to be apportioned in the following manner, though these figures vary widely between member states:

- Energy production = 44%;
- Agriculture = 21%, of which only 30% is returned to the same water body due to crop growth and evapotranspiration losses;
- Public water supply = 21%; and
- Industry = 11%.

Abstraction requirements vary greatly within and between sectors both in the volumes of water abstracted, the distance of water return to a water body, and the duration of time for this water to be returned. Therefore, based on the specifics of individual (or cumulative) abstractions, impacts to the natural environment vary greatly in terms of extent and severity (Section 2.3).

For energy production, which makes up the majority of water abstractions in Europe, water primarily serves as cooling water.[12] Generally, this abstracted water is returned to the same water body.

Within agriculture, abstraction occurs for the full range of agricultural practices in both animal production and crop husbandry. Water demand for animal drinking water, facility washing and crop irrigation can be significant, particularly on larger, intensive holdings, and can result in water being returned close to the point of abstraction, in water transfer across catchment (or sub-catchment) boundaries, and in removal of water from the water body (e.g. milk production, evapotranspiration). At present there is only a legislative requirement for intensive pig and

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[11] EEA (2009). Water resources across Europe - confronting water scarcity and drought. European Environment Agency Report 2/2009.

[12] EEA (2009). Water resources across Europe - confronting water scarcity and drought. European Environment Agency Report 2/2009.

poultry rearing facilities to provide water supply details for EPA licensing. Minimal data is available in Ireland regarding water supply sources and usage rates in other agricultural practices (e.g. tillage, dairy, cattle, and sheep).

For public water supplies, there can be large variations in the timing and location of water returning to the source water body because of, for example, the distribution networks between source and point-of-supply and siting of municipal wastewater treatment facilities and local authority stormwater networks following end use. This is of less significance for individual domestic wells where water is supplied and returned at a more local scale, typically via an on-site wastewater treatment system.

Within industry water abstraction varies greatly across different activities. Quarries and mines must abstract groundwater to provide dry working environments and preferably discharge to an area that will minimise recycling of water back to the abstraction point; breweries will abstract water for export nationally and internationally, while other industries (e.g. car wash) may return used water to the source within the confines of the activity.

Abstraction pressure increases with increased rate and volume and is therefore likely to grow in tandem with national growth. To mitigate against pressures, measures such as water conservation programmes, restricting unsustainable development, and providing alternative sources of water are required.

2.3 General Impacts

2.3.1 Introduction

Outlined below are the potential impacts that can occur due to abstractions from water bodies. This study looks at the impacts of water abstraction to surface waters (hydrological regime, morphological conditions, quality) and groundwater (storage and flow, quality, and GWDTEs), along with corresponding changes to the freshwater ecology. These can be exacerbated via cumulative impacts of water abstraction, or via future climate change.

Specific studies investigating the direct impact of abstraction in Ireland are relatively rare in the scientific literature. As both temporary and long-term abstractions from surface water and groundwater bodies that exceed recharge can cause a depletion in water level and flow, low flow studies are deemed to be a suitable proxy for the impacts of unsustainable water abstraction. This review looked at many of the low flow regime investigations within the scientific literature.

2.3.2 Hydrological Impacts

The integration of hydrology, hydrogeology and geomorphology has been recognised to be essential for understanding aquatic ecosystems[13]. Water abstraction has the ability to affect all three of these critical components.

2.3.2.1 Hydrological Regime

Water abstraction alters fluid dynamics and volumes in water bodies with impacts on flow and water level, especially during periods of natural low flow. Water abstraction can reduce downstream water volumes and therefore results in flow alteration. Flow alteration is recognised as inducing a variety of environmental and ecological responses[14] and can be considered in terms of magnitude, frequency and timing. Poff and Zimmerman[15] report that the risk of change in ecological response increases with increasing magnitude of flow alteration. Alterations to flow frequency were reported by these same authors[16] as decreases in frequency of floods or peak flows; decrease in the duration of floodplain inundation; loss of peak flows

[13] Poole G. C. (2010) Stream hydrogeomorphology as a physical science basis for advances in stream ecology. *Journal of the North American Benthological Society* **29**, 12-25.

[14] Bunn S.E. & Arthington A.H. (2002) Basic principles and the ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management* **30**, 492-507.

[15] Poff N.L. & Zimmerman J.K.H. (2010). Ecological responses to altered flow regimes: A literature review to inform environmental flows science and management. *Freshwater Biology* **55**, 194-205.

[16] Ibid.

(stabilisation); alterations in seasonality of peak flows; change in mean and total discharge; reduction in baseflow and reduction in extreme low flows.

Numerous studies have established a direct link between flow alteration (due to abstraction) and ecological impacts[17]. Lloyd et al.[18] examined 70 studies for relationships between hydrologic change and ecological or geomorphological response and reported that 87% of the studies documented changes in either or both of these variables in response to reduced flow volumes. Bradley et al.[19] found that the greatest ecological impacts occurred when the deviation from Q_{75} (daily mean flow exceeded 75% of the time, as determined from long term flow statistics between 1990 and 2007) due to abstraction exceeded 60%. The resulting reduction in flow is most critical when flows and dissolved oxygen levels are lowest towards the end of the summer and in early autumn and before the rate of runoff/recharge increases[20]. Given these impacts to rivers, and in order to mitigate against them, maximum abstraction rates for rivers were set in the UK at 15-35% of natural flows (depending on flow magnitude and time of year) for the least sensitive rivers, and 7.5-25% for the most sensitive[21].

Abstraction pressures manifest in lakes as increased fluctuation in water levels and changes in

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[17] E.g. Bunn, S.E., Arthington, A.H., 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. *Environmental Management* **30**, 492–507.

[18] Lloyd N., Quinn G., Thoms M., Arthington A., Gawne B., Humphries P. & Walker K. (2003) Does flow modification cause geomorphological and ecological response in rivers? A literature review from an Australian perspective. *Technical Report 1/2004, CRC for Freshwater Ecology*.

[19] Bradley D.C., Streetly M., Farren E. & Cadman D. (2013) Establishing hydroecological relationships to manage the impacts of groundwater abstraction. *Water and Environment* **28**, 114-123.

[20] EDA (2008). Groundwater resources of the Central Leinster Area and their potential to augment the Dublin Region Water Supply. Appendix C of Water Supply Project – Dublin Region. Eugene Daly Associates and RPS Consulting Engineers.

[21] Acreman, M., Dunbar, M., Hannaford, J., Mountford, O., Wood, P., Holmes, N., Cowx, I., Noble, R., Extence, C., Aldrick, J., King, J., Black, A., Crookall, D., 2008. Developing environmental standards for abstractions from UK rivers to implement the EU Water Framework Directive. *Hydrological Sciences Journal* **53**, 1105–1120.

residence time[22] due to volumes removed (and potentially returned). Changes in the range of water level fluctuation alter the frequency of shoreline immersion, which affects the degree of desiccation, and the duration of the minima and maxima levels. The depth/area of the shallow littoral zone also changes and thus the degree that wave action can affect sediments, plants and animals.[23]

2.3.2.2 Morphological Conditions

Along natural rivers, channel morphology is determined by the interaction of channel gradient and width, flood magnitude and frequency, sediment supply, and vegetation[24]. Channel morphology controls flow velocity[25] and water level, and the frequency, siting and depth of pools, glides and riffles. Understanding the relationships between flow and morphology is critical to the science of environmental flows (see Section 2.4), because geomorphic features can mediate the effects of altered flow regime on ecological processes.[26]

[22] The mean time water remains in a given water body. This is especially important where pollutants are concerned, with high residence time indicating longer persistence of pollutants.

[23] CDM (2009b). Eastern River Basin District - National Programme of Measures Study: Revised risk assessment methodology for surface water abstractions from lakes.

[24] Petts G.E. (1984). *Impounded River*. John Wiley & Sons, Chichester, UK.

[25] Mosisch T.D. (2001) Effects of desiccation on stream epilithic algae. *New Zealand Journal of Marine and Freshwater Research* **35**, 173–179.

[26] Meitzen K.M., Doyle M.W., Thoms M.C. & Burns, C.E. (2013) Geomorphology within the interdisciplinary science of environmental flows. *Geomorphology* **200**, 143-154.

Lower flows due to abstraction can result in reduced flow velocities. In wide, flat channels or low weirs, abstraction schemes can dry out sections of streams, thus strongly reducing their longitudinal connectivity[27] and the surface area of in-stream habitats.[28]

Rinaldi et al.[29] illustrated how abstraction, and other human activities, can have a profound effect on sedimentation in river systems, which can have wider implications such as channel narrowing, island formation, alteration to river braiding and meandering. These changes in sedimentation influence substrate conditions as a medium for vegetative growth.

Flow alteration also affects Thalweg profiles, these being longitudinal profiles of the streambed measured along the deepest portion of the stream[30]. Depressions in the Thalweg represent pools (deep habitats), while crests represent riffles (shallow habitats). During temporary low flows the Thalweg is susceptible to drying out and under more sustained low flows is more At Risk of blockages due to sedimentation and deposition of coarse particulate organic matter.[31] The important role that flood flows play in flushing out Thalweg channels and controlling Thalweg topography[32] can be lost during reduced flows due to water abstraction.

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[27] Malmqvist B. & Rundle S. (2002) Threats to the running water ecosystems of the world. *Environmental Conservation* **29**, 134–153.

[28] Stanley E.H., Fisher S.G. & Grimm N.B. (1997) Ecosystem expansion and contraction in streams. *BioScience* **47**, 427–435.

[29] Rinaldi M., Gurnell A.M., Gonzalez del Tanago M., Bussettini M., Hendricks D. (2016) Classification of river morphology and hydrology to support management and restoration. *Aquatic Sciences* **78**, 17-33.

[30] E.g. Mossup B. & Bradford M.J. (2006) Using Thalweg profiling to assess and monitor juvenile salmon (Oncrohynchus spp.) habitat in small streams. *Canadian Journal of Fisheries and Aquatic Sciences* **63**, 1515-1525.

[31] Death R.G., Dewson Z.S. & James A.B.W. (2009) Is structure or function a better measure of the effects of water abstraction on ecosystem integrity. Freshwater Biology **54,** 2037-2050.

[32] Madej M.A. (1999) Temporal and spatial variability in thalweg profiles of a gravel-bed river. *Earth Surface Processes and Landforms* **24**: 1153-1169.

Large dams and weirs (which can be associated with points of water abstraction) clearly influence channel morphology and also impact sediment transport.[33] Reduced flows can exaggerate the impacts of barriers such as weirs, which have been demonstrated to hinder the passage of migratory fish.[34]

2.3.2.3 Water Quality

Surface water quality refers to the biological and chemical status of riverine systems and lakes. Water abstraction can impact water quality, particularly through the reduction of flow velocities, resulting in changing concentrations of dissolved and suspended matter and temperature. Water abstraction can reduce the volume of water in water bodies thereby decreasing the capacity of that water body to assimilate pollutants. Over-abstraction of water in rivers and lakes leads to increasing concentrations of nutrients in reduced water volumes and becomes an additional factor enhancing eutrophication under warmer conditions.[35] A review paper by Jeppesen et al.[36] describes how low lake water levels are characterised by increased turbidity, conductivity, P concentrations, suspended solids and chlorophyll-a, and reduced dissolved oxygen, all indicative of deterioration of ecological status, and that these trends were exacerbated by abstraction. The increased concentrations of phosphorus, which may be

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[33] Tena A., Batalla R.J., Vericat D. & Lopez-Tarazon J.A. (2011) Suspended sediment dynamics in a large regulated river over a 10-year period. *Geomorphology* **125**, 73-84.

[34] DEFRA (2013). Managing abstraction and the water environment. Department for Environment, Food and Rural Affairs, Wales.

[35] Özen A., Karapinar B., Kucuk I., Jeppesen E. & Beklioğlu M. (2010). Drought-induced changes in nutrient concentrations and retention in two shallow Mediterranean lakes subjected to different degrees of management. Hydrobiologia 646, 61–72.

[36] Jeppesen E., Brucet B., Naselli-Flores L., Papastergiadou E., Stefanidis K., Noges T., Noges P., Attayde J.L., Zohary T., Coppens J., Bucak T., Fernandes Menezes R., Freitas F.R.S., Kernan M., Sondergaard M. & Beklioglu M. (2015) Ecological impacts of global warming and water abstraction on lakes and reservoirs due to changes in water level and related changes in salinity. *Hydrobiologia* **750**, 201-227.

exacerbated by abstraction, particularly at low flows, promote growth of filamentous algae and macrophytes, which in turn reduce light and food for other river species.

Reduction of flow velocity in rivers has been shown to have a negative impact on biofilm biomass[37] and a decline in nutrient cycling, renewal[38] and diffusion.[39] A reduction in turbulence, energy and physical abrasion due to lower flow velocities can also result in less organic matter breakdown[40] and a more general decline in a river's ability to clean itself by flushing.[41] Abstraction has also been shown to reduce oxygen concentrations in rivers, through lower flow velocity[42] resulting in calmer flow conditions dissolving less air.

Poff and Zimmerman[43] outline studies where flow alterations have resulted in changes to environmental drivers such as temperature and sediment. Abstraction of river water can lead to a raising of water temperature[44] which can degrade habitat quality and adversely affect species populations (see Section 2.3.4). This is particularly a problem when periods of low rainfall lead

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[37] Mosisch T.D. (2001) Effects of desiccation on stream epilithic algae. *New Zealand Journal of Marine and Freshwater Research* **35**, 173–179.

[38] Wollheim W., Peterson B.J., Deegan L.A., Hobbie J.E., Hooker B. & Bowden W. (2001) Influence of stream size on ammonium and suspended particulate nitrogen processing. *Limnology and Oceanography* **46**, 1–13.

[39] de Beer D., Stoodley P. & Lewandowski Z. (1996) Liquid flow and mass transport in heterogeneous biofilms. *Water Research* **30**, 2761–2765.

[40] Hieber M. & Gessner M.O. (2002) Contribution of stream detrivores, fungi, and bacteria to leaf breakdown based on biomass estimates. *Ecology*, **83**, 1026–1038.

[41] Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington.

[42] James A.B.W., Dewson Z.S. & Death R.G. (2008) The effect of experimental flow reductions on macroinvertebrate drift in natural and streamside channels. *River Research and Applications* **24**, 22–35.

[43] Poff N.L. & Zimmerman J.K.H. (2010). Ecological responses to altered flow regimes: A literature review to inform environmental flows science and management. *Freshwater Biology* **55**, 194-205.

[44] Rader R.B. and Belish T.A. (1999) Influence of Mild to Severe Flow Alterations on Invertebrates in Three Mountain Streams. *Regulated Rivers: Research and Management*, **15** , 353–363.

to reduced flow in river channels.[45] However it should be noted that an experiment by Arroita et al.[46] found no such effect on these physicochemical variables and dissolved oxygen.

2.3.3 Hydrogeological Impacts

2.3.3.1 Impacts to Surface Water

Abstraction of groundwater can have a significant impact on stream and river flow, with two primary mechanisms: (i) intercepting groundwater moving to its natural discharge points, and (ii) withdrawing water directly from streams and rivers which are close to abstraction boreholes[47]. These reduce the flow and volume of surface water. The effect of groundwater abstraction on river flows may not be apparent in early stages (e.g. Year 1), with impact being measurable potentially over a number of years.

Declining groundwater levels affect surface water bodies connected to groundwater bodies for all, or part of their flow. In these instances, changes to groundwater will affect surface water. Many rivers rely on groundwater connections, which are essential for maintaining specific biological requirements related to differences in water chemistry between surface waters and groundwaters[48]. Rinaldi et al.[49] gives a useful synopsis of how different aquifers affect river water quality under normal conditions as follows. Rivers in a hydrogeological setting consisting

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[45] Moorkens E.A. (1999) Conservation management of the freshwater pearl mussel Margaritifera margaritifera. *Irish Wildlife Manuals No. 8. National Parks & Wildlife Service*.

[46] Arroita M., Flores L., Larranaga A., Martinez A., Martinez-Santos M., Pereda O., Ruiz-Romera E., Solagaistua L. & Elosegi, A. (2016) Water abstraction impacts stream ecosystem functioning via wetted-channel contraction. *Freshwater Biology* **62**(2), 243-257.

[47] Theis C.V. (1941) The effect of a well on the flow of a nearby stream. *Tranasctions American Geophysical Union **22**,734-738.*

[48] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21.

[49] Rinaldi M., Gurnell A.M., Gonzalez del Tanago M., Bussettini M., Hendricks D. (2016) Classification of river morphology and hydrology to support management and restoration. *Aquatic Sciences* **78**, 17-33.

of low permeability bedrock or thin, shallow aquifers depend largely on precipitation for their runoff and will run dry during periods of drought. The aquifer–river connectivity is low and water quality of such rivers is determined mainly by the interaction between rainwater and the upper soil profile, and the resulting runoff composition. On the other hand, rivers fed by thick and well-connected sand/gravel aquifers with high permeability exhibit high base flow (i.e. have a large groundwater contribution) and are much more resilient to drought. It is these, connected rivers that are most vulnerable to changes in groundwater levels, and therefore abstraction impacts.

Groundwater abstractions affect the water balance (inflow vs. outflow) in catchments of rivers in hydraulic continuity with groundwater and may lead to reductions in river baseflow.[50] Water abstraction can affect groundwater level and models show that a reduction in groundwater level can reduce river level due to head differential between river level and groundwater level,[51] thickness and permeability of streambed layer[52] and streambed clogging.[53]

Hydrogeological characteristics that control water levels and thereby river flows during abstraction include horizontal and vertical hydraulic conductivities of aquifers and confining aquitards (i.e. sedimentary layers or barriers that are impermeable to water);[54] aquifer depth; specific yield (or effective porosity). All of these factors vary based on the specific geology and morphology of water bodies. The degree of flow connectivity between the aquifer and the river

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[50] Kirk S. & Herbert A.W. (2002) Assessing the impact of groundwater abstractions on river flows. *Geological Society of London, Special Publications*, **364**, 289-302.

[51] Theis C.V. (1941) The effect of a well on the flow of a nearby stream. *American Geophysical Union Transactions* **22**, 734-738.

[52] Hantush M.S. (1965) Wells near streams with semipervious beds. *Journal of Geophysical Research* **70,** 2829-2838.

[53] Hunt B. (1999) Unsteady steam depletion from groundwater pumping. *Groundwater* **37**, 98-102.

[54] Cheng C. & Chen X. (2007) Evaluation of methods for determination of hydraulic properties in an aquifer-aquitard system hydrologically connected to a river. *Hydrogeology Journal* **15**, 669-678.

is dictated by river bed material, stream bank sediments, stream bank depth, stream bank thickness and the extent to which the channel of the river intersects the saturated part of the aquifer. Gravel aquifers can be replenished during sustained high river flows where connectivity between the river and aquifer is high.

The reduction in river flow occurs in two ways: (i) when the aquifer head is above river level and the abstraction simply reduces groundwater baseflow contribution to the river; or (ii) when the aquifer head is below river level and the groundwater abstraction indirectly withdraws river water. In exceptional circumstances where aquifer level is reduced below river bed elevation, river water may drain to the aquifer under gravity. Parkin et al.[55] provides further case studies demonstrating some of these different hydrogeological settings and how they interact with river flow.

The list of combinations of aquifer type, aquifer head and river sediment properties, river penetration and river stage is extensive, all of which may vary in space and over time. There is often no definitive answer to the question of how to evaluate the impact of the abstraction on the river without significant levels of investigation and modelling.[56]

2.3.3.2 Groundwater Storage

All groundwater abstractions initially lead to a decrease of stored groundwater volume within the radius of influence around the pumping well[57]. The radius of influence can stabilise if

[55] Parkin G., Younger P.L. & Birkinshaw, S. (2000). Impact of groundwater abstractions on river flows: Phase 2 – A numerical modeling approach to the estimation of impact. R & D Project Record W6-046/PR, University of Newcastle.

[56] ESL (1999) *Impact of groundwater abstractions on river flows*. Draft presentation for Environment Agency. Environmental Simulations Ltd.

[57] Doll P., Muler Schmied H.M., Schuh C. & Portmann F.T. (2014) Global-scale assessment of groundwater depletion and related groundwater abstractions: Combining hydrological modeling with information from well observations and GRACE satellites. *Water Resources Research* **50**, 5698-5720.

recharge to the aquifer balances the abstraction.[58] If, however, groundwater abstractions cannot be balanced by recharge over a number of years, a long-term decline of hydraulic head and groundwater storage will result,[59] and groundwater levels will stabilise at a lower equilibrium level than pre-abstraction. The impact on groundwater levels (and potentially surface water levels if connectivity exists) will vary depending on timing (frequency, i.e. periodic vs. steady-state, and duration) of abstractions[60] and abstraction volumes, and can be significant. In Spain, Bromley et al.[61] report groundwater level decline of over 50 m due to abstraction on-going since the 1970s. A heavy aquifer drawdown can lead to drying out of soil surface layers, promote sealing, and reduce the rate that water can be absorbed by the soil during rainfall.[62]

2.3.3.3 Groundwater Quality

Groundwater quality can vary with water abstraction, with implications for connected surface water bodies. Differences occur based on the environment of abstraction (e.g. terrestrial and coastal), with incursions of surface water or saline water into the aquifer.

In an alluvial, terrestrial setting, over-abstraction of groundwater can lead to surface water

[58] Zhou Y. (2009). A critical review of groundwater budget myth, safe yield and sustainability. *Journal of Hydrology* **370**, 207–213.

[59] Doll P., Muler Schmied H.M., Schuh C. & Portmann F.T. (2014) Global-scale assessment of groundwater depletion and related groundwater abstractions: Combining hydrological modeling with information from well observations and GRACE satellites. *Water Resources Research* **50**, 5698-5720.

[60] Darama Y. (2001) An analytical solution for stream depletion by cyclic pumping of wells near streams with semipervious beds. *Ground Water* **39,** 79-86.

[61] Bromley J., Cruces J., Acreman M., Martinez L. & Llamas M.R. (2010) Problems of sustainable groundwater management in an area of over-exploitation: The Upper Guadiana catchment, Central Spain. *International Journal of Water Resources Development* **17**, 379-396.

[62] United Nations, 2012. *System of environmental-economic accounting for water*. Department of Economic and Social Affairs, United Nations.

entering the aquifer. Mauclaire and Gibert[63] showed evidence of changes in groundwater level, oxygen concentration, pH, redox potential, conductivity and temperature as a result of this interaction. Expansion of the radius of influence during abstraction (due to increased removal of water) increases the area at the surface contributing recharge, and thereby the area capturing potential contaminants. These can be point sources (e.g. landfills, leaky septic tanks) and non-point sources (e.g. landspread fertiliser). Groundwater abstraction can also induce poorer quality groundwater to move from other parts of the aquifer.[64] A reduction in baseflow can limit the dilution function where there are other pressures to groundwater quality in the catchment. Wells not constructed in accordance with the aforementioned guidelines[65] can themselves also act as a conduit for surface pollution to reach underlying groundwater.[66] The on-going safe operation of wells is the responsibility of the well owner, but many wells are not properly maintained.[67] The most common threat to the integrity of a private water well is contamination arising from surface water entering either the well, or down the outside of the well casing due to poor construction or maintenance.[68] Depending on the contaminants, this can impact the water quality of the water body.

Water abstraction can also lead to saline intrusion. In coastal locations, under natural conditions it is the flow of groundwater towards the sea that limits the landward encroachment of

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[63] Mauclaire L. & Gibert, J. (1998). Effects of pumping and floods on groundwater quality: a case study of the Grand Gravier well field (Rhone, France). *Hydrobiologia* **389**, 141-151.

[64] DEFRA (2013). Managing abstraction and the water environment. Department for Environment, Food and Rural Affairs, Wales.

[65] Institute of Geologists of Ireland: Guidelines for water well construction (2015). Available at: *igi.ie/assets/files/Water%20Well%20Guidelines/Guidelines.pdf.*

[66] Simpson, H., 2004. Promoting the management and protection of private water wells. *Journal of Toxicology and Environmental Health*, **Part A 67**, 1679–1704.

[67] Ibid.

[68] US EPA (1993) Private wells: Guidance for what to do after the flood. EPA Publication 813-F-93-001.

seawater.[69] Where abstraction of groundwater lowers groundwater levels the balance between fresh groundwater and seawater is disturbed. Reduced pressure of overlying freshwater layers permits the seawater to intrude usable parts of the aquifer (Figure 2.4).[70] Localised saline intrusion risk can develop where future new supplies are located close to the coastline, or as a result of over-abstraction from existing sources.

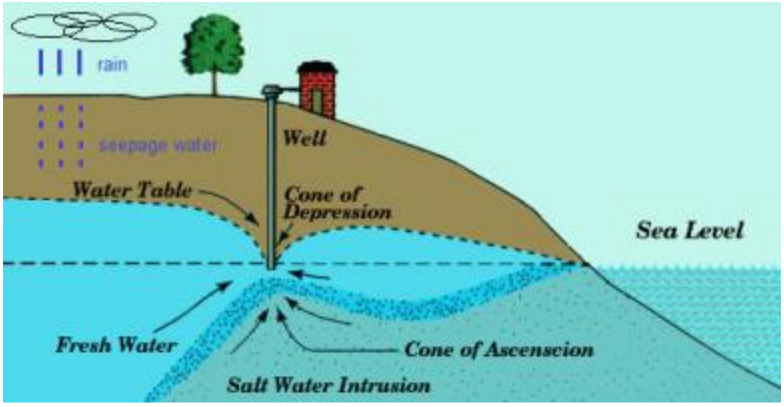

Figure 2.4: Salt water intrusion from water abstraction[71]

2.3.3.4 Groundwater Dependent Terrestrial Ecosystems

Groundwater Dependent Terrestrial Ecosystems (GWDTEs) are habitats/species, such as turloughs and fens, that are dependent on groundwater to maintain the environmental supporting conditions required to sustain that habitat and/or species.[72] Defining water needs for

[69] Domenico P.A. & Schwartz F.W. (1998) *Physical and Chemical Hydrogeology*. John Wiley & Sons.

[70] Ibid.

[71] Source: https://althealai.wordpress.com/2015/10/25/groundwater/.

[72] Kilroy G., Dunne F., Ryan J., O'Connor A., Daly D., Craig M., Coxon C., Johnston P. & Moe H. (2008) *A framework for the assessment of groundwater dependent terrestrial ecosystems under the Water Framework Directive.* Report ERC No. 12, Environmental Protection Agency.

wetlands is challenging, not least because the term ‘wetland’ embraces such a range of different ecosystem types that have wide-ranging hydrological/hydrogeological characteristics, even when they are geographically close to one another.[73]

In order for a groundwater body (GWB) to be classified based on the presence of a GWDTE within it, the GWDTE needs to be directly dependent on the GWB. This means that the GWB should provide sufficient quantity (level and flow) and quality to sustain the GWDTE.[74]

The hydrological interaction between groundwater and such ecological systems is frequently complex and dependent on site-specific conditions. An EC Technical Report[75] outlines the four scenarios whereby groundwater is essential to a GWDTE:

1. A groundwater source directly irrigates the ecosystem and is visible as a spring or seepage, e.g. tufa springs (n.b. where springs feed a permanent lake or river system this would not be considered a GWDTE but an aquatic ecosystem);
2. Groundwater collecting above impermeable strata, such as clay, in depressions in the landscape, i.e. fens;
3. High groundwater tables maintaining a seasonally waterlogged condition, e.g. bogs; and
4. A seasonally fluctuating groundwater table flooding depressions intermittently, e.g. turloughs.

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[73] de la Hera, P.A. & Murillo, D.J.M. (2014). Identification of wetland water sources for environmental flow assessment; a case study of the Miguel Ibáñez Wetlands (Segovia, Spain). *Hydrological Sciences Journal* **59,** 3–4.

[74] EC (2011) Technical report on groundwater dependent terrestrial ecosystems. Technical Report No. 6. European Commission.

[75] EC (2011) Technical report on groundwater dependent terrestrial ecosystems. Technical Report No. 6. European Commission.

Altered catchment hydrology from groundwater abstraction poses a threat to GWDTEs worldwide.[76] Declining groundwater levels due to abstraction can have negative ecological effects associated with decreased base flow to rivers, lakes and wetlands and may in extreme cases result in drying out of wetlands.[77]

As with lakes, abstractions that have connectivity with groundwater in wetlands cause disturbance to water levels and the reliant zonation. Johansen and Pedersen[78] used pumping tests to explore this impact on a Danish fen and found that whilst the abstraction caused a reduction in spring flow to the fen there was some uncertainty regarding the effect this was having on fen water levels, compared to non-pumping conditions. Groundwater levels controlling ecology in wetlands can also be impacted upon when abstractions from the groundwater catchment feeding the wetland exceeds recharge across the same area, or where the radius of influence intersects a part of the GWDTE (i.e. water moves away from the GWDTE towards the abstraction point).

Kilroy et al.[79] refer to turloughs as groundwater fed temporary lakes in karst depressions. In describing the various hydrogeological input controls to turloughs, Sheehy Skeffington et al.[80] surmises that mechanisms for filling and emptying of turloughs is complex and is a reflection

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[76] Van Diggelen R., Middleton B., Bakker J., Grootjans A. & Wassen M. (2006) Fens and floodplains of the temperate zone: present status, threats, conservation and restoration. *Applied Vegetation Science* **9**, 157-162.

[77] Doll P., Muler Schmied H.M., Schuh C. & Portmann F.T. (2014) Global-scale assessment of groundwater depletion and related groundwater abstractions: Combining hydrological modeling with information from well observations and GRACE satellites. *Water Resources Research* **50**, 5698-5720.

[78] Johansen O. M. & Pedersen M. L. (2011) Effect of groundwater abstraction on fen ecosystems. *Journal of Hydrology* **402,** 357-366.

[79] Kilroy G., Coxon C., Ryan J., O'Connor A. & Daly, D. (2005) Groundwater and wetland management in the Shannon river basin. *Environmental Science & Policy* **8**, 219-225.

[80] Sheehy Skeffington M., Moran J., O'Connor A., Regan E., Coxon C.E., Scott N.E. & Gormally M. (2006) Turloughs - Ireland's unique wetland habitat. *Biological Conservation* **133**, 265-290.

of the aquifers feeding them. Naughton et al.[81] showed that extensive topographical and bathymetric surveying is an effective method for determining turlough volume, and subsequently basing inflows and outflows on change in water level. Naughton et al.[82] demonstrated flood depths ranging from 3.0 - 15.4 m in 21 selected turloughs in Ireland. An increase in annual maximum turlough levels due to transboundary transfer of groundwater brought about by abstraction/discharge or water supply networks can cause an increase in flood risk due to reduced storage capacity in the hydrological regime: i.e. if water is abstracted from one catchment and discharged into another which includes turloughs, flooding may occur if the discharged water results in maximum turlough level being exceeded.

Fen habitats are largely groundwater fed, being located in topographic hollows or below springs or seepages of water that has been in contact with mineral ground.[83] The composition of the fen vegetation reflects (i) the chemical composition of the dominant water supply and (ii) the duration of a mean water level.[84] The combination of these factors dictates what type of fen develops and its hydrological regime.[85] Aldous and Bach[86] found that, for fens in Oregon, USA, water table depth is the critical issue rather than flow, with a required water table within 35 cm of the surface. A drop in water level (as could occur through abstraction) affects chemical

[81] Naughton O., Johnston P. M. & Gill L. W. (2012). Groundwater flooding in Irish karst: The hydrological characterisation of ephemeral lakes (turloughs). *Journal of Hydrology* 470, 82-97.

[82] Ibid.

[83] Proctor M.C.F. (2010). Environmental and vegetational relationships of lakes, fens and turloughs in the Burren. *Biology and Environment: Proceedings of the Royal Irish Academy* **110B**, 17-34.

[84] Regan S., Gill L., Connaghan J., Brew T., Gilligan N. (2016). Assessing the conservation status of GWDTEs under the Habitats Directive and Water Framework Directive: A case study from Tory Hill Fen SAC. *National Hydrology Conference, Office of Public Works, Ireland*.

[85] McBride A., Diack I., Droy N., Hamill H., Jones P., Schutten J., Skinner A. & Street M. (2011) *The Fen Management Handbook*. Scottish Natural Heritage, Perth.

[86] Aldous .R. & Bach L.B. (2014) Hydro-ecology of groundwater-dependent ecosystems: applying basic science to groundwater management. *Hydrological Sciences* **59**, 3–4.

processes in the organic topsoil and can lead to acidification[87] and enhanced nutrient release due to aeration and following decomposition of organic matter.[88] Furthermore, a drop in water table leaves empty pore spaces that can be filled with rainwater with a lower buffer capacity than the alkaline groundwater,[89] potentially having a negative impact on the ecology of the fen. A reduction in the regional groundwater level is likely to extend the period where this drying out of the top-soil occurs and hence increase degradation and release of nutrients beyond natural levels.[90] Hydrochemical patterns across groundwater fed wetlands, especially carbonate, sulphate and redox gradients, can influence phosphorus availability and water table drawdown has been shown to facilitate accumulation of phosphorus, with a likely negative effect on species diversity.[91]

2.3.4 Freshwater Ecological Impacts

Water abstraction also impacts on water-body ecology. The following sections provide a summary of these communities, the physical changes than can occur in these communities arising from water abstraction and how these changes can impact upon the surface water ecosystem as a whole. It looks first at the impacts of low water levels in lakes before considering impacts to biotic assemblages. The individual assemblages considered include macro-

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[87] Van Haesebroeck V., Boeye D., Verhagen B. & Verheyen R.F. (1997) Experimental investigation of drought induced acidification in a rich fen soil. *Biogeochemistry* **37**(1), 15–32.

[88] Devito K.J. & DIllon P.J. (1993) The influence of hydrologic conditions and peat oxia on the phosphorus and nitrogen dynamics of a conifer swamp. Water Resoures Research **29**(8), 2675–2685.

[89] Schot P.P., Dekker S.C. & Poot A. (2004) The dynamic form of rainwater lenses in drained fens. Journal of Hydrology 293, 74–84.

[90] Johansen O. M. & Pedersen M. L. (2011) Effect of groundwater abstraction on fen ecosystems. *Journal of Hydrology* **402,** 357-366.

[91] Bradley K.M.B. & Bedford B.L. (2008) Groundwater-induced redox-gradients control soil properties and phosphorus availability across four headwater wetlands**.** *Biogeochemistry **90**(3), 259-274.*

invertebrates, macrophytes, phytoplankton and fisheries. As water wells used during abstraction can provide a direct pathway for contaminants to migrate, this is also discussed.

Previous studies of the direct impacts of water abstraction upon macro-invertebrates, macrophytes and plankton are limited and few experimental studies on the impacts have been carried out, despite the increasing demand on our water resources.[92] Therefore, research, results and conclusions from studies investigating (the impacts of) reduced and low flow rates were referred to as these situations have similar impacts to those of water abstraction.

2.3.4.1 Low Water Levels in Lakes

Lakes are a vital source of food and water in the developing and developed world, and home to much biodiversity. Most lakes and ponds are subject to natural changes in water levels over seasons and longer periods of time.[93] These natural changes are usually gradual and predictable in nature[94]. They can be considered as essential for the survival of some species and can support both the biodiversity and productivity of littoral regions.[95] However, alterations in the natural patterns of water level fluctuations can have major ecological impacts upon lake ecosystems.[96] These human induced water level fluctuations have the potential to alter the integrity of whole lake ecosystems, affecting them directly through the modification of the habitat structure of the

[92] Eastern River Basin District (2008) National Urban Pressures POM/Standards Study. A Review of the Environmental Flow Methods Focusing on their Use with Various Biotic Groups to Assess the Effects of Abstraction Pressures in Ireland.

[93] Garcıa-Molinos, J. and Donohue, I. (2014) Downscaling the Non-Stationary Effect of Climate Forcing on Local-Scale Dynamics: The Importance of Environmental Filters. *Climatic Change*, **124**, 333 – 346.

[94] White, M.S., Xenopoulos, M.A., Metcalfe, R.A. and Somers, K.M. (2010) On the Role of Natural Water Level Fluctuation in Structuring Littoral Benthic Macroinvertebrate Community Composition in Lakes. *Limnology & Oceanography*, **55** , 2275 – 2284.

[95] E.g. Coops, H. and Hosper, S.H. (2002) Water-Level Management as a Tool for the Restoration of Shallow Lakes in the Netherlands. *Lake and Reservoir Management*, **18**, 292 – 297.

[96] Zohary, T. and Ostrovsky, I. (2011) Ecological Impacts of Excessive Water Level Fluctuations in Stratified Freshwater Lakes. *Inland Waters*, **1** ,47 – 59.

drawdown zones,[97,98] the sediment-water interface,[99] water residence times[100] or the internal nutrient loading regimes.[101] However, the impacts of amplified water level fluctuations are likely to be greatest in the littoral zone,[102] where even small drawdowns can lead to significant impacts[103] by converting large areas of standing water to air-exposed habitats and vice versa.[104]

The lake littoral zone supports the main populations of macrophytes and macro-invertebrates. Littoral zones also provide habitats for the majority of biological diversity in lakes[105] and they provide key food sources both to aquatic habitats and the neighbouring riparian zones.[106,107]

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[97] Brauns, M., Garcia, X.F. and Pusch, M. (2008) Potential Effects of Water-- Level Fluctuations on Littoral Invertebrates in Lowland Lakes. *Hydrobiologia*, **613**, 5 – 12.

[98] Evtimova, V. (2013) Water Level Fluctuations and their Effects on Lake Ecology. PhD thesis. Trinity College Dublin, Ireland.

[99] Rorslett, B. (1984) Environmental Factors and Aquatic Macrophyte Response in Regulated Lakes. *Aquatic Botany*, **1** , 199 – 220.

[100] Brauns, M., Garcia, X.F., Pusch, M.T. and Walz, N. (2007) Eulittoral Macroinvertebrate Communities of Lowland Lakes: Discrimination Among Trophic States. *Freshwater Biology*, **52**, 1022 – 1032.

[101] Zohary, T. and Ostrovsky, I. (2011) Ecological Impacts of Excessive Water Level Fluctuations in Stratified Freshwater Lakes. *Inland Waters*, **1**,47 – 59.

[102] Solimini, A.G., Free, G., Donohue, I., Irvine, K., Pusch, M., Rossaro, B., Sandin, L. and Cardoso, A.C. (2006) Using Benthic Macro-Invertebrates to Assess Ecological Status of Lakes - Current Knowledge and Way Forward to Support WFD Implementation . Report EUR 22347 for the European Commission, Institute for Environment and Sustainability. Office for Official Publications of the EC, Luxembourg.

[103] Smith, B.D., Maitland, P.S. and Pennock, S.M. (1987) A Comparative Study of Water Level Regimes and Littoral Benthic Communities in Scottish Lochs. *Biological Conservation*, **39** , 291 – 316.

[104] Palomäki, R. (1994) Response by macrozoobenthos biomass to water level regulation in some Finnish lake littoral zones. *Hydrobiologia*, **286** , 17 – 26.

[105] Vadeboncoeur, Y., McIntyre, P.B. and Zanden, M.J.V. (2011) Borders of Biodiversity: Life at the Edge of the World's Large Lakes. *BioScienc*e , **61** , 526 – 537.

[106] Vander Zanden, M.J. & Vadeboncoeur, Y. (2002) Fishes as Integrators of Benthic and Pelagic Food Webs in Lakes. *Ecology* , **83** , 2152 – 2161.

[107] Wesner, J.S. (2010) Aquatic Predation alters a Terrestrial Prey Subsidy. *Ecology* , **91** , 1435 – 1444.

The significance of these effects depends largely on the extent, duration and timing of the abstraction as well as the biota's ability to recover.[108] In the case of severe abstraction impacts, the volume withdrawn can exceed the ability of the lake's catchment to restore the water level to typical seasonal high levels resulting in the long-term decline in the lake water level. Macrophytes can become more exposed due to decreases in water level and if roots are exposed for a prolonged period, then this could result in the plant drying out.[109]

Observational studies have suggested that amplified water level fluctuations may reduce macrophyte diversity and cover, therefore potentially resulting in their complete disappearance from lake margins, thereby reducing the productivity and structural diversity of littoral habitats.[110,111] The latter has important implications for the structural heterogeneity of the associated biotic assemblages.[112] Although benthic invertebrates (i.e. invertebrates that live on the bottom sediments of lakes and rivers) tend to be comparatively mobile, their community structure is highly dependent upon lake habitat structure.[113] Importantly, benthic invertebrate

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108 CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

109 ERBD (2010). River basin management plan 2009 2015. Eastern River Basin District. Retrieved from http://www.wfdireland.ie/docs/1_River%20Basin%20Management%20Plans%202009%20-%202015/ERBD%20RBMP%202010/ERBD%20RBMP%206%20July%202010.pdf on 7th May 2017.

110 Rorslett, B. (1984) Environmental Factors and Aquatic Macrophyte Response in Regulated Lakes. *Aquatic Botany*, **19**, 199 – 220.

111 Rorslett, B. (1985) Death of Submerged Macrophytes - Actual Field Observation and Some Implications. *Aquatic Botany*, **22**, 7 – 19.

112 Donohue, I., Jackson, A.L., Pusch, M.T. and Irvine, K. (2009) Nutrient Enrichment Homogenizes Lake Benthic Assemblages at Local and Regional Scales. *Ecology*, **90**, 3470 – 3477.

113 Tolonen, K.T., H am alainen, H., Holopainen, I.J. and Karjalainen, J. (2001) Influences of Habitat Type and Environmental Variables on Littoral Macroinvertebrate Communities in a Large Lake System. *Archiv fur Hydrobiologie*, **152**, 39 – 67.

consumers form key links not only in whole lake food webs[114] but also in the adjacent riparian and terrestrial ones.[115]

Despite the significant impacts of water level fluctuations on the benthic macro-invertebrates of littoral zones and consequently the impacts on the lake system as a whole, there have been few studies of the mechanisms of the effects. An Irish study by Evtimova & Donohue[116] addressed this somewhat by conducting experiments on the impacts of alterations of water level regimes on littoral zones in standing water ecosystems. The study found that water level fluctuations reduced the benthic algal biomass and the density and taxonomic distinctness of benthic invertebrate assemblages. Both the taxonomic and trophic structure of benthic assemblages were altered significantly in ponds with water level fluctuations and consequently the productivity and biological diversity of the lake littoral zones being reduced.

A further study by Evtimova & Donohue[117] demonstrated that lakes with high water level fluctuations have significant reductions in smaller sized littoral substrates and coverage of macrophyte vegetation in the shallows, compared to lakes with low water level fluctuations. Lakes with high level fluctuations also had a greater proportion of mobile diatom species and omnivorous benthic invertebrates in shallow waters, altered taxonomic and trophic structure of benthic consumers and more homogenous algal and benthic invertebrate assemblages.

[114] Vander Zanden, M.J. & Vadeboncoeur, Y. (2002) Fishes as Integrators of Benthic and Pelagic Food Webs in Lakes. *Ecology*, **83** , 2152 – 2161.

[115] Wesner, J.S. (2010) Aquatic Predation alters a Terrestrial Prey Subsidy. *Ecology*, **91**, 1435 – 1444.

[116] Evtimova, V.V. and Donohue, I. (2014) Quantifying ecological responses to amplified water level fluctuations in standing waters: an experimental approach. *Journal of applied ecology*, ***51***,.1282-1291.

[117] Evtimova, V.V. and Donohue, I. (2016) Water-level fluctuations regulate the structure and functioning of natural lakes. *Freshwater Biology*, ***61***, 251-264.

Alteration in water level can also alter the light penetration. This could impact the growth of submerged macrophytes as light is one of the major limiting factors of vegetation growth[118]. The limitation of light can affect lakes differently: e.g. the vegetated zone in peat-based lakes are limited due to low light penetration and so these lakes would be more sensitive to these changes in water level regimes.

Overall, it is concluded that (similar to rivers – see sections below) amplified water level fluctuations can impact significantly on the structure and functioning of whole lake ecosystems.

2.3.4.2 Macro-invertebrates

A comprehensive review of the impacts of low flow on the macro-invertebrate community in streams was undertaken by Dewson et al.[119] These studies summarised the outcomes of the relevant research and they compared the sometimes conflicting results of the effects of reduced discharge on invertebrates. Overall, it was shown that reduced flow can affect in-stream invertebrate density, taxonomic richness and drift.

With low flow rates and decreased discharge, there is usually a loss of wetted area, which reduces the habitat availability for the macro-invertebrate community.[120,121] In addition, water

[118] Barko, J.W. and Smart, R.M. (1981). Comparative Influences of Light and Temperature on the Growth and Metabolism of Selected Submerged Freshwater Macrophytes. *Ecological Monographs*, **51**, 219–236.

[119] Dewson, Z.S., James, A.B. and Death, R.G. (2007a) A Review of the Consequences of Decreased Flow for Instream Habitat and Macro-Invertebrates. *Journal of the North American Benthological Society*, **26**, 401-415.

[120] Brasher, A.M.D. (2003) Impacts of Human Disturbances on Biotic Communities in Hawaiian Streams. *Bioscience*, **53**, 1052–1060.

[121] Cowx I.G., Young, W.O. and Hellawell, J.M. (1984) The Influence of Drought on the Fish and Invertebrate Populations of an Upland Stream in Wales. *Freshwater Biology*, **14**, 165–177.

velocity and depth are also reduced.[122,123] Changes to nutrients concentration,[124,125] increased water temperatures[126,127] and lower dissolved oxygen levels[128,129] have also been cited. All these factors can contribute to changes in invertebrate density, causing either an increase or decrease.

In some cases, low flows can cause a decrease in invertebrate densities.[130] McIntosh et al.[131] suggested that density decreased in response to changes in competition and predation because habitat area decreased and food quality and quantity were altered by flow reduction. Conversely, in other situations, the density of benthic invertebrates has been found to increase with decreased flow.[132] Reduced wetted area can sometimes explain these increases because

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[122] McIntosh M.D., Benbow M.E. and Burky A.J. (2002) Effects of Stream Diversion on Riffle Macroinvertebrate Communities in a Maui, Hawaii Stream. *River Research and Applications,* **18**, 569–581.

[123] Wright, J.F. and Berrie, A.D. (1987) Ecological Effects of Groundwater Pumping and a Natural Drought on the Upper Reaches of a Chalk Stream. *Regulated Rivers: Research and Management*, **1**, 145–160.

[124] Rader R.B. and Belish T.A. (1999) Influence of Mild to Severe Flow Alterations on Invertebrates in Three Mountain Streams. *Regulated Rivers: Research and Management*, **15**, 353–363.

[125] Ladle M. and Bass J.A.B. (1981) The Ecology of a Small Chalk Stream and its Responses to Drying During Drought Conditions. *Archiv fur Hydrobiologie*, **90**, 448–466.

[126] Rader R.B. and Belish T.A. (1999) Influence of Mild to Severe Flow Alterations on Invertebrates in Three Mountain Streams. *Regulated Rivers: Research and Management*, **15**, 353–363.

[127] Everard, M. (1996) The Importance of Periodic Droughts for Maintaining Diversity in the Freshwater Environment. *Freshwater Forum*, **7**, 33–50.

[128] Everard, M. (1996) The Importance of Periodic Droughts for Maintaining Diversity in the Freshwater Environment. *Freshwater Forum*, **7**, 33–50.

[129] Jowett I.G. (1997) Environmental Effects of Extreme Flows. In: Floods and Droughts: the New Zealand Experience (Eds M.P. Mosley & C.P. Pearson), pp. 104–116. The Caxton Press, Christchurch, New Zealand.

[130] Dewson, Z.S., James, A.B. and Death, R.G. (2007a) A Review of the Consequences of Decreased Flow for Instream Habitat and Macro-Invertebrates. *Journal of the North American Benthological Society*, **26**, 401-415.

[131] McIntosh M.D., Benbow M.E. and Burky A.J. (2002) Effects of Stream Diversion on Riffle Macroinvertebrate Communities in a Maui, Hawaii Stream. *River Research and Applications*, **18**, 569–581.

[132] Dewson, Z.S., James, A.B. and Death, R.G. (2007a) A Review of the Consequences of Decreased Flow for Instream Habitat and Macro-Invertebrates. *Journal of the North American Benthological Society*, **26**, 401-415.

individuals are concentrated into a smaller area.[133,134] However, changes in habitat suitability or food resources can cause invertebrate densities to increase, even when the wetted area remains constant.[135,136]

Studies that report variable density responses provide some insight into the factors that might influence invertebrate responses to changes in flow.[137,138,139] In rivers with high nutrient concentrations, filamentous green algae and invertebrate density increased significantly during summer low flows. In the river with low nutrient concentrations, the diatom-dominated periphyton assemblage supported a stable invertebrate community.[140] Thus, responses of food resources, such as algae and organic matter to low flow can strongly influence invertebrate

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[133] Wright, J.F. and Berrie, A.D. (1987) Ecological Effects of Groundwater Pumping and a Natural Drought on the Upper Reaches of a Chalk Stream. *Regulated Rivers: Research and Management*, **1**, 145–160.

[134] Gore J. A. (1977) Reservoir Manipulations and Benthic Macro-Invertebrates in a Prairie River. *Hydrobiologia*, **55**, 113–12.

[135] Dewson, Z.S., Death, R.G. and James, A.B.W. (2003) The Effect of Water Abstractions on Invertebrate Communities in Four North Island Streams. New Zealand Natural Sciences 28:51-65.

[136] Wright J.F. and Symes, K.L. (1999) A Nine-Year Study of the Macroinvertebrate Fauna of a Chalk Stream. *Hydrological Processes*, **13**, 371–385.

[137] Armitage, P. D. and Petts, G.E. (1992) Biotic Score and Prediction to Assess the Effects of Water Abstractions on River Macro-Invertebrates for Conservation Purposes. *Aquatic Conservation: Marine and Freshwater Ecosystems* **2**:1–17.

[138] Rader R.B. and Belish T.A. (1999) Influence of Mild to Severe Flow Alterations on Invertebrates in Three Mountain Streams. *Regulated Rivers: Research and Management*, **15**, 353–363.

[139] Suren A.M., Biggs B.J.F., Duncan M.J. and Bergey L. (2003a) Benthic Community Dynamics During Summer Low-Flows in Two Rivers of Contrasting Enrichment. *New Zealand Journal of Marine and Freshwater Research*, **37**, 71–83.

[140] Suren, A.M., Biggs, B.J.F., Kilroy, C. and Bergey, L. (2003b) Benthic Community Dynamics During Summer Low-Flows in Two Rivers of Contrasting Enrichment . *New Zealand Journal of Marine and Freshwater Research*, **37**, 53-70.

density responses.[141,142] It was concluded by Suren et al.[143] in their study on rivers in New Zealand, that the degree of river enrichment should be taken into account when assessing in river flow requirements and that enriched rivers with high nutrient concentrations are more sensitive to the impacts of abstraction.

It should be noted that changes in the habitat brought about by altered flow regimes can affect various taxa differently.[144] For example, when fine chalk sediments accumulated in a small English chalk stream during a drought, *Sialis lutaria* (alder fly larvae) density increased whilst that of *Gammarus pulex* (amphipod) decreased.[145]

2.3.4.2.1 Invertebrate Richness

Low or reduced flows in permanent streams can often cause a decrease in taxonomic richness, which can be attributed to the loss of habitat types and habitat diversity during these periods of reduced flows.[146,147] The importance of habitat diversity is reinforced by studies comparing

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[141] Hart, D. D. and Finelli, C.M. (1999) Physical-Biological Coupling in Streams: The Pervasive Effects of Flow on Benthic Organisms. *Annual Review of Ecology and Systematics* **30**:363–395.

[142] Smakhtin, V. U. (2001) Low Flow Hydrology: a Review. Journal of *Hydrology* **240**:147–186.

[143] Suren, A.M., Biggs, B.J.F., Kilroy, C. and Bergey, L. (2003b) Benthic Community Dynamics During Summer Low-Flows in Two Rivers of Contrasting Enrichment . *New Zealand Journal of Marine and Freshwater Research*, **37**, 53-70.

[144] Dewson, Z.S., James, A.B. and Death, R.G. (2007a) A Review of the Consequences of Decreased Flow for Instream Habitat and Macro-Invertebrates. *Journal of the North American Benthological Society*, **26**, 401-415.

[145] Wood, P. J. and Petts, G.E. (1994) Low Flows and Recovery of Macro-invertebrates in a Small Regulated Chalk Stream. *Regulated Rivers: Research and Management* **9**:303–316.

[146] Cazaubon, A. and Giudicelli, J. (1999) Impact of the Residual Flow on the Physical Characteristics and Benthic Community (Algae, Invertebrates) of a Regulated Mediterranean River: the Durance, France. Regulated Rivers: *Research and Management* **15**:441–461.

[147] McIntosh M.D., Benbow M.E. and Burky A.J. (2002) Effects of Stream Diversion on Riffle Macroinvertebrate Communities in a Maui, Hawaii Stream. *River Research and Applications*, **18**, 569–581.

multiple streams. For example, Armitage and Petts[148] found that water abstraction generally had less effect on the fauna of upland streams than on the fauna of small, lowland streams in the UK. They concluded that habitat diversity and connectivity decreased in the lowland streams, whereas a diverse range of suitable microhabitats remained available in the upland streams after water abstraction, and the presence of numerous tributaries facilitated recolonization in the upland streams.

The effects of low or reduced flow on richness can also vary among habitats within streams. In a perennial section of a UK chalk stream, Wright and Symes[149] observed that some biotopes (*Berula*, *Ranunculus* and silt) supported fewer invertebrate taxa than normal during a major drought, whereas taxonomic richness was unchanged in other biotopes (*Callitriche* and gravel). It is believed that taxonomic richness decreased due to a combination of increased water temperatures, sedimentation and altered algal assemblages.[150]

2.3.4.2.2 Drift

Reduced discharge and flows have also been implicated in increasing the active drift of macro-invertebrates.[151,152] If low flow conditions due to abstraction create unsuitable conditions for

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[148] Armitage, P. D. and Petts, G.E. (1992) Biotic Score and Prediction to Assess the Effects of Water Abstractions on River Macro-Invertebrates for Conservation Purposes. *Aquatic Conservation: Marine and Freshwater Ecosystems* **2**:1–17.

[149] Wright J.F. and Symes, K.L. (1999) A Nine-Year Study of the Macroinvertebrate Fauna of a Chalk Stream. *Hydrological Processes*, **13**, 371–385.

[150] Dewson, Z.S., James, A.B. and Death, R.G. (2007a) A Review of the Consequences of Decreased Flow for Instream Habitat and Macro-Invertebrates. *Journal of the North American Benthological Society*, **26**, 401-415.

[151] Radford D.S. and Hartland-Rowe R. (1971) A Preliminary Investigation of Bottom Fauna and Invertebrate Drift in an Unregulated and a Regulated Stream in Alberta. *Journal of Applied Ecology*, **8**, 883–903.

[152] Gore J.A. (1977) Reservoir Manipulations and Benthic Macro-Invertebrates in a Prairie River. *Hydrobiologia*, **55**, 113–12.

invertebrates, individuals might seek refuge or leave that stream reach.[153] Drift enables organisms to escape unfavourable conditions and it can occur actively or passively.[154] Passive drift decreases in response to low water velocities during periods of low flow, but many studies have shown that active drift increases during periods of low flow.[155] Invertebrates might drift actively at low water velocities because flow is insufficient to meet their nutritional, physiological[156] or preferred habitat[157] requirements. Active drift can also be caused by predator avoidance behaviour, which can increase at low flows if predator density increases.[158]

2.3.4.3 Macrophytes

Macrophytes are also a vital component of the surface water ecosystems, both flowing and standing. Macrophytes provide shelter for invertebrates, fish and birds and they are also a major contributor to the intricate food webs and synergistic relationships of the freshwater ecosystems. Macrophytes have a role in the stabilisation of sediments, the regulation of the nutrient cycle and the slowing of water currents.[159] Water levels have been thought to be responsible for the variability in biomass and species composition of aquatic macrophytes in

[153] Dewson, Z.S., James, A.B. and Death, R.G. (2007a) A Review of the Consequences of Decreased Flow for Instream Habitat and Macro-Invertebrates. *Journal of the North American Benthological Society*, **26**, 401-415.

[154] Brittain, J. E., and Eikeland, T.J. (1988) Invertebrate Drift—A Review. *Hydrobiologia* **166**:77–93.

[155] Dewson, Z.S., James, A.B. and Death, R.G. (2007a) A Review of the Consequences of Decreased Flow for Instream Habitat and Macro-Invertebrates. *Journal of the North American Benthological Society*, **26**, 401-415.

[156] Kohler, S. L. (1985) Identification of Stream Drift Mechanisms: An Experimental and Observational Approach. *Ecology* **66**:1749–1761.

[157] Brittain, J. E., and Eikeland, T.J. (1988) Invertebrate Drift—A Review. *Hydrobiologia* **166**:77–93.

[158] Kratz, K. W. (1996) Effects of Stoneflies on Local Prey Populations: Mechanisms of Impact across Prey Density. *Ecology* **77**:1573–1585.

[159] Zhao, D. Jiang, H., Yang, T., Cai, Y., Xu, D., An, S. (2012) Remote Sensing of Aquatic Vegetation Distribution in Taihu Lake Using an Improved Classification Tree with Modified Thresholds. *J Environ. Manage*. **95**, 98–107.

many freshwater ecosystems.[160,161] Although artificial management and manipulation of water levels have been practiced widely, the effect of managed water levels on aquatic macrophytes has not been fully understood in most cases because of the complex relationship between macrophytes and water level.[162] Generally, it is considered that lower flows can lead to an increase in opportunist and ruderal macrophytes, i.e., species that are first to colonise disturbed ground and a decrease in hygrophilous (drought sensitive, flood resistant) species. These impacts are discussed in greater detail below.

Research that has been carried out on macrophytes and their tolerance to different flow regimes has shown that different types of macrophytes have different flow tolerances. The UK Vegetation Classification[163] assigns broad flow tolerances to twenty four different communities of aquatic macrophytes, whilst Kirmond and Barker[164] ranked 50 macrophyte species and groups in order of their sensitivity to flow reductions.

Many studies have investigated the environmental factors that determine the establishment of plants in river systems, such as those related to physical habitat[165] and habitat disturbance.[166]

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[160] Liira, J., Feldmann, T., Mäemets, H., Peterson, U. (2010) Two Decades of Macrophyte Expansion on the Shores of a Large Shallow Northern Temperate Lake-a Retrospective Series of Satellite Images. *Aquat Bot* **93**: 207–215.

[161] Paillisson JM, Marion L (2011) Water Level Fluctuations for Managing Excessive Plant Biomass in Shallow Lakes. *Ecol Eng* **37**: 241–247.

[162] Geest GJV, Wolters H, Roozen F, Coops H and Roijackers R. (2005) Water-Level Fluctuations Affect Macrophyte Richness in Floodplain Lakes. *Hydrobiologia* **539**: 239–248.

[163] Rodwell, J.S. (ed) (1995) British Plant Communities. Volume 4, Aquatic Communities, Swamps and Tall-Herb Fens. Cambridge: Cambridge University Press.

[164] Kirmond, J. and Barker, I. (1997) Surface Water Abstraction Licensing Procedure (SWALP): Guidance for the Application for Proposed Methodology. Working Draft: Version 1.1. Bristol: Environment Agency.

[165] Riis T. (2001) Plant Distribution and Abundance in Relation to Physical Conditions within Stream Reaches and Location Within Stream Systems. *Hydrobiologia* **448**: 217–228.

[166] Henry, C.P., Bornette, G., Amoros, C., (1994) Differential effects of floods on the aquatic vegetation of braided channels of the Rhone River. *J. N. Am. Benthol. Soc*. **13**,439–467.

Flow disturbance provides prime areas for the establishment of opportunist plant species[167] and ruderal and stress tolerant riparian macrophytes.[168] When short-term flow fluctuations are frequent, it is difficult for vegetation to establish on the riverbed[169] whilst a general decrease of the discharge leads to siltation of the riverbed and its colonization by less hygrophilous competitors.[170] Long-term responses to water-level regulation of river margin vegetation were also studied by comparing regulated and free-flowing rivers from Sweden. Regulated rivers presented a significantly lower richness[171] and a different floral composition, with a higher number of infrequent species and annuals.[172]

2.3.4.4 Phytoplankton

Phytoplankton are photosynthesizing microscopic organisms that inhabit the upper layers of almost all oceans and bodies of fresh water. They are primary producers of energy and may be the base of many food webs in freshwater ecosystems. Low flow or low water levels in aquatic ecosystems can lead to increased temperatures, higher nutrient concentrations and reduced current velocities, which in turn can result in a succession of phytoplankton species, whereby the community will change from a low-biomass diatom dominated community to a high-

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[167] Rørslett, B. (1988), Aquatic weed problems in a hydroelectric river: The R. Otra, Norway. Regul. *Rivers: Res. Mgmt.*, **2**: 25–37.

[168] Blanch, S.J. and Walker, K.F. (1998) Littoral Plant Life History Strategies and Water Regime Gradients in the River Murray, South Australia: *Verhandlungen der Internationalen Vereinigung fur Theoretische und Angewandte Limnologie* **26**: 1814–1820.

[169] Garcia de Jalon, D., Sanchez, P. & Camargo, J.A. (1994) Downstream Effects of a New Hydropower Impoundment on Macrophyte, Macroinvertebrate and Fish Communities. *Regulated Rivers: Research & Management* **9**: 253–261.

[170] Henszey RJ, Skinner Q.D. and Wesche, T.A. (1991) Response of Montane Meadow Vegetation after Two Years of Streamflow Augmentation. *Regulated Rivers: Research & Management* **6**: 29–38.

[171] Nilsson C, Jansson R and Zinko, U (1997) Long-Term Responses of River-Margin Vegetation to Water-Level Regulation. *Science* **276**: 798–800.

[172] Nilsson C, Ekblad A, Gardfjell M and Carlberg B. (1991) Long-term Effects of River Regulation on River Margin Vegetation. *Journal of Applied Ecology* **28**: 963–987.

biomass, filamentous algae community (i.e., algal blooms).[173,174] Surren et al.[175] found that in nutrient enriched streams there was a substantial increase of filamentous algae during low flow conditions, however in unenriched streams, low biomass diatoms remained dominant. They state that the shift to filamentous algae could result in potential deleterious effects to the invertebrate and fish community.

2.3.4.5 Fisheries

2.3.4.5.1 Overview and General Impacts

Fish are mobile and so in some regards are less susceptible to water level changes; however their spawning habitats in the shallow littoral zone can be severely impacted upon by abstraction, particularly for pike and salmonids,[176] including Arctic char.[177] The littoral zone can also be a significant feeding zone for certain species of fish. Also, changes in water levels or velocities can impair the access of some fish to associated rivers.[178] Poff and Zimmerman[179]

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[173] McIntire, C.D. (1966) Some Effects of Current Velocity on Periphyton Communities in Laboratory Streams. *Hyrobiologia*, **27**, 559-570.

[174] Proff, N.L., Voelz, N.J., Ward, J.V. and Lee, R.E. (1990) Algal Colonization Under Four Experimentally Controlled Current Regimes in a High Mountain Stream. *Journal of the North American Benthological Society*, **9**, 308-318.

[175] Suren, A.M., Biggs, B.J.F., Kilroy, C. and Bergey, L. (2003b) Benthic Community Dynamics During Summer Low-Flows in Two Rivers of Contrasting Enrichment. *New Zealand Journal of Marine and Freshwater Research*, **37**, 53-70.

[176] Byrne, C. and O'Leary, C (2008). Extracting Water from Lakes and Rivers and its Effect on Their Ecology. 24th Annual Environmental Conference - Water the Challenges for Users. 39- 44.

[177] Igoe, F., O'Grady, M.F., Tierney, D. and Fitzmaurice, P. (2003) Arctic Char *Salvelinus Alpinus* (L.) in Ireland – A Millenium Review of its Distribution and Status with Conservation Recommendations. Biology and Environment: *Proceedings of the Royal Irish Academy*. **103B**, 9–22.

[178] James A.B.W., Dewson Z.S. & Death R.G. (2008) The effect of experimental flow reductions on macroinvertebrate drift in natural and streamside channels. River Research and Applications 24, 22–35.

[179] Poff N.L. & Zimmerman J.K.H. (2010). Ecological responses to altered flow regimes: A literature review to inform environmental flows science and management. *Freshwater Biology* **55**, 194-205.

reported that over-abstraction reduces flows to rates that are outside the tolerable range of habitat conditions for chosen species, assuming these ranges can be defined for each species. As the effect of river flow regime on aquatic organisms is specific to the physiology of a particular species and sub-species, and can vary between water bodies, it can prove difficult to establish general relationships.

Low flow and low water levels can have direct and indirect impacts upon coarse and salmonid fishery resources. Indirect impacts include an alteration of the complex food webs of the river or lake ecosystem. Fish are one of the top predators in the aquatic ecosystem, therefore bottom up impacts can affect them by altering their food supply.

Furthermore, fish can be directly impacted by water abstraction in a number of different ways. Water abstraction is generally associated with low flows and low water levels. These can be a significant problem in summer months, when the combined impacts of less rainfall, less runoff from land, more evaporation and water abstraction become apparent. These direct impacts comprise:

- Lower dissolved oxygen levels in water –one of the leading causes of sudden fish kills.
- Increased temperature – many fish species have specific temperature needs during different stages of their life-cycles.[180]
- Loss of habitats for spawning, loss of riffles etc. – marginal habitats and gravel beds are vital for the spawning of salmonids. Loss of riffle habitats can be associated with the loss of macro-invertebrate communities, which the fish feed on.

[180] Elliott, J.M. & Elliott, J.A. (2010) Temperature requirements of Atlantic salmon *Salmo salar*, brown trout *Salmo trutta* and Arctic charr *Salvelinus alpinus*: predicting the impacts of climate change. *Journal of Fish Biology* **77**, 1793-1817.

2.3.4.5.2 Salmon (Salmo Salar)

One of Ireland's most valued fish species is the salmon *Salmo salar*. Salmon are an anadromous species, which means that the juveniles leave the freshwater river to migrate to the sea before returning to their original river to spawn in the winter months. These return migrations of adults prior to spawning can be affected by a number of constraints such as low flow, low dissolved oxygen, high temperatures and physical barriers to migration. At a sufficiently high severity, these constraints may lead to a reduction in adult salmon returns and possibly a reduced juvenile recruitment.[181]

Salmon are initially attracted to river systems by the flow of river water into the estuaries in which they are holding, i.e. where they wait in an estuary before continuing their migration to the freshwater rivers to spawn.[182] Reduction in the level of flow is thought to reduce or delay entry into the river.[183] River entry of salmon will naturally cease totally at extreme low flows.[184] In addition, returning adult salmon may also be susceptible to increases in water temperature and resulting decreases in dissolved oxygen[185] and these conditions can be exacerbated by low flow conditions. For salmonids 20 – 21^{o}C should be accepted as the upper permissible temperature during the warmest seasons of the year.[186] Analysis of salmon radio tracking data

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[181] Knight, C and Horsfield, R (2007) Kenmare Water Supply Scheme, Sheen Falls Abstractions Fisheries Considerations. Study undertaken for Kerry County Council.

[182] Knight, C and Horsfield, R (2007) Kenmare Water Supply Scheme, Sheen Falls Abstractions Fisheries Considerations. Study undertaken for Kerry County Council.

[183] Ladle, M. (2002) Review of Flow Needs for Fish and Fisheries. Environmental Agency R&D Technical Report W159.

[184] Peters, J.C., Farmer, H.R. and Radford, P.J. (1973) A Simulation Model of the Upstream Movement of Anadromous Salmonid Fish. Water Resources Board Publication No. 21. 76 pp.

[185] Alabaster, J.S. (1990) The Temperature Requirements of Adult Atlantic Salmon *Salmo salar* L, during their Upstream Migration in the River Dee. *Journal of Fish Biology*. **37**. 659-661.

[186] Alabaster, J.S. and Lloyd, P. (1982) Water Quality Criteria for Freshwater Fish (2nd Ed). FAO and Butterworths, London.

for rivers in the south and south west of England noted that the number of fish passing the tidal limit when water temperatures exceeded 21°C fell sharply.[187]

Such changes in water temperature often occur during low flow conditions when the width of the river remains the same but the volume of water reduces, concentrating the effects of solar radiation. Solomon[188] noted that halving the discharge while maintaining surface area will double the heating effect of solar radiation, potentially doubling the temperature rise of any given reach. This relationship is not linear however, as increasing water temperature will increase heat loss by evaporation and radiation.

Salmon are a listed species in Annex II of the EU Habitats Directive and under the requirements of this Directive, Ireland is obliged to protect and enhance the conservation status of this species.

2.3.5 Future Impacts

The two important future impacts that relate to water abstraction are likely to be climate change and intensification of agriculture.

Anthropogenic climate change has the ability to alter the global water cycle with evidence for this over the last 50 years.[189,190] These changes include changes to the intensity of heavy

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[187] Knight, C and Horsfield, R (2007) Kenmare Water Supply Scheme, Sheen Falls Abstractions Fisheries Considerations. Study undertaken for Kerry County Council.

[188] Solomon, D.J. (2005) Anthropogenic Influences on the Temperature Regime in a Chalk River. Environmental Agency Report SC040025/SR.

[189] Gedney, N., Cox, P.M., Betts, R.A., Boucher, O., Huntingford, C., Stott, P.A., (2006). Detection of a direct carbon dioxide effect in continental river runoff records. *Nature* **439**, 835–838.

[190] IPCC (2007) *Climate Change 2007: Synthesis Report*. Geneva. pp104.

precipitation,[191] increased flood frequencies,[192] increased droughts[193] and increased rainfall at high latitudes.[194]

All these impacts of projected climate change will alter the hydrologic regime and result in more variable flows. Many of the impacts will result in lower flows than currently experienced at certain times of the year. Given that the impacts of water abstraction outlined above are exacerbated at periods of low flow, this suggests increased future impacts of water abstraction. This is likely to be catchment specific and would depend on the interaction of future climate change with the physical characteristics of the catchment.

Intensification of agriculture is also likely to increase the rate of water abstraction. In EU states, agriculture accounts for 21% of water abstraction, with only 30% of this returned to local water bodies.[195] Increased risk to water bodies will particularly apply in regions where sectors of agriculture with high water use such as irrigated agriculture,[196] and cattle and dairy farming[197] are undergoing intensification.

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[191] Groisman, P.Y., Knight, R.W., Easterling, D.R., Karl, T.R., Hegerl, G.C., Razuvaev, V.N., (2005) Trends in intense precipitation in the climate record. *Journal of climate* **18**, 1326–1350.

[192] Milly, P.C., Dunne, K.A., Vecchia, A.V., (2005) Global pattern of trends in streamflow and water availability in a changing climate. *Nature* **438**, 347–350.

[193] Dai, A., Trenberth, K.E., Qian, T., (2004) A global dataset of Palmer Drought Severity Index for 1870–2002: relationship with soil moisture and effects of surface warming. *Journal of Hydrometeorology* **5**, 1117–1130.

[194] Milly, P.C., Dunne, K.A., Vecchia, A.V., (2005) Global pattern of trends in streamflow and water availability in a changing climate. *Nature* **438**, 347–350.

[195] EEA (2009). Water resources across Europe - confronting water scarcity and drought. European Environment Agency Report 2/2009.

[196] Vörösmarty, C.J., Green, P., Salisbury, J., Lammers, R.B., (2000) Global water resources: vulnerability from climate change and population growth. *Science* **289**, 284–288.

[197] Parker, D.B., Perino, L.J., Auvermann, B.W., Sweeten, J.M., others, 2000. Water use and conservation at Texas High Plains beef cattle feedyards. Applied Engineering in Agriculture 16, 77–82.

2.4 Environmental Flows

A relatively recent methodology for assessing the impact of river flow on ecological characteristics has been developed and is being implemented in several jurisdictions. In particular, it acknowledges the fact that low flows are not necessarily detrimental to water courses and recognises the need to sustain flow variability that mimics the natural, climatically driven variability of flows.

Flow is viewed as a 'master variable' that shapes many fundamental ecological characteristics of river ecosystems.[198] Until recently, mitigating ecological impact to rivers has focussed on maintaining established low flows. Poff et al.[199] stated that prolonged low flows can cause: (i) reduced concentration of aquatic organisms,[200,201] (ii) diminished plant species diversity,[202] (iii)

[198] Power M.E., Sun A., Parker G., Dietrich W.E. & Wootton, J.T. (1995). Hydraulic food-chain models. *Bioscience* **45**, 159-167.

[199] Poff N.L., Allan J.D., Bain M.B., Karr J.R., Prestegaard K.L., Richter B.D., Sparks R.E. & Stromberg J.C. (1997). The natural flow regime, a paradigm for river conservation and restoration. *Bioscience* **47**, 769-784.

[200] Cushman R.M. (1985) Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. *North American Journal of Fisheries Management* **5,** 330-339.

[201] Petts G.E. (1984). *Impounded River*. John Wiley & Sons, Chichester, UK.

[202] Taylpr D.W. (1982) Eastern Sierra riparian vegetation: ecological effects of stream diversion. *Mono Basin Research Group – Report to Inyo National Forest*.

desertification of riparian species composition[203,204] and (iv) physiological stress leading to reduced plant growth rate, morphological change or mortality.[205,206]

Low flows were initially intended as a means of assessing the capacity of a watercourse to assimilate pollutant discharges, but have since been applied to regulate minimum flows for habitat protection and aquatic life support.[207]

These recommended minimum flow characteristics are derived from data that has been collected over long periods, at various temporal scales and frequencies. One such commonly used low flow method is the application of various flow duration exceedance percentiles (e.g. Q_{95}, Q_{98}).

However, low flows are not entirely detrimental to watercourses and can indeed provide cues for initiating life cycle transitions including spawning, egg hatching, rearing and migration.[208,209] This has led to a recognition that a focus on maintaining flow above a pre-determined low flow rate fails to take account of natural fluctuations and patterns in flow and may be inadequate in terms of protecting river ecosystems and aquatic life. At the other

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[203] Busch D.E. & Smith S.D. (1995) Mechanisms associated with decline of woody species in riparian ecosystems of the Southwestern US. *Ecological Monographs* **65**, 347-370.

[204] Stromberg J.C., Tiller R., Richter B. (1996). Effects of groundwater decline on riparian vegetation of semiarid regions: the San Pedro River, Arizona, USA. *Ecological Applications* **6**, 113-131.

[205] Kondolf G.M. & Curry R.R. (1986). Channel erosion along the Carmel River, Monterey County, California. *Earth Surface Processes and Landforms* **11**, 307-319.

[206] Rood S.B., Mahoney J.M., Reid D.E. & Zilm, L. (1995) Instream flows and the decline of riparian cottonwoods along the St Mary River, Alberta, Canada. *Canadian Journal of Botany* **73**, 1250-1260.

[207] Pyrce, R. 2004. *Hydrological low flow indices and their uses*. WSC Report No. 04-2004 Watershed Science Centre, Trent University, Canada.

[208] Sparks R.E. (1995) Need for ecosystem management of large rivers and their floodplains. *Bioscience* **45**, 168-182.

[209] Trepanier S., Rodriguez M.A. & Magnan P. (1996) Spawning migrations in landlocked Atlantic salmon: time series modeling of river discharge and water temperature effects. *Journal of Fish Biology* **48**, 925-936.

extreme, floods can make available critical spawning/nursery habitat to fish when lateral habitat connectivity provides critical slack water refugia for species during periods of severe in-channel disturbance.[210]

The fundamental principle for the sustainable management of river ecosystems in surface waters is now regarded as the need to sustain flow variability that mimics the natural, climatically driven variability of flows at least from year to year and from season to season, if not from day to day.[211]

Bunn and Arthington[212] summarised these issues under four specific principles: (i) flow is a major determinant of physical habitat in rivers, which in turns is a major determinant of biotic composition; (ii) maintenance of the natural pattern of habitat connectivity (a) along a river and (b) between a river and its riparian zone and floodplain is essential to the viability of populations of many riverine species; (iii) aquatic species have evolved life history strategies primarily in response to the habitats that are available at different times of the year and in both wet and dry years; (iv) the invasion and success of exotic and introduced species along river corridors is facilitated by flow regulation, especially with the loss of natural wet-dry cycles.

Subsequently, the concept of environmental flows was more formally developed, which has been defined by Arthington[213] as follows: *"environmental flow describes the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems"*. It is considered to be a

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[210] Petts G.E. (1984). *Impounded River*. John Wiley & Sons, Chichester, UK.

[211] Naiman R.J., Bunn S.E., Nilsson C., Petts G.E., Pinay G. & Thompson L.C. (2002) Legitimising fluvial ecosystems as users of water: An overview. *Environmental Management* **30**, 455-467.

[212] Bunn S.E. & Arthington A.H. (2002) Basic principles and the ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management* **30**, 492-507.

[213] Arthington, A.H. (2012) *Environmental Flows: Saving rivers in the Third Millenium*. University of California Press, Berkeley, CA.

more holistic approach that considers flow-related biophysical components and ecological processes of the in-stream habitat within the broader context of connected groundwater, lakes, wetlands and floodplains, and can therefore encompass the understanding of geomorphology, channel morphology, hydraulic habitat and water quality, as well as diverse aquatic and river-dependent communities.[214]

The environmental flow methodology is particularly effective at differentiating and classifying flashy, surface-water fed rivers against those that are more reliant on groundwater baseflow and have a more stable hydrometric regime. Environmental flows can also help improve water quality, such as diluting effluent and maintaining oxygen levels and water temperature.[215] Improved understanding of environmental flows should lead to progressive implementation of temporal and spatial abstraction (and discharge) systems that are sustainable in terms of the impact they have on flow variability.

2.5 Conclusions

It can be seen from the sections above that the pressure of water abstraction can have wide-ranging impacts on the hydrological, hydrogeological and ecological parameters of surface and groundwater bodies and GDWDEs. There are complex interactions between water abstraction and its aquatic environment and the impacts of these depend on a range of factors that include: the volume of water abstracted; the time and duration of abstraction and return to a water body; the hydrology and morphology of water bodies; and the degree of connectivity between different components of the hydrological cycle. Abstraction resulting in the lowering of groundwater levels can negatively impact GWDTEs. The impacts of water abstraction are

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[214] Arthington, A.H. (2012) *Environmental Flows: Saving rivers in the Third Millenium*. University of California Press, Berkeley, CA.

[215] Acreman M.C., Overton I.C., King J., Wood P.J., Cowx I.G., Dunbar M.J., Kendy E. & Young W.J. (2014) The changing role of ecohydrological science in guiding environmental flows. *Hydrological Sciences* **59**, 433-450.

largely dependent on the relative rate of abstraction and discharge. The impacts of abstraction are generally only experienced when localised discharge is lower than abstraction, yielding reduced baseflows in rivers, lakes and groundwater bodies. These reduced flow volumes (and related velocities), and lower flow levels will be particularly exacerbated during periods of natural low flow.

This has hydrological, hydrogeological, morphological, and ecological implications for water bodies. With regards to hydrology, reduced flow in rivers decreases peak flows and floodplain inundation and yields fluctuating lake water levels, with direct impacts to aquatic biota. Flow variation can alter water quality with changes to turbidity, and dissolved and suspended material. The ability of water bodies to dilute contaminants is also reduced. Within hydrogeology, unsustainable water abstraction lowers groundwater levels. This affects connected surface water bodies, soil surface layers and connected GWDTEs. In its most extreme, it can result in the drying out of wetlands. The lowering of groundwater levels can also result in inflow of saline or surface waters, altering the chemistry of the GWB, and reducing its ability to dilute contaminants. Poorly maintained abstraction wells can also provide a conduit for contaminants to GWBs. Morphological changes include changes to the width and depth of water body, altering flow dynamics, sediment transport and aquatic habitats (e.g. riffles and pools, riparian, littoral).

All of the above changes can have a major impact on the biota of the water body, and dependant habitats. Aquatic flora, invertebrate fauna and fish fauna can all be altered by changes to the hydrology, hydrogeology and morphology of aquatic habitats. Physical changes to the environment can reduce the habitat available to organisms and reproductive and behavioural changes can alter species assemblages.

Negative alteration of the biological, hydromorphological and chemical elements for status classification will result in the downgrading of a water body, resulting in a breach of the WFD. Abstraction controls are required where abstraction is assessed to pose a risk to any of these classifying elements which would result in the water body being classified either at less than good status, or (if within-status trends indicate) are At Risk of deterioration to a lower status.

CHAPTER 3: WATER RESOURCES IN IRELAND

3.1 Introduction

Ireland's freshwaters are an essential resource for society and biodiversity. Surface waters and groundwater are a source of drinking water for the majority of Irish citizens (with groundwater supplying 20-25% of water supplies nationally[216]) and essential for agriculture and industry. In addition, Ireland's fishery and water sports sectors are a vital component of tourism in Ireland.[217] Freshwater resources form an essential part of our landscape and provide a range of habitats that support a wealth of wildlife including fish, birds and invertebrates. Therefore, even aside from the requirements of the WFD, the sustainable use of these precious freshwater resources is vital.

This chapter consists of:

- An overview of the Water Framework Directive (before more in-depth analysis of it in Chapter 4);
- A description of the Water Framework Directive in Ireland, including status of water bodies; and
- An appraisal of water pressures relevant to abstraction with regard to available data.

[216] Wall B., Derham J. & O'Mahony, T. (2016). *Ireland's Environment 2016: An assessment.* Environmental Protection Agency.

[217] Wilson, S., Annet, J. (2009) *Determination of waters of national tourism significance and associated water quality status*. Fáilte Ireland, Dublin, pp 52.

3.2 Water Framework Directive (2000/60/EC)

The WFD[218] provides the framework for the protection of all waters, rivers, lakes, canals, reservoirs, estuaries, coastal waters and groundwater, wetlands and other water-dependent ecosystems and associated habitats. It has since been widely recognised as one of the most comprehensive and progressive pieces of EU environmental legislation ever enacted, as it requires Member States to take a holistic, inclusive and ecological approach to water management.

Risk assessment is a fundamental part of the WFD as it allows environmental problems to be identified, monitoring programmes to be designed, and appropriate, cost-effective protection and improvement measures to be formulated and implemented.

The WFD introduced new elements to water-resource management, including:

- Comprehensive and mandatory water-environment objectives focussed on achieving good ecological status, encompassing parameters beyond traditional water quality;
- An implementation strategy based on a six year cycle; and
- An integrated and participative water-resource management approach.

The Directive requires that the 'status' of water bodies to be measured using a range of ecological and other parameters rather than solely on traditional physical and chemical parameters, with more emphasis on the quality of the biological communities of a water body. Annex 5 of the Directive outlines the assessment criteria for the various water body types based on biological, hydromorphological and physico-chemical elements, with status categories comprised of 'high', 'good', 'moderate', 'poor' or 'bad'. Each element has different definitions to determine status, with the overall water status being the lowest scoring element. There are differences in how the WFD addresses groundwater and surface waters. The WFD objectives

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[218] Water Framework Directive (2000/60/EC).

for groundwater focus on quantitative and chemical status, whereas WFD objectives for surface water focus on ecological and chemical status.

The WFD is looked at in more detail in Chapter 4, with focus on abstraction, obligations of the Irish government, existing policy and legislation, and formation of the national abstraction register.

3.2.1 Principle Objectives

Of particular importance to the impacts of water abstraction and the WFD are the principal objectives of the Directive, which are set out in Articles 1, 4 and 11 and require each member state of the EU to:

- Prevent further deterioration, and to protect and enhance the status of aquatic ecosystems; and, with regard to their water needs, those terrestrial ecosystems and wetlands which directly depend on aquatic ecosystems (Article 1 (a));
- Achieve ‘good status’ for all these waters by 2015, or by 2021 or 2027, in the case of certain exemptions;
- Promote the sustainable use of water (Article 1 (b));
- Ensure the progressive reduction of pollution of groundwater and prevent its further pollution (Article 1 (d));
- Lessen the effects of flooding and drought (Article 1 (e));
- Establish controls over the abstraction of surface water and groundwater, review and update these controls periodically, require all abstractions to be authorised, and the authorisations to be periodically reviewed (Article 11.3 (e)); and
- Ensure that the quantity of groundwater abstracted does not exceed the average recharge rate, so as to maintain the quantitative status of the groundwater resource (Article 4 (b)).

These objectives were required by the Directive to be achieved by December 2015. However, Article 4 also provides for strict circumstances under which exemptions to these objectives may be applied, including time extensions to this deadline.

3.2.2 Characterisation

Member states must identify the location and boundaries of water bodies and characterise all bodies in accordance with the methodologies outlined in Annex II and Annex III of the WFD.[219] Once characterised, these water bodies must then be classified.

3.2.3 Classification

The main objective of the WFD is the achievement of good status in all water bodies and the maintainence of high status where this already exists. For a surface water body to be at High Ecological Status it must have virtually natural conditions. In terms of hydrology this means that the quantity and dynamics of flow and the connection to groundwater must be very close to natural.[220] Good status is the default objective set in River Basin Management Plans (RBMPs) for the surface water environment and represents a good healthy ecology,[221] requiring biological, hydromorphological and chemical targets to be met. Status is based on a number of quality elements as outlined in Table 3.1.

Table 3.1: Elements for classification of water bodies that can be affected by water abstraction

Elements for classification	**Rivers**	**Lakes**	**Groundwater**
Biological Elements (Rivers and Lakes)	Composition and abundance of aquatic flora Composition and abundance of benthic invertebrate fauna	Composition, abundance and biomass of phytoplankton Composition and abundance of other aquatic flora	N/A

[219] Water Framework Directive (2000/60/EC).

[220] DEFRA (2013). Managing abstraction and the water environment. Department for Environment, Food and Rural Affairs, Wales.

[221] Ibid.

<table>
<tr><td></td><td>Composition, abundance and age structure of fish fauna</td><td>Composition and abundance of benthic invertebrate fauna

Composition, abundance and age structure of fish fauna</td><td></td></tr>
<tr><td>Hydromorphological elements supporting the biological elements
(Rivers and Lakes)

OR

Quantitative Status
(Groundwater)</td><td>Hydrological regime
• Quantity and dynamics of water flow
• Connection to GWB

River continuity

Morphological conditions
• River depth and width variation
• Structure and substrate of the river bed
• Structure of the riparian zone</td><td>Hydrological regime
• Quantity and dynamics of water flow
• Residence time
• Connection to GWB

Morphological conditions
• Lake depth variation
• Quantity, structure and substrate of the lake bed
• Structure of the lake shore</td><td>Groundwater level</td></tr>
<tr><td>Chemical and physico-chemical elements supporting the biological elements
(Rivers and Lakes)

OR

Chemical Status
(Groundwater)</td><td>General
• Thermal conditions
• Oxygenation conditions
• Salinity
• Acidification status
• Nutrient conditions

Specific pollutants
• Priority substances
• Other substances</td><td>General
• Transparency
• Thermal conditions
• Oxygenation conditions
• Salinity
• Acidification status
• Nutrient conditions

Specific pollutants
• Priority substances
Other substances</td><td>Concentration of pollutants

Conductivity</td></tr>
</table>

As outlined in Section 2.3, over abstraction from surface water bodies and GWBs has the potential to impact upon all the quality elements outlined in Table 3.1.

3.2.3.1 Biological Elements

In Section 2.3.4, research was presented to show that abstraction can impact upon the structures and diversity of plankton, macrophytes and macro-invertebrates and this will directly relate to the biological quality elements. In the case of macro-invertebrates, a less diverse community consisting of fewer sensitive taxa (such as mayflies and stoneflies) will result in a lowering of the status of the water body. Unsustainable abstraction can also lead to potential impacts upon fisheries, which also has the potential to impact WFD status, since "Composition, abundance and age structure of fish fauna" is one of the biological quality elements required by the directive to be used in determining the ecological status of river and lake water bodies.[222] Direct impacts include the loss of habitat (gravel spawning beds, cooler and deeper pools), an increase in temperature which can lead to lower dissolved oxygen levels and potential fish kills, also impacting on the ecological status of the water body

3.2.3.2 Hydromorphological

The Hydromorphological quality element is used to help differentiate between good and high status water bodies.[223] Since abstraction can involve hydromorphological modifications to water bodies, the hydromorphological elements for high status in lakes are presented as an example in Table 3.2 For the other status/potential classes, the hydromorphological elements are required to have "conditions consistent with the achievement of the values specified for the biological quality elements." Thus, the assignment of water bodies to the good, moderate, poor or bad ecological status is made on the basis of the monitoring results for the biological quality elements and also, in the case of the good ecological status the physico-chemical quality elements.

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[222] Water Framework Directive (2000/60/EC): Annex V.

[223] Byrne, C., Fanning, A. (2015) Water Quality in Ireland 2010-2012. Environmental Protection Agency, Wexford.

Table 3.2: Lake hydromorphological quality elements for high status

Element	**High Status**
Hydrological regime	The quantity and dynamics of flow, level, residence time and the resultant connection to groundwaters reflect totally or nearly totally undisturbed conditions.
Morphological conditions	Lake depth variation, quantity and structure of the substrate, and both the structure and condition of the lake shore zone correspond totally or nearly totally to undisturbed conditions.

If hydromorphological pressures are significant they will have an impact on one or more of the biological quality elements and the status of the affected quality elements will reflect this. As outlined in Sections 2.3.2.1 and 2.3.2.3, abstraction that reduces the baseflow of water in rivers and lakes can alter hydrological elements such as quantity and dynamics of water flow, connection to GWB, and residence time (in lakes). Similarly, outlined in the same sections abstraction can alter water body width and depth, structure and substrate of water body beds and margins. While these hydromorphological changes themselves will not directly cause a drop below a status classification of good, due to the provisions of the directive, as outlined in Section 2.3.4 they will have a negative impact on the biological elements of the water body which can downgrade the status below that of good.

In the case of groundwater, abstraction of water can lead to a lowering of the level of the water body. A persistent lowering would indicate that abstraction is greater than the rate of recharge, thus in breach of WFD guidelines (Article 4 (b)). Additionally, a lowering of the GWB level has the potential to negatively impact connected GWDTE (Section 2.3.3.4).

3.2.3.3 Chemical and Physico-Chemical Elements

In relation to physico-chemical quality elements, over abstraction will lead to a reduction in volume or flow of the water body (Sections 2.3.2 and 2.3.3). This will lower the dilution and attenuation capacity of that water body. Attenuation capacity calculations are vital when determining whether a specific water body can accommodate a discharge from a wastewater treatment plant. If abstraction is unmanaged or not regulated properly, then the basis for the original attenuation capacities calculated (which are based on 95% flow) will be incorrect, and the discharge into the water body might be above what it can attenuate. An increase in the levels of pollutants, especially nitrates and phosphates, will also lead to negative impacts upon the biological elements of the water body due to increases in the composition and abundance of phytoplankton and flora (Section 2.3.4).

The over abstraction from rivers or lakes may also impact upon the environmental quality standards (EQS) for specific pollutants, e.g., arsenic, chromium, phenol. If the dilution factor or the attenuation capacity of the water body is lowered due to lower flows and levels, then the increased relative proportion of pollutant could exceed the EQS for the specific pollutant, resulting in a down-classing of status. The EQS for these specific pollutants is outlined in a discussion document prepared by the EPA.[224]

For groundwater, a reduction in groundwater level arising from abstraction has the potential to change the chemical composition of the water body (Section 2.3.3.3). Internal movement of water within the GWB can alter the chemistry, an increased area of recharge can increase the number of pollution point sources, saline and surface water intrusion can alter chemical makeup with conductivity increasing with the former, and potential changes to O_2 concentrations, pH, redox potential, conductivity and temperature with the latter. If these changes are sufficiently large, they will result in a downgrading of the classification of the GWB.

[224] EPA (2007) Proposed Quality Standards for Surface Water Classification. A Discussion Document. EPA, Co. Wexford, Ireland.

3.3 Implementation in Ireland

3.3.1 Overview

The objective of the WFD is to ensure that the required water quality improvements are achieved through a catchment based approach to water management, via a co-ordinated approach by stakeholders across the water sector, and through public engagement and participation in the development and implementation of plans. Ireland has now entered the second cycle of the WFD, which runs from 2015 to 2021. The preparation of the 2nd cycle River Basin Management Plans is now in the consultation phase (until August 2017).

The WFD catchments are referred to as river basin districts (RBDs). Seven RBDs were introduced under the first cycle of RBMP for the period 2009 - 2015. These were subsequently revised down to two under the second RBMP cycle which runs from 2018 – 2021; the Eastern, South Eastern, South Western, Western and Shannon RBDs being merged to form the Irish RBD; the North Western and Neagh Bann were combined into the International RBD to facilitate cross-border cooperation with Northern Ireland.

3.3.2 Water Bodies

The Irish RBD covers 70,273km^2 (225). It has been further divided into 46 catchment management units, with a lower tier of 583 sub-catchments containing 4,832 water bodies. The 2nd cycle RBMP consultation document[226] reports on the status of 3,192 rivers, 812 lakes, 194 transitional water bodies, 110 coastal and 513 groundwater bodies. Artificial or heavily modified surface water bodies form a supplementary category. At time of writing there are

[225] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[226] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

4,829 water bodies with breakdown as follows: 3,192 rivers, 818 lakes, 195 transitional, 111 coastal and 513 groundwater bodies.[227]

3.3.2.1 Surface Water Bodies

Surface water bodies in Ireland range from small upland streams to the large, low-lying lakes of the Shannon system. Ireland has over 75 major rivers, including important tributaries, and a further 167 minor rivers and streams with catchment areas ranging from 10 km^2 to 130 km^2. The Shannon is the largest river in the British Isles and other major rivers include the Erne, Bann, Corrib, Barrow, Lee, Nore, Suir and Munster Blackwater. The total estimated length of the larger rivers and tributaries is approximately 14,000 km[228] whilst total river channel length amounts to around 70,000 km.[229] For the purposes of the WFD surface water bodies were grouped into 12 classes based on hydromorphological characteristics: altitude, depth, size, flow, catchment rock type, tidal regime and water chemistry as hardness.[230]

There are a total of 12,000 lakes[231] which includes approximately 4,000 lakes greater than 0.05 km^2, 23 lakes greater than 10 km^2 whilst Loughs Neagh, Corrib, Derg, Lower Erne and Ree all exceed 100 km^2. [232] Lakes were also divided into 12 classes, based on alkalinity (low, moderate

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[227] EPA CatchmentsWebsite: www.catchments.ie; accessed 29th April 2017.

[228] Reynolds, J.D. (1998) Ireland's Freshwaters. Societas Internationalis Limnologiæ (SIL) International Association of Theoretical and Applied Limnology XXVII Congress, Dublin, Ireland, August 9-14, 1998.

[229] Wall B., Derham J. & O'Mahony, T. (2016). *Ireland's Environment 2016: An assessment.* Environmental Protection Agency.

[230] WFD Ireland, 2005 The Characterisation and Analysis of Ireland's River Basin Districts, National Summary Report Available at: http://www.wfdireland.ie/Documents/Characterisation%20Report/Ireland_Article_5_WFD.pdf.

[231] Wall B., Derham J. & O'Mahony, T. (2016). *Ireland's Environment 2016: An assessment.* Environmental Protection Agency.

[232] Reynolds, J.D. (1998) Ireland's Freshwaters. Societas Internationalis Limnologiæ (SIL) International Association of Theoretical and Applied Limnology XXVII Congress, Dublin, Ireland, August 9-14, 1998.

or high), depth (less than 4 m and greater than 4 m) and size (less than 50 ha and greater than 50 ha), with one additional group for lakes at elevations above 300 m OD. Lakes less than 50 ha are only counted if located in protected areas (e.g. in SACs or used for water abstraction for drinking water purposes). The number of lakes classified in such a manner is 210.

3.3.2.2 Groundwater Bodies

A groundwater body (GWB) is a specific WFD term used to subdivide aquifers into effective management units, largely based on hydrogeological rules in relation to boundaries, e.g. a 'no-flow' boundary.[233] The aquifers were grouped into four GWB types: (i) karstified aquifers (27% by number; 20% by area), (ii) gravel aquifers (9% by number; 2% by area), (iii) productive fissured aquifers (14% by number; 7% by area), and (iv) poorly productive bedrock aquifers (50% by number; 71% by area), with further description as follows:

- Karstified GWBs – generally distinctive karst landforms; drainage largely underground in solutionally-enlarged fissures; variable to high transmissivity; high groundwater velocity; low effective porosity; high degree of interconnection between groundwater and surface water, with sinking streams and large springs; streams often flashy and may be dry in summer; baseflow variable; groundwater level and stream flow hydrographs usually peaky; drainage density low; potentially long groundwater flow paths.
- Productive Fissured GWBs – groundwater flow in fissures; moderate to high transmissivity; low effective porosity; contribute baseflow to streams and maintain dry weather flows; occasional large springs may occur; potentially long groundwater flow paths; confined in places.
- Gravel GWBs – intergranular flow; high permeability; high effective porosity; tend to be relatively small in area; occasional large springs; contribute substantially to stream baseflow; low drainage density; potentially long flow paths.

[233] Groundwater Working Group (2005) Water Framework Directive (WFD) River Basin District Management Systems: Approach to Delineation of Groundwater Bodies. Guidance Document No. 2.

- Poorly Productive GWBs – groundwater flow in fissures, most flow is at shallow depth in the weathered layer at the top of the bedrock; significant flows can occur in widely dispersed deeper fracture zones; low transmissivity; high groundwater gradients; low baseflow contribution to streams; high drainage density; generally short underground flow paths.

Surface water catchment boundaries were often used to complete groundwater body delineation. A total of 383 groundwater bodies were initially delineated using the above principles. Where point pollution sources or the predicted impact on GWDTEs placed areas within these groundwater bodies 'At Risk', new groundwater bodies were delineated using hydrogeological boundaries, giving a total of 757 groundwater bodies, and subsequently reduced to 513[234]. These range in size from 0.02 km^2 to 1,884 km^2. [(235)]

3.3.2.3 Groundwater Dependant Terrestrial Ecosystems

Of the 513 GWBs in Ireland, 266 contain groundwater dependant terrestrial ecosystems (GWDTEs).[236] The term GWDTE covers a range of wetlands such as turloughs, fens, wet woodlands and bogs[237]. Only those considered to be of European importance (i.e. SACs or SPAs) have been considered under the WFD. Ireland has 430 SACs, of which 358 are listed as

[234] As this report went to print, the new EPA Water Quality report for 2012-2015 reported that "it was determined for many water bodies that there was no risk of failing the WFD status objective" which "resulted in a reduction in overall number of water bodies to 513."

[235] WFD, 2005a. Water Framework Directive River Basin District Management Systems: Approach to delineation of groundwater bodies. Paper by the Working Group on Groundwater. Guidance document no. GW2.

[236] Kilroy G., Dunne F., Ryan J., O'Connor A., Daly D., Craig M., Coxon C., Johnston P. & Moe H. (2008) *A framework for the assessment of groundwater dependent terrestrial ecosystems under the Water Framework Directive.* Report ERC No. 12, Environmental Protection Agency.

[237] WFD, 2005b. Water Framework Directive River Basin District Management Systems: Guidance on the impact of groundwater abstractions. Paper by the Working Group on Groundwater. Guidance document no. GW5.

having water dependency.[238]

3.4 Status of Water Bodies in Ireland

The WFD status of water bodies is critical as the attainment of at least "good" status for water bodies is the key objective of the WFD. WFD classification of surface water consists of ecological status and chemical status, while groundwater consists of quantitative status and groundwater chemical status. Status is designated on biological, hydromorphological and chemical qualitative elements which were outlined in Section 3.2.3).

The most recent report on the environment in Ireland, including water status, is the Draft Consultation for the 2nd RBMP, which provides a detailed review of all the main issues related to the quality of the aquatic environment in Ireland, and provides guidance towards the protection and enhancement of water resources in Ireland.

3.4.1 Monitoring

The EPA implements the national water quality monitoring programme under the requirement of Section 65 of the EPA Act, 1992. National reviews of water quality in Ireland commenced in 1972; however, in 1999 the programme was strengthened by the inclusion of River Basin Management Plans and catchment monitoring and management systems.[239] The current water monitoring programme is now largely driven by Ireland's obligations under the WFD.

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[238] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[239] EPA (1999) Water Quality Management Planning in Ireland. EPA, Co. Wexford, Ireland.

The current monitoring network consists of the following:[240]

- 336 groundwater monitoring sites
- 3,191 river monitoring sites across 2,343 river water bodies
- 216 lake monitoring sites and 9 reservoirs
- 80 transitional water bodies
- 43 coastal water bodies

Water levels and flows in Ireland are monitored on a continuous basis at a number of river, lake, canal and transitional water monitoring points. The surface water hydrometric level network in Ireland is operated and managed by the following bodies:

- EPA = 236 stations
- OPW = 391 stations
- ESB = 21 stations
- Marine Institute = 18 stations
- Waterways Ireland = 102 stations

For groundwater WFD Article 8 stipulates that a monitoring network is required to measure the following parameters, with the objective of achieving good chemical and quantitative status for groundwater:

- Groundwater quality;
- Groundwater level and flow; and
- Status of protected areas.

There are approximately 210 groundwater abstractions for drinking water included in the EPA

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[240] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

groundwater quality monitoring network, with a total of 276 groundwater quality monitoring points in the EPA database (the balance is made up of monitoring boreholes, springs and GWDTEs).

3.4.2 Surface Water Bodies: Classification

Surface water bodies are assigned to one of five ecological status classes (high, good, moderate, poor or bad). The status assigned is determined by the poorest classed quality element. The WFD provides the definition of good ecological status as the state of the system in the absence of any anthropogenic pressures, or a slight biological deviation from what would be expected under undisturbed/reference conditions.[241]

The EPA found for the period of 2013 – 2015, that 55% of monitored river water bodies were at a satisfactory (high or good) ecological status, which was an increase of 1% since the previous monitoring period.[242] For lakes, 46% reached a satisfactory ecological status; a decrease of 3% since the previous monitoring period.[243] A summary of the 2013 - 2015 findings can be seen in

[241] EC (2016) *Introduction to the New EU Water* Framework *Directive.* Retrieved from http://ec.europa.eu/environment/water/water-framework/info/intro_en.htm on 29th April 2017.

[242] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[243] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

Table 3.3.

Table 3.3: Summary of 2013-2015 water quality results by percentage[244]

Water Body Type	High	Good	Moderate	Poor	Bad
Rivers	10.4	44.6	27.2	17.6	0.2
Lakes	11.1	34.7	33.3	12.4	8.4

Compared to the 2007-2009 assessment, there has been a 3% decline in the number of rivers and lakes at satisfactory ecological status,[245] indicating that the status of Irish waters are not improving on a national scale. Preliminary assessment by the EPA suggests that the presence of phosphorus exceeding national thresholds is usually the limiting factor in terms of reaching target status.

A continued long-term decline in high status river sites is also continuing. In the 2013-2015 monitoring period, 18% of monitored river sites had high status, compared to 30% in 1987-1990.[246] When compared on a water body basis, there has been a reduction in high status water bodies by 3% from 13% in 2007-2009 to 10% in 2013-2015.[247]

[244] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[245] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[246] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[247] Ibid.

3.4.3 Groundwater Bodies: Classification

3.4.3.1 Groundwater Bodies

Groundwater bodies are classified by the EPA as being of either good or poor status with qualifiers to prescribe the level of confidence in the assigned status (low or high). The classification is based upon quantitative and/or chemical status. If either the quantitative or chemical status is poor then the overall status will be poor. Tests that are conducted to assess groundwater quantitative status are:

- Water balances of groundwater bodies (i.e. abstraction);
- Impacts to the natural flow conditions of rivers and streams;
- Impacts to groundwater flow, discharges and levels within the catchment boundaries of groundwater dependent wetlands; and
- Saline intrusion in coastal settings.

Good quantitative status is assigned if:[248]

- "The level of groundwater in the GWB is such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction";
- There is no "significant damage to terrestrial ecosystems which depend directly on the GWB"; and
- "The chemical composition of the groundwater body is such that the concentration of pollutants do not exhibit the effects of saline or other intrusions".

[248] Water Framework Directive 2000/60/EC.

The EPA found for the period of 2013 – 2015, that 91% (468) of monitored groundwater bodies were at a satisfactory (good) ecological status, which was a decrease of 6% since the previous monitoring period of 2007-2012.[249]

Table 3.4: Summary of 2013-2015 water quality results by percentage[250]

Water Body Type	Good	Poor
Groundwater	91	9

Groundwater bodies assigned poor chemical status are due primarily to elevated phosphorus levels or historical contamination from mining activities and industrial development.[251]

3.4.3.2 Groundwater Dependant Terrestrial Ecosystems

Groundwater quality and quantitative monitoring is required in groundwater bodies associated with GWDTE to determine the impacts of groundwater on these ecosystems.

If the quantity or quality of the groundwater a GWDTE receives causes a GWDTE to be significantly damaged this will result in a GWB to be classified at poor status. The term 'significant damage' is derived from the magnitude of the damage and the ecological or socio-economic significance of the terrestrial ecosystem.

Of 63 GWDTEs failing their conservation objectives, groundwater was judged to be a

[249] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[250] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[251] Wall B., Derham J. & O'Mahony, T. (2016). *Ireland's Environment 2016: An assessment.* Environmental Protection Agency.

contributing factor for 29 of these. Of these 29, three were confirmed as being *At Risk*, and the remaining 26 are under review.[252]

3.4.4 Risk Status

Characterisation reports were produced under the 1st RBMP to outline which water bodies were considered to be ‘At Risk’ or ‘not At Risk’. Interim classifications of ‘probably At Risk’ and ‘probably not At Risk’ are used where further work is needed and help to prioritise the investigation of water bodies. ‘At Risk’ does not necessarily infer that the water bodies are already suffering poor status, rather it highlights where appropriate management actions need to be applied to ensure ‘good status’. The breakdown of WFD risk classifications for water bodies in Ireland is currently[253]:

- Not At Risk = 2,098 (43%)
- Review, i.e. probably ‘not At Risk’ or probably ‘At Risk’ = 1,191 (25%)
- At Risk = 1,540 (32%)

Water bodies may be At Risk from qualitative or quantitative pressures. The public consultation document on the River Basin Management Plan for Ireland (2018-2021)[254] shows significant pressures to the 1,134 river and lake water bodies At Risk are:

- Agriculture = 64%
- Urban wastewater = 22%
- Hydromorphology = 19%

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[252] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[253] As of 29th April 2017 on www.catchment.ie.

[254] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

- Forestry = 16%
- Peat extraction = 10%
- Domestic wastewater = 12%
- Urban runoff = 10%
- Industry = 7%
- Abstraction = 3%

Thresholds adopted by river water bodies for abstraction risk assessment are shown in Table 3.5. Where the net abstraction was greater than 40% of the river 95%ile flow the water body was deemed 'At Risk'; where the net abstraction was between 10-40% of the river 95%ile flow the water body was deemed 'probably At Risk'.

Table 3.5: Thresholds adopted for abstraction risk assessment for river water bodies[255]

Criteria	*'not At Risk'*	*'probably not At Risk'*	*'probably At Risk'*	*'At Risk'*
Volume of abstraction as a percentage of dry weather flow	< 5%	5 – 10%	10 40%	> 40%

The 2nd RBMP consultation document[256] also states that *'there are 62 groundwater abstractions (associated with 19 abstraction schemes/activities) being taken from 23 (4%) groundwater bodies that have also been identified where these abstractions may potentially pose a risk to the flow conditions needed to support the ecology in an adjacent river.'*

The groundwater risk assessment of 2008, which determined 23 groundwater bodies to be At Risk due to abstraction pressures is based on the relative percentages of abstraction versus

[255] SWRBD, 2008. *A future for our waters.* South Western River Basin District.

[256] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

recharge volumes computed for each groundwater body. Diffuse recharge is calculated using assigned recharge coefficients which define the proportion of effective rainfall (potential recharge) that becomes recharge.[257]

The draft RBMP[258] notes that these assessments of At Risk water bodies are conservative and that the actual level of impact on river or lake ecology is likely to be less. The risk review process is intended to be conservative as it determines whether the water body is At Risk of failing to meet its WFD objectives due to ecological impacts resulting from abstraction, not that it will fail. The review process, due to proceed on a case by case basis over the next RBMP cycle, will look at the environmental supporting conditions for the water body, improve estimates of flow, clarify abstraction data and review the biological/ecological impact(s).[259] Improved understanding is required concerning the impact of abstractions on lakes in terms of hydrological controls (i.e. level) and their relationship with ecological receptors.

Developments to improve the knowledge and understanding of risks of water abstraction that have thus far been undertaken include:[260]

1. Updating of the water abstraction database (as discussed in Chapter 4);
2. Publication of EU guidance on ecological flows;
3. A review of the national hydrometric programme by the EPA; and
4. Completion of bathymetric surveys by EPA for 53 lakes.

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[257] Misstear B.D., Banks D. & Clark L. (2006) *Water Wells and Boreholes*. Wiley & Sons Ltd: Chichester, pp514.

[258] DHPCLG (2017) Public consultation on the river basin management plan for Ireland (2018-2021), pp103

[259] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[260] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

Overall, the draft RBMP[261] assesses the risk posed by abstraction as “low”, with only 4% of water bodies nationally having been identified as potentially At Risk of over abstraction (Figure 3.1). This includes 3% of rivers (98), 9% lakes (73) and 4% groundwater bodies (23). Further assessment of these water bodies over the course of the river basin planning cycle (up to 2021) will occur.

[261] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

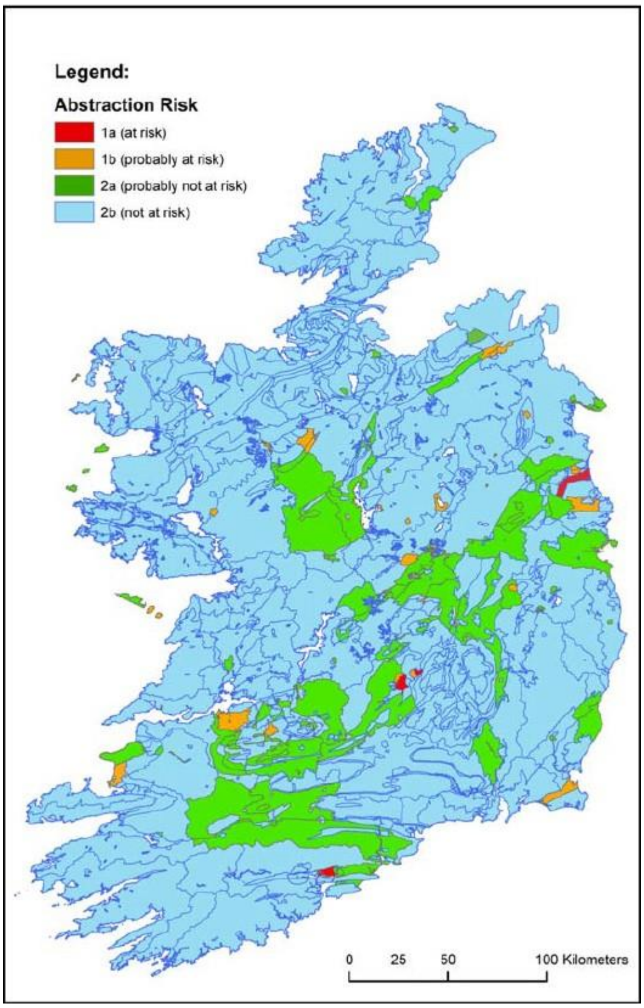

Figure 3.1: Groundwater abstraction risk assessment (2007 data). Legend: red = At Risk; orange = probably At Risk; green = probably not At Risk; blue = not At Risk. Source[262]

In preparatory work for the first cycle it proposed that following the review process, any water bodies that are determined to still be At Risk of failing to meet WFD objectives due to abstractive pressures may then require supplementary measures to manage the abstraction (or could be candidates for lower objectives if there isn't anything technically or economically

[262] CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102. "Figure 7".

feasible that can be done, i.e. the abstraction is necessary and cannot be mitigated to such a level that the environmental objectives will be met.[263] No mention of this is made in the draft plan for the second cycle.[264]

In southern England, where alternative water supplies aren't economically feasible mitigation measures instead focus on environmental improvements such as river restoration.[265]

3.4.5 Water Status: Summary

In the latest review available, there are 55% of monitored river water bodies 46% of lakes and 91% of GWBs at a satisfactory ecological status. Preliminary results indicate that there has been no overall improvement in water status over the first river basin planning cycle.[266] In fact, water bodies achieving a status of at least "good" has declined from the last assessment, with surface waters bodies declining by 3% and GWBs by 6%. A similar pattern was observed in England with a 4% decline in the proportion of water bodies that achieved good status or better between 2009 (26%) and 2015 (22%), despite the significant expenditure on Programmes of Measures.[267] A continued long-term decline in high status river sites is also continuing, which is of concern with ongoing compliance of the WFD.

This is relevant when considering abstraction because the impacts of abstraction can lead to a further deterioration in the quality of water bodies. If water bodies are declining nationally for

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[263] CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

[264] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[265] Packman M. (2017) Sustainable groundwater resource planning and management. Proceedings of the International Association of Hydrogeologists (Irish Group).

[266] Ibid.

[267] Environment Agency (2015). *Update to the river basin management plans in England: National Evidence and Data Report.* Retrieved from https://www.gov.uk/government/collections/river-basin-management-plans-2015 on 2017.

a number of reasons independent of abstraction, the impacts of abstraction will further compound these.[268] High nutrient levels are one reason many water bodies are failing to achieve "good" status. As we have seen in Chapter 2 abstraction can lead to a decrease in dilution effects of rivers and an increase in the lake's residence time, thereby increasing the available time for nutrient uptake by algae, periphyton and macrophytes,[269] thus exacerbating this situation. The fact that many lakes and rivers have been identified as At Risk to lower flows from groundwater abstraction is therefore pertinent.

3.5 Abstraction Pressure

Compared to other jurisdictions, Ireland has low abstraction pressure and is classified as having "little or no water scarcity" by the UN World Water Assessment Programme.[270] It has one of the lowest Water Exploitation Index (annual water abstraction as a percentage of long-term available water) in Europe.[271]

To put context on abstraction, Figure 3.2 shows precipitation in Ireland. Precipitation helps to offset impacts of abstraction by allowing recharge of surface and groundwater volumes. Rainfall is highest in the west of the country, and in mountainous regions with high topographic relief, where precipitation can exceed 1,500 mm/yr. The driest parts are in the east of the country where annual precipitation is less than 500mm. Abstraction pressures are likely to be greatest in the regions with lowest precipitation.

[268] Matthaei, C.D., Piggott, J.J., Townsend, C.R., 2010. Multiple stressors in agricultural streams: interactions among sediment addition, nutrient enrichment and water abstraction: Sediment, nutrients & water abstraction. *Journal of Applied Ecology* **47**, 639–649.

[269] Eastern River Basin District (2007) Abstraction Pressure Assessment, Background to Water Matters Report.

[270] United Nations (2012). Managing Water under Uncertainty and Risk. United Nations World Water Development Report 4, Volume 1. Available online: www.un.org.

[271] http://www.eea.europa.eu/publications/environmental-indicator-report-2012/environmental-indicator-report-2012-ecosystem.

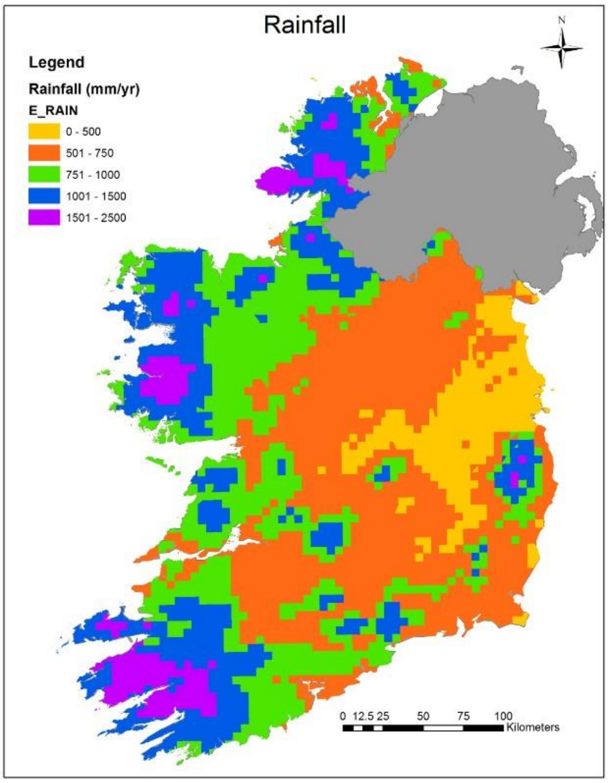

Figure 3.2: Precipitation rates in Ireland. Source [272]

Recent work on abstraction pressures indicate that effective rainfall abstracted from catchments ranged from 0% to 32%.[273] In 90% of the catchments, less than 5% of the effective rainfall is abstracted.[274] This indicates a low abstraction pressure.

The Geological Survey Ireland have produced a national groundwater recharge map, providing an annual estimate of groundwater recharge in mm / yr. Recharge was estimated by multiplying

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[272] Data obtained from Geological Survey shapefiles for groundwater recharge available at: http://www.dccae.gov.ie/en-ie/natural-resources/topics/Geological-Survey-of-Ireland/data/Pages/Data-Downloads.aspx.

[273] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21.

[274] Ibid.

the effective rainfall by a recharge coefficient (based on subsoil properties). This coefficient depends on the permeability and thickness of the subsoils, bedrock overlying the groundwater, and type of soils or peat. Figure 3.3 shows this national map, with Figure 3.4 highlighting only the regions where recharge is less than 100mm/year; it is these regions that would be most At Risk of groundwater abstraction.

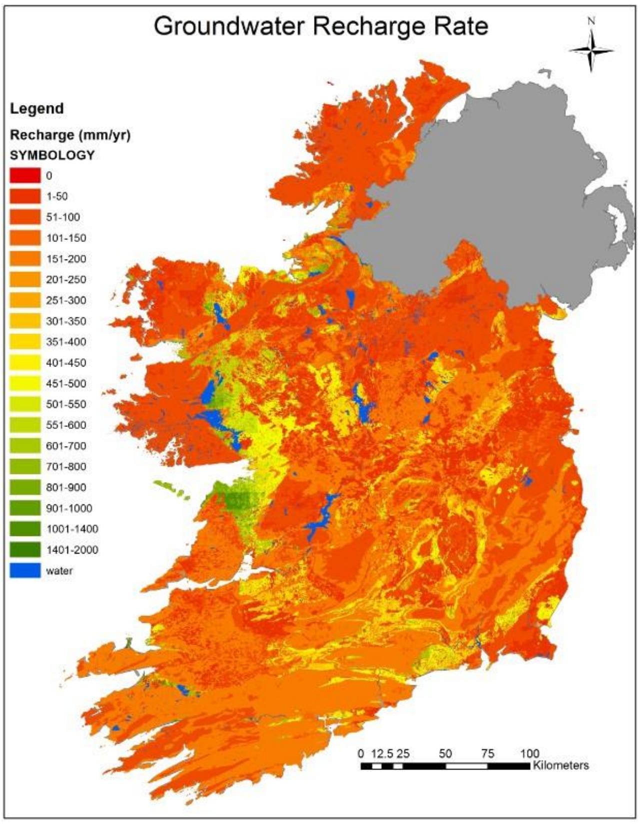

Figure 3.3: Groundwater recharge rate (Source[275])

[275] Data obtained from Geological Survey shapefiles for groundwater recharge available at: http://www.dccae.gov.ie/en-ie/natural-resources/topics/Geological-Survey-of-Ireland/data/Pages/Data-Downloads.aspx.

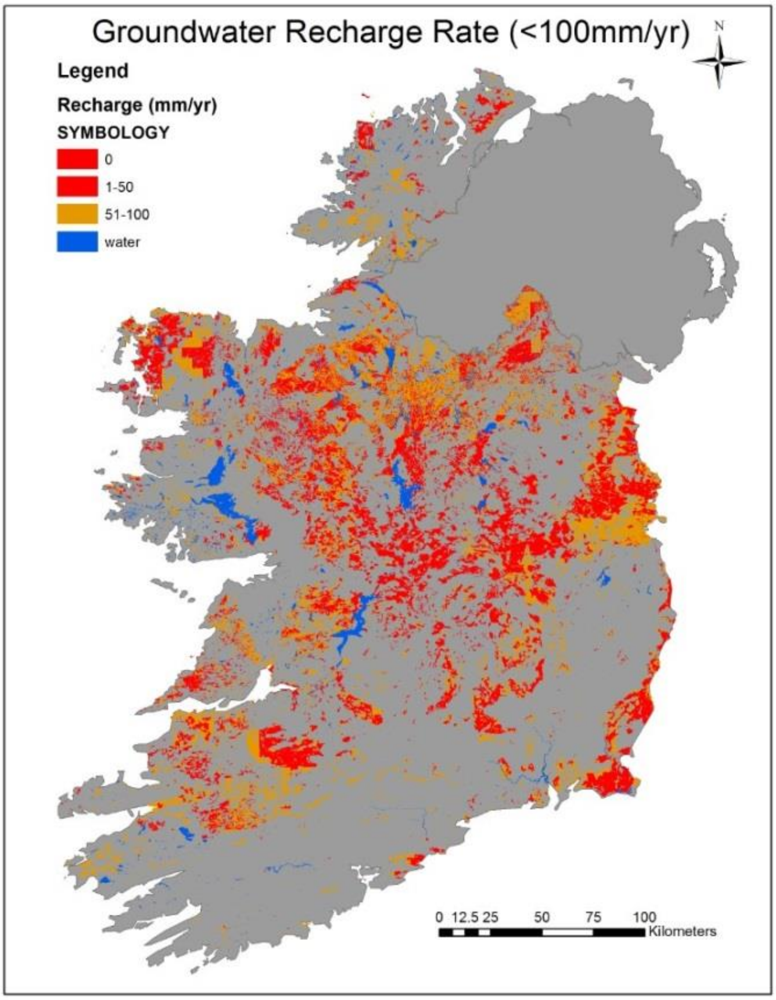

Figure 3.4: Groundwater recharge rate <100mm/yr. These are regions where groundwater abstraction would have greatest impact. Source[276]

Regions of low recharge are likely to be more affected by the impacts of abstraction of both groundwater and surface water (if hydraulically connected). Of the 513 designated GWBs in

[276] Data obtained from Geological Survey shapefiles for groundwater recharge available at: http://www.dccae.gov.ie/en-ie/natural-resources/topics/Geological-Survey-of-Ireland/data/Pages/Data-Downloads.aspx.

Ireland, 223 are designated either "At Risk" or "Probably At Risk"[277] (for all factors, not just abstraction), and these water bodies could potentially be downgraded in future WFD status classification (Figure 3.5). Within these GWBs, 185 intersect with regions of low recharge rate (<50mm / yr), with 130 being "At Risk", and 55 "Probably At Risk". It is these regions that could be most acutely affected by the impacts of abstraction as water bodies are already experiencing risk of downgrading, and recharge rate is low.

[277] EPA New Groundwater Bodies 2016 WFD data available at: http://gis.epa.ie/GetData/Download. Risk data last updated 2008.

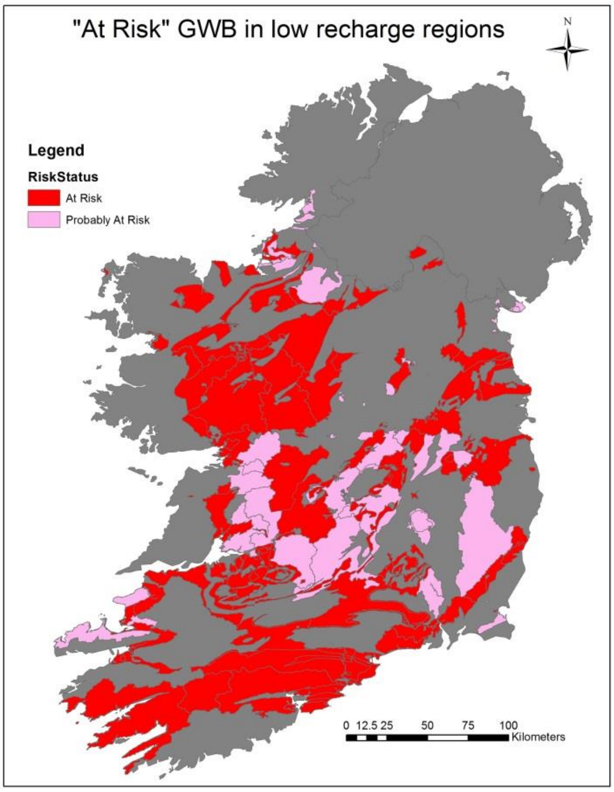

Figure 3.5: 223 GWBs classified as "At Risk" or "Probably At Risk" that intersect with regions of low recharge rate (<50mm / yr)[278]

Similarly SACs could be more sensitive to water abstraction in regions of low GWB recharge rate. 251 of 498 SACs (50%) intersect with regions of low recharge rate (<50mm / yr). Again, in these regions, water abstraction could have increased impact on the environment and increased levels of protection could be beneficial.

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[278] EPA New Groundwater Bodies 2016 WFD data available at: http://gis.epa.ie/GetData/Download. Risk data last updated 2008.

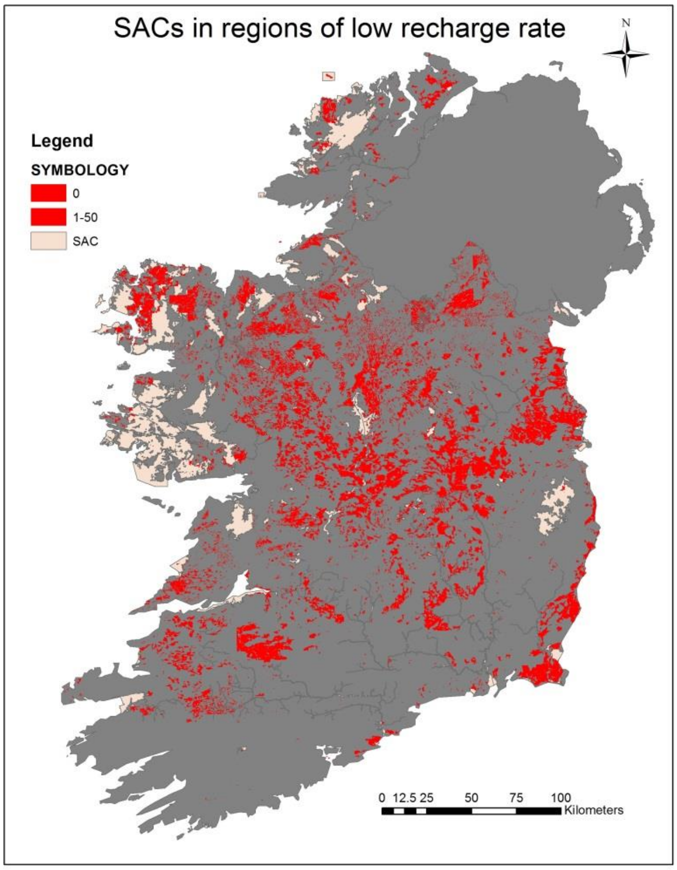

Figure 3.6: 251 of 498 SACs intersect with regions of low recharge rate (<50mm / yr)[279]

3.6 Conclusions

The WFD provides the framework for the protection of all waters bodies and associated habitats in EU member states with the aim to attain good water status classification. In the Republic of

[279] Source: National Parks and Wildlife Service SAC shapefile, available from: http://webgis.npws.ie/npwsviewer/

Ireland, there is now one RBD, with 46 catchment management units, 583 sub-catchments containing 4,832 water bodies. There is now published status of 3,192 rivers, 812 lakes, 194 transitional water bodies, 110 coastal and 513 groundwater bodies.

The EPA implements the national water quality monitoring programme with 3,191 river monitoring sites across 2,343 river water bodies, 216 lake monitoring sites and 9 reservoirs, and 336 groundwater monitoring sites. For the period of 2013 – 2015, 55% of monitored river water bodies and 46% monitored lakes were at a satisfactory classification status to comply with the WFD. This is an increase of 1% and a decrease of 3% since the previous monitoring period for rivers and lakes respectively. There is a continued long-term decline of high status sites. Regarding groundwater, 91% (468) of monitored groundwater bodies were at a satisfactory classification status to comply with WFD, which is a decrease of 6% since the previous monitoring period. These indicate that overall status of Irish water are in decline when compared to the last monitoring period, with elevated nutrient concentrations being the primary reason for this. This decline is worrying given evidence that the impacts of abstraction can be compounded when multiple stressors are acting on water bodies.

Abstraction pressure over the island of Ireland are generally considered to be low given the high levels of precipitation. However, parts of the country do experience lower amounts of precipitation, yielding reduced surface runoff. Additionally, groundwater recharge rates vary across the country. Areas with low groundwater recharge rates will be more susceptible to water abstraction.

CHAPTER 4: REGULATORY FRAMEWORK

4.1 Introduction

Abstraction legislation is set out in the Water Supplies Act 1942, which governs the abstraction, by local authorities of water from various water sources. The Groundwater and Surface Water Regulations 2000-2006 set out further provisions regarding water abstraction including regulations for abstraction, pollution thresholds and relevant environmental impact assessments and associated thresholds. The Water Framework Directive requires controls over the abstraction of fresh surface water and groundwater, and impoundment of fresh surface water, including a register or registers of water abstractions and a requirement of prior authorisation for abstraction and impoundment. These controls must be periodically reviewed and, where necessary, updated.

This chapter identifies and describes the abstraction regime which applies to ground and fresh water bodies in the domestic legislation and then the Water Framework Directive ('WFD' or 'the Directive'). It describes the existing legislative arrangement, appraises that approach and finally, compares and contrasts that approach with what occurs in Scotland and Northern Ireland.

4.2 Abstraction in the Water Framework Directive

Abstraction plays a very limited role within the text of the Directive itself. Unlike pollution the number of textual references to abstraction and related subjects is notably modest and it plays a significant role in only three of the Directive's Articles (3, 4 and 11). The basic 'abstraction structure' provided for in the Directive is as follows.

4.2.1 Article 3 – Coordination of Administrative Arrangements within River Basin Districts

Article 3 imposes an obligation on Member States to assess all groundwater bodies within their territory and, where relevant, cross-Border. This Article is the ultimate origin of the obligation to identify and collate water bodies into River Basins. These River Basins are the basic unit in the Directive and, once identified Member States are obliged to carry out systemic analysis of the status of those bodies via periodic River Basin Management Plans. The water bodies that are identified for the purposes of Article 3 must meet the objectives stipulated in Article 4. The objectives vary whether the body is a groundwater or surface water body but the overall obligation is to achieve 'good' ecological status, nominally by 2015. In the same manner that Article 3 and Article 4 are linked Article 4 is given practical effect via Article 11 of the Directive. This Article provides for the measures which must be implemented by Member States in order to achieve the objectives identified in Article 4 in relation to the water bodies the subject of Article 3.

In very simple terms Article 3 therefore simply provides for the administrative arrangements by which Member States must organise the relevant water bodies within their jurisdiction into units. It is purely a process Article and says nothing substantive about the environmental obligations which rest on the Member States.

4.2.2 Article 4: Environmental Objectives

Article 4 on the other hand is the operational or substantive Article for the achievement of the 'good status'. Article 4(1) requires that (emphasis added):

> *(b) <u>For groundwater</u>*
>
> *(ii) Member States shall protect, enhance and restore all bodies of groundwater, <u>ensure a balance between abstraction and recharge of groundwater</u>, with the aim of achieving good groundwater status at the latest 15 years after the date of entry into force of this Directive, in accordance with the provisions laid down in Annex V, subject to the application of extensions determined in accordance with paragraph 4 and to the application of paragraphs 5, 6 and 7 without prejudice to paragraph 8 of this Article and subject to the application of Article 11(3)(j);*

In relation to surface water the Article contains the same obligation to achieve 'good status' but, notably, there is no obligation to achieve a balance between abstraction and recharge as there is in relation to groundwater. In other-words, the only reference in the primary operational Article of the Directive is the imposition of an obligation on Member States to *"ensure a balance between abstraction and recharge of groundwater"*.

This Delphic pronouncement is not explained further and there is, for example, no restriction in this Article (or elsewhere in the Directive) on overall or gradual reduction in quantitative status, albeit within the context of the general obligation to achieve 'good status'. Although there is a supervening obligation to achieve "good status" no further guidance is provided as to what that obligation should entail and no thresholds are provided in terms of assessing what "balance" might mean for the purposes of the Directive.

Notably absent is any obligation to avoid, in imperative terms, any overall diminution of the volume of ground or surface water bodies via abstraction. Recital 20 of the Directive simply notes *"(20) The quantitative status of a body of groundwater may have an impact on the ecological quality of surface waters and terrestrial ecosystems associated with that groundwater body."*

Also of note is Recital 26 where it states; *"Quantitative status" is an expression of the degree to which a body of groundwater is affected by direct and indirect abstractions."*

However, this observation is not translated forward into a 'hard' obligation not to diminish quantitative status. In other words the Directive acknowledges the potential relationship between quantitative status and overall status but imposes only a soft obligation on Member States to control the balance between abstraction and recharge. This is made clear and reinforced in Annex V 2.1.2 which defines good quantitative status for groundwater as:

> "*… the level of groundwater is not subject to anthropogenic alterations such as would result in: - failure to achieve the environmental objectives specified under Article 4 for associated surface waters. - any significant diminution of the status of such waters; - any significant damage to terrestrial ecosystems which depended directly on the groundwater body*".

Therefore the achievement of "*good status*" for groundwater is dependent on, *inter alia,* ultimately ensuring that there is a balance between recharge and abstraction. It is crucial to state at the outset that there is no fixed prohibition on the reduction in overall volume in the Directive, once that overall reduction does not entail overall status consequences. Unlike the far more severe and absolute prohibitions on, for example, the introduction of pollutants into water bodies, abstraction pressures are placed within a permissive space where Member States may, *once properly informed via a national register*,[280] licence abstraction from water bodies once that abstraction does not impinge on the environmental objectives contained in Article 4.

In other-words the worldview adopted by the Directive is not to prohibit or regard abstraction as inherently undesirable (unlike the introduction of pollutants) but rather as engaging the terms of the Directive only once that abstraction has environmental consequences prohibited by the Directive. It is this approach which underpins the central abstraction 'tool' in the Directive – the obligation to measure and collate abstractions in the central register. Even though cast in softer terms than the prohibition on the introduction of pollution, the obligation to ensure 'balance' is set at nought if there is no record of the levels of abstraction.

4.2.3 Article 7: Water Used for the Abstraction of Drinking Water

For the sake of completeness, we note that Article 7 states:

> *Waters used for the abstraction of drinking water*
>
> *1. Member States shall identify, within each river basin district:*
>
> *- all bodies of water used for the abstraction of water intended for human consumption providing more than 10 m^3 a day as an average or serving more than 50 persons, and*
>
> *- Those bodies of water intended for such future use.*
>
> *Member States shall monitor, in accordance with Annex V, those bodies of water which according to Annex V, provide more than 100 m3 a day as an average.*
>
> *2. For each body of water identified under paragraph 1, in addition to meeting the objectives of Article 4 in accordance with the requirements of this Directive, for surface water bodies including the quality standards established at Community*

[280] Emphasis added by author.

level under Article 16, Member States shall ensure that under the water treatment regime applied, and in accordance with Community legislation, the resulting water will meet the requirements of Directive 80/778/EEC as amended by Directive 98/83/EC.

3. Member States shall ensure the necessary protection for the bodies of water identified with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water. Member States may establish safeguard zones for those bodies of water.

Annex V states that surface water bodies which are designated for the purposes of Article 7 and which provide more than 100 m^3/day as an average shall be designated as monitoring sites and shall be subject to such additional monitoring as may be necessary to meet the requirements of that Article. Such bodies shall be monitored for all priority chemical substances discharged and all other substances discharged in significant quantities which could affect the status of the body of water and which are controlled under the provisions of the Drinking Water Directive. Annex V Regulation 2.2.2 and 2.2.3 then go on to require that the monitoring regime for such bodies will be of sufficient density and frequency to capture the rate and level of abstractions.

In other words while Article 4 says nothing about the obligations (other than an oblique reference to 'balance' abstraction and recharge) resting on Member States in respect of abstraction for the purposes of those water bodies subject to River Basin Management Plans, Article 7 imposes particular obligations on Member States to identify and monitor significant drinking water bodies. However, even within the heightened protections provided by Article 7, there is no obligation on a Member State to prohibit or prevent abstractions from significant drinking water bodies (those which provide more than 100 cubic metres per day) which go beyond the recharge rate of that body.

In other words Article 7 says nothing at all about regulating the control of abstraction from drinking water bodies or the necessity to strike a balance between abstraction and recharge. Strikingly, the terms of Article 7 envisage, on their face, abstraction for the purposes of drinking and say nothing at all about recharge. In other-words, once a body of surface water is designated for the purpose of drinking water supply the necessity to strike a balance between recharge and abstraction does not appear to apply. It is arguable that the general obligation to ensure 'good status' is a supervening obligation within the Directive but the interaction between Article 7 and that obligation is not at all clear - as there is simply an obligation on the Member States to subject those drinking water bodies to measure (as opposed to prohibit) abstractions from those bodies.

4.2.4 Article 11: Programme of Measures

The only specific obligations in respect of abstractions in the entire Directive are those contained in Article 11. This Article is entitled Programme of Measures. These are the basic measures which must be implemented by all Member States in respect of each River Basin Management Plan. The Article provides;

> *"1. Each Member State shall ensure the establishment for each river basin district, or for the part of an international river basin district within its territory, of a programme of measures, taking account of the results of the analyses required under Article 5, in order to achieve the objectives established under Article 4. Such programmes of measures may make reference to measures following from legislation adopted at national level and covering the whole of the territory of a Member State. Where appropriate, a Member State may adopt measures applicable to all river basin districts and/or the portions of international river basin districts falling within its territory.*
>
> *2. Each programme of measures shall include the "basic" measures specified in paragraph 3 and, where necessary, "supplementary" measures.*
>
> *3. "Basic measures" are the minimum requirements to be complied with and shall consist of*
>
> *…*
>
> *(e) <u>Controls over the abstraction of fresh surface water and groundwater, and impoundment of fresh surface water, including a register or registers of water abstractions and a requirement of prior authorisation for abstraction and impoundment.</u> These controls shall be periodically reviewed and, where*

> *necessary, updated. Member States can exempt from these controls, abstractions or impoundments which have no significant impact on water status".*

This is very significant and the broad sweep of Article 11(3)(e) largely elides and implodes any distinction in terms of the treatment of abstraction in the Directive as between ground and surface water. While Article 7 appears to envisage that abstraction controls are limited to all groundwater and surface waters for human consumption, the only practical elements of abstraction control (registration and licencing) in the Directive are applied to **all** surface and groundwater bodies.

The Article therefore requires Member States to introduce "controls" over abstraction and identifies a specific obligation to organise a register of abstractions and a requirement of prior authorisation for abstraction. The language of this Article is of significant interest. Member States **must** ('*shall*') introduce 'controls', including but not limited to the licencing and register. The structure of the Directive therefore makes abundantly clear that those two obligations are inclusive but not exhaustive of mechanisms which a Member State must introduce. When we turn to discuss the two elements in more detail it is important to remember that, even if satisfactorily in place, those two elements do not exhaust the Member State's obligations.

4.3 Obligations of the Irish Government in Meeting WFD Requirements

In the authors' view it is useful to break down the obligations in relation to abstraction in the Directive into three parts.

Firstly, there is an overarching obligation on a Member State to ensure a balance between recharge and abstraction. This definition and obligation is contained in Article 4 and, as above, is of limited practical application due to the absence of a formal definition of what constitutes a 'balance'. Member states are free to identify what "balance" is for the purposes of the Directive, but the authors have no knowledge of this occurring in Ireland.

Secondly, there is an obligation on a Member State to compile a register of abstractions (Article 11). This obligation is of clear practical utility. Without comprehensive information as to the overall level of abstraction it is difficult to see how the over-arching obligation described above can be achieved. There is no threshold above which abstractions have to be included in the register of abstractions and *prima facie* **all** abstractions are to be included. While Member States are entitled to exempt abstractions which *"have no significant impact on water quality"* an exemption presupposes, in the authors' view, that such an abstraction is at least measured and assessed in the first instance before an exemption could be granted.

Thirdly, there is an obligation on a Member State to institute a system of prior authorisation or licencing for abstractions (Article 11). Again this is of clear practical utility. While the Directive regards quantitative status as only indirectly influencing overall status, it equally recognises that abstraction licencing offers the only method by which balance can be achieved.

4.4 Existing Policy and Legislation

4.4.1 Water Supplies Act

The Water Supplies Act 1942 provides that whenever a sanitary (local) authority desires to take from a source of water (whether within or without its district) a supply of water for the purpose of increasing, extending, or providing a supply of water under the Local Government (Sanitary Services) Acts 1878 to 2001, or the Water Services Act 2007, they may make, under and in accordance with the Act, a proposal for so taking such supply from such source of water. The expression "source of water" for the purposes of the Act is defined to mean "any lake, river, stream, well, or spring". Groundwater is not explicitly stated as a source, but is implied by the terms "well or spring". The Act was primarily intended to compensate downstream riparian landowners from losses caused by the abstraction of water for public water supply purposes However, the Act's status as the sole piece of legislation covering abstraction projects has given it de facto status as the means of assessing (often by means of a public hearing) and regulating abstractions and attaching conditions to their management. Section 3 sets out the requirements for the statements to be included in the proposal. Section 4 then sets out certain procedures that the water services authority must follow once it has made the proposal referred to above.

These include:

(1) Taking all reasonable steps to ascertain the persons (if any) to whom damage may be caused by the taking of water in accordance with the proposal and estimate as nearly as may be the amount of (every) if any such damage;

(2) Prepare in duplicate a list (which is called a "book of reference") showing the names and addresses of those persons as ascertained;

(3) Deposit for inspection one copy of the proposal and one copy of the book of reference;

(4) Give to every person listed in the book of reference a written notice in the prescribed format; and

(5) Publish a notice in the required format in a newspaper circulating in the district concerned.

The copy of the proposal and the book of reference must be deposited, and available for inspection free of charge, at the principal office of the water services authority concerned, or some other place to which the public have access within a specified period of time, and must be kept in that location until either the proposal has been adopted and any time limits for applications for compensation have expired, or until the proposal has been abandoned. A person listed in the book of reference, or any "aggrieved person", may then make an objection to the proposal by giving the water services authority a written statement of the objection and its grounds prior to the date specified in the notice, which must be at least one month from the date of giving the notice to the person listed in the book of reference or the date of publication of the notice in the newspaper, as appropriate.

As well as persons listed in the book of reference, aggrieved persons are stated to include:

(1) Any person who is a rated occupier of property in the sanitary district concerned; and

(2) Any other water services authority.

The procedure for making an objection to a proposal is set out in section 6. If no objection is made, the proposal is deemed to have been agreed to and the water services authority is empowered to take a supply of water in accordance with the proposal. However, if an objection is made and not withdrawn, the water services authority must apply to An Bord Pleanála (the "Board") for a "provisional order" declaring that such proposal may come into force. The procedure for such an application is set out in s.8 of the 1942 Act and also in section 217 of the Planning and Development Act 2000. The application must be made within six weeks of receiving the objection.

The Board may then refuse the application, make a provisional order in accordance with the application, or alter the proposal in a number of ways, such as by inserting such restrictions or conditions as appear proper and then making a provisional order in respect of the altered proposal. A copy of all such provisional orders made by the Board since 2001 should be available on the Board's website, along with the relevant inspectors' reports. In principle once the provisional order has been made, the water services authority is then under certain obligations to notify those appearing in the book of reference, which will then permit them to make an application for compensation in respect of the damage which has been or will be caused by the taking of the supply of water concerned. The Act of 1942 also sets out provisions in relation to calculating the amount, if any, of compensation payable. The Act was primarily intended to compensate downstream riparian landowners from losses caused by the abstraction of water for public water supply purposes but did not consider groundwater and associated environmental impacts per se. The Act's status as the sole piece of legislation covering abstraction projects has given it *de facto* status as the means of assessing and regulating abstractions.

Those who objected to the original proposal have an automatic right of petition to the Circuit Court in respect of the board's provisional order. Essentially, the 1942 act confers on water services authorities' powers akin to compulsory acquisition, in the sense that the granting of a water abstraction order by the board grants a right to take water from a specified source in a specified manner. The right of petition to the Circuit Court is not a judicial review, but a statutory right of appeal. The lack of alignment of the 1942 act with the Planning Acts generally and in terms of compliance with the requirement for environmental impact assessment (EIA) and appropriate assessment (AA) under the EIA Directive and the Habitats Directive has been highlighted by recent case law and in a submission made by the board to the Department of the Environment in 2014.

The recent Circuit Court case of *Danny O'Connor & Others v Kerry County Council and An Bord Pleanála* (South Western Circuit, 24 February 2014) involved a provisional water abstraction order from the Sheen River to supply Kenmare. The plaintiff riparian owners argued, among other things, that the entire development should have been subject to EIA and AA. The order was quashed by the Circuit Court on the basis that the proposed abstraction had not been subject to AA (the court held on the facts that the EIA Directive did not apply). It should be noted that, although local authority development is exempted development and does not require planning permission, section 175 and 177AE of the Planning Acts impose an obligation to carry out an EIA and AA, if required. The board's 2014 submission to the department noted that, in light of the requirement under section 175 and 177AE for a local authority to carry out an EIA and AA in respect of development underlying any proposed water abstraction, it seemed contrary to the thrust and coherence of the consenting process for an additional and parallel EIA and AA to be conducted for the water abstraction itself pursuant to the 1942 act. In order to clarify this, the board recommended the definition of 'development' under section 3 of the Planning Act be amended to include water abstraction and the implications of this be teased out. The board also suggested, in light of the transfer of functions to Irish Water, that it be clarified whether Irish Water would be in the position of a local authority (and subject to section 175 and 177AE) or a normal private applicant. Finally, the board recommended its decision pursuant to the 1942 act be subject to review by way of judicial review in the normal way rather than by petition to the Circuit Court.

Although not specifically set out in the Act of 1942, there are a number of other issues in practice that the water services authority must also take into account when making the proposal. In summary, these include the following:

- In some cases, an Environmental Impact Assessment (EIA) will be required, depending on the nature and extent of the project concerned. In particular, the following categories of specified development require mandatory EIA:

- The volume of water abstracted is equivalent to or exceeds 10 million cubic metres; and,
- Groundwater abstraction not included in Pt 1 of Sch.5 to the Planning and Development Regulations 2001, where the average annual volume of water abstracted would exceed 2 million cubic metres.

4.4.2 Groundwater and Water Policy Regulations

The overarching obligation contained in Article 4 of the WFD has been given practical effect in this jurisdiction via, primarily, Article 3(1)(a) of the *European Communities (Water Policy) Regulations 2003*. This states that it shall be the obligation of each local authority to "*exercise its functions in a manner which is consistent with the provisions of the Directive and which achieves or promotes compliance with the requirements of the Directive*".

That sub-section goes on to state that an obligation shall rest on such local authorities to take such actions as may be appropriate to secure compliance with the Directive and sub-sections (c) and (d) go on to fasten specific obligations on the local authorities in terms of the provision of information. To date the Minister has "*established environmental objectives*" in relation to groundwater in accordance with Article 4 of the Directive under the terms of the power given by the Regulation under the *European Communities Environmental Objectives (Groundwater) Regulations 2010* (S.I. 9 of 2010). These reproduce, in a slightly different format, many of the objectives included in Article 4 of the Directive. It settles an obligation on all public authorities to:

- Prevent or limit, as appropriate, the input of pollutants into groundwater and prevent the deterioration of the status of all bodies of groundwater;

- Protect, enhance and restore all bodies of groundwater and *ensure a balance between abstraction and recharge of groundwater with the aim of achieving good groundwater quantitative status and good groundwater chemical status by not later than 22 December 2015;*

- Reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order to progressively reduce pollution of groundwater; and

- Achieve compliance with any standards and objectives established for a groundwater dependant protected area included in the register of protected areas established under Regulation 8 of the 2003 Regulations by not later than 22 December 2015, unless otherwise specified in the Community legislation under which the individual protected areas have been established.

It also settles a positive obligation on public authorities not to exercise their functions in a manner which will knowingly impinge on the objectives of the Directive.

In part these are more ambitious than required by Article 4 such as in Regulations 21 and 22 which provide that breach of the Regulations shall be a criminal offence punishable by severe fines or terms of imprisonment. This is not required by the Directive. However, for present purposes the 2010 Groundwater Regulations provide the first workable structure of how abstraction is to be regulated. Regulation 4(b) reproduces the obligation to strike a balance between abstraction and recharge in absolutely identical terms to that contained in the Directive. Meat is then put on this obligation in Regulation 37 which enables the Environmental Protection Agency to; *"estimate the long-term annual average rate of abstraction for each groundwater body referred to in Schedule 4"* by, *inter alia,* requiring any person or body corporate to provide them with information on the location and rate of abstraction from any of the relevant bodies. Schedule 4 provides the metric for assessing groundwater quality. It provides that groundwater bodies which fail to satisfy a particular pollution metric will be, *inter alia,* be subjected to abstraction monitoring required in Regulation 37. The table in the Regulation is as follows:

Conditions for applying test	Criteria for poor groundwater quantitative status
Apply to all bodies where there are groundwater abstractions	(a) The long-term annual average volume of water abstracted from the groundwater represents more than 80% of the long-term annual volume of recharge (i.e. water that replenishes the groundwater); or (b) The long-term annual average volume of water abstracted from the groundwater represents more than 20% of the long-term annual volume of recharge in bedrock groundwater bodies (30% in gravel bodies) and there is evidence of a long-term drop in groundwater levels in the body of groundwater; or (c) A Groundwater dependent terrestrial ecosystem (GWDTE), included in the register of protected areas established under Regulation 8 of the 2003 Regulations, is damaged and the long-term annual average volume of water abstracted from the groundwater represents more than 5% of the long-term annual volume of recharge in the groundwater body containing the GWDTE and there is evidence of a long-term drop in groundwater levels in the groundwater body.

Regulation 8 of the 2003 Regulations refers to the *European Communities (Water Policy) Regulations 2003* and the obligation resting on the EPA to establish a register of protected areas (whether groundwater or surface water) by December 2004 for the purposes of the Regulations.

The second element of abstraction control in the 2010 Regulations is that contained in Regulation 38. This provides that in order for the Agency to determine: *"...whether the level of groundwater in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction, as required in Table 4 of Schedule 3, the Agency shall monitor levels in the national groundwater level monitoring network established for the purposes of Regulation 10 of the 2003 Regulations and shall keep water balance estimations updated using recharge and abstraction rates for each groundwater body characterised as being At Risk of failing to achieve good groundwater quantitative status in accordance with Regulation 7 of the 2003 Regulations."*

Regulation 38, when read with Regulation 37 and Table 4 of Schedule 3 means that any groundwater body which fails to meet any one of the three tests contained in Table 3 **must** be monitored by the Environmental Protection Agency to ensure that the rate of recharge is not exceeded by the rate of abstraction. Interestingly, the formula used in Regulation 38 is such that it does not place a prohibition *per se* on the imbalance between abstraction and recharge – it implies that there should be no such imbalance, and it requires that water balance estimations are maintained in respect of vulnerable groundwater bodies but it is important to emphasise that Regulation 38 is a determinative and information forming Regulation rather than a prohibitive Regulation. Its primary purpose is to place the EPA in a position where it can 'determine' whether there is an imbalance between recharge and abstraction rather than to prevent that occurring. It is unclear what effect any such determination would have. Presumably, that information would be the lynch-pin of an appropriately functioning licencing regime and would feed directly into a decision by the EPA or a local authority (as appropriate and for more detail on licencing see below) to licence abstraction. In other words a determination by the EPA for the purposes of section 38 would not directly affect an individual but would feed into a WFD appropriate licencing regime.

4.4.3 Surface Water Regulations

By contrast the European Communities Environmental Objectives (Surface Water) Regulations) 2009 (as amended) make no mention of abstraction apart from reproducing the Directives obligation for the Minister to introduce measures measuring abstraction and providing for an authorisation regime. As discussed below, in the authors view no sufficient measures have been taken to address this obligation. This structure, but not the provisions in relation to abstraction, was overhauled by the *European Union (Water Policy) Regulations 2014* which replaced the primary function of the local authorities with a three tier structure of the Minister as co-ordinating authority, the EPA with a scientific and reporting function and the local authorities as the regional implementation bodies.

The Regulations sketched above purport to discharge the obligation contained in Article 4 to "strike a balance" between recharge and abstraction. That obligation is faithfully reproduced.

However, it is equally clear that the monitoring programme contained in the Regulation is not an adequate discharge of the obligation identified in the Directive above to introduce a national register of abstractions. Critically, Regulations 37 and 38 required only that the EPA "estimate" abstraction rates for groundwater bodies nationally and that it is only where one of the key criteria contained in Table 4 of Schedule 3 is met, that the EPA is under an imperative obligation to ensure that the rate of recharge is not exceeded.

If one of those criteria is not met, but the water body is otherwise At Risk of not achieving good status, then the Agency is simply required to maintain estimates of the relative balance between recharge and abstraction for those water bodies. If none of the criteria are met, and the water body is not classified as being At Risk of achieving good status then there does not appear to be any obligation on the EPA to maintain estimates of abstraction.

This is not consistent with the Directive. The Directive requires that the Member States introduce Basic Measures in respect of **all** River Basins. The obligation to introduce those measures is not limited only to those water bodies which are regarded as being At Risk of not achieving '*good status*'. The obligation, in other words, to compile a register of abstractions is a general one which does not distinguish between River Basins and applies to all water bodies irrespective of their status.

This fundamental deficiency in terms of scope of the register is compounded by the type of information available to the EPA. As will become clear there are serious lacunae in the abstraction register dealt with in Section 4.5.

In addition to development regulations, an EIS produced by a developer is obliged to include inter alia, the use of natural resources from a proposed development. This should include the use of water abstracted to serve the project. Article 4 of the European Communities Environmental Objectives (Surface Waters) Regulations 2009 (the "2009 Regulations"), outlines requirements for a public authority to ensure, insofar as its functions allow, that surface water bodies comply with the relevant environmental quality standards specified in the Schedules contained in the 2009 Regulations, a requirement that protected areas achieve compliance with any standards and objectives laid down for such areas, establish or make operational such measures appropriate to its functions as are necessary to achieve the environmental objectives and quality standards established.

Article 5 of the Regulations requires that a public authority shall not, in the performance of its functions, undertake those functions in a manner that knowingly causes or allows deterioration in the chemical status or ecological status of a body of surface water. Accordingly, when exercising its functions as a water services authority, a local authority must be cognisant of its obligations under the 2009 Regulations.

4.4.4 Birds and Natural Habitats Regulations

The European Communities (Birds and Natural Habitats) Regulations 2011 consolidate the *European Communities (Natural Habitats) Regulations 1997–2005 and the European Communities (Birds and Natural Habitats) (Control of Recreational Activities) Regulations 2010*, and increase the obligations of various public bodies in regard to Natura 2000 sites designated for the protection of endangered wildlife have been clarified and strengthened.

These sites consist of Special Protection Areas (SPAs) designated for the protection of birds, and Special Areas of Conservation (SACs) designated for the protection of other important habitats such as raised bogs, native woodland and sand dune systems, and so on. Collectively these sites form part of the EU-wide Natura Network. The 2011 Regulations complement relevant provisions of the Planning and Development Act 2010. Local authorities and An Board Pleanála now have legal responsibilities and powers under the Planning and Development Acts to ensure that the requirements of the Birds and Habitats Directives are adhered to in the adoption of development plans and the granting of development consents.

Accordingly, the water services authority/the Board must consider whether the site in question lies within a Natura 2000 site or adjacent to such a site. This is termed appropriate assessment screening “AA screening”. Its purpose is to determine, on the basis of a preliminary assessment and objective criteria, whether a plan or project, alone and in combination with other plans or projects, could have significant effects on a Natura 2000 site in view of the site's conservation objectives. An environmental report must be prepared which should identify whether there is any impact on conservation sites applying the criteria referred to in the “Appropriate

Assessment Guidelines", or whether there are any protected species, or whether any impacts are likely to occur on any European sites, but are not likely to be adversely affected, by the proposed taking of the water supply.

While not confined to the question of abstraction under the *European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2010*, amended by the *European Communities (Good Agricultural Practice for Protection of Waters) (Amendment) Regulations 2011*, local authorities are required to carry out, or cause to be carried out, such monitoring of surface waters and groundwater at selected measuring points within their functional areas as makes it possible to establish the extent of pollution in the waters from agricultural sources and to determine trends in the occurrence and extent of such pollution.

4.4.5 Water Pollution Act 1977

Finally, it should be noted that s.9(2) of the Local Government (Water Pollution) Act 1977 also requires water services authorities to maintain a register of water abstractions in their functional areas, except for abstractions which do not exceed 25 cubic metres in any period of 24 hours. However, the authors can locate no more information about this registration obligation and in a broad sample of counties no information on the abstraction register (as opposed to the discharge obligations in the Act which are beyond the scope of this report) required pursuant to the Act was available. That is borne out by the patchy quality of the Abstraction Register discussed in more detail in the context of the WFD (Section 4.4.4).

4.5 The National Abstraction Register

4.5.1 The Register

An "Initial Characterisation" of abstraction pressures was reported to the European Commission (EC) by the Environmental Protection Agency (EPA) in the national report titled

"The Characterisation and Analysis of Ireland's River Basin Districts".[281] This report provided a general assessment of abstraction pressures in each of six river basin districts delineated in Ireland and identified water bodies that are deemed to be 'At Risk' from meeting environmental status objectives, as defined by the WFD, by year 2015. This Characterisation identified only six groundwater bodies to be At Risk from meeting WFD good status objectives by year 2015, while a further 36 were considered to be "probably At Risk", involving less certainty and reduced confidence in the assessment. Of the 36 "probably At Risk" cases, only 12 were linked directly to abstraction rates or saline intrusion, while 24 were linked to perceived threats of drainage impacts other than abstraction. However, there was absolutely no information contained in the Initial Characterisation as to how information on abstraction pressures were compiled.

This EPA characterisation report simply says:

> *"A database of significant water abstractions including public and private water supply and industrial use have been provided by the Department of the Environment, Heritage and Local Government (DEHLG) and augmented by the RBD projects. Map 3-1 shows the known significant groundwater and surface water abstractions in Ireland."*

And again at paragraph 3.2.2 (emphasis added):

> *"The assessment of significant abstraction pressures was undertaken by comparing known significant groundwater abstractions with the available estimated natural recharge of each water body. The risk category for each water body was identified depending on the proportion of recharge abstracted, supported by observed water level trends in boreholes/monitoring wells. The*

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[281] EPA (2005) The Characterisation and Analysis of Ireland's River Basin Districts. National Summary Report, Ireland, 2005.

quantification of recharge methodology and the thresholds used are described in the background documents…"

Further detail on unregulated abstractions such as agricultural will be collected as part of further characterisation process."[282]

This concern as to an absence of data was repeated at page 103 of this same report where it was noted:

"Examination of the data requirements presented in the CIS Reporting Sheets identified some specific data needs that must be addressed by further data collection and investigation during the preparation of the river basin management plan, for example:

- *Further details of uncontrolled or private abstractions."*

Finally, the absence of data on abstraction is noted in Table 3-31 entitled "Key Data Gaps" acknowledges:

"A number of unregulated activities abstract water – the impact of these activities is unknown but may be significant in certain cases – improved monitoring and/or management of these activities will be considered."

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[282] The same approach was adopted for surface water (para 3.2.2) *"The assessment of significant abstraction pressures was undertaken by comparing the nett volume of known significant surface water abstractions with the characteristic low flow in each river waterbody. The risk category was identified based on a percentage threshold of the 95 percentile low flow abstracted. The methodology used to calculate the low flow and nett abstraction for each waterbody and the thresholds used are described in the background documents... Further detail on unregulated abstractions such as abstractions for irrigation will be collected during the development of the first river basin management plan."* As per Table 3-18 on page 89 of the Report there were 90 surface water bodies at risk from abstraction pressures representing 12% of all such water bodies and .7% of the total River Basin Districts.

A follow up report was commissioned by the ERBD called the *"Abstraction Pressure Assessment Background to Water Matters Report – 22 June 2007"*[283] which indicated that the *"The national abstraction project is developing methods to examine the effects of abstractions from surface and groundwater to reduce uncertainty in the Initial Characterisation results so status can be assigned.*

This ERBD abstraction pressure report noted (at paragraph 4.1) that a National Register of Abstractions had been formed from unspecified input from each RBD and local authorities and that *"the updated register is considered an improvement over 2005 as records have been cross- and error checked, new abstractions have been added or removed as appropriate and some wells have been removed (e.g., if decommissioned)."* Significantly it noted that:

- The register does not include domestic wells, as these are too numerous and considered less important from a resource quantity point of view. Most of the domestic abstractions are returned to ground via septic systems, and whilst this has an impact on groundwater quality, it has less of an impact on quantities.
- All abstractions have been assigned as either surface water or groundwater, and new or revised volumes of abstractions have been added where available.
- Its belief that most, if not all, public and group water schemes have been identified and included, but it is unlikely that all industrial and miscellaneous small private abstraction schemes (e.g., schools, hospitals) are captured in the new register.
- Data on abstraction volumes is available for over 90% of the surface water abstraction points. The ERBD abstraction pressure report noted that over 1.3 million m^3/day is currently being abstracted from the over 400 surface water abstractions that have abstraction rates. Approximately 367 abstraction points

[283] CDM (2007) Abstraction Pressure Assessment Background to Water Matters Report – 22 June 2007. ERBD. pp18.

supply more than 100 m^3/day, whilst over 100 points supply less than 100 m^3/day. Among the supplies with known abstraction rates, the median surface water abstraction is 410 m^3/day.

- Table 4.2 of this same ERBD abstraction pressure report summarises all groundwater abstractions included in the national register, as reported by individual RBD projects. By way of example it identified 64 wells in the Northwest RBD, 41 in Neagh-Bann and 180 in the Southeast. These numbers are stated to include supply wells and springs that serve public supply and industrial purposes but not wells or springs used for domestic purposes whereby water is returned to septic systems.

The ERBD abstraction pressure report[284] concludes that the "*numbers presented are believed to provide a reasonably complete picture of total abstractions, although a few scenarios have yet to be fully verified, notably related to mine dewatering and quarry abstractions*". It noted that approximately 530,000 m^3/day is presently being abstracted from almost 1,900 identified supply wells or springs. The highest total groundwater abstractions occur in the Shannon and Southeastern RBDs. The single largest groundwater abstraction nationally is associated with the Lisheen mine in Tipperary North, at 65,000 m^3/day, or more than 10% of the national total[285]. Approximately 100 abstraction points nationally supply more than 1,000 m^3/day, while a further 500 abstraction points produce greater than 100 m^3/day. The majority of supply wells and springs produce between 10-100 m^3/day.

The ERBD 2007 report notes that it is an interim report only and that it was hoped to have a final methodology for assessing abstraction pressures allegedly due to be completed by mid-

[284] CDM (2007) Abstraction Pressure Assessment Background to Water Matters Report – 22 June 2007. ERBD. pp.18.

[285] The mine has subsequently closed. See: Taylor (2016) Lisheen mine in Tipperary makes final shipment. Irish Times 25 Jan 2016.

2008 and the report is replete with references to on-going work to determine abstraction metrics in relation to lakes and rivers. The report notes that while abstraction pressure on groundwater is "not generally considered to be a significant pressure" (paragraph 4.4):

> *"…abstraction pressures are expanding in line with national growth, and expanded use of groundwater resources will require improved monitoring and centralised water resources management. The revised risk assessment builds on the work carried out by individual river basin district projects as part of Water Framework Directive implementation in Ireland. A national groundwater recharge map has been developed from GIS processing of related hydrogeological inputs, and forms an important basis for assessment of new and significant groundwater abstractions.*
>
> *The remaining tasks to be carried out are:*
>
> *(a) Preparing a report on the work associated with the revised national risk assessment;*
>
> *(b) Developing technical guidance towards establishing a suitable national groundwater abstraction registry and/or licensing system. The project is targeted to be completed in December 2007."*

In the following paragraphs the Report notes that the groundwater and recharge assessments conducted in 2005 had been revisited and had remained largely the same.

A Further Characterisation of these bodies was carried out by CDM on a River Basin basis, reporting in February 2009.[286] All the data from the 2005 and 2009 Initial Characterisation and Further Classification were included in a national abstraction register. It is unclear how comprehensive this CDM Further Characterisation has been. It notes (at page viii) that it is part of a national Further Characterisation study of groundwater abstraction pressures carried our as

[286] CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

part of the Programme of Measures phase of the WFD. The objectives of the Report are described as follows:

a) To update the national register of groundwater abstractions;

b) To update the national risk assessment of groundwater abstractions that was submitted to the EC in 2005; and

c) To develop technical guidance towards establishing a future groundwater abstraction licensing system.

It goes on to note that the National Register of Groundwater Abstractions (page viii):

> *"…has been collated from information collected and verified across each river basin district in Ireland. From the present Register, an estimated 575,000 m3/day is known to be abstracted from groundwater sources. The Register is a relatively complete representation of public water supply and group water schemes, but is almost certainly underestimating the total number of abstraction points across the country, particularly in the industrial and commercial sectors. As a result, the total abstraction volumes may also be under-represented. Groundwater abstractions associated with domestic supplies for single houses are not included in the Register. However, such abstractions are of reduced consequence from a quantitative water management perspective, as the majority of the water is returned to the groundwater system through onsite septic systems."*

A perusal of the CDM report does not give any indication of the methodology by which the Register was compiled, quality checked or maintained. This is a matter of considerable concern. In other-words from the initial characterisation in 2005, through the update in 2007 to the Further Characterisation Report in 2009 it is not apparent that there has been any systematic attempt to identify and quantify abstraction points other than those identified by the Department in 2005. Nor does the data which is being advanced in 2009 appear to be any different to that provided in 2005.[287] While all three (2005, 2007 and 2009) reports refer to on-going quality and cross-checking and improvement of the data in the National Abstraction Register there is no visibility on how this is being achieved, who is undertaking these tasks, in what format the Register is stored or any basis for concluding that the Register represents a robust picture of all groundwater abstractions above a *de minimis* level.

The CDM 2009 report does give a revised figure of nearly 2,000 identified (known) groundwater abstraction schemes or points, which combined pump approximately 575,000 m^3/day (an increase of 45,000 m^3/day from 2005) of groundwater. However, it is noted in respect of the 2009 report that:

- The Register does not include abstractions associated with domestic supplies for single houses. Wright[288] estimated that more than 200,000 private domestic wells may exist (in 1999), but this number could be significantly higher given the construction and housing boom in the intervening years.
- That there are a significant number of small scale public schemes which are extracting small volumes of water but those volumes and that number of schemes are unknown and potentially significant.
- That the current national abstractions Register includes only public supply schemes and private abstraction points that are known from information collected and verified by individual RBD projects. The collated data is primarily based on

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[287] Although see paragraph 2.1.1 “Overall, the updated Register is considered an improvement over that used in 2005. Data for supply wells and springs have been cross- and error-checked by each RBD project, and abstraction schemes have been added or removed as appropriate. While the vast majority of public and group water schemes that are used for water supply have been identified and included, the majority of industrial, commercial, and small private abstraction schemes (e.g., farms) have not.”

[288] Wright, G. 1999. How many wells are there in Ireland? The GSI Groundwater Newsletter, Vol. 35.

Local Authority records, as well as information researched with the GSI, EPA, well drillers, and consulting firms.

- The updated Register is almost certainly underestimating the total number of abstraction schemes or points across the country, and as a result, the total abstraction volumes may also be under-represented.
- Domestic supply wells aside, the total number of non-domestic abstractions that may be missing from the current Register could be in the hundreds, if not thousands.

It is also apparent from the 2009 CDM report[289] (and the preceding aforementioned ones in 2005 and 2007) that important categories of non-domestic users of groundwater have not necessarily been included in the Register. These include:

4.5.1.1 Quarries

Groundwater is abstracted in quarry operations for dewatering purposes, processing of aggregate, and cement production. While the Geological Survey maintains a register of active quarries, a review of local authority submissions for the purposes of Section 261(4) of the Planning and Development Act 2000 quickly demonstrates that information about water use generally and groundwater abstraction specifically is cursory or missing in the vast majority of cases. It therefore appears, and was the assumption of the Report, that the number of quarries which operate pumping wells and actual quantities abstracted are not known. Some (but by no means all) quarry operators hold Integrated Pollution Prevention Control (IPPC) licences with the EPA, from a sample of the licences reviewed few include information about sources of water used or dewatering operations.

[289] CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

4.5.1.2 Farms

Agricultural uses that pump groundwater may use the water for domestic purposes, general farm operations, and irrigation. There are no readily available statistics for water use associated with irrigation. An EU-wide report[290] concludes that while water demand for irrigation is "relatively insignificant" in Ireland, irrigation is practiced in the south and east of the country. Quoting Teagasc, this report states that less than 1,000 hectares (ha) of potato and vegetables crops, and 100 ha of strawberries, are actively irrigated which would suggest that groundwater abstractions for irrigation purposes could total 700,000 m^3/yr. This EU Report (at para 3.1.1.2) also notes the high rate of water consumption on dairy farms and provides an estimate of groundwater abstraction in the order of 130,000 m3/day by dairy farmers.

4.5.1.3 Golf Courses

There are approximately 420 golf courses in Ireland and the CDM 2009 groundwater abstraction report[291] acknowledges that it has little or no information on abstraction for this source. It notes, in a somewhat startling conclusion that (emphasis added):

> *"Limited information obtained during this study would suggest that abstraction rates for any given golf course can vary from less than 10 m^3/day up to 1,000 m^3/day. Assuming an average of 200 m^3/day, and an effective pumping period of 30 days in a year, <u>this would equate to a total abstraction rate of 2,500,000 m^3/yr (for 420 golf courses). This is 5 times higher than the current total of the national abstractions Registe</u>r, and while it is very likely an overestimate, it points out the*

[290] Baldock, D. et al, 2000. The Environmental Impacts of Irrigation in the European Union. A Report to the Environment Directorate of the European Commission. March 2000.

[291] CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

need to carry out a detailed national survey of abstractions and irrigation of golf courses."

4.5.1.4 Industry/Commerce/Other

There are numerous potential other unregistered groundwater users in the industrial and commercial sectors. It is unknown what quantity of water is abstracted by industry from surface water. Only 160 industrial wells have been identified in the National Register but this captures only a tiny fraction of users such as hotels, sports clubs, equestrian facilities, car washing facilities, creameries, and the food and drinks industry. As a rule, planning permission records generally do not include details of sources of water supply, and there is currently no formal reporting mechanism in place to capture such potential abstractions.

4.5.2 Limitations in the Register

Noting that there is no primary legislation covering abstraction of groundwater or surface water in Ireland it candidly noted the limitations of the current Register. The CDM report[292] accepted that there were data gaps in the Register (as noted above) and that additional targeted efforts were required to address groundwater use by, for example, quarries, golf courses, the hospitality industry, mining and use of groundwater by farming for the purposes of irrigation. It noted a particular concern in relation to the absence of any requirement for uniform standards in well construction for mining and that, in the absence of same, the data which was being provided to the EPA on groundwater use via the Integrated Pollution Control process was frequently unavailable and of questionable value (at page xi) as it is rarely provided.

From 2009 to date little progress appears to have been made in relation to these obligations. There has been no systemic updates of the National Register (which is not yet publicly available, with the data in the hands of (primarily) the Local authorities and county councils).

[292] CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

Nor does any progress appear to have been made in closing the data gaps identified in 2009. This is demonstrated in the most recent report (March 2015) made by the State to the European Commission as part of the Water Information System for Europe (WISE) initiative.[293] While it noted that abstraction was a pressure on less than 10% of the water bodies (thus reflecting the figures from both 2005 and 2009) it went to state that there had been a delay with, *inter alia*, bringing forward regulations implementing Basic Measures because of the delayed implementation of the Water Quality Framework Bill. At page 30 of the WISE report it went to state:[294]

> *"Assessment of measures for the achievement of WFD objectives:*
>
> *Ireland indicated 6 RBDs where basic measures would be insufficient to meet WFD objectives in lake and river water bodies for water abstraction. There is currently a legislative gap for the control of abstractions and this is being addressed as part of a wide ranging review of the legislative framework."*

Unfortunately it is not possible to identify what Ireland was referring to when they referred to the *"wide ranging review of the legislative framework"*. None of the Water Services Act 2007, the Water Services (No. 2) Act 2013 or the Water Services Act 2014 provides for the implementation of any measures relating to abstraction in general or in relation to the establishment of a comprehensive National Abstraction Register in particular. The only mention across the suite of Acts is section 32 of the 2007 Act which provides that a water services authority 'may' take whatever measures are necessary to ensure compliance with its obligations under:

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[293] WRC (2015) Assessment of Member States' progress in the implementation of Programme of Measures during the first planning cycle of the Water Framework Directive – Member State Report: Ireland. European Commission Report: available at: http://ec.europa.eu/environment/water/water-framework/pdf/4th_report/country/IE.pdf.

[294] WRC (2015) Assessment of Member States' progress in the implementation of Programme of Measures during the first planning cycle of the Water Framework Directive – Member State Report: Ireland. European Commission Report.

> *"(a) the abstraction, impoundment, treatment, purchase or supply of water for drinking or any other purpose, in accordance with relevant provisions of this Act or any other enactment, or regulations made under this or any other enactment".*

However, this appears to be simply one amongst the many aspirational objectives contained in that Act. The authors are not aware of any further concrete initiatives, from Irish Water or on its behalf to revise or address the acknowledged legislative lacunae, with the arguable exception of the Abstraction Working Group's work on guidelines for regulation.

4.5.3 The RPS Report

The EPA appointed RPS Engineers Ltd in October 2015 to assist in the development of a National Abstraction and Discharge Database. In their final report of April 2016[295] RPS noted that they had collected the following data (page 6);

- 2,505 abstractions (groundwater and surface water). These are primarily a combination of public and private water supply abstractions, which were identified from data provided by the Local Authorities, Irish Water, Geological Survey Ireland and NFGWS. The number of abstractions relates to points of abstraction rather than number of facilities[296];
- 189 abstractions from lakes; and
- 10 abstractions associated with active quarries.

In other-words RPS appear to have relied on the existing datasets as the basis for compiling their report. While they did undertake field surveying of some 791 of these abstraction points,

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[295] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

[296] Abstraction volumes are apparently known, but not included in the report.

it is not apparent from the RPS report that the lacunae identified from 2005 and 2009 have been substantially addressed. This is borne out by a comparison of the number of abstraction points identified in the RPS report with those used in the earlier reports. While the overall numbers have crept up from approximately 2000 (in the earlier reports) to approximately 2,600 there is no basis in the RPS report to conclude that this latter number is comprehensive or that the earlier deficiencies have been addressed. No criticism of RPS is implied in this observation.

The major exception to this observation is that RPS appear to have engaged substantially with the National Federation of Group Water Schemes (NFGWS) and to have captured significant new data from those schemes as described at section 3.4. However, at page 31 of the report RPS acknowledges that this data captured only 60% of the groundwater supported water schemes in the country (approx. 600 of an estimated 900 schemes[297]). While they did engage in additional validation and follow-up with NFGWS officials at a local level it is unclear whether that additional effort has led to a comprehensive picture of the abstraction rates from these Schemes.

With the greatest respect therefore it is not clear to the authors that RPS was in fact in a position to conclude "*With the information collated from Irish Water together with abstraction information received from the GSI, EPA and Local Authorities, RPS was able to develop a national abstraction database*." While RPS clearly did valuable work in compiling metadata from disparate sources, engaging in validation of some of that data and building a technology solution for an overall national abstraction database, significant concerns remain around the quality and comprehensive nature of that data.

A good insight into the deficiencies in the primary data is provided by the example of the IPC regime. RPS noted that they were required under the scope of the project to review abstractions associated with IPC/IE licenced installations/facilities (at section 3.13).

[297] pers. comm. EPA, 2017.

"This presented certain challenges as the recording of abstraction information is generally not a requirement of the licence. However, more recently AER [Annual Environmental Reports] now request information on "resource use" including if groundwater or surface water is abstracted for use at the installation/facility. Many of the AERs are now also available on-line and where the AERs are presented in the new tabular format, this information is readily available."

The RPS report continues;

"Of the existing 709 IPC/IE licences, RPS concentrated their review of abstraction information to the 328 sites, which are located within the Tier 1 "At Risk" catchments. Of these 328 sites, AERs available on the Agency's website were accessed to avail of information. It should be noted that approximately 200 of the 328 sites did not have information uploaded to the Agency's website. The EPA also provided RPS with a separate spreadsheet of 62 IPC/IE installations/facilities, which included data on abstractions. This spreadsheet was also examined. RPS was able to assess information on abstractions from 114 IPC/IE installations/facilities. The abstractions from these premises ranged from $2m^3$ /year (5.4l/day) to $2,214,040m^3$ /year ($6,065m^3$ /day) and RPS has submitted this information as part of the abstraction MS Access database file and GIS layer."

In other words the data from IPC licences is partial (as there is no requirement for abstraction data to be reported back) and even within that data set RPS focused their efforts on less than half the total number. While it is unclear the exact relationship between the various pieces of data in the quoted paragraph it is clear that the data relied upon by the RPS is patchy and does not, even on their account, represent an accurate national picture.

There is little evidence in the RPS report that previously identified lacunae around mining, hotels, farming, domestic water schemes and miscellaneous industrial abstractions have been addressed.

Viewing the development of the reports (from 2005-2016) in the round it is difficult to reconcile the professions of faith in the abstraction register with the data gaps which are acknowledged at one and the same time. While the Register does appear to have incrementally improved since

2005, and the most recent iteration by RPS does appear to have substantially advanced the centralisation and accessibility of abstraction data, it is clear that the overwhelming amount of information contained therein is in fact from local authority or large public water schemes and that mines, hotels, private water schemes, farming and private wells have not been adequately captured in the Register.

In the authors' view, it is difficult to have any faith in the accuracy of the figure of 575,000 m^3 /da**y** as being even remotely accurate as an estimate of the total abstraction volume across the country.

It is important to emphasise that there is no allowance in Article 11 of the Directive to exclude certain activities from the abstraction register. It is not therefore open to a Member State to, at one and the same time, identify yawning gaps in their data and conclude that they are in possession of sufficient information to provide accurate estimates.

As discussed above Article 11(3)(e) requires that Member States introduce both a Register of abstractions and a prior authorisation regime. In respect of the Register the deficiencies are clear and there does not appear to be any comprehensive proposals to address same.

In this regard the authors note the latest Consultation documents opened in respect of River Basin Management Plan 2018-2021 which expires on August 31st 2017[298]. This consultation document does not contain any comprehensive proposals to establish an abstraction register. While it does identify a number of water bodies which the EPA has deemed to be At Risk from abstraction pressures and (page 44):

> *"All of the above 194 identified water bodies with abstractions require further assessment to confirm if the abstractions are in fact contributing to an ecology impact in the river and lake water bodies. This will be achieved by improving estimates of flow*

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[298] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

> *in these water bodies, undertaking more detailed assessment where the flow is regulated e.g. controlled by dams and an examination of available ecological monitoring information."*

However, this does not address the deficiencies identified above. It is not, in the authors view sufficient to identify a small number of water bodies and concentrate resources on those. The Directive requires that a comprehensive national abstraction register is created and there are no proposals in respect of same in the new Consultation document beyond a bald statement (page 65):

> *"Register of water abstractions:*
>
> *Building on the existing EPA abstractions database, the establishment of a comprehensive and maintained national register of water abstractions is essential in order to assess and manage the potential risk of over-abstraction on an on-going basis. It is therefore proposed, in the short to medium term, to advance legislative proposals establishing a requirement to maintain a register of abstractions, including abstraction amounts, for all surface water and groundwater abstractions greater than 25 cubic meters per day."*

No detail is provided as to how this might work, or when these proposals will be brought forward and there is nothing in the current legislative programme which addresses same. In the authors view this statement, apart from a tacit admission that the current Register is insufficient, does not dilute, deflect or cure the criticisms made above.

4.6 Licencing

It is quite clear from the terms of the Article that the Directive envisages that prior authorisation (referred to, in the context of this paper, as 'licencing') is a mandatory element of the abstraction regime. While Member States may introduce additional measures above and beyond the national register and a form of licencing, neither of these elements is optional. Nor, the structure of the Article makes clear, could alternative measures (even if they had been implemented in this jurisdiction) be regarded as acceptable substitutes (emphasis added):

"…***including*** *a register or registers of water abstractions and a requirement of prior authorisation for abstraction and impoundment."*

It is also worth noting at this juncture that the Member States are entitled to remove certain abstractions from both the Register and the licencing system if those abstractions have "*have no significant impact on water status;"* However, this latitude does not provide any justification for the exclusion or non-implementation of a licencing regime *at all*.

The State is aware of its obligations in this regard. For example in the Dublin City Council *"Further Characterisation/Programme for Measures, Groundwater Abstractions Pressure Assessment"*,[299] the mandatory nature of Article 11(3) and its absence in this jurisdiction was noted (at page ix):

> *"Article 11.3(e) (Programme of Measures) of the WFD requires that abstraction controls be introduced that include a register of abstractions and a requirement for "prior authorisation". Primary legislation to cover abstraction licensing in Ireland does not yet exist."*

That document then noted that:

> *"A risk-based licensing framework" is proposed whereby environmental risk increases with abstraction rates and proximity to ecologically sensitive receptors and saltwater. Within the proposed framework, potential impacts are initially screened against a set of distance criteria and abstraction thresholds."*

[299] CDM (2009a) Groundwater Abstraction Pressures Assessment – Dublin City Council: Further characterisation/Programmes of Measures Final Report

It continued to note the broad requirements of that proposed framework. They noted that the framework would require a preliminary assessment and, where necessary, further technical assessment. As envisaged in 2009 this would involve the following elements:

- Abstractions less than 250 m^3/day would be approved in the majority of cases, provided the following information is submitted: well construction diagrams, boring logs, aquifer test results, and water quality data (the latter would only be required if the abstraction is to be used for drinking water);
- Abstractions greater than 100 m^3/day and within 250 m of a GWDTE (Groundwater Dependent Terrestrial Ecosystems) would be subject to greater technical scrutiny and input from the NPWS;
- Abstractions greater than 250 m^3/day but less than 1,000 m^3/day would require a greater level of technical assessment, and depending on the initial screening, may require the involvement of the licensing supervisory body in the scoping of field work;
- Licences would be granted upon submittal of an Environmental Report provided that no significant impacts are identified: and
- Abstractions greater than 1,000 m^3/day would automatically be deferred to the licensing supervisory body.

The CDM Further Characterisation report concluded with the uncontroversial observation that the level of assessment envisaged would in principle become more complex with greater abstraction rates and proximity to groundwater users or receptors. It noted the necessity for annual reporting requirements on the basis that no assessment could be made in respect of a licencing application unless the total abstraction pressure on a given water body was known. While these comments and draft framework were prepared in the context of groundwater specifically (and there is no equivalent for surface water bodies that the authors are aware of), there is no reason why they are not equally applicable to surface freshwater abstraction licencing.

There are four notable features to the proposal:

Firstly, it is notable that the proposal envisaged setting up a dedicated agency to both maintain the Register and issue licences. Although only in draft form the proposal did not envisage that the licencing authority would be nested within the Environmental Protection Agency. Although Irish Water has been established in the meantime it is unclear whether they would have either sufficient independence or the resources to discharge the functions of a consent authority in the same vein as the EPA or An Bórd Pleanála. More to the point there is no provision in the statutory authority establishing Irish Water which would allow it to expressly discharge those functions.

Secondly, the test proposed in the framework i.e. a licence being granted if there are "no significant impacts" on the water body from the proposed abstraction. This is a test reminiscent of that contained in Article 6(3) of the Habitats Directive (92/43/EC) which prohibits, except in several limited categories, the carrying out of any development which would have a significant impact on any Natura 2000 site or species of community concern. If carried forward into action it would impose a considerable justificatory and exploratory burden on a potential abstractor to satisfy the consent authority that their proposal (presumably considered cumulatively with all other current and proposed abstractions from that water body) would not have a significant impact on the water body or indeed any surrounding Natura 2000 sites. Although impossible to say definitively at this remove it would appear to set up a skeleton framework that bears a more than passing resemblance to the Screening, Natura Impact Statement and Appropriate Assessment process which developers must go through if their proposed development *could* impact on a Natura 2000 site. This brings with it significant cost and time implications for potential abstractors.

Thirdly, if the draft proposal (or a version thereof) was to be implemented it would have to engage the public participation obligations under the Aarhus Directive. Unlike the Environmental Impact Assessment Directive, the WFD Directive is notoriously vague in relation to the degree and type of public participation which is required. It provides, for example:

> *"The success of this Directive relies on close cooperation and coherent action at Community, Member State and local level as well as on information, consultation and involvement of the public, including users."* - Preamble 14
>
> *"To ensure the participation of the general public including users of water in the establishment and updating of river basin management plans, it is necessary to provide proper information of planned measures and to report on progress with their implementation with a view to the* ***involvement of the general public before final decisions*** *on the necessary measures are adopted."* - Preamble 46 (emphasis added)
>
> *"Member States shall encourage the active involvement of all interested parties in the implementation of the Directive, in particular in the production, review and updating of the river basin management plans…On request, access shall be given to background documents and information used for the development of the draft river basin management plan."* - Article 14.1

With the possible exception of the highlighted section none of these commitments to public participation come close to imposing an obligation to consult in advance of any abstraction licence decisions being taken.[300] Nor does the Commission Guidance on the interaction between public participation and the WFD provide any guidance on whether these principles should be applied to licencing decisions or how that might work.[301] In this vein the *European Communities (Water Policy) Regulations 2003* (S.I. No. 722/2003), stipulates only the following vague obligations in relation to co-ordination and public involvement in relation to RBMPs but not necessarily licence conditions:

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[300] See generally "The Water Framework Directive, Assessment, Participation and Protected Areas: What are the Relationships?" (Collingwood, Imperial College London 2007).

[301] "Guidance on Public Participation in Relation to the Water Framework Directive (Active Involvement, Consultation, and Public Access to Information)", EU Public Participation Working Group (2002).

> Article 3(c) requires public authorities to *"consult, cooperate and liaise with other public authorities and the competent authorities in Northern Ireland…to ensure coordination of the requirements of the Directive…in relation to the whole of each…international river basin district";* and
>
> Article 3(e) also requires public authorities to *"encourage the active involvement of all interested parties in relation to the measures being taken by the authority for implementation of the Directive"*.

In other words even in draft form it is notable that the skeleton framework does not envisage a public participation requirement in relation to any licence decisions.

Finally, the most notable aspect of the proposal is that it has not been developed, brought into force or otherwise given effect to. Since that discussion there has been no attempt to create a licencing authority, to develop legislation for that purpose or even to engage in consultation as to what any future scheme might look like. While the failure to introduce a prior authorisation regime was the subject of an adverse finding by the Commission in November 2011[302] and the subject of discussion at the time, the issue appears to have fallen from the agenda. For example in the major public consultation launched by the Department of the Environment, Community and Local Government (as it then was) launched in June 2015 and entitled *"Significant Water Management Issues in Ireland"*[303] there is not a single mention of abstraction controls or licencing in that paper.

The Water Policy Advisory Committee, established and led by the Department of Housing, Planning, Community and Local Government in 2015 has established a working group on abstraction. In the minutes of the first meeting in March 2015 the Working Group noted that:

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[302] See "*New Water Regime Will Bring Changes*" (Irish Independent) (24th July 2013).

[303] http://www.housing.gov.ie/sites/default/files/publicconsultation/files/2015_swmi_public_consultation_final_2015-06-17.pdf.

*"**Control of Abstractions***

The Water Framework Directive is the primary piece of EU environmental water legislation and was adopted in 2000. Ireland has acknowledged to the European Commission that some further legislative measures are necessary to ensure that the regulatory regime in Ireland is fully consistent with the requirements of the Water Framework Directive, including those relating to the abstraction and impoundment of surface water. While no decisions will be made on this matter until extensive research and public consultation is undertaken, it is hoped a proportionate abstraction control regime will effectively manage abstraction risks and pressures without imposing unnecessary regulatory burden: recognising the relatively low abstraction pressures in Ireland it is expected that a regime would focus on the most significant abstraction volumes and pressures. The Department has commenced an initial research phase on the possible design of an abstractions control regime and a working group has recently been established to advise the Minister in this regard. The WPAC noted the progress of the DECLG-led working group on abstractions and impoundments in this context."[304]

Since then the Working Group does not appear (from an examination of the publicly available minutes) to have considered the matter again apart from noting, without any further details, the progress of that working group a year later in April 2016. It is instructive that Deputy John Brady questioned the Minister for Housing, Planning, Community and Local Government on 17th November 2016 as to when an abstraction licencing regime would be introduced. The Minister replied as follows:

"The Water Framework Directive requires that abstractions of surface water or ground water which are likely to have a significant effect on water status must be regulated. My

[304] Minutes of all meetings are available here http://www.housing.gov.ie/water/water-quality/water-quality-advisory-committee-wqac/water-policy-advisory-committee-meeting.

Department is currently examining how best to address this requirement in a proportionate and efficient way.

While no decisions will be made on any proposals in this regard until thorough public consultation is undertaken, I expect that a proportionate abstraction control regime can be developed that would effectively manage abstraction risks and pressures without imposing an unnecessary regulatory burden. Recognising the relatively low abstraction pressures in Ireland, the scale and extent of which will be set out in a draft River Basin Management Plan I expect to publish for public consultation in the coming months, it is expected that such a regime would focus on the most significant abstraction volumes and pressures, recognising that the Directive does not require the registration and licensing of private wells serving individual domestic dwellings."

It is therefore the case that there is no provision for licencing currently and no prospect of any immediate progress despite the fact that those sections of the WFD have been applicable since 2003. It is also apparent that:

- There is not any legislative urgency in respect of abstraction licencing;
- There is no dedicated public consultation process in being or in close contemplation; and
- There is no immediate prospect of abstraction licencing being introduced.

Article 11(3) contains an obligation to provide for two mandatory measures as a minimum safeguard against abstraction pressure. The National Register exists, albeit there are significant and easily identifiable lacunae. However, the requirement on the Member State to introduce prior authorisation does not appear to be remotely imminent.

Finally, it is noted that in the current River Basin Management Plan 2018-2023 Public Consultation document, at 7.7.2, adds that:

"In addition to developing a national register of water abstractions, it will be necessary to develop an appropriate regulatory framework for relevant abstractions. This will be integrated with the river basin management process and will serve to manage overall water abstraction at the water body level or catchment scale. It is envisaged that the

proposed management framework will apply to those abstractions which are required to register; that is abstractions greater than 25 cubic metres per day. The framework will comprise a system of general binding rules for the majority of registers abstractions and provide for the individual licensing of the more significant abstractions, typically where the abstraction is greater than 250 cubic meters per day. The proposed approach will be subject to separate public consultation to ensure the regulation of abstractions is both effective and proportionate and does not impose unnecessary regulatory burden."

However, no detail is provided on how or when this will be achieved and there does not, with respect to the authors of that document, appear to be any great awareness of the degree of default in terms of Ireland's obligation on this front.

4.7 Other Jurisdictions

Given the absence of any regulatory structure worthy of the name in this jurisdiction it may be useful to examine the structure in Northern Ireland and Scotland.

4.7.1 Northern Ireland

By contrast, in Northern Ireland there is a comprehensive suite of Regulations governing abstraction. The *Water Abstraction and Impoundment (Licensing) Regulations (Northern Ireland 2006*, as amended by the *Water Abstraction and Impoundment (Licensing) (Amendment) Regulations (Northern Ireland) 2007* are the primary regulations. Water is not charged for abstraction.

The Regulations provide for a comprehensive licensing system. They provide that an authorisation is required from the Northern Ireland Environment Agency (NIEA) to abstract and/or impound water in Northern Ireland. Abstraction for the purposes of the Regulations is defined as the removal of water from the natural environment by mechanical means, pipe or any engineering structure or works. It applies to water removed or diverted permanently or temporarily, even if the aim is to transferring the water to another part of the natural environment.

No authorisation is required if an individual intends to abstract less than 10 cubic metres per day. However, even if below the threshold all abstractors must comply with Permitted Controlled Activities (PCA) conditions. These conditions are (Schedule 1):

> *"(a) There shall be a means of demonstrating that the abstraction is less than 10 m^3 n any one day;*
>
> *(b) Water leakage shall be kept to a minimum by ensuring all pipe work, storage tanks and other equipment associated with the abstraction and use of the water are maintained in a state of good repair;*
>
> *(c) Subject to paragraphs (d) and (e) the abstraction shall not cause the entry of water of a different chemical composition into any water contained in any underground strata;*
>
> *(d) Drilling fluids may be introduced into a well or borehole if necessary to facilitate the drilling of the well or borehole provided this does not result in pollution of the water environment;*
>
> *(e) Potable water may be introduced into a well or borehole to test the hydraulic properties of an aquifer; [and]*
>
> *(f) When a well or borehole is not being used for abstraction, it shall be back-filled or sealed to the extent necessary to avoid loss of any water contained in any underground strata."*

When an abstractor is proposing to abstract between 10 and 20 cubic metres per day the requirements are the same with an additional obligation to:

> *"(a) There shall be a means of demonstrating that the abstraction is less than 20m^3 in any one day; [and]*
>
> *(b) The operator shall notify the Department of the location and volume of the abstraction —*
>
> *(i) In any case where he is carrying on that activity on the date of the coming into operation of these regulations, within 12 months of that date; and*

(ii) *In all other cases, within 28 days of the date on which he commences the activity".*

The owner of a bore-hole which abstracts less than 150 cubic metres in 12 months is equally exempt from the obligation to own a licence once they comply with similar conditions.

The Regulations go on to provide for the form of the licence application.[305]

Regulation 9 provides that if the Department of Agriculture, Environment and Rural Affairs is of the view that significant effects on a water body are likely that the application must be advertised and public participation opened.

The Department may grant the licence subject to conditions or refuse it (Regulation 10(3)). The Department may unilaterally revoke a licence where it is satisfied that (Regulation 16) "*the revocation is necessary in order to protect the water environment from serious damage*". Part 5 of the Regulations provides a suite of enforcement powers. The first layer provides that the Department may write to the holder of a licence and impose additional conditions and/or require the cessation of abstraction. In the case that this is insufficient or the enforcement notice is ignored the Department may apply to the High Court for enforcement. Part 7 provides both civil and criminal penalties for infractions of licence conditions or carrying out of non-exempt abstraction without a licence. The latter include sentences of imprisonment of up to 5 years. Finally there is provision for an Appeals Committee for dis-satisfied applicants in Part 6, Regulation 29. This Appeals Committee enjoys the same powers as the Department and may refuse or grant subject to conditions. It is unclear if the Appeals Commission is independent of the Department or of whom it is composed.

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[305] This can be done online at https://www.daera-ni.gov.uk/articles/abstraction-and-impoundment-licensing-requirements.

Of note is Part 6 which stipulates simply that a Register shall be maintained and that the Register shall contain the following:

- Particulars of all applications;
- Particulars of all licences granted, modified transferred or surrendered;
- Particulars of all enforcement notices;
- Particulars of all public advertisements;
- Particulars of all submissions received in respect of any licence;
- Particulars of all appeals made to the Appeals Commissioners; and
- Particulars of all environmental information received by the Department in the course of discharging its functions.

In other words the approach in Northern Ireland is not to have an independent Register but to harvest information from the licencing system to build the Register.

Given the comprehensive nature of the licencing requirements this is a logical approach. If all abstraction activities above a *de minimis* level are required to apply for and report to the Department in respect of their abstraction activities it follows that a Register constructed from that material will be far more comprehensive than the *ad hoc* approach adopted in this jurisdiction.

The approach in Northern Ireland to abstraction is singularly impressive. The dedicated Regulations have provided for a one-stop shop for licencing with abstraction activities interfacing with a single regulatory authority. That authority has all the information in relation to abstraction activity province-wide in its possession in order to allow it to make informed licence decisions. It also has considerable teeth in terms of enforcement for non-compliance with licence terms.

In comparison to this jurisdiction none of those elements are present – there is no comprehensive Register of Abstractions, no central regulator, no requirement for an abstraction licence, no penalties for breaching a non-existent licence requirement and no capacity for a regulator to halt abstraction activities (whether licenced or unlicensed) where those activities are in breach of a licence or not.

4.7.2 Scotland

Scotland has adopted a similar model. It is controlled in its entirety by the Scottish Environmental Protection Agency (SEPA). Section 20 of the *Water Environment and Water Services Act (Scotland) 2003* gave Ministers powers to introduce regulatory controls over activities in order to protect and improve the water environment. The Ministers exercised this power and passed the *Water Environment (Controlled Activities) (Scotland) Regulations 2011*. The Regulations were accompanied by a comprehensive Policy Statement explaining the background to the Regulations.[306]

This noted the approach taken in respect of abstraction. They noted that although a number of abstractions were controlled via the planning system the vast majority of the 40/50,000 estimated abstractions were not subject to any controls. As opposed to the position in Northern Ireland where all abstractions were required to be registered the Scottish approach is:

> *"Small abstractions of less than 10m^3 a day are included in the scope of the Controlled Activities Regulations and users must comply with general binding rules. Although SEPA have to monitor the impact of such abstractions in order to assess cumulative impacts, the Regulations do not include a requirement for these abstractions to be registered. That is because the Executive is also developing Private Water Supply Regulations with the intention of including a requirement for local authorities to compile a register of all such abstractions; SEPA would have access to that data for monitoring purposes."*

Unlike Northern Ireland the CAR Regulations place a general duty on all water users to use water effectively. Within that general duty the Regulations sketch three different levels of control. Although complex these can be shortly stated as:

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[306] Available at http://www.gov.scot/Publications/2005/05/0995747/57495.

4.7.2.1 General Binding Rules

The Regulations make clear that general binding rules are intended for activities which represent a small risk to the water environment. Consequently, they are appropriate for low risk activities which are unlikely to represent a cumulative impact where the abstraction level is less than 10 m^3/day. The activities covered by the general binding rules are:

- A large number of passive weirs constructed before 1st April 2006 that do not affect fish passage;
- Abstractions of less than 10m3/day;
- Construction/extension of wells/boreholes and subsequent abstraction;
- Ditch dredging activities;
- Construction and maintenance of temporary/minor bridges;
- Laying of pipeline/cable by boring;
- Works to control the erosion of a bank of a river, burn or ditch using revetments;
- Operation of vehicles, plant/equipment; and
- Low risk surface water discharges.

The General Binding Rules are tailored (in Regulation 6, Schedule 3 of the Regulations) to each activity. Therefore the operation of a weir does not require licencing if it simply does not impede the passage of salmon while each of the other activities have very extensive and tailored lists of requirements attendant on each.

4.7.2.2 Registration

Registration is used in the Regulations to control relatively simple activities where the environmental impacts are predictable but where cumulative impacts are likely. Registration will encompass such activities as septic tank discharges, small abstractions and minor engineering works and abstractions greater than 10 m^3/day but less than 50 m^3/day. It is apparent from the Policy Statement that SEPA took the view that once it was aware of these low level activities for the purposes of registration there was no justification for the additional burden entailed in licencing of these activities. It noted that there were approximately 100,000 septic tank Control of Pollution Act licences in existence and that the vast majority of these would migrate into the abstraction registration regime. The Policy Statement noted that it had reserved a right to SEPA to impose conditions on registrants but that it was not anticipated that these conditions would be scaled into the complex determinations required in relation to licences:

> *"There is scope for SEPA to identify conditions in respect of registrations. This provides beneficial flexibility enabling SEPA to set limited constraints without the need to use a licence. For example it is expected that SEPA will set conditions for abstractions between 10 and 50 m^3/day similar to those set out in the GBR for abstractions less than 10m^3/day. It is stressed that any conditions associated with Registrations will remain simple and will not include the detailed site-specific standards which found in licences."*[307]

4.7.2.3 Licences

Licences are designed by the Regulations to control those activities posing the greatest risk to the water environment. Although the total number of licences is not known it was estimated at the time of the passage of the Regulations that approximately 15,000 abstractions would require to be licenced. Licencing is provided for in Regulation 8 of the 2011 Regulations and provides for a similar process as that undergone in Northern Ireland. SEPA is obliged to consider all other abstraction activities in relation to a given application and, unlike Northern Ireland appears to have scope to consider the personal suitability of each applicant (Regulation 8(6)(b)). If SEPA anticipates significant adverse impacts from the application on either the water environment or other users of the water environment it must advertise an application and seek submissions on same (Regulation 13). There are no further guidance given as to what constitutes a 'significant' adverse impact, however the Regulations also depart from the

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[307] The Water Environment (Controlled Activities) (Scotland) Regulations 2005 Policy and Regulatory Impact Assessment available at http://www.gov.scot/Publications/2005/05/0995747/57495

Northern Ireland approach in listing the elements that SEPA must have regard to before taking a decision. Regulation 15 provides that the following must be "had regard to" prior to a licencing decision being made. SEPA must, *inter alia*:

> *"(a) Assess the risk to the water environment posed by the carrying on of the activity referred to in the application;*
>
> *(b) If the application is in respect of an activity that it considers has or is likely to have a significant adverse impact on the water environment—*
>
> *(I) Assess the indirect effects of that impact on any other aspects of the environment likely to be significantly affected;*
>
> *(ii) Consider any likely adverse social and economic effects of that impact and of any indirect environmental effects identified…* [and]
>
> *(iii) Consider the likely environmental, social and economic benefits of the activity;*
>
> *(c) Assess the impact of the controlled activity on the interests of other users of the water environment;* [and]
>
> *(D) Assess what steps may be taken to ensure efficient and sustainable water use…"*

There is no parallel in the Northern Irish Regulations for the matters raised in 15(2)(b)(ii) & (iii). There is equally no parallel in those Regulations for the provision contained in Regulation 20, whereby the relevant Scottish Ministers can require SEPA to refer the application to it for determination. While the Minister must consult with SEPA prior to making a determination, this provision would be most unusual in an Irish context. Once a power has been delegated to a regulatory authority there is normally no provision for a decision or decisions to be repatriated directly back to the executive in this jurisdiction. This is particularly so where the accountability provisions in the Regulations may be bypassed:

> *"(6) If, by reason of an emergency, the Scottish Ministers consider that an application they have directed SEPA to refer to them under paragraph (1) requires to be determined urgently, the Scottish Ministers may—*

(a) Dispense with consultation with public authorities as would otherwise be required by regulation 12;

(b) Dispense with advertisement of the application as would otherwise be required by regulation 13; [and]

(c) Determine the application within such timescale as they consider appropriate".

It is unclear why it was thought necessary to give the Scottish Ministers, rather than SEPA these emergency powers. Part 5 of the Regulations is very similar in terms of enforcement powers which SEPA enjoys, including a notably broad power to seek whatever orders it requires in a court of competent jurisdiction if it is of the view that communications will be ineffectual. Finally, it is notable that Regulation 37 of the 2011 Regulations provides, as with Northern Ireland, that all of the information obtained by SEPA in the course of its duties shall be available in a public register. Commercially sensitive information may be excluded if an application is made. This is the same approach as that employed in Northern Ireland. It decouples the requirement to maintain a Register for the purposes of Article 11 of the Directive and simply builds that Register from the information gleaned from the registration/licencing exercise.

This is the opposite of that being employed, however poorly, in this jurisdiction. Although very difficult to speculate on owing to the absence of any consultation documents, Ireland appears to be trying to construct an abstraction licencing system entirely distinct from the Register. Certainly there has been no suggestion that the licencing system, if it is ever introduced, will form the basis of the Register. If this is the approach that is ultimately adopted it is difficult to see the justification for same or how it could work in practice. This is particularly the case where the lacunae in the Register are all too apparent and it does not provide information which is even close to comprehensive.

4.8 Problems with the Current Regulatory System

Once a thorough understanding of the likelihood of impacts from water abstraction has been secured, the second element of a robust governance system, is a strong and effective legislative and regulatory system. Previous sections outline the lack of a coherent regulatory system which is effectively non-existent and therefore does not provide sufficient protection to ensure compliance with the WFD. Public water supplies are subject to regulation under the 1942 Water Supplies Act, but otherwise no legislative system of abstraction control is in place. While information on large commercial activities (> 25 m^3/day) may be captured through planning permissions if this is an issue which the planning authority wishes to inquire into, data can only be estimated by examining licensed discharge volumes (as proxies for abstraction values) which are not themselves metered. Aside from these, until such time as Article 11 of the WFD is transposed, no comprehensive mechanism to manage abstractions exists in the State.

Although RPS were commissioned to compile a National Abstraction Database in conjunction with the EPA,[308] major discrepancies remain as follows:

- Several data sources were used in forming the database with inconsistent metrics;
- Collation of data and upkeep of records is not performed in a coherent, structured manner meaning there is variation in the type of information held by different authorities (such as the EPA, Geological Survey and Irish Water);
- Only abstractions above 25 m^3/day are included;
- There is no facility in place to update the registry. There are concerns that this database is already out of date. It was compiled as a once-off task and there are no plans of which the authors are aware for it to be maintained as an on-going and iterative database;
- The current database lists approx. 1300 public water schemes, though this figure is believed to be closer to 2000. Similarly, the database lists approx. 600 NFGWS whereas this figure is believed to be closer to 900 (pers. comm., EPA, 2017);
- The database is not available to the public;

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[308] RPS (2016) Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

- Quarry abstractions are included on the registry but data is not considered to be accurate. It is based on discharge licenses, the responsibility of which rests with individual local authorities and does not take into account activity status of quarries; and
- It omits golf courses and farms and includes only a small proportion of industrial users such as hotels, sports clubs, equestrian facilities, car washing facilities, creameries, and the food and drinks industry.

As noted in Section 4.5.3 there is no allowance in Article 11 of the Directive to exclude certain activities from the abstraction register. It is not therefore possible for a Member State to identify shortcomings in their data (as has occurred with regard to the RPS dataset) and conclude that they are in possession of sufficient information to provide accurate estimates.

Additionally, the recent controversy surrounding the establishment of Irish Water and introducing water bills has made a political issue of water legislation. It is considered likely that politicians are unwilling to take a strong stance on water abstraction legislation. This will result in a weakening of any proposed legislative framework at the expense of environmental concerns.

The lack of a strong regulatory regime is particularly unsatisfactory when both Scotland and Northern Ireland have introduced comprehensive Regulations to provide for both requirements of Article 11 of the WFD in relation to water abstraction. The system in those jurisdictions have the great benefit of a single regulatory agency, web portals for applications, public accessibility to the information obtained and real enforcement powers in the event of default. In the authors' views they offer a model around which public consultation could be quickly and easily launched in this country.

4.9 Conclusions

The current position in Ireland is entirely unsatisfactory. Although the Directive has relatively little to say about abstraction, it is absolutely clear that Member States are required to both identify all abstractions above a *de minimis* level and control abstractions via a licencing system. Ireland is not compliant with either obligation. Neither is there any strong evidence to suggest that this situation is being addressed with any urgency. With respect to the Register there are clear and acknowledged gaps in relation to domestic water supplies, agriculture and hospitality (for example) where the level of abstraction is entirely unknown. Although these gaps are acknowledged the authors are unaware of any concrete attempts to address them, and the RPS updated register still contains these gaps as noted in Section 4.5.3. In the authors' view it would be therefore inaccurate and misleading to refer to the information available to the EPA as a Register for the purposes of the Directive.

In relation to prior authorisation or licencing the situation is even worse. While a Working Group on the topic has been established there is, again, no evidence that this Working Group is moving toward a licencing scheme. In this regard it is relevant that this is addressed (at p.65) in the current RBMP consultation documentation that simply identifies the fact that "it will be necessary" to develop an appropriate regulatory framework around abstraction but gives no detail on how or what this might look like or when it can be expected, other than the proposal that registration will only be required for abstractions greater than 25 m^3/day, with licensing required for "significant" abstractions typically greater than 250 m^3/day. Notably, bearing the caveat around the current River Basin consultation in mind, there is no public consultations open in respect of same and the minutes of the Group give no indication that any progress is imminent. While counties require a licensing regime for discharges, the authors found no record for abstraction licencing under either domestic legislation or the WFD.

The unsatisfactory position in respect of both of these requirements is particularly egregious when viewed against both Scotland and Northern Ireland who have introduced comprehensive Regulations to provide for both requirements of Article 11. Although there is minor differences between them, both regulatory systems provide an off-the-shelf model upon which the obligation to both register and licence abstraction in this country could, and in the authors' views, should be modelled. The system in those jurisdictions have the great benefit of a single regulatory agency, easy to use web portals for applications, public accessibility to the information obtained and real enforcement powers in the event of default. In the authors' views they offer a model around which public consultation could be quickly and easily launched in this country, with a view to adopting a modified form of those Regulations as soon as possible.

CHAPTER 5: ABSTRACTION IN IRELAND

5.1 Introduction

Given the lack of a comprehensive centralised abstraction database (Section 4.5), information that is available on abstraction is patchy and incomplete. This hampers quantitative investigation of abstractions and their impacts. To try to complete this database is beyond the scope of this report, and the information provided in this chapter, while attempting to provide an overview of available data highlights the limitations of an incomplete database. This chapter includes a collation of the data found by the authors in respect to abstraction in Ireland; it is not a complete picture.

This chapter consists of:

- An assessment and appraisal of the national information available in relation to water abstraction; and
- An assessment of qualitative impacts on surface water and groundwater resources in Ireland.

5.2 Abstractors in Ireland

5.2.1 Overview

The summary of the RPS compiled abstraction database[309] is the best starting point to assess abstraction in Ireland. This has been the only centralised source of abstractions found by the authors but as noted in Section 4.5.3, there are significant data gaps associated with this register

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[309] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

of abstractions; it represents an underestimate of the number of abstractions. Within the RPS compiled abstraction database ~50% of abstractions on the Irish database are public drinking water supplies, ~20% for group water supplies, with the remaining ~30% associated with IPC/IE installations, bottled water plants, power generation plants, quarries, mines, schools and private supplies. Approximately 1000 of these abstractions are greater than 100 m^3/day. Private household wells are not included, with these expected to have <10 m^3/day.

The number and type of abstraction were summarised as follows:

- 2,505 abstractions (of which 2032 are groundwater). These were obtained from local authorities, Irish Water, Geological Survey and NFGWS;
- 189 abstraction from lakes or within 100 m of a lake;
- 10 abstractions associated with active quarries plus 116 Section 4 discharge licenses associated with active quarries;
- 125 abstractions associated with IPC/IE installations; and
- 21 abstractions associated with water bottling plants.

This data is presented below in

Table 5.1. The number of abstractions refer to points of abstraction rather than number of facilities. The table shows that groundwater sources make up over 80% of the 2,500 abstractions listed.

- **Table 5.1: Abstraction data provided by local authorities**[310]

Local Authority	*Total Records*	*Public*	*Private*	*Groundwater*	*Surface Water*
Carlow	28	20	8	21	7
Cavan	38	11	27	17	21
Clare	47	30	17	29	17
Cork City	1	1	0	0	1
Cork County	258	234	24	219	36
Donegal	63	40	23	53	10
Dublin City	10	3	7	6	3
Dun Laoghaire	5	5	0	2	3
Fingal	8	5	3	7	1
Galway City	10	1	9	9	1
Galway County	245	54	191	219	16
Kerry	113	98	15	53	51
Kildare	41	24	17	37	1
Laois	61	44	17	60	1
Leitrim	14	5	9	13	1
Limerick	116	57	59	98	7
Longford	15	9	6	10	5
Louth	47	30	17	36	10
Mayo	94	27	67	55	39
Meath	78	71	7	73	5

[310] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

Monaghan	92	27	65	63	28
Offaly	112	53	59	97	6
Roscommon	77	49	28	67	9
Sligo	26	11	15	13	13
South Dublin	1	1	0	1	0
Tipperary	275	68	207	254	18
Waterford	139	117	22	130	9
Westmeath	24	10	14	5	19
Wexford	118	76	42	74	17
Wicklow	71	54	17	56	15
Total	**2505**	**1277**	**1228**	**2032**	**393**

RPS[311] also included a summary table showing a breakdown of combined surface water and groundwater abstractions by river basin district (data sourced from RBD, 2008), which yielded a total number of abstractions of 2,542.

Based on another indicative geodatabase compiled during investigations of environmental flows[312], water abstraction usage within Ireland is estimated as follows:

- Energy production = 35%
- Public water supply = 52%

[311] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

[312] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21.

- Industry = 12%
- Agriculture = unknown

In 2007, over 1.3million m^3/day was being abstracted from the 400+ surface water abstractions that have known abstraction rates. Approximately 367 abstraction points supply more than 100 m^3/day, whilst over 100 points supply less than 100 m^3/day. Among the supplies with known abstraction rates, the median surface water abstraction is 410 m^3/day.[313]

5.2.2 Drinking Water Abstractions

The population of Ireland are provided with potable water from the following supply types (by number and % population served),[314] though abstractions less than 10 m^3/day are not included.

- Public water supplies (962) = 83%
- Public group water scheme (498) = 2%
- Private group water scheme (418) = 4%
- Small private commercial/public activity supply (1,760) = 1%
- Household wells (estimated >200,000[315]) = 10%

The same records indicate that 781 water abstractions supply in excess of 100 m^3/d, and 235 public water supply points provide over 1,000 m^3/d.

[313] Eastern River Basin District (2007) Abstraction Pressure Assessment, Background to Water Matters Report.

[314] EPA (2016b). Drinking Water Report for Public Water Supplies 2015. Environmental Protection Agency.

[315] Wright, G. 1999. How many wells are there in Ireland? The GSI Groundwater Newsletter, Vol. 35.

The EPA[316] state that 81.5% of drinking water across both public and private water supplies is sourced from surface water (i.e. river and lakes), 11.5% is sourced from groundwater and 7% is sourced from springs.

5.2.2.1 Public Water Supplies

83% of the population are supplied with drinking water from 962 Irish Water supplies.[317] These abstraction points are generally located close to population centres. All Irish Water public drinking water abstractions and known non-domestic private supplies (as collated by local authorities) are listed on the EPA website.[318] Details of population served, volume supplied, type of treatment and an approximate location or grid reference are provided for each abstraction.

However, there is a clear discrepancy in the databases that are currently available regarding abstraction of public water supplies from: the EPA; Irish Water; and the Geological Survey. Table 5.2 shows some of the discrepancies between information garnered from these sources. The RPS report[319] states that the EPA has a compilation of 2505 abstraction points, while Irish Water dataset comprises a total of 2,351 abstractions with the Geological Survey database containing information on 650 groundwater abstraction sources (boreholes, springs, infiltration galleries, dug wells). Estimated abstraction volumes were obtained from a 2009 report,[320] with total daily abstraction of 573,591 m^3/day. This report also had significant departures in the

[316] EPA (2016) Ireland's Environment – An Assessment 2016. EPA, Co. Wexford, Ireland.

[317] EPA (2016) Ireland's Environment – An Assessment 2016. EPA, Co. Wexford, Ireland.

[318] http://www.epa.ie/pubs/advice/drinkingwater/publicdrinkingwatersupplies/.

[319] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

[320] CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

number of known abstraction points from the other three sources, but was compiled seven years prior to the other databases.

Table 5.2: Summary of abstractions and discharges by local authority. Table compiled by authors by combining tables contained within reports by RPS[321] and CDM.[322]

Local Authority	*EPA List of Abstractions*	*Irish Water List of Abstractions*	*GSI List of Groundwater Abstractions*	*Known Abstraction Schemes/Points*	*Total Estimated Abstractions, m^3/d*	*Total Estimated Abstraction from Public Supplies, m^3/d*
	RPS (2016)			CDM (2009a)		
Carlow	28	41	14	14	11,730	8,765
Cavan	38	57	4	45	8,535	1,489
Clare	47	15	20	109	6,099	3,978
Cork City	1	1		312	98,979	49,526
Cork County	258	332	131			
Donegal	63	110	27	40	9,823	8,957
Dublin City	10	9		18	13,187	4,428
Dun Laoghaire	5		3			
Fingal	8	4	5			
Galway City	10	1	15	252	34,276	17,052
Galway County	245	33				
Kerry	113	195	27	87	18,888	14,911
Kildare	41	2	7	39	31,789	22,787

321 RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

322 CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

Laois	61	142	27	44	30,609	6,249
Leitrim	14	16	1	42	3,173	1,598
Limerick	116	115	43	220	23,033	11,160
Longford	15	5	5	48	3,754	2,633
Louth	47	68	6	33	10,040	9,293
Mayo	94	157	9	64	17,466	7,158
Meath	78	62	60	147	42,857	19,165
Monaghan	92	52	2	21	14,897	14,217
Offaly	112	71	24	66	18,017	12,381
Roscommon	77	36	12	83	50,454	45,266
Sligo	26	42	1	14	1,807	344
South Dublin	1			included in Dublin		
Tipperary	275	54 (N) + 52 (S)	43	87	80,705	12,197
Waterford	139	158	83	47	8,750	6,360
Westmeath	24	1	1	28	6,822	4,514
Wexford	118	330	40	48	14,677	12,447
Wicklow	71	74	20	67	8,397	4,896
Total	**2505**	**2351**	**650**	**1986**	**573,591**	**305,208**

5.2.2.2 Public Group Schemes

Public Group Schemes are supplies where the abstraction and treatment of the water is supplied by Irish Water and the distribution of treated water to the users is managed by a local community group. No additional details on these source types were uncovered as part of this review document.

5.2.2.3 Private Group Schemes

Private Group Schemes are supplies where the abstraction, treatment and distribution of treated water are all managed and owned by a local community group, most of which operate under the auspices of the National Federation of Group Water Schemes (NFGWS) and are typically located in rural areas.[323]

The RPS report[324] estimates 340 sources, based on 60% of NFGWS groundwater sources included in a GSI/NFGWS study of 2013 - 2015. The average sized scheme serves approximately 190 houses, whilst 47% of all privately sourced schemes have 60 houses or less. Confirmation from NFGWS on number of sources was not obtained at time of writing.

The majority of these schemes are metered at point of supply and at network distribution points, with some charging by usage. Both of those measures have reduced abstraction rates significantly (by between 22-90%).[325] Metering was successfully introduced as a conservation measure due to many schemes reporting a considerable drop in groundwater levels at abstraction points.

5.2.2.4 Small Private Supplies

These are supplies serving a commercial or public activity, and the abstraction, treatment and distribution of treated water are managed by the commercial or public entity. Examples of commercial or public activities served by small private supplies include pubs, restaurants, crèches and national schools. Some of this information is available online.[326] Details of

[323] EDA (2008) Groundwater resources of the Central Leinster Area and their potential to augment the Dublin Region Water Supply. Appendix C of Water Supply Project – Dublin Region. Eugene Daly Associates and RPS Consulting Engineers.

[324] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

[325] Deane B. (2011) Reducing abstraction pressure on groundwater sources: the lessons of universal metering in the Group Water Scheme sector. *Proceedings of the International Association of Hydrogeologists (Irish Group)*.

[326] http://www.epa.ie/pubs/advice/drinkingwater/publicdrinkingwatersupplies/.

population served, volume supplied, type of treatment and an approximate location or grid reference are provided for each abstraction. It is noted that many abstractions list the daily abstraction at 9 m^3/day, though there is no indication if this is an accurate figure.

5.2.2.5 Household Wells

Household wells supply a volume of water less than 10 m^3/day or serve fewer than 50 people, and do not supply a commercial or public activity[327]. The EPA[328] estimate that 10% of the population have their own private wells. A consultancy report[329] estimates the density of household wells to be 1 well/km^2 in rural areas, increasing to up to 5 wells/km^2 closer to urban areas. The RPS register does not include domestic wells, as these are too numerous and considered less important from a resource quality point of view,[330] but it is thought there are greater than 200,000 private wells.[331]

Based on the EPA guidelines[332] a dwelling with an occupancy of 5 persons will use less than 1 m^3/d. Much of this water is returned underground to the same water body via wastewater treatment systems and percolation areas and so has minimal impact to overall water abstraction from a water body. CSO data on wells and public water supply are provided in Figure 5.1.

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[327] Roche, M., Page, D. (2017) Focus on Private water Supplies. Environmental Protection Agency: Wexford, Ireland. 20pp.

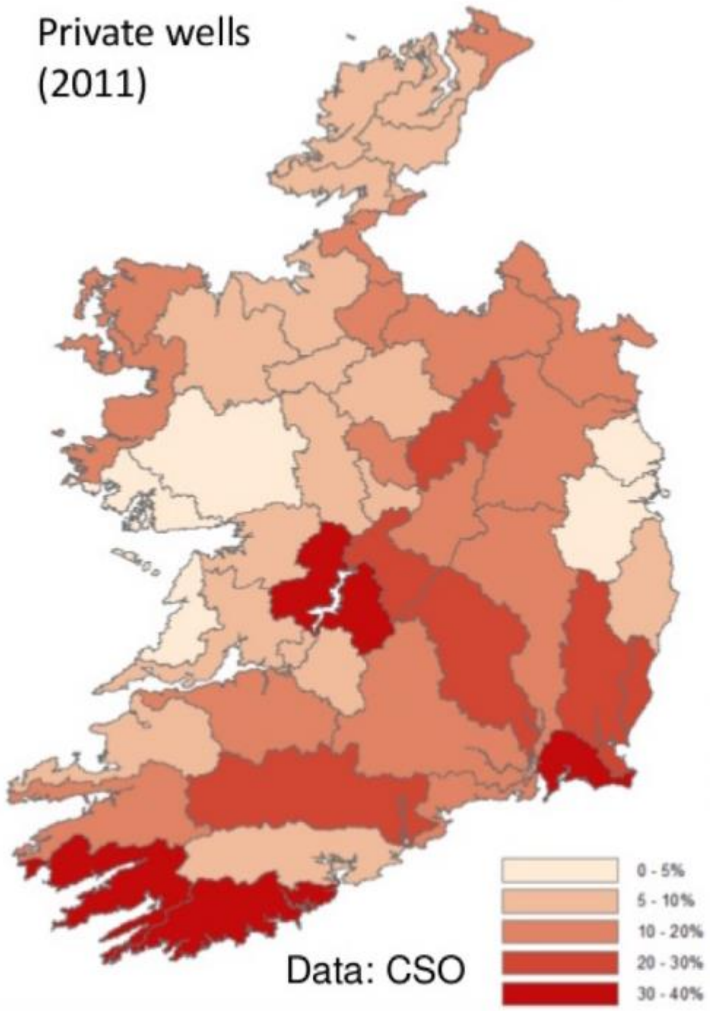
[328] EPA (2016b). Drinking Water Report for Public Water Supplies 2015. Environmental Protection Agency.

[329] EDA (2008). Groundwater resources of the Central Leinster Area and their potential to augment the Dublin Region Water Supply. Appendix C of Water Supply Project – Dublin Region. Eugene Daly Associates and RPS Consulting Engineers.

[330] Ibid.

[331] Wright, G. 1999. How many wells are there in Ireland? The GSI Groundwater Newsletter, Vol. 35.

[332] EPA (2009) Code of Practice Wastewater treatment and disposal systems serving single houses (p.e. <10). Environmental Protection Agency.


Private wells
(2011)
0 - 5%
5 - 10%
10 - 20%
20 - 30%
30 - 40%
Data: CSO

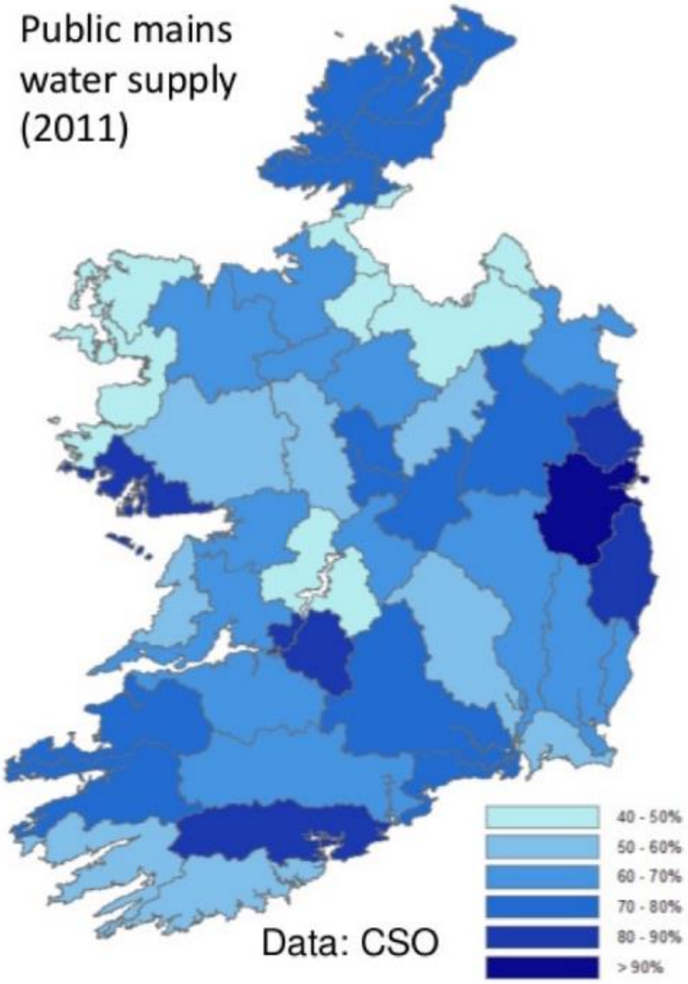


Figure 5.1: Geographical spread and density of private wells and public water supplies in 2011. [333]

[333] CSO (2016) *Use of GIS in CSO environment statistics*. Presentation at Irish Organisation for Geographic Information 17th October 2016. Central Statistics Office.

5.2.2.6 Bottled Water Production Facilities

The RPS abstraction database[334] shows that there are 21 abstractions associated with water bottling plants. According to the HSE[335] there are 23 bottled water production facilities in Ireland. Annual water production volumes for these bottling plants are shown in Table 5.3.

Table 5.3: Water production volumes of bottled water facilities in Ireland. Mean daily volumes to the nearest 5m3

Water production volumes	Mean daily production volumes	Number of Facilities
30,000 - 40,000 m^3/yr	80 – 110 m^3 / day	2
10,000 - 20,000 m^3/yr	25 – 55 m^3 / day	3
5,000 - 10,000 m^3/yr	15 – 25 m^3 / day	5
1,000 - 5,000 m^3/yr	5 – 15 m^3 / day	2
< 1,000 m^3/yr	<5 m^3 / day	9

5.2.3 Industry

5.2.3.1 IPC/IE Licensed Facilities

There are 709 IPC/IE licenses in Ireland. The number of these that have private abstractions is not known. 328 of these sites are in “At Risk” catchments. Of the 114 records of these licensed facilities investigated as part of a sample by RPS[336], abstractions ranged greatly from 0.005

[334] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

[335] EPA (2016) Ireland’s Environment – An Assessment 2016. EPA, Co. Wexford, Ireland.

[336] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

m^3/day to 6,065 m^3/day. The full extent of the impact of these licenses on water bodies cannot be determined with the existing data, and it is not known how many of these 114 samples are in "At Risk" catchments.

5.2.3.2 Extractive Industries

The EPA list 1189 sites under the Extractive Industries Register. Each local authority maintains a list of Section 4 discharge licenses. These have been merged into a national discharge register[337]. Several quarry operators abstract groundwater at rates in excess of 1,000 m^3/d; the largest known abstraction is in excess of 20,000 m^3/day.[338] The national discharge database[339] reports that there are 116 Section 4 discharge licenses associated with active quarries. Mine water management also involves dewatering of sections beneath the water table. When operational, Lisheen mine was the single largest groundwater abstraction scheme in Ireland with approximately 65,000 m^3/day pumped to surface.[340] Galmoy Mine was abstracting up to 20,000 m^3/day.

5.2.3.3 Other

Industries not listed under IE or IPC licensing that may use significant volumes of water include breweries, swimming pools, creameries and car washing facilities. There is no currently no planning requirement to provide proposed or existing abstraction rates for any of these activities.

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[337] Ibid.

[338] CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

[339] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

[340] Ibid.

5.2.4 *Energy Production*

In Ireland water use in energy production is primarily for the generation of hydroelectricity and makes up 0.2% of the total number of abstraction points. The majority of this water is rapidly returned to the same water body and so would have minimal impact on the associated water bodies.

5.2.5 *Northern Ireland*

The sole public provider of water in Northern Ireland is Northern Ireland Water (previously referred to as Water Service) and this is the largest single abstractor of water. It is estimated that this body accounts for almost 90% of the total volume abstracted water in the province.[341] NI Water currently abstracts around 570,000 m^3/day of water for distribution every day and is authorised to abstract up to 1.045 M m^3/day under license. Water resources are currently limited by NI Water's water treatment capacity of approximately 830,000 m^3/day.[342]

5.3 Appraisal of Information

There is an overall lack of comprehensive data on water abstraction in Ireland. While the EPA is making efforts to resolve this with the recent compilation of the RPS database,[343] the full report is not publicly available and is not comprehensive (Section 4.5.3).

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[341] Department of the Environment (NI)/ Environmental Policy Group (2006) The Draft Water Abstraction and Impoundment (Licensing) Regulations (Northern Ireland) 2006.

[342] Department for Regional Development Northern Ireland (2016) Sustainable Water, A Long Term Strategy for Northern Ireland 2015 – 2040. DRDNI, Belfast, 2016.

[343] RPS (2016). Catchment science desk studies and field based assessments - Development of a national abstraction database and a national discharge database. RPS Consulting Engineers for Environmental Protection Agency.

The most comprehensive dataset available relates to drinking water abstraction, but even available compilations of this data (from EPA, Irish Water and Geological Survey) show large discrepancies. Of these the EPA dataset is probably the most comprehensive and most recently compiled, but the full dataset is not publicly available. While data does exist for the public and group water schemes, no data is available for private household wells, or which nearly 200,000 are believed to exist,[344] >150,000 unlicensed agricultural wells,[345] and golf courses (Section 4.5). While these smaller wells would be expected to abstract reduced quantities of water (<10 m^3/day), their locations are unknown and there is no way of verifying the quantity abstracted.

With regard to industrial abstractions, the total number of abstractions, or the rate of abstraction is largely unknown. The sample survey conducted by the EPA show large variations in the amount of water abstracted, and many abstraction points are within catchments designated "At Risk". The low level of information surrounding these abstraction points is therefore cause for concern, especially as much of the impacts of abstraction are on the local scale (Section 2.3).

Indeed, much of the data about abstractions refers to the volume of water that is licensed for abstraction, rather than the volume that is abstracted. The absence of meters at abstraction points, and a centrally located and publicly available database of both licensed volumes and actual volumes of abstracted water means it is extremely difficult to obtain an accurate reflection of water abstraction, both in terms of volume abstracted and its spatial distribution. As the impacts of water abstraction can vary considerably both spatially and temporally, it is essential that accurate data is available for consideration.

In order to conduct a full appraisal of abstraction pressures, especially in At Risk water bodies, the following information is crucial: the location of abstraction points, the volume abstracted (as opposed to the volume licensed) and the timings of abstraction. This is currently not the

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[344] Wright, G. 1999. How many wells are there in Ireland? The GSI Groundwater Newsletter, Vol. 35.

[345] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21.

case, with the data not collected and therefore not available publicly or otherwise. To help fill this critical knowledge gap researchers[346] have recently called for:

- Documentation of abstraction points, including accurate location;
- Temporal resolution of abstraction volumes on a daily timescale (or monthly at minimum);
- Integration of surface and groundwater abstractions as currently the authors estimate that for 34% of abstractions, there is no information on if this is from surface water or groundwater;
- Spatial scaling of abstraction locations to assess cumulative impacts; and
- Increased investigation of biological impacts of abstraction.

5.4 Abstraction Impacts in Ireland

5.4.1 Overview

Abstraction impacts as outlined in Section 2.3 arise from removing water from a water body, with a spatial or temporal separation of its eventual return to a water body. The return of this abstracted water to a water body is either via discharge, or through the hydrological cycle (transpiration, evaporation and condensation). Impacts arising from water abstraction include: reductions in river flow, fluctuating lake water levels, and declining groundwater levels. These impacts further alter biological and chemical components of the water body.

Ireland, with a temperate climate, has a relatively high level of precipitation (750 mm in east of the country, up to > 2000 mm along the mountainous west coast – see Figure 3.2)[347]. Recharge and runoff rates are dictated by land use, soil/subsoil permeability and geology with estimates

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[346] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21.

[347] Met Eireann (2017) Rainfall in Ireland: available at www.met.ie/climate-ireland/rainfall.asp.

provided for all parts of the country on publicly available Geological Survey maps (See Figure 3.3). There are limited peer-reviewed published examples of the direct impacts of abstraction in Ireland due to a lack of study into these impacts. The lack of a comprehensive database on abstractions is a hindrance to studying the impacts in this country as it is difficult to ascribe cause to ecological degradation when the information of pressures (i.e. abstraction) are unknown and unquantified. As noted in Webster et al.[348] "*Progress on evaluating the current status of abstraction for Irish rivers…and for screening stations…was severely hampered by the lack of an integrated national database of abstraction and discharge. This is a key priority for many research and management activities*". The same authors go on further to say: "*Documenting the cumulative effects of these different modes of abstraction within Irish catchments is a high priority for understanding the effects on flow regime and ecological responses*".[349] Given the heterogeneity of Irish hydrogeology and temperate climate, it is unclear how applicable the international research, which is often conducted in arid environments, is to an Irish context.

The following section outlines the known impacts of water abstraction on surface water, groundwater, and groundwater dependent terrestrial ecosystems (GWDTEs) in Ireland. While the available data is limited, in certain catchments there is evidence indicating that water abstraction is leading to impacts to some of the inland surface waters, groundwater and groundwater dependant terrestrial ecosystems, often based on the authors' experience. These include reductions in surface water flows and reductions in groundwater levels.

[348] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21. p55.

[349] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21. p55.

5.4.2 Impacts of Abstraction

5.4.2.1 Surface Water Flows

Surface water abstractions have a direct impact on river flows with indirect impact from groundwater abstractions on connected river flows (Sections 2.3.2 and 2.3.3). Lower water flows affect biological components and reduce the ability of water bodies to dilute contaminants and this can lead to elevated nutrient concentrations in the water due to the lower attenuation capacity.

One method for assessing abstraction impact is to perform statistical analysis of long-term hydrometric records. For the purposes of establishing environmental flows Webster et al.[350] performed an analysis of long term flow records at a number of hydrometric stations in Ireland. Daily flow records were limited to the period 1984 to 2014 (timeframe selected to avoid known step changes in Ireland's precipitation in the 1970s). Datasets were then screened for completeness and known sources of error. The author stated that they could not reliably screen for abstraction pressures due to uncertainties in establishing reference condition credentials for each hydrometric station. The preferred Ecological Limits of Hydrologic Alteration methodology that this study applied requires a hydrologic foundation built using unimpacted reference sites. In other words the pre-abstraction and post-abstraction hydrometric records were not sufficiently large to confirm significant difference.

In Ireland, Inland Fisheries Ireland have utilised the principle of compensation flow when reviewing prospective small scale hydroelectric schemes.[351] Compensation flow refers to the

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[350] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21.

[351] Inland Fisheries Ireland (2005) Guidelines on the construction and operation of small-scale hydro-electric schemes and fisheries. Central and Regional Fisheries Boards and Engineering Division, Department of Communications, Marine and Natural Resources.

minimum flow of water to be maintained at all times in the natural channel. A minimum compensation flow provision of 12.5% of the long-term annual mean flow is recommended (i.e. compensation flow can never be allowed to fall below 12.5% of annual mean flow during abstraction). The residual flow is the (varying level of) flow remaining in the river when abstraction is taking place. To ensure an adequate residual flow, some planning authorities stipulate that the hydro station throughput should never exceed 50% of the total available flow.[352] Attempts to quantify the flow requirements of fish in rivers has rarely been successful and regulation flows are often too high or too low to maintain the fish population in their pre-regulation state.[353] A preferred approach by what was the National Rivers Authority (UK) was to estimate minimum survival and migration flows by reference to measurements of riverbed width; Stewart[354] regarded a flow 0.03 m^3/s per meter of stream bed as an absolute survival flow for salmonids. Information from fish counters indicated that upstream migration of salmon typically commenced at a flow of 0.08 m^3/s per meter width.

The adequacy of residual flow depends largely on the type of river bed in the depleted reach and varies greatly from site to site. Murphy[355] argues that it is more important to protect the macro-invertebrate fauna and ensure that resident fish have adequate cover as it is unlikely that any significant fish run will occur in low flow conditions. It is suggested that an initial approach of estimating what flow would be required in the existing channel to protect invertebrates and provide adequate cover for fish. If this figure proved to be unrealistically high, then one could carry out riverbed works to achieve the objective with a smaller flow. This would consist of

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[352] Ibid.

[353] Petts, G.E. (1988) Regulated rivers in the United Kingdom. Regulated Rivers: *Research and Management* **2**: 201-220.

[354] Stewart, L. (1969) Criteria for safeguarding fisheries. Fish migration and angling in rivers. *Proceedings of the Institute of Water Engineers*. **23**: 39-62.

[355] Murphy, D.F. (2000) Salmonid passage provision at small hydro-electric and similar riverine developments. Went Memorial Lecture 2000. *Royal Dublin Society*. ISSN 0791-461X.

creating a string of pools, interconnected by a Thalweg channel along the depleted reach. This was done successfully by the Southern Regional Fisheries Board in a mile long channel in the River Suir at Holycross.[356] Similarly, Baxter undertook an extensive review of flow requirements required for the preservation of migratory fish life.[357] He concluded that the heights of water required are substantially those represented by the dry weather flow, subject to the maintenance of a minimum flow of 12.5% average daily flow during periods of hot weather. Recommendations regarding compensation flows at lake abstractions should be dealt with on a case by case basis.[358]

Water abstractions are causing significant pressures on waters within the Eastern River Basin District, due to the population density of the major urban areas in the East.[359] Water resources in the regions are well established, but increasing demand is necessitating greater abstractions of the use of new sources. One of the rivers that this ERBD report identified as being At Risk from over abstraction, was the River Liffey, from Ballymore Eustice to Leixlip. This is the section of the Liffey immediately downstream of the Pollaphuca Reservoir. The status of the River Liffey along this stretch varies from moderate to good and overall it has been described as being At Risk due to abstraction.

In Ireland, when an abstraction is causing undue pressure to the water body it is generally reduced, and ultimately switched off if necessary. The precise criteria which determine when

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[356] Inland Fisheries Ireland (2005) Guidelines on the construction and operation of small-scale hydro-electric schemes and fisheries. Central and Regional Fisheries Boards and Engineering Division, Department of Communications, Marine and Natural Resources.

[357] Baxter, G. (1961) River utilisation and the preservation of migratory fish life. *Proc. Inst. Civil Engineers*. **18**: 225-244.

[358] Inland Fisheries Ireland (2005) Guidelines on the construction and operation of small-scale hydro-electric schemes and fisheries. Central and Regional Fisheries Boards and Engineering Division, Department of Communications, Marine and Natural Resources.

[359] ERBD (2009b) Abstraction Pressures – National POM/Standards Study. The Assessment of Abstraction Pressures in Rivers in Ireland.

the supply is unsustainable is unclear but is most likely influenced by abstraction point infrastructure than a pre-determined potential for ecological damage. Restrictions are imposed on end-users and these restrictions can be long term. Examples at time of writing are as follows:

- Lough Bane: following excessive water abstraction 2004-2006 leading to a disturbed littoral zone and increased filamentous green algae,[360] over abstraction was addressed and a study to investigate the recovery of vegetation. There was a return of the lake to good ecological status within three years following the actions of the council;[361]
- Lough Owel which has been requesting customers to restrict water since February 2017. Water levels in Lough Owel continue to fall due to reduced rainfall and are currently at a historically low level for the time of year;[362] and
- Inis Mor and Inis Oirr – Irish Water has urged residents, businesses and visitors to the Aran Islands to conserve water during the summer of 2017. Irish Water has had to impose these restrictions and issue the water conservation notices due to the unseasonably dry weather conditions which have resulted in historically low water levels on the islands for this time of year.[363]

When long-term demand cannot be satisfied alternative sources are sought. The largest population centre in Ireland is currently undergoing this process. Dublin City Council currently supplies water to a population of about 1.5 million people. The existing water supplies for the Dublin Region are dominated by surface water resources in the Vartry, Dodder and Liffey river

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[360] Roden, C. (2009) The effect of excessive water abstraction on the vegetation and conservation status of Lough Bane, county Meath/ Westmeath. Results of monitoring programme. July 2008-July 2009. 2nd Report for Meath County Council. pp18.

[361] Roden, C. (2010) The effect of excessive water abstraction on the vegetation and conservation status of Lough Bane, county Meath/ Westmeath. 3rd Report for Meath County Council. pp8.

[362] www.water.ie, 26th June 2017.

[363] www.water.ie, 13th June 2017.

catchments in counties Wicklow, Kildare and Dublin. The current supply of 540 ML/day is equivalent to the 95 percentile flow (flow which is equalled or exceeded 95% of the time) of many of the larger rivers in the east of Ireland,[364] indicating that significant proportions of these existing surface waters volumes are already currently being abstracted. Planning authorities are responsible for balancing current and future impacts during periods of projected growth at existing sources verses the potential impacts of new abstractions.

Elevated nutrient concentrations (phosphorus and nitrogen) continue to be the most widespread water quality problem in Ireland,[365] arising primarily from agriculture and wastewater discharges from towns, villages and rural dwellings with the most recent EPA State of the Environment Report[366] reflecting this. This report highlights the fact that the quality of Ireland's freshwaters are amongst the best in Europe, however as noted in Section 3.4, there has been a worsening in the status of surface waters, and a decline in the number of high status sites. Given that multiple stressors increase the impacts of water abstraction, this is a cause for concern.

5.4.2.2 Groundwater Levels

Boreholes which penetrate bedrock form the most common type of drinking water supply point in Ireland. Boreholes into groundwater are considered to be less susceptible than surface water to unsustainable yield during extended periods of dry weather, and have less variability in relation to water quality parameters, when compared to spring supplies. However, if abstraction rates are greater than recharge rates, groundwater levels will fall.

[364] EDA (2008). Groundwater resources of the Central Leinster Area and their potential to augment the Dublin Region Water Supply. Appendix C of Water Supply Project – Dublin Region. Eugene Daly Associates and RPS Consulting Engineers.

[365] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021.* Department of Housing, Planning, Community and Local Government.

[366] EPA (2016) Ireland's Environment – An Assessment 2016. EPA, Co. Wexford, Ireland.

An example of a water body impacted by abstraction is Knockatallon GWB in Monaghan which was designated 'At Risk' due to abstraction pressures[367]. Since the 1980s the aquifer has been under significant stress from abstraction, such that by 2000 groundwater levels has become depressed by up to 40 m below pre-pumping levels.[368] The depletion was attributed to low recharge through a thick layer (up to 53 m) of low permeability subsoil. The long term abstraction from this GWB altered flow patterns by directing groundwater flow towards the pumping wells, rather than towards the local River Blackwater. There was no hydrometric station in the vicinity of the well field to quantify the impact on river flows. The pumping level has been greatly reduced in recent years because of falling groundwater levels.[369]

Similarly, The Lusk-Bog of the Ring GWB is classified as 'At Risk, high confidence' due to abstraction pressure.[370] The Bog of the Ring water supply incorporates four boreholes in a well field which provide a combined volume of 3,500 m^3/d. Borehole depths are between 50 - 100 m. Non-pumping groundwater levels are within 8 m of surface, and the reduction in groundwater level incurred during pumping (i.e. drawdown) in each well is around 15 m. The wells abstract water from limestone bedrock and gravels. The overlying wetland (Bog of the Ring) may be At Risk of damage due to reduced water levels'.[371] An ecological assessment[372] carried out in 2006 reported that there was no significant difference between habitat surveys

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367 CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

368 Misstear B., Brown L. & Hunter Williams T. (2005) The Knockatallon aquifer in County Monaghan: A bedrock aquifer in Ireland under significant stress from pumping. *Proceedings of the International Association of Hydrogeologists* (Irish Group).

369 EPA (2011) Water Framework Directive Groundwater Monitoring Programme. Site Information: Tydavent PW-A. Environmental Protection Agency.

370 EPA (2011) Water Framework Directive Groundwater Monitoring Programme: Site Information Bog of the Ring – PW3. Environmental Protection Agency.

371 CDM (2009a). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

372 TES (2006). Groundwater monitoring of the Bog of the Ring – Final Hydrogeological Assessment Report. *Fingal County Council*.

conducted in 1999 (prior to commencement of abstraction) and 2006 (3 years following abstraction). Marginal changes in vegetation were observed between 1999 and 2006, with these changes attributed to lack of site management and some drying of land.[373] The impact of the groundwater cone of depression extending into the River Delvin was considered imperceptible.[374]

In the Dublin region, in addition to the surface water supply abstractions provided in the preceding section, there are also reportedly 249 non-domestic boreholes in the ERBD region, with an average yield of over 150 m^3/day.[375] It is estimated that an additional supply of the order of 300 ML/day (3.5 m^3/s) will be required by the year 2030.[376] When exploring the feasibility of utilising additional groundwater sources to supply the Dublin area, a 2008 consultancy groundwater report[377] recognised that the contribution of aquifers to baseflow in streams and rivers, and the role groundwater plays in maintaining wetland habitats would be limiting factors, indicating this increased rate will put pressure on water resources. This report[378] estimates that dry weather flow (annual minimum daily mean flow with a return period of 50 years) tends to be 5-10% of the average flow of the main rivers; the 95%ile flow

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[373] TES (2006). Groundwater monitoring of the Bog of the Ring – Final Hydrogeological Assessment Report. *Fingal County Council*.

[374] Ibid.

[375] EDA (2008). Groundwater resources of the Central Leinster Area and their potential to augment the Dublin Region Water Supply. Appendix C of Water Supply Project – Dublin Region. Eugene Daly Associates and RPS Consulting Engineers.

[376] EDA (2008). Groundwater resources of the Central Leinster Area and their potential to augment the Dublin Region Water Supply. Appendix C of Water Supply Project – Dublin Region. Eugene Daly Associates and RPS Consulting Engineers.

[377] EDA (2008). Groundwater resources of the Central Leinster Area and their potential to augment the Dublin Region Water Supply. Appendix C of Water Supply Project – Dublin Region. Eugene Daly Associates and RPS Consulting Engineers.

[378] EDA (2008). Groundwater resources of the Central Leinster Area and their potential to augment the Dublin Region Water Supply. Appendix C of Water Supply Project – Dublin Region. Eugene Daly Associates and RPS Consulting Engineers.

meanwhile is considered approximate to the low flow in the a river that would occur at the end of a normal summer.

There are also examples of extractive industries having impact on the groundwater levels of adjacent GWBs. Where quarries abstract large amounts of groundwater from a quarry sump, the water is typically discharged to a receiving watercourse down gradient of the quarry, to avoid recirculation. If the invoked radius of influence extends to the watercourse as it flows adjacent to the quarry, or to sections of the watercourse up gradient of the quarry, then there is a risk of reducing surface water flows to negligible rates. Examples of this include: Bettystown GWB in Co. Louth, which is considered to be 'At Risk' due to quarry dewatering;[379] and Midleton GWB is considered 'At Risk' by having failed the water balance test due to groundwater abstractions (>80% recharge; with the actual ratio being 95%)[380] and potential for saline intrusion from quarry dewatering along the south coast (see Section 2.3.3.3).

5.4.2.3 Saline Intrusion

Lowering of groundwater levels in coastal regions can allow the intrusion of saline water which is detrimental to the ecosystems of the water body (Section 2.3.3). The Fardystown GWB in Wexford and the island GWBs off the west coast of Ireland (Inisheer and Inishmaan) provide examples of GWBs experiencing potential saline intrusion. These were classified as 'At Risk' due to abstraction pressures resulting in potential saline intrusion.[381] Inishmaan is seasonally operating a small-scale desalination unit in line with increased summer demand coinciding with

[379] CDM (2009). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

[380] Ibid.

[381] CDM (2009). Groundwater Abstraction Pressure Assessment - Final Report. 39325/PP/DG 43-S, pp102.

reduced rainfall[382]. However, saline intrusion is not widespread and is not considered to be a major water management issue in Ireland.[383]

5.4.2.4 Impacts to Natura 2000 sites and Groundwater Dependent Terrestrial Ecosystems

Many of the major water abstraction programmes in Ireland are taken from lakes and rivers that have been designated as Special Areas of Conservation (SACs) under the EU Habitats Directive or Special Protection Areas (SPAs) under the EU Birds Directive. These sites have been designated for the protection of certain habitats and species. In general, the main objective of the designation is to maintain or restore the favourable conservation condition of the habitat or species. Plans or projects that have the potential to impact upon the conservation objectives of these Natura 2000 site by way of affecting the favourable conservation condition of the listed habitats or species, must undergo an Appropriate Assessment, as outlined in Article 6 (3) of the Habitats Directive.

Of the 430 SACs listed in Ireland, 358 have at least one water dependent Annex I habitat or water-dependent Annex II species listed as a qualifying interest.[384] There are 44 different water dependent habitats types and 22 water dependent species that have been identified by the NPWS.[385] Five (11%) of these water dependent habitats are deemed to be at Favourable Conservation Status, whilst 11 (50%) water dependent species are at Favourable Conservation

[382] Ibid.

[383] Ibid.

[384] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[385] NPWS (2013). The status of EU protected Habitats and Species in Ireland. Retrieved from https://www.npws.ie/article-17-reports-0 on 7th May 2017.

Status.[386] Based on the authors' experience, the Annex I habitats potentially impacted upon by water abstraction in Ireland comprise:

- Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea;*
- Oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*);
- Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp;
- Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation;
- Natural dystrophic lakes and ponds;
- Turloughs;
- Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation;
- Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation;
- Petrifying springs with tufa formation (*Cratoneurion*);
- Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae; and
- Alkaline fens.

The Annex II species potentially impacted upon by water abstraction in Ireland include:

- Otter *Lutra lutra;*
- Crayfish *Austropotamobius pallipes;*
- Atlantic Salmon *Salmo salar;*
- Sea lamprey (*Petromyzon marinus*);
- Brook lamprey (*Lampetra planeri);*
- River lamprey (*Lampetra fluviatilis*);
- Arctic Char;

[386] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

- Freshwater Pearl Mussel *Margaritifera margaritifera;*
- *Vertigo* species;
- Allis Shad *Alosa alosa;*
- Twaite shad *Alosa fallax; and*
- Killarney shad *Alosa fallax killarnensis.*

The draft River Basin Management Plan 2018 – 2021[387] recognises that many of the SACs require retention of high status classification. Overall, 320 rivers and 37 lakes must meet high status, as defined by the WFD.[388] The Appropriate Assessment (AA) and subsequent Natura Impact Statement for the draft RBMP[389] identified that there is a risk of direct and indirect, and cumulative impacts arising from abstractions on SACs and SPAs. This NIS also recommended that the abstraction risk assessment should include potential impacts to the protected habitats and species, particularly those that are water dependent.

Examples of SACs where water is currently being abstracted include:

- Lough Carra/Mask Complex SAC 001774;
- Lough Forbes Complex SAC 001818;
- Lough Derg North-East Shore SAC 002241;
- Lough Corrib SAC 000297;
- Slaney River Valley SAC 000781;
- River Barrow and River Nore SAC 002162; and
- River Boyne and River Blackwater SAC 002299.

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[387] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

[388] Water Framework Directive (2000/60/EC).

[389] DoHPCLG (2017) *Public consultation on the river basin management plan for Ireland 2018-2021*. Department of Housing, Planning, Community and Local Government.

Water abstraction outside an SAC could impact upon surface or groundwater dependent habitats or species within the SAC or on a protected species in a river downstream of the abstraction point, by reducing flow and/or by reducing the dilution or assimilative capacity for existing point discharges.[390]

There are some examples of GWDTE, including fens and turloughs, being impacted by water abstraction (including dewatering via drainage). Water abstraction from a lake or river could impact adversely on any GWDTE or protected species associated with the lake, whether or not the surface water habitat itself is listed as a qualifying interest for the SAC.[391] Loss and fragmentation of these wetlands can affect the numbers of birds the wetlands can support as the number of species present in an area is likely to decline if its habitat is reduced.[392]

Pollardstown Fen, Co Kildare is on the shoulder of a large glacial outwash plain (The Curragh) where springs are the source of the wetland water. A quantitative risk assessment of dependent ecosystems identified the attached GWB as 'probably At Risk' due to significant dewatering 5 km away during the construction of the M7 and continued drainage via drains located along the motorway embankments.[393] This fen provides an important, low resilient habitat to the key species mollusc *Vertigo geyeri.*[394] Analysis of the hydrology of the Pollardstown Fen system defined a specific threshold water level below which the sensitive mollusc habitat could not be

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[390] Mayes, E (2008) Water Framework Directive - Programme of Measures -High Status Site – Annex IV Protected Areas – Water Dependent Habitats and Species. Western River Basin District and ESB International.

[391] Ibid.

[392] Johnson, D. (2001) Habitat Fragmentation Effects on Birds in Grasslands and Wetlands: A Critique of our Knowledge. Great Plains Research: *A Journal of Natural and Social Sciences*. Paper 568.

[393] EDA (2008). Groundwater resources of the Central Leinster Area and their potential to augment the Dublin Region Water Supply. Appendix C of Water Supply Project – Dublin Region. Eugene Daly Associates and RPS Consulting Engineers.

[394] Johnston P., Regan S., Naughton O. & Osman, H. (2015) Defining hydrological damage in Groundwater Dependent Terrestrial Ecosystems. *Proceedings of the International Association of Hydrogeologists* (Irish Group).

maintained.[395] Water level below this threshold level serves as an alarm that damage is being done, but does not necessarily cause instantaneous extinction of the identified species. The risk due to construction dewatering has now passed and the residual risk due to on-going drainage is being evaluated. If groundwater levels continue to decline, the health of the mollusc species would be in threat.

In Co. Limerick, an ecological investigation classified the fen habitat at Tory Hill, as being a 'poorly developed alkaline fen' due to the widespread occurrence of vegetation indicative of dry conditions.[396] The reasons for the low groundwater tables causing the dry conditions of the GWDTE may be the result of two processes: (i) regional drainage abstraction of the aquifer/groundwater body recharging the fen, and (ii) the drain that borders the fen is causing a drawdown of the groundwater level.[397]

Kimberley et al.[398] also report that Newtown Lough fen (Co. Westmeath) and Askeaton fen (Co. Limerick) are potentially At Risk from both abstraction and diffuse pressures, Derravaragh (Co. Westmeath) and Fedamore fen (Co. Limerick) may be At Risk due to abstraction, while Inny alkaline fens (Counties Meath and Cavan) have been damaged due to arterial drainage. Fens are priority habitats under the EU Habitats Directive.

Decreased water volume in a turlough results in (i) reduced flooding in winter, drier in summer and selective towards terrestrial plant species, (ii) proliferation of tree growth due to lack of critical flooding level, (iii) increased area of land for agricultural use due to reduced flooding

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395 Ibid.

396 Regan S., Gill L., Connaghan J., Brew T., Gilligan N. (2016). Assessing the conservation status of GWDTEs under the Habitats Directive and Water Framework Directive: A case study from Tory Hill Fen SAC. *National Hydrology Conference, Office of Public Works, Ireland*.

397 Ibid.

398 Kimberley S., Naughton O. & Regan S. (2014) Assessing significant damage to selected Irish GWDTE types as part of groundwaterbody classification under EU Water Framework Directive. *Proceedings of the International Association of Hydrogeologists (Irish Group)*.

time, and (iv) loss of turlough flora and turlough habitats.[399] Kimberley et al.[400] report that Shrule Turlough in County Mayo may be At Risk from abstraction.

5.4.2.1 Rationalisation

Rationalisation involves combining numerous schemes of drinking water supply and thereby increasing abstraction rate from a single, consolidated supply point. Given increased rates of abstraction from single point sources, the potential for impacts such as lower surface water flows and reduced groundwater levels are increased. Irish Water (and to a lesser extent NFGWS) include rationalisation in future planning; though, as yet, no timeline is available for this.

5.4.3 Cumulative Impacts with Abstraction

Cumulative impacts or effects are changes in the environment that result from multiple human-induced, small-scale alterations. Cumulative impacts can be thought of as occurring through persistent additions or losses of the same resource.[401]

Water abstraction and the subsequent low water levels and low flows are pressures on our water resources. When considered in-combination with the impacts outlined above, these pressures can be compounded leading to cumulative impacts upon water bodies. While some work exists

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[399] Ni Bhroin, N. (2008) Ecological Impact Assessment of the Effects of Statutory Arterial Drainage Maintenance Activities on Turloughs. Office of Public Works Series of ecological assessments on arterial drainage maintenance no. 8. ISSN 1649-9840.

[400] Kimberley S., Naughton O. & Regan S. (2014) Assessing significant damage to selected Irish GWDTE types as part of groundwaterbody classification under EU Water Framework Directive. *Proceedings of the International Association of Hydrogeologists (Irish Group)*.

[401] Bowers Marriott, B. (1997) *Practical Guide to Environmental Impact Assessment: A Practical Guide*. Published by McGraw - Hill Professional, 1997, 320 pp.

on the cumulative impact of abstractions in arid and semi-arid regions,[402] there is a dearth of research on this in temperate climates such as Ireland, where constraints over water resources are generally reduced, particularly at a national and regional scale. In arid regions, cumulative impacts of abstraction have resulted in streamflow reduction and decline of lake levels, reduction or elimination of vegetation, land subsidence, and seawater intrusion into coastal aquifers.[403] In New Mexico, abstraction of a hydraulically connected aquifer of the Rio Grande river caused a decrease in flow within the river, even though the Rio Grande's streamflow is allocated in its totality to further downstream abstractions.[404] In this instance, groundwater abstraction had to be offset with surface water abstractions from the river to ensure continued flow of the Rio Grande.

The interaction of cumulative abstractions can be complex. Cumulative impacts can arise due to multiple stressors. Matthaei et al.[405] found a multiplying effect through nutrient enrichment, elevated fine sediment and water abstraction for irrigation. They found that abstracting water from a stream with high fine sediment inputs will probably have a much worse impact on invertebrate fauna than abstraction from a similar stream with lower sediment levels, with implications for WFD classification.

Similarly, spatial distribution of abstraction points can alter the impacts of abstraction. While ten abstraction points, each removing 9 m^3/day, will remove the same volume as 1 abstraction

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[402] E.g. Zektser, S., Loáiciga, H.A., Wolf, J.T., 2005. Environmental impacts of groundwater overdraft: selected case studies in the southwestern United States. Environmental Geology 47, 396–40.

[403] Ibid.

[404] Zektser, S., Loáiciga, H.A., Wolf, J.T., 2005. Environmental impacts of groundwater overdraft: selected case studies in the southwestern United States. *Environmental Geology* **47**, 396–40.

[405] Matthaei, C.D., Piggott, J.J., Townsend, C.R., 2010. Multiple stressors in agricultural streams: interactions among sediment addition, nutrient enrichment and water abstraction: Sediment, nutrients & water abstraction. *Journal of Applied Ecology* **47**, 639–649.

point removing 90 m^3/day, the interaction of local geology, hydrology and aquifer recharge rate can mean the cumulative impact can be greater than, or less than the one point. If recharge rate is high and the 10 small abstraction points are spatially distributed, natural recharge is likely to replenish the abstracted water before it impacts the local environment and the diffuse abstraction is likely to have less of an impact than the single, large point abstraction. If recharge rate is low and below the abstraction rate, the impacts of the ten small abstractions will be spread over a larger area than the one abstraction. Additionally, however, if the smaller abstractions discharge back into the same water body, impacts of abstraction will be mitigated.

This highlights the fact that it is extremely difficult to comment on the general effects of cumulative abstraction as abstraction is site specific, other than to look at the one variable of total volume of water abstracted. In this case, the cumulative impacts of smaller point abstractions will equate to larger abstractions and associated impacts as outlined in Section 2.3.

5.4.4 Impacts of Climate Change in Ireland

Human induced climate change will have varying and far reaching consequences for worldwide water resources, e.g., by altering river flows (increased rainfall or increased evaporation causing greater or lesser average flows) and groundwater recharge.[406,407,408,409] This in turn will affect

[406] Arnell, N.W. (2003a) Relative effects of multi-decadal climatic variability and changes in the mean and variability of climate due to global warming: future stream-flows in Britain. *Journal of Hydrology* **270,** 195–213.

[407] Arnell, N.W. (2003b) Effects of Climate Change on River Flows and Groundwater Recharge Using the UKCIP02 Scenarios. Report to UK Water Industry Research Limited, University of Southampton.

[408] Leavesley, G.H. (1994) Modelling the Effects of Climate Change on Water Resources – a Review. *Climatic Change* **28**, 159– 177.

[409] Wilby, R.L., Greenfield, B. and Glenny, C. (1994) A Coupled Synoptic– Hydrological Model for Climate Change Impact Assessment. *Journal of Hydrology* **153**, 265–290.

the ecology of freshwater environments.[410,411,412,413] Adapting to climate change has been identified as a key challenge by water supply companies and regulators.[414],[415]

Many climate change scenarios show important changes in precipitation patterns which could affect recharge and seasonal water availability in Ireland and there is broad agreement that anthropogenic climate change is likely to have a large impact on water resources.[416] Also, climate change is predicted to increase the rate of sea-level rise.[417] Sea level rise would increase the risk of saline intrusion into coastal aquifers, exacerbating abstraction-led saline intrusions (Sections 2.3.3.3 and 5.4.2.3).

Climate change may result in reduced groundwater levels during summer periods, which may impact GWDTEs, drinking water supplies and baseflow to watercourses. This will result in

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[410] Beaugrand, G. and Reid, P.(2003) Long-Term Changes in Phytoplankton, Zooplankton and Salmon Related to Climate. *Global Change Biology* **9**, 801–817.

[411] Hiscock, K., Southward, A., Tittley, I. and Hawkins, S. (2004). Effects of Changing Temperature on Benthic Marine Life in Britain and Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems* **14**, 327–331

[412] Moss, B., McKee, D., Aktinson, D., Collings, S.E., Eaton, J.W., Gill, A.B., Harvey, I., Hatton, K., Heyes, T. And Wilson, D. (2003) How important is Climate? Effects of Warming, Nutrient Addition and Fish on Phytoplankton in Shallow Lake Microcosms. *Journal of Applied Ecology* **40**, 782 – 792.

[413] Sommer, T.R., Harrell, W.C., Solger, A.M., Tom, B. and Kimmerer, W. (2004) Effects of Flow Variation on Channel and Floodplain Biota and Habitats of the Sacramento River, California. *Aquatic Conservation* **14**, 247–261.

[414] Defra (2002) Directing the Flow: Priorities for Future Water Policy, Department of the Environment, Food and Rural Affairs.

[415] Environment Agency: (2001) Water Resources for the Future: A Strategy for England and Wales, Environment Agency: Bristol.

[416] Charlton, R., Fealy, R., Moore, S., Sweeney, J., Murphy, C., (2006) Assessing the impact of climate change on water supply and flood hazard in Ireland using statistical downscaling and hydrological modelling techniques. *Climatic change* **74**, 475–491.

[417] Rahmstorf, S., (2007) A semi-empirical approach to projecting future sea-level rise. *Science* **315**, 368–370.

reduced flow characteristics. The Eastern CFRAM study[418] estimated potential reduction in summer flows of up to 60% due to effects of climate change.

It is not possible to precisely predict future climate, therefore any assessment of the impacts of climate change on river flows and water resources must use scenarios of feasible future changes. These scenarios are generally constructed from the output of global scale climate models, run with assumptions about future greenhouse-gas emissions.[419] Arnell[420] described the implications of the UK Climate Impacts Programme (UKCIP) climate-change scenarios for river flows in Britain, focusing mainly on mean monthly runoff and Q95 flows (low flows). These studies predicted that by the 2020s, mean summer flows will be about 30% lower than the 1961-1990 mean and the Q95 will be reduced by approximately 25%, with larger reductions in southern and eastern England. Mean winter flows are predicted to moderately increase, with the greatest increase in the north and west. Reductions in the recharge season will result in lower flows in ground-water dominated catchments throughout the year.

Climate models for Ireland project an amplification of the seasonal cycle driven by increased precipitation and runoff flows in winter and decreased flows in summer, modulated by

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[418] ECFRAM (2015) *Eastern CFRAM Study: HA07 Hydrology Report*. Office of Public Works.

[419] Arnell, N.W. (2003b) Effects of Climate Change on River Flows and Groundwater Recharge Using the UKCIP02 Scenarios. Report to UK Water Industry Research Limited, University of Southampton.

[420] Ibid.

catchment properties[421,422,423] with up to up to 20% reduction in precipitation under the high emission scenarios.[424] Although uncertainties in these models are large, catchment specific impacts of these may pose challenges to water management.[425,426,427] Already, climate studies in Ireland could be backing up these models. Sheridan[428] studied historical rainfall (1941 to 1999) and found that for many stations rainfall totals, rain days and wet days have increased in March and decreased in July, with other research showing that extreme rainfall events are becoming more common in Ireland.[429] However, this change may not be uniform across Ireland. Charlton et al.[430] predict a decrease in annual precipitation in the east and southeast, with an

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421 Charlton, R., Fealy, R., Moore, S., Sweeney, J., Murphy, C., (2006) Assessing the impact of climate change on water supply and flood hazard in Ireland using statistical downscaling and hydrological modelling techniques. *Climatic change* **74**, 475–491.

422 Dunne, S., Hanafin, J., Lynch, P., McGrath, R., Nishimura, E., Nolan, P., Venkata Ratnam, J., Semmler, T., Sweeney, C., Varghese, S. and Wang, S. (2008) Ireland in a Warmer World, Scientific Predictions of the Irish Climate in the Twenty-First Century. Community Climate Change Consortium for Ireland (C4I).

423 Bastola, S., Murphy, C., Sweeney, J., (2011a) Evaluation of the transferability of hydrological model parameters for simulations under changed climatic conditions. *Hydrology and Earth System Sciences Discussions* **8**, 5891–5915.

424 Gleeson, E., McGrath R. and Treanor, M. (2013) Ireland's Climate: the Road Ahead. Dublin: Met Éireann.

425 Bastola, S., Murphy, C., Sweeney, J., (2011b) The role of hydrological modelling uncertainties in climate change impact assessments of Irish river catchments. *Advances in Water Resources* **34**, 562–576.

426 Bastola, S., Murphy, C., Sweeney, J., (2011c) The sensitivity of fluvial flood risk in Irish catchments to the range of IPCC AR4 climate change scenarios. *Science of the Total Environment* **409**, 5403–5415.

427 Murphy, C., Bastola, S., Hall, J., Harrigan, S., Murphy, N., Holman, C., 2011. Against a 'wait and see'approach in adapting to climate change. Irish Geography 44, 81–95.

428 Sheridan, T. (2001) Analysis of trends at some Irish rainfall stations. Technical Report 59/2001. Dublin: Met Eireann.

429 Leahy, P.G., Kiely, G., (2011) Short duration rainfall extremes in Ireland: influence of climatic variability. *Water resources management* **25**, 987–1003.

430 Charlton, R., Fealy, R., Moore, S., Sweeney, J., Murphy, C., (2006) Assessing the impact of climate change on water supply and flood hazard in Ireland using statistical downscaling and hydrological modelling techniques. *Climatic change* **74**, 475–491.

increase in the northwest. Another study (1960 to 2000) showing winter increases in the northwest of the country, and decreases in the southwest,[431] though these changes were not statistically significant. Similarly, Murphy et al.,[432] did not find significant increases in winter river flow attributed to climate change (they actually recorded slight decreases), but this could be down to the relatively short measurement window where data was available (1976 to 2009).

This change in precipitation will be reflected in the stream flows, i.e., a rise in winter stream flows and a reduction in summer flows. The reduction of summer flows will have an undeniable impact upon water availability, water quality, fisheries and recreational water use. Extended low flow periods during dry summer months will lead to loss of the biodiverse and heterogeneous riparian habitats. This will impact upon macrophytes and the macro-invertebrates that rely on these riparian habitats. The spawning gravels that salmonids depend on might be lost, whilst lower dissolved oxygen levels and higher water temperatures may lead to fish kills.

There are implications that this projected climate change will have on water abstraction. Climate change has the potential to significantly alter river flow regimes in a river catchment, along with changes to lake water levels and groundwater recharge. Consequences of climate change will be superimposed on normal weather variations which can either mask or amplify the climate change signal.[433] Due to this, the past will no longer be a suitable predictor of the future in water resource planning and management as historical river flows and groundwater recharge rates are likely to be altered.

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[431] McElwain, L., Sweeney, J., (2007) Key meteorological indicators of climate change in Ireland. Environmental Protection Agency Johnstown Castle, Wexford, Ireland.

[432] Murphy, C., Harrigan, S., Hall, J., Wilby, R.L., (2013) Climate-driven trends in mean and high flows from a network of reference stations in Ireland. *Hydrological Sciences Journal* **58**, 755–772.

[433] Arnell, N.W., 1998. Climate change and water resources in Britain. *Climatic Change* **39**, 83–110.

Studies show increasing river flows in Ireland during the winter and spring, along with reductions in summer and autumn.[434,435,436] In a modelled study of water abstraction in the River Moy Catchment area, Hall and Murphy[437] found indications of an emerging vulnerability to water stress of the public water supply under all four modelled scenarios for areas which currently have plenty of water availability. While this approach has not been replicated in other regions, it highlights the importance of water managers planning for the future and anticipating and mitigated detected vulnerabilities. Information on the locations and volumes of abstracted water will be key within this.

Overall, it can be concluded that the existing pressures on our freshwater ecosystems arising from water abstraction are likely to be exacerbated by the predicted increases in climatic variability, particularly during drier summer months. Water managers need to take this into consideration to mitigate the effects of predicted climate change.

5.5 Conclusions

While information does exist on water abstraction in Ireland, it is far from complete. Current databases of abstraction are neither complete, nor contain the necessary data to fully assess impacts of abstraction. In particular, comprehensive data on locations of abstraction points, and

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[434] Dunne, S., Hanafin, J., Lynch, P., McGrath, R., Nishimura, E., Nolan, P., Venkata Ratnam, J., Semmler, T., Sweeney, C., Varghese, S. and Wang, S. (2008) Ireland in a Warmer World, Scientific Predictions of the Irish Climate in the Twenty-First Century. Community Climate Change Consortium for Ireland (C4I).

[435] Charlton R, Moore S (2003) The impact of climate change on water resources in Ireland. In: Sweeney J (ed) *Climate change: Scenarios and impacts for Ireland Final Report*. Environmental Protection Agency, Co. Wexford, pp 81-102.

[436] Murphy C, Charlton R (2006) The impact of climate change on water resources. In: Sweeney J (ed) *Climate change: Scenarios and impacts for Ireland Final Report*. Environmental Protection Agency, Co. Wexford, pp 39-81.

[437] Hall, J., Murphy, C., (2010) Vulnerability analysis of future public water supply under changing climate conditions: A study of the Moy Catchment, Western Ireland. *Water resources management* **24**, 3527–3545.

volumes abstracted are missing. Given that impacts of abstraction are localised, it is fundamental to our understanding of water abstraction pressures that these are known and assessed, particularly where there are impacts upon protected habitats and species.

Impacts of abstraction have been recorded in Ireland, but are not prevalent in the scientific literature. It is not known if this is due to a lack of impacts, or a lack of study into the impacts of abstraction. Impacts that do exist include those to surface water and groundwater. Several GWBs in Ireland have experienced lower groundwater levels causing desiccation and fragmentation of the associated wetland. Coastal GWBs have been identified as being At Risk to saline intrusion due to lower groundwater levels through abstraction. The direct results of these have the potential to alter biological and chemical components of the water body, leading to downclassing of status within the WFD. This is especially relevant in the context of increasing water supplies to centralised urban regions such as Dublin.

Cumulative impacts are difficult to quantify and limited peer-reviewed or other research conducted into the relative impact of these was found. If looking at volumes of water abstracted, then multiple, smaller abstractions equates to larger abstractions. As small abstractions ($<25m^3$) do not need licenses, and there is currently no registration system, there is no accurate information on their locations or abstraction rates in Ireland.

Climate change models predict increased precipitation and river flows in winter months with drier periods in the summer. While the projected increased winter precipitation will assist in water body recharge, the lower summer rainfall and river flows could mean that abstraction pressures will increase in Ireland over time. Work has been conducted that suggests that competition for water resources is likely to increase in the future, with water scarcity predicted in regions that currently experience sufficient water supply.

Chapter 6: Stakeholder Survey

6.1 Introduction

The methodology for this research project provided for the inclusion of interviews with stakeholders in order to enrich the overall understanding of the practical management issues involved in meeting WFD commitments for abstraction management.

There are two dimensions to this qualitative appreciation of the challenges involved: one is the perspective of key decision-makers and those with relevant responsibilities in state agencies, and the other is the range of views amongst those who are engaged in abstraction or experiencing the impacts of it. When considering the introduction of any new system of management or regulation, it is useful to ascertain the perceptions of those who are likely to be affected, and how they are disposed towards the introduction of such controls. Such information can potentially assist in optimising both the design and the successful introduction of a management system that effectively delivers the desired objectives. In addition, it provides the opportunity to capture the concerns identified by stakeholders as related to abstraction, to examine whether all the potential requirements of an abstraction management regime identified by stakeholders are being considered by decision-makers, how well emerging proposals address the concerns identified related to abstraction, and what challenges need to be met to bring an effective regime into being.

6.2 Methodology

In gathering stakeholder feedback to the above end, this research module aimed broadly to capture views on:

- The existence of any impacts or pressures arising from present abstraction;
- The adequacy of the present abstraction management regime;
- Whether an enhanced abstraction management regime is needed and, if so, what elements it should include;

- Any anticipated difficulties in the development and introduction of such a regime; and
- Any concerns regarding the introduction of such a revised regime.

A matrix of stakeholders was developed taking into consideration the various roles and interests in an abstraction management regime. Some stakeholders (principally government agencies) are concerned in developing and/or implementing the management regime, whilst others are affected by the operation of that regime either as abstractors or those experiencing the impacts of abstraction. Similarly, stakeholders' interest in abstraction can be broadly distinguished by those concerned with abstracting for use (in public and private supplies) and those concerned with the impacts of those abstractions. These different roles and categories of interest are not always mutually exclusive; a householder with their own borehole for water supply may be consciously concerned with obtaining water, but also potentially with the impact of abstractions that might affect the production of their borehole. Similarly, state agencies may be involved in both ensuring the safety of water supplies and the minimisation or mitigation of impacts of such abstractions on the environment.

From this matrix, a list of stakeholders representative of different roles and interest was generated. A total of 25 stakeholders were contacted including both statutory and non-statutory bodies, as shown below. The purpose of the research was explained and an invitation to participate in an informal telephone interview was extended. When a positive response was received, a convenient interview time was then arranged with the stakeholder. It was made clear to respondents that while the organisations contacted would be listed, respondents interviewed (agencies and individuals) would not be identified and comments not attributed, in order to encourage them to speak as freely as possible.

Statutory Stakeholders Contacted

- County and City Management Association (CCMA)
- Department of Housing, Planning, Community and Local Government (DHPCLG)
- Department of Agriculture, Food and Marine (DAFM)
- Environmental Protection Agency (EPA)
- Inland Fisheries Ireland (IFI)

- Irish Water
- Local Authorities Water and Communities Office (LAWCO)
- National Parks and Wildlife Service (NPWS)
- Water Service Section – Local Authority

(Interviews were secured with staff in 6 of these 9 agencies.)

<u>Non-Statutory Stakeholders Contacted</u>

- Agriculture &Related
  - Irish Farmers' Association (IFA)
  - Irish Creamery Milk Supplier Association (ICMSA)
  - Irish Organic Farmers and Growers Association (IOFGA)
  - Farming co-operatives[438]*
- Business
  - Irish Business and Employers Confederation (IBEC)
  - Small Firms Association (SFA)
  - Irish Hotels Federation (IHF)
  - Golf Union of Ireland
  - Bottled water suppliers *
- Water consumers
  - National Federation of Group Water Schemes
  - Irish Rural Link

[438] As these were individual enterprises rather than representative bodies, several businesses were contacted and invited to participate.

- Environmentalists
    - Environmental NGO representative
    - Angler

(Interviews were secured with 5 of these 13, incl. 1 from each category.)

Qualitative research of this nature allows us to gain deeper insights into the attitudes, understanding and motives involved in relation to abstraction by systematically investigating a wide range of stakeholders with different interests in abstraction. Regulating and managing abstractions are human actions and a greater understanding of this human dimension is valuable. This is particularly true at a given point in time when the question of introducing change (regulation) is being considered, to help inform how this may most effectively be done. While no claim is made that the above stakeholders constitute a representative sample, responses were secured from across the range of stakeholder interests.

Interviews lasted between 50 minutes and 2 hours. Interviewees were encouraged to expand on questions around the 5 main areas of interest (Section 5.1 above) as relevant to their own organisation or sector, and associated experience. (In one case an agency chose to submit their responses in writing.) Interviews were transcribed for analysis.

6.3 Findings

It is interesting to note the apparent reluctance to participate both on the part of certain agencies that have a clear interest in abstraction management and/or its impacts, and similarly amongst a majority of non-statutory stakeholders. A number in each category declined to take part, multiple email and telephone attempts were made to obtain a response from others (a minimum of 5 attempts in all cases).

The non-statutory groups that did not wish to take part declared themselves unable to participate because of a lack of knowledge or information on abstraction. It is not possible to determine whether this was a tactical response but if not, it suggests that these representative groups across all sectors do not identify themselves or their members as stakeholders, i.e. they did not see that they had any interest in the control or management of abstraction. Likewise, the reason that others with an evident interest in abstraction management (both statutory and non-statutory) chose not to engage cannot be determined. However, each of the groups of stakeholders identified above was mentioned, often multiple times, in the interviews that were completed, and were clearly perceived to have an interest in the issue. Those that were spoken to anticipated that some non-statutory sectors might wish to stay "below the radar"; appearing to be less significant stakeholders, and thus draw less attention or restrictions to their practices in any management regime that is introduced. It is quite possible that these groups did not identify participation in the research as a priority in their already busy schedules, however most are vocal advocates for the interests of their sector and so it was somewhat surprising that they did not take this opportunity to make their case.

As it was not possible to speak with all of the relevant state agencies, care must be taken in interpretation of findings. While two-thirds of state bodies contacted did respond, the significant role of each individual agency means that a more comprehensive response would have been necessary to give confidence that full picture of the official position was captured.

Likewise, it is useful to know that (non-statutory) sectors which are identified widely as having an interest in abstraction do not perceive themselves as such. The total sample is very small and inferences drawn from responses can only be indicative. If awareness were raised, there might be considerable difference in the level of engagement and views expressed. However, the broad categories of water users included here are likely to have shared concerns of quality, quantity, cost and so on.

The findings are presented below according to the five broad lines of enquiry pursued in the interviews (Section 6.2).

6.3.1 Impacts and Pressures Associated with Abstraction

It is worth noting that those that declined to participate in these interviews from amongst the non-statutory stakeholder were clear that they did not have any, or adequate, knowledge to comment on abstraction, with one citing awareness only of the "proposed Shannon-Dublin water supply project". While other non-statutory stakeholders understandably had a particular perspective on the matter, all exhibited considerable awareness and some in-depth knowledge concerning aspects of abstraction. Similarly differences in perspective were evident between respondents from different state bodies, who all tended to bring particular expertise to bear on the question of management. In the majority of cases, issues concerning the impacts of abstraction on the broader aquatic ecosystem (as described in Chapter 2) were largely referred to in a very general sense, compared to frequent more specific focus on safe water supplies for human consumption. In part this may have been a reflection of the limited length of the interview, and the focus on the management regime. However, in only a minority of cases there was a clear awareness or understanding of the diverse and complex impacts that abstraction could have. These results are unsurprising given that most respondents did not have backgrounds in environmental sciences or similar, whilst all shared a personal interest in water supply for human use. There was considerable variation in the familiarity with the potential impacts of abstraction across the statutory agencies with whom interviews were conducted and that have an interest in this matter; greater understanding was concentrated amongst those agencies with specific environmental remit, as would have been anticipated.

Most respondents noted the lack of information on present abstractions; their location, the volumes abstracted, and the periodicity of that abstraction, and the corresponding information on the relevant zones of contribution, aquifer type, dependent rivers or ecosystems, etc. This deficit means that current knowledge and understanding of the impacts and pressures of abstraction in Ireland is necessarily far from complete, as outlined in Chapter 4.

While flow rates from other jurisdictions and secondary data, for example on wells and stocking rates collected by the Central Statistics Office, can be used for initial modelling purposes, it was argued that use of secondary data is not sufficient, especially as abstraction pressures are site and time dependant (Chapter 2). As such, accurate knowledge of the Irish situation must be significantly enhanced to ensure development of an effective abstraction management regime over time (Chapter 4).

A number of specific concerns were raised that fall broadly into the two categories; those relating to alterations in aquatic systems, and those that relate to the governance system (or lack of one).

6.3.1.1 Alterations to Aquatic Systems

- There is evidence that abstraction is exceeding recharge rates in a number of ***aquifers in the Midlands, which are effectively being pumped dry*** (Section 5.4.2.2).

- In at least two coastal areas, ***salinisation*** of groundwater is occurring because of abstraction demands (Section 5.4.2.3).

- ***Impacts on Groundwater Dependent Ecosystems*** are a cause for concern. The relationship between these and abstractions within their zones of contribution are complex, often site-specific, and not yet fully understood. Even very small abstractions can have a significant impact on these and the present lack of comprehensive information on abstraction makes it difficult to assess the significance of this activity on such sites, or to address this where problems are identified (Section 2.3.3.4).

- Concern was expressed that ***upstream impacts*** of abstraction are not currently being considered in evaluations; where they can change the dynamics of feeder streams and rivers and conditions for all species therein.

- While ***ecological response metrics*** for rivers are considered robust, this is not so for lakes where better measurement standards are needed to identify pressures and necessary responses.

- Incidence of ***over-abstraction coinciding with [periods of] particular ecological sensitivity*** are extremely complex and difficult to identify or respond to (Section 2.3.4). However, the absence of information on abstractions makes this a considerably harder problem to assess or address (Chapter 5). Moreover detecting the contribution made by abstractions where other impacts (land-drainage, de-watered rivers[439], modifications,

[439] Where water is removed from the river, sometimes completely if diverted, to allow for works, etc.

leading to changes in channel morphology and river flow, etc.) are also evident is exacerbated by lack of basic information on these activities.

- ***Reduced navigability*** in some water bodies, was seen as representing a problem for recreationalists and the environment. It is difficult to determine whether some of the changes in aquatic flora that may impede navigation is a result of changes in the ecosystem brought about in whole, or in part, by abstraction (Section 2.3.4).

6.3.1.2 Governance Issues

- ***Source protection areas*** for abstraction points are not adequately defined, recognised or protected which poses risks for drinking water. Increased levels and different types of contaminants are being found in water. Of particularly concern are the levels of pesticides now being detected which existing treatment facilities were not designed to deal with. This is not a pressure of the abstraction *per se*, but links abstraction to the wider management of the catchment. Respondents were clear that this information was necessary in order to develop appropriate integration of controls; in this case on the use of pollutants and the siting and use of abstractions.

- There is no consideration or control of the ***cumulative effects*** of abstraction. This is likely to be an increasing problem as demands for water rise; with more abstraction points and increased volumes pumped from existing ones (Section 5.4.3). This was seen as critical for successful longer-term management. This was raised by all but one respondent and several also expressed concern that no regime was fit for purpose if this was not included as it would amount to ignoring (possibly even creating and exacerbating) issues that will arise in the future.

- Despite changes in ***governance*** relating to water, the present system is not seen as able to deliver the integrated response to abstraction management that is needed to proactively manage this resource. Early implementation of the Water Framework Directive in Ireland was recognised as fragmented. To address this, a revised governance structure was introduced that was intended to address this. Under this revised structure, the Minister is responsible for setting objectives, making Programmes of Measures and adopting the River Basin Management Plans (Tier 1), advised by the EPA which is responsible for monitoring

Ireland’s delivery of its objectives (Tier 2). The implementation of RBMPs and their Programme of Measures, and regional co-ordination of this work is the responsibility of local authorities (Tier 3). The Water Policy Advisory Committee (WPAC) was established as an inter-agency body to advise the Minister on policy implementation at Tier 1. In practice, no operational authority across government departments has been established to ensure measures needed to deliver of WFD objectives will be operationalised, so that any measures introduced remain the best possible negotiated compromise between government departments and agencies. This contrasts starkly with UK system where a single agency manages “water shares” and allocates users a share of available water up to the total amount that is determined can be abstracted. The lack of effective coherent governance; where individual departments cannot be obliged to contribute their part in delivering objectives to which the state has committed was seen as a major on-going problem in relation to all water management and one for regulation of abstraction also (see Chapter 4).

- Examples were cited of localised conflicts between group water schemes, farmers, local residents and others, where supplies are limited. If disagreements arise over water use (or other matters), the water itself can become a “weapon” with diversion or reduction in stream flows depriving some of access to water. Ultimately, in rural areas if access to limited water is unregulated this will become ***a social issue***, where those with the resources to sink deeper wells will be able to capture the supplies.

- Challenges of maintaining both water supply and water quality from abstractions occur in sustained dry periods of dry weather, resulting in the need to ***tanker water to communities*** at considerable cost. This is intermittent and limited to certain areas at present but considering the impacts of climate change, increasing water demands, and agricultural intensification, it is anticipated that these abstraction-related challenges will increase (Section 5.4.4).

- In some cases, a public abstraction from a river may require to be managed so as to maintain a minimum river flow as part of the permission granted by the Minister under the Water Supply Act 1942. As in the above point, during particularly dry periods ***compliance with such conditions may be compromised***, as the priority to supply water consumption demands overrides other considerations, such as navigation or ecological needs. The absence of any inspection or enforcement regime means that such breaches are not checked.

- ***Enterprises sinking wells*** to avoid water charges are unregulated and the impact of this on the surrounding aquifer, or other existing water users is not considered. No standards of construction are required, or inspection carried out, generating further concern about possible damage to quality as well as quantity of groundwater available.

- Poorly constructed, maintained, badly sited, or improperly decommissioned boreholes can act as ***conduits of pollution***. Low levels of awareness around this issue and an absence of any controls on the sinking of wells exacerbate this problem (Section 2.3.3.3).

- Many abstractions have been in place for a long duration and pre-date any requirement permission. A significant proportion of those public supplies that were established under permit are of very long-standing. There has never been a system of inspection or a requirement for renewal, suggesting that these abstraction sites are likely to involve ***poorer construction*** and associated problems as in the above point.

- The long-standing nature of many abstractions means that many were never assessed against the Habitats Directive (or other designations) for environmental impacts and may have effects in what are subsequently ***designated areas***. Such water bodies are essentially modified by these abstractions, and retrospective assessment is required to see if corrective action is necessary.

As a pressure, it was noted by several respondents (mostly statutory) that abstraction is perceived as a lesser problem in Ireland than challenges around eutrophication, sedimentation and hydro-morphological challenges. This assessment results from investigation of the significant pressures where monitored water bodies are not awarded “good ecological status”. Several respondents cautioned that this perception is questionable given the current data and understanding is far from complete (as outlined in Section 5.3). While there may not be widespread or significant problems caused by abstraction at present, this does not mean that these will not arise in time through continued practice, or as exacerbated by cumulative effects or climate change. The absence of effective legislative controls could lead to some serious issues in a relatively short term.

While it was widely recognised that more information has been gathered on abstraction during 2016 particularly in relation to public water supplies and group water schemes, it was also acknowledged that more is needed. It was suggested by one organisation that those abstractions for which data is not currently captured (domestic wells, farming, small enterprises, etc.) have a limited impact as they pump out and return a high proportion of that water in the same locality/ catchment. Whether because the respondents recognised the complexity of water management challenges or because they simply felt that "all the pieces of the jigsaw were necessary to see the complete picture", the majority of respondents felt that data on *all* abstractions *is* needed.

While agriculture was identified by most respondents as a significant stakeholder in relation to abstraction, those interviewed concerned with this sector felt that it is in farmers' own interests to protect the quality of their water, and that they are aware of relevant issues such as the siting of septic tanks and compliance with standards for these. They were unaware of situations where abstractions for agricultural or horticultural use created any impacts or challenges for those undertaking abstractions, other parties or for the environment. Farmers perceive themselves as already tightly regulated; cross compliance under the Basic Payments Scheme, the Nitrates regulations and Council Directive 92/46 were all mentioned as mechanisms that ensure water is responsibly used.

6.3.2 The Present Abstraction Management Regime

Apart from the agriculture sector, all respondents acknowledged that the present system of abstraction management is inadequate and effectively almost non-existent, as outlined in Chapter 3. Public water supplies established since the 1940s, for which Irish Water is now responsible, are subject to regulation under the 1942 Water Supplies Act, but otherwise no legislative system of abstraction control is in place. Information on large commercial activities with abstractions of over 25m^3/day may be captured through planning permissions, Environmental Impact Statements or IPCC licensing, but data can only be estimated by examining discharge volumes which are not themselves controlled. Reference was made to some statutory instruments and guidelines that may be in place, but no specifics were identified.

Until such time as Article 11 of the Water Framework Directive is enacted, no comprehensive mechanism to manage abstractions exists in the State.

The agriculture-related stakeholders interviewed were clear that existing regulations and controls on the sector are more than adequate to address any potential impacts of abstraction for agricultural uses (see earlier comments in section 6.2). The only specific requirement in relation to water abstraction identified was the requirement by the Department of Agriculture, Forestry and Marine's Horticulture Division to list the points of water abstraction on their food safety management plan.

6.3.3 Requirements for an Enhanced Abstraction Management Regime

A range of elements were identified as necessary for an effective management regime.

(i) A "live" log of all surface and groundwater abstractions, including episodic

This should be continually updated and include ***all*** public and private abstractions, location, the volumes taken and when these are abstracted. It would need to identify not just new abstractions but instances where increased use is made of existing abstractions. This is essential to allow the detection or prediction of possible impacts which can be complex. If abstractions are to be managed on an aquifer by aquifer basis, then it is important to know the information on all abstractions, including one-off housing. Logically, planning permissions could be used to capture this data. This information needs to be held nationally, kept updated and made accessible to all relevant agencies, and possibly also to the wider public if water is considered a shared resource of strategic importance and not one where "commercial sensitivity" is an acceptable reason for failing to ensure complete transparency. Fundamentally, the absence of data (as outlined in Section 5) means that it is not possible to assess the issue to see if there are problems. What constitutes adequate data varied considerably by respondent, but ecological concerns and local perspectives led to requests for more detailed information.

(ii) A licensing regime for significant abstractions

This needs to be sufficiently flexible and responsive to the particular situation, taking into account cumulative impacts, periodicity, and requirements for responsiveness to rapid change within the water system, for example to maintain minimum river flows, etc. In order to enable enforcement of such licenses, metering of abstractions is necessary as is monitoring of logs of real time abstraction volumes.

(iii) Apply the environmental flow concept

This concept seeks "to maintain the quantity, quality and duration of the flow sufficient to maintain the river and riparian ecosystem in a good state".[440] To enable this, data should be captured for ecologically meaningful periods, something that is not commonly considered by hydrologists. The importance of this was seen in conflict that arises with Irish Water's prime concern to maintain supplies of drinking water often at ecologically sensitive periods, such as prolonged dry weather. Appropriate management is only possible in this context if informed by relevant data. One respondent cautioned that this needs to be part of an integrated and comprehensive management system that can prevent environmental flow constraints being by-passed for example while limiting direct abstraction from a river, siting boreholes along the river banks and essentially drawing river water indirectly.

(iv) Cumulative impact assessment as part of licensing

There was strong support across most respondents for any licensing regime to consider cumulative impacts, *even of small abstractions* which can have significant impacts in more sensitive areas. This was seen as benefitting all abstractors and needs to be informed by a complete log of abstractions (see above). Localised instances of water pressure need to be managed. For example, where domestic wells (and others) are drilled around a stream indirectly taking water previously supplying a group water scheme.

(v) Water rights / rights of access to water and water use

Some adjudication on the issue of access to water is needed as well as clarity on water rights; is water a State-owned mineral? And, if so, the State should provide comprehensively for the use of this resource. It was noted that water, being perceived as free, is often misused ("tragedy of the commons"). In situations where demand for abstractions exceeds supply, or supply of

[440] *Environmental flow – an important river restoration method in regulated rivers.* S. Olin & M. Arola, 2013.

potable water, some prioritisation on the basis of water use will be needed, i.e. public water supplies for reasons of sanitation and health, navigation, etc.

<u>(vi) Integration with planning and development functions</u>

Planning laws are not presently designed to consider the implications of water demands. Integrating abstraction with the development planning function in Local Authorities would allow better informed decision-making, such as appropriate location of commercial development; considering demands of “thirsty” activities such as pharmaceuticals, IT and food businesses, or water body constraints such as saline intrusion in coastal aquifers, or ecologically sensitive river systems. This was described as a sustainability-proofing measure within planning practice, to save problems emerging later, and make necessary adjustments at planning stages, rather than requiring more costly retrofitting or retrospective works.

At a more local level, it was proposed by several respondents that demonstration of access to clean water with acceptable well construction standards should be a requirement for planning permission for individual dwellings and other developments in areas with no mains supply or group water scheme. Planning permission could be granted according to present guidelines, but construction of the development only be allowed to commence once a borehole/ well is sunk and water tested with acceptable results. On completion of building, the appropriate construction of the well would need to be signed off on by a competent agent as part of the planning requirements. A further proposal is that a tax back scheme could be made available for new connection fees, encouraging wider provision of public or group water scheme supply.

<u>(vii) A catchment management approach</u>

Such a comprehensive approach to management of water is critical. It is particularly critical in the context of climate change, fluctuating demands, varying sensitivities of zones of contribution, etc. Such an approach allows consideration of changes in land use, such as agricultural intensification which raises the risk of contamination of water bodies, in appropriate siting of abstraction points. This integrated approach enables an understanding of risks that can inform the regulatory system. In this way thresholds and other controls are decided on the basis of what is needed and relevant.

(viii) Risk-based

Any management regime introduced should be risk-based. Within the River Basin Management planning process there should be the ability to identify areas At Risk in the first instance. This would be the driver for applying differing thresholds of a licensing requirement in different areas on a needs basis considering, for example, ecological flows. Without such flexibility indiscriminate, blanket rules may be set that do not adequately address complex issues best suited to a catchment-based approach.

(ix) Address legacy issues

Management must address legacy issues through the review of existing abstractions, ensuring that these are compliant retrospectively with environmental (and any other relevant) legislation. It was noted that there is considerable retrospective work involved in the ecological and environmental assessments needed to do this. One starting point mentioned would be to consider designated areas, and carry out appropriate assessments particularly in SACs with specific conservation objectives that include hydrological objectives. It is not necessarily the case that abstractions will have resulted in significant impacts that require changes, but it would be possible where impacts have been missed to make changes to mitigate these. For example, in a salmon spawning river with reductions in water flows where data is unavailable on abstractions, it is not possible to see IF abstraction is a problem, or if it is, how it might be addressed.

(x) Introduced on a phased basis

Historically water supplies have developed in Ireland on an *ad hoc* basis, with numerous, often small, abstraction points (over 1,000 public water supply abstractions alone) about which very little information is available on safe yield, related aquifers, etc. A number of respondents suggested it would be pragmatic to phase the introduction of a management regime. Begin with collecting data on location, rate and periodicity of abstractions. This in turn should be used to inform the thresholds set using a risk-based management approach, with consideration of cumulative impact and the vulnerability/ sensitivity of the water bodies. Flexibility should be built in until there is an understanding of the impacts of any regulatory system. No delays should be allowed in delivery of such a phased programme of introduction, once initiated.

In addition to these regulatory elements, it was recognised that:

a) On-going research on the impacts of abstraction, both the immediate zone of contribution and the whole catchment system, are necessary, and should involve co-ordinated initiatives across agencies with particular relevant expertise (EPA, Geological Society of Ireland, NPWS, IFI, etc.); and
b) There is a significant piece of education and awareness-raising work needed to inform citizens at a minimum about how their own behaviours can affect water quality and aquatic environments and how this relates to them.

It is important to note that one statutory respondent expressed concern about the establishment of a demanding registration and licensing system, with lower thresholds for licensing requirements, creating a disproportionate administrative burden relative to the significance of abstraction as a pressure on water bodies. This respondent was clear that if the regime was kept simple, it would be straightforward to put in place. This response essentially captured the evident tension between two distinctly different perspectives. On the one hand the desire to make possible the institution of some form of useful regulation as required under the State's Water Framework Directive commitments. This view favoured a regime of essentially minimal management that would not arouse protest that might make its introduction difficult, and that would be deliverable within resource constraints; an essentially pragmatic response. On the other hand, there was a clear desire to put in place a proactive regime that recognises and addresses first and foremost the information gathering needed to deliver a full understanding of the impacts of abstraction which, in turn, informs a management regime introduced on a phased basis. This latter perspective allowed for consideration of difficult issues such as water rights, and recognised the need for a dynamic approach in light of climate change, fluctuating demands, and other factors to which an adaptive regime is best suited. These respondents took the view that the state could be proactive and comprehensive in the regime introduced, without making it unreasonably onerous and avoiding pushing down the road challenges around water rights and complexities in the aquatic system; they sought a comprehensive management response.

Those that favoured this latter approach were those with direct interest in the environment and water use or consumption. Those respondents, both statutory and non-statutory, whose role would involve convincing their constituents of the merits of a management regime tended favoured limited regulation.

Another respondent was clear that commercial operations securing a license for abstraction should be charged both for their license and according to the volume abstracted. Income from this should be ring-fenced to support the licensing regime.

6.3.4 Difficulties Anticipated in the Development and Introduction of a Revised Management Regime

All those interviewed identified the highly politicised nature of anything to do with water as a major impediment to the introduction of any new measures in relation to abstraction. Controversies around domestic water charging, septic tank regulations and Irish Water were all cited as contributing to making introduction of a new or revised regime challenging. Politicians were identified as too susceptible to vested interests and wary of negative reactions to introduction of any regulations at all. Regulations that introduce restrictions of any sort will exacerbate difficulties.

Cost was noted by a couple of respondents as creating a negative reaction amongst politicians and the public, and contrasting concerns were expressed regarding creation of an overly onerous and costly administrative burden on the one hand and the need to ensure an adequately robust, thorough and so useful regime on the other. The thresholds set for licensing and the associated costs were seen by several interviewees as determining the extent of opposition to the proposed regime. In rural areas if the threshold is set at a lower level it may bring in Bed and Breakfast businesses, larger schools and other small enterprises for whom the added burden of compliance will be significant, and who may object if they feel they are already paying for drilling, pumps, treatment units, and so forth, and will face additional costs. Licensing requirements were seen as less challenging for large enterprises familiar with certification demands and reasonably accepting of a licensing system that certifies them as compliant with all regulatory requirements.

Several respondents expressed the view that an initial system needs to be provided for in legislation that can then be revised and hopefully improved upon. This could be carefully facilitated by the phased introduction of measures. However, there were also repeated fears expressed about Ireland's poor record in enforcement of a range of similar environmental/ resource-related regulation, including other areas of water management such as septic tank inspections.

Other than the agricultural stakeholder, all respondents felt it was preferable that a management regime be put in place proactively than in response to a serious related incident. However, it was noted that motivation of necessary public support seems to follow such incidences. The majority of interviewees cited the agricultural sector as strongly resistant to any regulation. It was suggested that most farmers individually would respond positively to a proportionate management regime where the benefits were clear, however representative organisations were seen as a source of vocal opposition.

Some respondents mentioned that if retrospective action is required, for example to repair or even re-drill a properly constructed borehole (and cap the original), that some form of grant scheme, or tax back system for investments, may be needed. However, others felt that even moving away from a charging regime to general taxation will not prevent objections.

The need for comprehensive education about our finite water resources, the risks facing them, and the role all sectors of society can play in protecting them was repeatedly touched on by respondents. Interestingly, it was noted by a few that the necessary learning is impaired particularly in rural areas because of the reluctance people exhibit to being open about problems they encounter with their private water supplies. It is unclear precisely why this is the case, it may simply be a function of "keeping up appearances".

Handling how the issue is communicated was seen as critical; explaining to the public that these issues of water management are linked to significant costs around flooding, drought and safe water supply, and that action is needed (and most effective) in a co-ordinated manner. Pitching one objective against another is not a constructive way of doing business. It would be more sensible to take on the whole challenge of integrated water management on a phased basis so it is not overwhelming or too costly. Several respondents commented on the persistent lack of strategic governance on this issue. For example, dovetailing Water Framework and Flood Directives would help enable a sensible strategic prioritisation programme to be developed and coordinate action.

Pressure from the European Commission to secure compliance with Article 11of the Water Framework Directive was clearly identified as the driver for the introduction of an abstraction management regime. It was also felt that the EU action against Ireland on wastewater treatment will help to focus political minds, and a number of other factors favouring effective abstraction management were identified. These include pressure from consumers for clean water, and initiatives in the dairy sector requiring farmers to demonstrate sustainable practices (including related to water supply and use) to justify the green image of Irish agricultural produce.

6.3.5 Concerns Regarding the Introduction of such a Revised Regime

Genuine concern was expressed from a cross-section of those interviewed that the issue of abstraction management will not be addressed at all if the politicians can avoid it, and that much depends on the pressure that the European Commission maintains. One respondent expressed the view that the EU is aware that there is no appetite to pursue this in Ireland and may be unlikely to push too hard on it since it is not the most pressing issue facing water bodies in Ireland, and will not be seen as urgent.

It was suggested that the proposals for a regime will be put out to extensive consultation to push decision-making as far as possible into the future. A successful review of Irish Water may have an impact on government’s willingness to follow through on an abstraction regime, but there was a sense that suspicion amongst the media and the public of all government actions make this unlikely.

6.4 The Significance of Stakeholder Perspectives

Low levels of awareness of abstraction amongst respondents, and limited understanding of associated impacts, is not surprising. The issue of abstraction has not been the focus of much attention in Europe to date; "most governments have little information and no existing institutional infrastructure of abstraction licenses."[441] Ireland which, as several stakeholders stated, "is fairly wet", has had little exposure to conditions of water scarcity which would have increased awareness of abstraction and associated issues and of the possible needs to manage this activity. Water quality for human consumption has attracted attention where problems have arisen, such as in the *cryptosporidium* outbreak in Galway in 2007[442]. However, pollution control and improved water treatment facilities, rather than the importance of integrated water management and the regulation of abstraction practices within these, has been the focus of attention.

Taking a wider perspective, in states where problems of water scarcity have focused public attention on water management issues such as Australia, measures to regulate water rights and access to water have been developed. There is on-going research into how this might be most effectively done, which tends to highlight the challenge of managing human and environmental needs that are generally considered distinct.[443] The cognitive dimensions of policy-making in the water sector have attracted some attention[444] and entitlement and allocation of resources are

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441 Page, B. & Kaika, M. (2003) The EU Water Framework Directive: Part 2. Policy Innovation and the Shifting Choreography of Governance. *Eur. Env.* **13**, 328-343.

442 Pelly, H, Cormican M, O'Donovan D, Chalmers R, Hanahoe B, Cloughley R, McKeown P, Corbett-Feeney G. (2007) A large outbreak of cryptosporidiosis in western Ireland linked to public water supply: a preliminary report. *Eurosurveillance*, Volume 12, Issue 18, available http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=3187.

443 Young, M.D. (2014). Designing Water Abstraction Regimes for an Ever-Changing and Every-Varying Future. *Agri. Water Management* **145**, 32-38.

444 Molle, F. (2008). Nirvana concepts, storylines and policy models: Insights from the water sector. *Water Alternatives*, **1**, 131-156.

considered in this work, with a clear acknowledgement that the issue of water rights needs to be addressed.

While there is considerable literature looking at a wide range of impacts of abstraction (see Chapter 2), there is as yet little evidence of studies assessing the abstraction management regimes that European states are required to introduce under the Water Framework Directive, and none were identified in the views and responses of stakeholders in these jurisdictions. There is extensive work on the engagement of stakeholders in water governance and management,[445,446] recognising the significance of different stakeholder perspectives for successful water management.[447] Similarly, the relationship between stakeholders (state and non-state) and the design, implementation and effectiveness of abstraction management regimes has not yet received scrutiny.

However, the importance of these players has been recognised in Ireland in the Environmental Protection Agency's adoption of an Integrated Catchment Management (ICM) approach. This represents the internationally accepted best-practice model for management of the aquatic environment. Central to this is a move away from a traditional top-down administrative approach towards a more deliberative, inclusive and bottom up approach.[448] All stakeholders have an important role to fulfil for ICM to be effective. This requires awareness and

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[445] Craps, M. (ed) (2003) *Social learning in river basin management.* Report of work package 2 of the HarmoniCOP project (www.harmonicop.info).

[446] HarmoniCOP (2005) *Learning together to manage together: improving participation in water management.* HarmoniCOP, Osnabruck.

[447] Knox, J.W., Kay, M.G. & Weatherhead, E.K. (2012). Water regulation, crop production, and agricultural water management—Understanding farmer perspectives on irrigation efficiency. *Agricultural Water Management* 108, 3–8.

[448] Organisation for Economic Co-operation and Development (OECD) (2011). *Water governance in OECD countries: a multi-level approach*. OECD Studies on Water, OECD Publishing, Paris, France.

information, as well as active engagement and involvement of stakeholders in delivering objectives.

The complexity of the potential impacts of abstraction and the inter-relationships of these, perfectly illustrate the need for adaptive management approaches that consider human, physical, biological and biogeochemical components of the water system and their interactions. Such an integrated and iterative management approach is focused on increasing the adaptive capacity of the water system(s), making them more resilient and better equipped to respond to the unpredictability and complexity of stresses, such as climate change. This delivers long-term results in terms of ecological resilience and successful socio-ecological management systems.[449,450,451]

Research to date and current best-practice suggests that stakeholders need to be involved in delivery of successful environmental management and related resource provision. The very significant challenge of designing, introducing and operating a sufficiently comprehensive and inclusive abstraction management regime is unlikely to attract enthusiastic support from responsible administrators. This research suggests that this is widely acknowledged. However, all but one of the non-statutory stakeholders interviewed here favoured a comprehensive management regime, as did several of the statutory stakeholders. The majority of respondents clearly indicated that a regime which did not gather all the relevant information, and regulate abstraction in response to that information, would not be one that could command their confidence that all impacts were being identified or adequately addressed. There was recognition that variable thresholds or other spatially differentiated measures should be

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[449] Folke, C., Hahn, T., Oldsson, P. & Norberg, J. (2005). Adaptive governance of social ecological systems. *Ann, Rev. Environ. Resources*, **30**: 8.2-8.33.

[450] Pahl-Wostl, C. (2007) Transition towards adaptive management of water facing climate change and global change. *Water Res. Management*, **21**: 49-62.

[451] Pahl-Wostl, C., J. Sendzimir, P. Jeffrey, J. Aerts, G. Berkamp, and K. Cross. (2007). Managing change toward adaptive water management through social learning. *Ecology and Society* **12**: 30.

explored so that only those controls that are needed are introduced and no unnecessarily onerous blanket requirements imposed. Without having complete data collected, it is not possible to ensure that any management regime introduced is appropriately designed. There were doubts that such a system would be possible in face of the significant political difficulties in introducing any new water-related measures in Ireland at this time and the lack of willingness to invest sufficiently in the system. While other pressures on aquatic resources are considered more significant (e.g. nutrient enrichment), it was feared that investment in introducing a proactive abstraction management regime is unlikely.

Whatever regime is introduced, respondents identified consistently that education and awareness raising amongst stakeholders will be essential.

6.5 Conclusions

The interviews reported on here are targeted at the most informed, involved and relevant personnel in all cases but are not necessarily representative of state agencies or non-statutory sectors. Given this, it must be noted that those *not* immediately concerned with aquatic environments (who were in the minority) approached the issue of abstraction with a clear focus primarily on water supply for human consumption. The same respondents demonstrated low levels of awareness of the diverse and complex impacts of abstraction on aquatic environments. The introduction of an abstraction management regime is being driven by commitments made under the Water Framework Directive, but the focus on good ecological status of water bodies as the objective is far less apparent in how the issue is considered in practice.

While in-depth understanding of the impacts of abstraction may be limited, due primarily to a lack of awareness and data on abstractions and their impacts, a range of pressures were identified by respondents, including ecological impacts and shortcomings in governance (see section 6.3.1 above). Moreover some carefully considered proposals for an effective management regime were identified in interviews. There was a minority view amongst both statutory and non-statutory stakeholders that the regime should be “light” and limited. This was far outweighed by respondents in this research[452] who saw it as important to collect detailed registration and monitoring data to gain a comprehensive picture of abstraction in the State, in order to design a responsive, risk-based licensing system, to address retrospective assessment and mitigation and to be integrated into forward planning. There was a clear sense in the interviews that if it is worth introducing a management regime, it should be worth doing well, although revised governance provisions were not seen to enable this significantly.

There were universal concerns regarding a lack of political will to deliver a management regime, and a number of specific significant hurdles identified. However, the potential to capture the public's attention around the need for a comprehensive approach to protecting our future in all aspects of water management (safe water supplies, clean environment, flood and drought management, etc.) was also recognised. Fears were expressed that this will not be recognised by government and pressure from the EU may not be sufficient to ensure a robust and effective abstraction management regime is introduced in the foreseeable future.

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[452] While the sample involved in this research was small, all the key statutory agencies and non-statutory stakeholder groups were approached. A reasonable spread of responses was received across both groups, but it should be remembered that the overall number of interviews was small.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Overview

Abstraction of water from water bodies have impacts that vary spatially and temporally related to the volume of water abstracted, the volume of surface water flow or rate of recharge of the aquifer from which the water is abstracted, and the spatial and temporal nature of the discharge of the abstracted water. Impacts will be greater when the ratio of abstracted water to available water is larger, when there are lower rates of runoff and/or recharge, and when discharged water is separated from abstracted water by time and/or space. All of these yield reduced flow in the water body where the abstraction occurs.

Abstraction impacts arise when lower flow in surface waters, and lower groundwater levels in groundwater bodies occur, and these can lead to a change in status classification for the WFD. In surface waters, lower river flows decrease flow velocities and decrease the depth and/or cross-sectional width of rivers, resulting in altered WFD morphological factors such as river connectivity and channel type. In lakes, lower water levels alter the depth and width of the lake These alterations to surface water bodies can have direct impacts to the WFD biological and chemical components of surface water. Habitat size is reduced, associated floral assemblages can vary and animal behaviour can change. The water temperature and vertical mixing of rivers and lakes can also change, with the dilution potential of the surface water body to contaminants reduced. Again, these can cause changes to the WFD biological components of the water body.

In groundwater bodies, abstraction can result in lower groundwater levels. Immediately surrounding the point of abstraction, within the zone of influence, groundwater levels will decrease on initiation of abstraction. If abstraction rate is greater than the recharge rate of the aquifer, groundwater levels through the aquifer will eventually decrease. Lowering of groundwater levels has direct impacts to hydraulically connected surface water bodies (reducing flow in these connected systems), and reduces water delivery to connected GWDTEs (with negative impacts to associated flora and fauna). Lowering water levels in groundwater bodies will lead to a downgrading in the classification of these for the WFD and can impact the chemistry of the water body; surface water contamination of the water body can occur (altering temperature, pH, conductivity and levels of pollutants) and abstraction near coastal environments can cause salinization (altering conductivity). Inadequately constructed groundwater wells can also provide direct pathways for surface pollutants to reach groundwater.

While the impacts outlined above can be caused by abstraction, it is important to note that they all (with the exception of groundwater wells providing pollution pathways to GWBs) arise from abstraction rates exceeding threshold surface water flow rates and/or groundwater recharge rates. These rates will change spatially between water bodies (based on variations of precipitation, hydrology, geomorphology and geology) and temporally (based on seasonal variations of precipitation and the effects of hydrology and hydrogeology). If abstraction rates are low compared to surface runoff and/or groundwater recharge, the impacts of abstraction will be limited. If rates are high, impacts will manifest themselves locally, before expanding in scale if not remedied as baseflow will continue to decline.

In Ireland, given the high precipitation levels that are experienced, the risk of abstraction impacts on a national scale is considered by the authors to be low. High surface water flow and groundwater recharge rates over large parts of the country are expected to replenish most water bodies on an annual basis. However, on a local scale, in regions where there is low surface water flow, or low rates of aquifer recharge, negative impacts of abstraction could be experienced. In Ireland, there is currently not adequate characterisation of existing abstraction points to make fully informed and quantified assessments on the impacts of abstraction on a local scale. This has been recently highlighted, with researchers unable to reliably screen abstraction pressures due to inadequate baseline conditions and lack of data on abstraction.[453] However, there are specific examples in the scientific literature and local authority reports of impacts occurring to water bodies, Indeed, the recent EPA characterisation in the RBMP found that 98 rivers (3%), 73 lakes (9%) and 23 GWBs (4%) were identified as potentially At Risk of

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[453] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21.

over abstraction.[454] Though as the EPA's assessment of abstraction amounts used for the risk assessment are *"based on best available information of known abstractions from a recently collated EPA abstractions database"*[455] and, as outlined in this report, questions remain over the comprehensiveness of the current abstraction database (Section 4.5.2) this could be an underestimate of water bodies that are At Risk. The authors have not found any published information on the number of high status sites where abstraction is a risk to classification status, with data only on a case by case basis, or on a catchment scale.[456] Over-abstraction impacts (lowered groundwater levels and lower lake levels) have the potential to negatively impact biological and chemical WFD classification criteria to the point that the water body is downgraded in status. This is especially pertinent given that the occurrence of multiple stressors to a water body (e.g. nutrient enrichment combined with abstraction) has been shown to have a larger impact than each stress individually (Section 5.4.3).

The research into projected climate change in Ireland indicate seasonal changes to precipitation levels in Ireland, yielding wetter winters and dryer summers. This projected change has the potential to increase the impacts of water abstraction in the dryer seasons. Indeed, research that has been conducted into future water management in Ireland indicates that competition for water resources will increase in Ireland and certain regions that currently do not experience water scarcity, will experience it in the future (Section 5.4.4).

Given abstraction can cause impacts to water bodies in Ireland, and these impacts are likely to increase in the future with projected climate change, it is essential that an effective regulatory system is in place. It is regrettable that this is currently missing. Our analysis of the existing system shows that abstraction information is not being collated in a manner that permits

[454] DHPCLG (2017) Public consultation on the river basin management plan for Ireland (2018-2021), pp103.

[455] Ibid p.64.

[456] Ní Chatháin, B., Moorkens, E., Irvine, K., 2010. Management Strategies for the Protection of High Status Water Bodies (STRIVE Report No. 2010-W-DS-3). Environmental Protection Agency.

accurate analysis of the scale of abstraction. Existing domestic legislation does not require systematic collection of abstraction data and does not comply with the WFD. In response to this, a database of abstractions is in the process of being compiled. However, this database is not publicly available (so difficult to comment on), and already reports that it is not comprehensive, with only 2600 abstraction points included and only 60% of groundwater schemes from NFGWS included in the most recent version (Section 4.5.3). Abstractions below 25 m^3/day are not included, which omits the up to 200,000 small abstraction points that are believed to exist. While the WFD does allow omission of abstraction points from the abstraction register that have "*no significant impact on water status*" of the relevant water bodies, inherent in this is that there is an assessment of abstraction points. Currently, that is not being conducted, and apart from a recognition in the draft RBM Plan that a *"more detailed case-by-case assessment"* is needed,[457] there are no indications that this will occur. It is also of concern that this case-by-case assessment will be limited only to the water bodies designated At Risk from abstraction, when this designation was based on an incomplete abstraction database.

Proposed measures to mitigate against over-abstraction in identified At Risk water bodies include an upgrading of maintenance of the hydrometric network, register of water abstractions, and development of appropriate regulation for abstractions.[458] However, there are limitations to these measures. In the first instance, At Risk water bodies are identified by an as-yet incomplete EPA abstraction database, meaning some At Risk water bodies may not have been identified. Secondly, impacts of abstraction are spatially distributed, and it is possible the hydrometric network of 398 monitoring stations is not sufficient to fully identify locations were over abstraction is occurring. Thirdly, while the register of abstractions is welcome, it is unclear how the threshold value of 25 m^3/day was calculated, and there appears no allowance for spatial or temporal variations in surface water and groundwater flow rates. Finally, the regulations are

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[457] DHPCLG (2017) Public consultation on the river basin management plan for Ireland (2018-2021), p 64.

[458] Ibid p 65.

yet to be characterised and would appear to apply only to those abstractions greater than 25 m^3/day, with no mention of spatial and temporal variations in the impacts of abstraction, cumulative impacts of abstraction, nor future changes related to climate change.

There is good awareness of the impacts of abstraction among the stakeholders that participated in the survey for this report (Section 6.3). Amongst the respondents, there is general acceptance that, at present, there is an absence of effective regulation and legislation. This was outlined as being a primary cause for the lack of consistent and reliable information on the spatial and temporal extent of abstraction occurring. While the comprehensive data is absent, specific examples of impacts arising through abstraction were still highlighted. These tended to centre around low flows as noted in Sections 2.3 and 5.4, but also included the potential for water wells to act as conduits for pollution to enter groundwater. This led all but one participant to argue for a precautionary approach to future legislation that includes preventative safeguards (such as recording all abstractions, with specific regulations on larger ones) to avoid possible ecological damage. Where data is currently inadequate to fully assess the risks, these areas should be avoided for purpose of abstraction, or the potential impacts mitigated. Suggestions were made for a flexible approach that while accurately capturing the extent of abstraction in Ireland, allows for adaptation and modification of any regulatory system in light of new knowledge and insights that emerge.

7.2 Knowledge Gaps

There are significant knowledge gaps both in our understanding of abstraction rates in Ireland, but also on the specific impacts of abstraction in Ireland.

Due to an absence of legislation requiring accurate rates of abstraction in Ireland to be registered, there is no comprehensive, centrally-located register of abstractions. Information on abstraction is improving with the compilation by RPS of an abstraction database, but this only captures points >25m^3 / day, includes only licensed abstraction volumes (not actual volumes), and itself acknowledges that many abstraction points are missing. Absent are the up to 200,000 private domestic wells,[459] >150,000 unregulated agricultural groundwater abstractions,[460] and golf courses (of which one estimate has potentially abstractions up to five times more per year than the annual volume currently accounted on the whole RPS database - Section 4.5). This makes it impossible to accurately assess the impacts of abstraction in Ireland.

Additionally, there is a general dearth of peer-reviewed literature into the impacts of abstraction of Ireland. One reason for this is the lack of a comprehensive abstraction database on which to base investigations. Increased scientific investigations into the impacts of abstraction, including cumulative impacts, is required due to the recognised occurrence of abstraction impacts happening in Ireland, projected impacts of climate change, and indications that water scarcity will increase in the future in certain parts of Ireland. A characterisation of current impacts is required to understand future impacts comprehensively.

7.3 Conclusions

It is the authors' conclusion that while the national risk of abstraction in Ireland is low, abstraction can be a significant risk on a local scale, with the impacts capable of causing a downgrading in status classification of the water body under the WFD. The currently available data on the location, rate and duration of abstractions is inadequate and is preventing comprehensive studies on the impacts of water abstraction in Ireland. However, in Ireland, there are still documented localised impacts of abstraction and these impacts are likely to grow in scale and extent as projected climate change takes effect.

To successfully mitigate against the current and future impacts of abstraction, clear and effective governance of water resources is essential. In particular, comprehensive legislation

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[459] Wright, G. 1999. How many wells are there in Ireland? The GSI Groundwater Newsletter, Vol. 35.

[460] Webster K.E., Tedd K., Coxon C. & Donohue, I. (2017). *Environmental flow assessment for Irish rivers.* Environmental Protection Agency Research Report 2014-W-DS-21. p55.

regarding the location, rates and duration of abstraction points is critical, along with a national publicly-available comprehensive register of where and when these are occurring. To enable this, a process of stakeholder engagement is essential to highlight the shared nature of water resources, the threats to them, and how strong regulation can protect this vital resource. To facilitate the above issues, and to address the identified shortcomings, specific recommendations are made in the section below.

7.4 Recommendations

The three main requirements which must be fulfilled in order to minimise the impacts of abstraction are as follows:

(iv) Improved assessment of the impacts of abstraction in Ireland;

(v) Clear, consistent and strong legislation; and

(vi) Improved stakeholder engagement.

7.4.1 Assessment of Abstraction Impacts in Ireland

There is currently very little assessment of the impacts of abstraction in Ireland. During investigations of water bodies, abstraction pressure is usually combined with other pressures such has pollution and nutrient enrichment. If the full impacts of abstraction in Ireland are to be assessed, data on abstraction volumes must exist, and an improved monitoring strategy of the impacts of abstraction must be developed and implemented. Given the large volume of rainfall across most of the country, it is expected that in a large number of places, abstraction will not pose significant impacts. However, for the identification of water bodies where abstraction does cause impacts over a range of temporal scales (daily to annual), or is likely to cause impacts with cumulative impacts, future development, and predicted climate change, it is imperative that a full understanding of abstraction and associated pressures exists. An understanding of the extant pressures will help to provide the basis for a licensing regime that provides adequate protection to all water bodies, yet is flexible enough to prevent onerous regulations where risks of impacts due to abstraction are low.

For this to occur, the following are recommended:

a. All abstraction points, regardless of volume are metered. The introduction of new legislation on abstraction provides a unique opportunity to fully understand and characterise abstraction pressures in Ireland. Metering should occur for the purpose of information gathering and to demonstrate compliance (or exemption) for licensing purposes. Without reliable and accurate information on water abstraction, it is impossible to fully characterise impacts, and therefore to ensure protection of vulnerable water bodies.

b. To assess the impacts of water abstraction on a local and national scale, accurate abstraction data should be collated by a central agency. This would require a minimum of location and rate of abstraction to be recorded. Ideally, daily extracted volumes should be collated to understand the temporal nature of water abstraction in Ireland.

c. This newly collated data needs to be utilised by the state (e.g. EPA) academia and industry to assess spatial and temporal impacts due to abstraction in Ireland. This data would need to be analysed on a range of spatial (local to regional) and temporal scales (daily to annual).

d. To assist in the collection and analysis of this data, there should be development of an electronic portal (similar to FSU portal – opw.hydronet.com) to a) collate data; b) make it easily available to stakeholders and c) to inform management practices such as the calculation of environmental flows based on catchment characteristics.

e. To improve identification of water bodies and GWDTEs At Risk of abstraction pressures, a Geographical Information System, risk-based screening should occur. For this, publicly available GIS compatible data should be made publicly available including:

    i. Registered abstractions;

    ii. Zones of contribution as delineated for all Irish Water/ NFGWS sources, and private supplies abstracting over a threshold rate; and

    iii. Receptors sensitive to abstraction pressures and environmental flows.

f. To improve understanding on the impacts of water abstraction in Ireland, further collaborative work is needed between hydrologists, hydrogeologists and ecologists in both state agencies and academia to improve knowledge of the links between groundwater characteristics (e.g. flow, pH, temperature) and the ecology of receiving wetlands. This could be achieved with targeted multi-disciplinary funding calls through organisations such as the EPA or GSI.

7.4.2 Legislation

Both in tandem, and following improved information gathering of abstraction pressures, clear consistent and strong legislation is required to safeguard water. In the enacting of a new regulatory regime, there is a unique opportunity to fully safeguard water resources in the face of increased demand, and a changing climate. Many environmental problems with water ecosystems (including over abstraction) are due to water in the environment being an open access resource with few restriction on its use. This must change. To address this, the following recommendations are made:

1. **Consolidation of surface water and groundwater regimes:**

Currently, there is separation in the legislation applying to surface water and groundwater regimes. These need to be consolidated into a Regulation clearly identifying the regulatory regimes applicable to both and in a format easily accessible to non-lawyers and which is kept updated so as to be useful to all users. There is however, no reason why the abstraction and licencing regime needs to make any distinction between surface water and groundwater and the authors can see no justification for such a split. Equally the authors can see no reason why all Water legislation is not concentrated into a single Water Resources Act, modelled on the Planning and Development Act as a single legislative point of reference.

2. **Establishment of a coherent national abstraction register:**

To comply with the WFD and to be in a position to fully assess the impacts of abstraction to water bodies, a comprehensive National Abstraction Register must be established. This should be publicly available to permit analysis of abstraction impacts by interested parties. While there is not a WFD requirement to register all abstractions (exempting ones that have "*no significant impact on water status*"[461]), there is an inherent need to assess all abstractions to decide which ones are significant. This could form the basis of a registering process which encompasses all abstraction points. If the full impacts of water abstraction are to be understood, this register should contain all abstraction points, and not just licensed ones.

This register needs to be placed on a statutory footing with a central designated agency that serves as the focal point for all abstraction and licencing activities and maintains the register. This central agency should address the current deficits in the Register as a matter of urgency.

Technical Details

a. All abstractions points, regardless of volume, are included on the register.

[461] Water Framework Directive (2000/60/EC)

Management Details

b. The agency in charge of the register needs to be resourced and empowered to collate extant abstraction data from *inter alia* local authorities, the IPC regime administered by the EPA, Geological Survey and NFGWS.

c. That agency needs to be resourced to investigate non-declared or currently unknown abstraction pressures and to require the compilation of data from those abstraction points in a format agreeable to it.

d. That agency needs to be given enforcement powers and a right of entry to private property in relation to its abstraction and licencing function.

e. Small abstractions of less than 10 m^3/day are included on the register, but do not need licensing. Instead, similar to Scotland and Northern Ireland, users must comply to general binding rules to minimise impacts and demonstrate that volumes abstracted are not sufficient to require licensing.

f. The database must be made publicly available.

3. Establishment of a coherent licencing regime:

To comply with the WFD, to accurately measure abstraction volumes, and to be in a position to fully assess the impacts of abstraction to water bodies, a coherent licencing regime must be established. This needs to be risk-based (on comprehensive and accurate data) sufficiently flexible and responsive to the particular situation, and take into account cumulative impacts, periodicity, and requirements for responsiveness to rapid change within the water system. It also needs to address legacy issues through the review of existing abstractions.

This licencing regime needs to be placed on a statutory footing and vested in a central designated agency with all abstractions likely to pose a risk to water environments captured within the licencing regime. For this, the authors recommend those abstractions over 10 m^3/day to be included within the licencing regime, alongside abstractions identified within a vulnerable water body where risks of abstraction pressure have been identified. This *de minimis* level of 10 m^e/day is chosen in the absence of adequate scientific data that can provide a rigorous threshold of safe values, but should capture most significant points of abstraction, is currently a threshold value for exempted supplies in the Surface Water Regulations, and is in keeping with thresholds for countries with a similar climate to Ireland (Scotland and N Ireland). This de *minimis* level should change based on the information gathered from abstraction points (Section 7.4.1) Technical assessments must show that both groundwater and surface water abstractions, in terms of both their overall rates and abstraction regimes, do not compromise environmental flows and levels in water bodies. This relies on further work to develop ecology-flow relationships. Priority should be given to high-status sites, and sites on the threshold between good and moderate status, as well as those for which the qualifying interests may be sensitive to hydrological change. Significant work has been done by the Geological Survey in estimating recharge rates across a range of hydrogeological settings and this work is ongoing. These studies will enhance our understanding of the sustainability of specific abstractions.

Given most small abstractions discharge to the same water body as abstractions occur the authors believe it is impractical and onerous to licence less than 10 m^3/day, with the exception of vulnerable water bodies or sensitive areas,.

For this licencing regime, the following is recommended:

a. Licensing is introduced on a phased basis with the aim of protecting water bodies, and is based on accurate information.

b. This regime should be predicated on bi-annual renewals allowing regular oversight of the abstraction and licencing pressure on any given water body.

c. All abstractions greater than 10 m^3/day (or subsequent risk-based threshold value) should be licensed. A means of demonstrating compliance or exemption from this threshold is required (i.e. metering).

d. Proposed abstractions over 100 m^3/day should be further reviewed by a competent agency (e.g. local authority/EPA). This should include assessment of potential impact on groundwater flows and levels, surface water flows and levels, and an Ecological Impact Assessment.

e. Information on location of abstraction point and rate of extraction (daily, or at a minimum, monthly rates are required) must be provided, including existing abstraction points.

f. In order to address spatial and temporal variability regarding abstraction impacts, this licensing regime should be flexible to permit greater scrutiny where impacts of abstraction are likely to be greatest, particularly: in water bodies identified as "At Risk" from water abstraction; in areas close to GWDTEs; in regions of low precipitation and low GW recharge rate; and in regions due to cumulative impacts from abstraction or where knowledge of impacts are unknown. Where required, this would include abstractions below $10m^3$/day in these areas. The following is specifically recommended:

    i. A flexible licensing regime must be in place for abstractions below 10 m^3/day in vulnerable water bodies, sensitive areas, or where cumulative impacts are likely.

    ii. Abstractions from designated protected areas should be liable for further technical assessment. SACs and SPAs should be subject to an Appropriate Assessment regardless of volume extracted and abstractions from NHAs should also be subject to an Ecological Impact Assessment.

    iii. Abstractions greater than 10 m^3/day and less than 100 m from a GWDTE would require further technical assessment to determine specific impact on water body and any mitigating measures necessary with input from NPWS or independent ecologist.

g. All water bottling plants should be licensed and included on a national register regardless of the abstracted volume.

h. Finally, it is recommended that the licensing authority have the power to designate particular water bodies or catchment areas as areas of significant concern and prescribe bespoke conditions for those areas, even for *de minimis* levels of abstraction until 'good status' had been restored.

7.4.3 Stakeholder Engagement

Stakeholder engagement is absolutely critical for the success of any abstraction regime enacted by the state. Broad categories of stakeholders exist, from individual citizens to large, multi-national corporations and their specific requirements need to be acknowledged and their engagement actively encouraged. In this study, while it is extremely important to note the small sample size of stakeholders that responded to our survey, there was a majority view on the absence of reliable information on water abstractions, and a recognition for the need of a risk-based licensing system to be integrated with forward planning. While responsibility for the design and execution of the regulation rests with the competent authority, increasing understanding by stakeholders of challenges posed by water abstraction that must be addressed allows for stakeholder input in the development of the most effective mitigation measures and ultimately to a greater level of support and compliance with these.

Only once people appreciate their interest in aquatic resources; the finite and integrated nature of these, the pressures on them and the associated risks, etc. can they then begin to engage productively (see b. below). Awareness of the need to manage these resources and human interactions with them in a holistic sense is vital. While aspects of this can then be considered individually, such as abstraction, it is important to see how they are interconnected. In parallel with this awareness-raising work, regulation that requires registration and metering will generate information and consequently a better understanding of the abstraction taking place. These together will then support productive engagement with stakeholders in refining the more sophisticated and responsive elements of abstraction control in the regulation regime. For example, if it becomes clear that abstraction is resulting in negative pressures on a particular water-body, or water-body type, then stakeholder representatives should have a role in discussions at an appropriate scale to generate effective controls to alleviate these pressures.

To achieve this requires:

a. Initiation of an enduring information and awareness-raising campaign to win the hearts and minds of citizens to an understanding the shared nature of our water resources and the complex interdependencies involved in its status. This must develop and increase the appreciation amongst the population of their stakeholding in water matters, including why being prepared to protect and conserve aquatic environments is vital. Abstraction is one part of this picture.

b. Active engagement with stakeholder representative bodies should also be enabled and included in the regulatory regime. The above awareness-raising work is a necessary pre-requisite to this; enabling organisations to fully understand the nature of aquatic resources and the extent of their interests in them, and the pressures on them.