Supporting document

Groundwater Draft Classification Methodology Overview 2020/2021

***Sustainability** at the heart of a living, working, active landscape valued by everyone.*

NIEA Northern Ireland Environment Agency
www.daera-ni.gov.uk

An Agency within the Department of Agriculture, Environment and Rural Affairs
www.daera-ni.gov.uk

Groundwater Classification Methodology Overview

Background

Groundwater is an important water resource supporting local industrial and private supplies through abstraction from boreholes, wells and springs. It is also used as a source for public supply on Rathlin Island. In addition, it plays a significant role in supporting surface water flows and levels through natural discharge from the ground to rivers, lakes, streams and wetlands. This contribution to surface waters can also act to dilute pollutant concentrations in the surface water, therefore helping support the overall ecological and amenity value of these systems. On the other hand, groundwater can be a pathway for pollutants that have entered groundwater in vulnerable areas and thus reaching sensitive receptors like surface water or wetlands. The process of managing land use and water resources together is often referred to as integrated catchment management.

The European Water Framework Directive (2000/60/EC) (WFD) requires the status of groundwater management units (groundwater bodies) within each river basin to be determined as 'good' or 'poor'. This document summarises the approach taken to determining status for groundwater bodies in Northern Ireland, the results of which are reported in the draft River Basin Management Plans 2021-2026.

Groundwater Body Delineation

Groundwater bodies were first delineated across Northern Ireland as part of the WFD Article 5 assessment for the assessment and management of the available groundwater resources. The bodies were assigned to specific River Basin Districts (RBDs) and in some places extend across the border between Northern Ireland and the Republic of Ireland according to their natural hydrogeological boundaries. Further information on the methodology used for groundwater body delineation can be found on the UKTAG website in the document titled: *'Defining & Reporting on Groundwater Bodies'.* Some groundwater bodies were re-delineated for the second river basin planning cycle as more detailed geological mapping had become available and superficial groundwater bodies were introduced too. More details are available in the document entitled: *'Proposed water boundary changes for the second river basin plans'* on the DAERA webpage. The distribution of groundwater bodies can be seen on our interactive maps on the River Basin Plan Map Viewer on the DAERA webpage.

The aquifer classification system used in Northern Ireland is based on geological strata types, relative resource productivity and flow types. The classification scheme was published and implemented by the Geological Survey of Northern Ireland in 2004 on behalf of the Environment and Heritage Service (the predecessor organisation of the Northern Ireland Environment Agency). More details can be found in the publication 'Water Framework Directive – Aquifer Classification Scheme for Northern Ireland' produced by the Geological Survey of Northern Ireland (see also appendix 2).

Pressures on Groundwater

Whilst the pressures from groundwater abstraction in Northern Ireland are generally much less than many parts of the United Kingdom and Republic of Ireland, any abstraction of groundwater has the potential to impact water levels or flows at nearby rivers, lakes or wetlands. For this reason it is important to have knowledge of where abstraction takes place and how much water is being abstracted. It is then possible to construct a 'water balance' for groundwater bodies and associated sub-catchments, comparing inputs (recharge) against outputs (abstraction and flows required to support dependent ecology). See appendix 1 for more information on groundwater recharge.

The natural 'quality' of groundwater is such that it is usually suitable for drinking without or with only minimal treatment being required. This is partly due to the filtration and other natural processes that occur as water passes slowly through the geological strata. There are, however, a wide variety of activities that occur within the river basin districts that have the potential to impact on this natural quality and cause the groundwater to become polluted to varying degrees.

Diffuse pressures include agricultural activity where overuse of organic and inorganic fertilisers can lead to elevated concentrations of nitrate and phosphorus. The overuse or inappropriate disposal of pesticides can lead to detections of pesticide compounds in groundwater. Such substances can also enter groundwater where they are used in association with amenity, infrastructure or forestry land use.

Point sources such as industrial sites where hydrocarbons or solvents are used or stored can also result in local impact on groundwater quality if a pollution event occurs. Impacts on local groundwater quality can also occur in the vicinity of waste management sites e.g. landfills where leachate generated in the waste mass leaks to the underlying water table. Similarly, percolation from land contaminated by industrial use can result in deterioration in groundwater quality. Other activities that can lead to local impacts on groundwater quality include the illegal dumping of waste or other hazardous materials and the poor siting, construction or maintenance of septic tanks. Considering that Northern Ireland has approximately 130,000 onsite waste water treatment systems, these point sources may compound into a diffuse-type source.

The likelihood that groundwater beneath a particular locality or within a specific catchment will be impacted from surface activity also partly depends on the nature of the soils and geological material above the water table in addition to the nature of the strata in which the groundwater is stored. This last factor can also influence how widespread an impact may extend from a particular pollution event. How likely underlying groundwater in a particular location would be impacted from pollution occurring from surface activities is partly described as groundwater vulnerability. By considering the different nature of the soils and sub-soils in a specific area, 'groundwater vulnerability' can be mapped to show where groundwater is more or less likely to be impacted. Where the strata containing the groundwater (the aquifer) is overlain by thick deposits of poorly draining clayey material and clay-rich soils then the groundwater is protected to some degree (but not necessarily entirely) from impact and vulnerability is usually considered to be low. Where the water table is very close to the surface or where the material comprising or overlying the aquifer is more permeable and allows drainage readily through it then groundwater is more vulnerable.

Groundwater Monitoring

Groundwater quality in Northern Ireland is assessed in accordance with NIEA's groundwater monitoring programme through the collection of water samples from boreholes and springs that are mostly owned and operated by third parties. The public water supply provider (Northern Ireland Water) does not currently utilise groundwater with the exception of Rathlin Island, a small island off the north coast of Northern Ireland. Hence NIEA rely mostly on third party boreholes and the co-operation of land/ property owners to continue sampling from their groundwater sources for the chemical monitoring. This means that the network can change due to businesses closing or changing their groundwater usage and datasets for trend assessments are often small. The network consists mainly of industrial boreholes where groundwater is utilised for manufacturing or food/ drinks production. A small number of springs or boreholes purpose-installed by NIEA, which are purged prior to sampling, are also monitored. The selection of monitoring stations to date has been based on a pressure-pathway assessment of the groundwater bodies and the availability of potential monitoring points.

Regional monitoring of groundwater across Northern Ireland began in 2000. A major review of the network was undertaken in 2007 and is summarised in the document titled: *'Approach to Groundwater Monitoring for Northern Ireland, United Kingdom to meet the requirements of the Water Framework Directive'* published by the Environment and Heritage Service in February 2007. The emphasis during the 2021-2026 cycle will be on maintaining and increasing the spatial distribution of the network.

The WFD requires the operation of three monitoring programmes:

- Surveillance: core suite, parameters indicative of risks;
- Operational: parameters where groundwater body at risk achieving objectives; and
- Drinking Water Protected Area monitoring: to identify any deterioration in the quality of abstracted water that may potentially lead to an increase in the level of purification/ treatment. Monitoring is required in groundwater bodies where more than 100 m^3/d is abstracted for drinking water purposes. Often potable sources used for food/ beverage production are part of the regional groundwater monitoring network.

Due to the finite number of stations forming the network, these programmes have been combined into one. The location of the stations can be viewed on the DAERA website using the River Basin Plan Map Viewer. The monitoring frequency and selection of determinands follows UKTAG guidance. Each station monitored was analysed twice a year for the core suite consisting of dissolved oxygen, pH-value, electrical conductivity, nitrate, ammonium, temperature, phosphorus and a suite of major ions. A suite of trace ions was monitored once a year. Based on their risk, assessment stations were also monitored once a year for either diffuse pressures (pesticides) or urban pressures (hydrocarbons, PCB, semi/-volatile organic carbons).

Results of monitoring data can be requested by contacting DAERA through WaterInfo@daera-ni.gov.uk.

Data from the groundwater monitoring network was used to identify or help determine actual impact on groundwater quality, and trends for certain parameters to see where impacts may be beginning to occur or further deteriorating.

Groundwater Classification

All groundwater bodies were classified using a number of tests determining chemical and quantitative status. These tests are shown schematically in Figure 1. Figure 1 also shows that a single failure of any test results in the overall failure of status; that is the so-called ‘one out, all out’ principle.

Classification was undertaken following the WFD United Kingdom Technical Advisory Group (UKTAG) guidance to ensure consistency in assessment across the UK and Republic of Ireland (for cross-border bodies) and across different river basin districts. This guidance follows overarching guidance produced at European level. An overview of the classification process and more details on each test can be found in the following UKTAG papers (www.wfduk.org):

- Paper 11 b(i) Groundwater chemical classification March 2012
- Paper 11b(ii) Groundwater Quantitative Classification March 2012

To enable classification to be undertaken properly, it is important to consider the relationship between groundwater bodies, the surface water bodies and wetland systems to which they eventually discharge to. Hence in addition to considering resource availability and the general quality of groundwater within the body, it was also necessary to understand where nearby surface water systems were under stress and/ or not meeting their environmental objectives and consider whether the volume or quality of groundwater discharging was a significant contributory factor to this impact.

Separate classification methodology statements are available for:

- Groundwater classification methodology: Drinking Water Protected Area test.
- Groundwater classification methodology: general chemistry.
- Groundwater classification methodology: saline intrusion.
- Groundwater classification methodology: Groundwater dependant terrestrial ecosystem (GWDTE).
- Groundwater classification methodology: water balance.
- Groundwater classification methodology: surface water – qualitative test (chemical test).
- Groundwater classification methodology: surface water – quantitative test.
- Groundwater classification methodology: trend assessment, points for trend reversal.

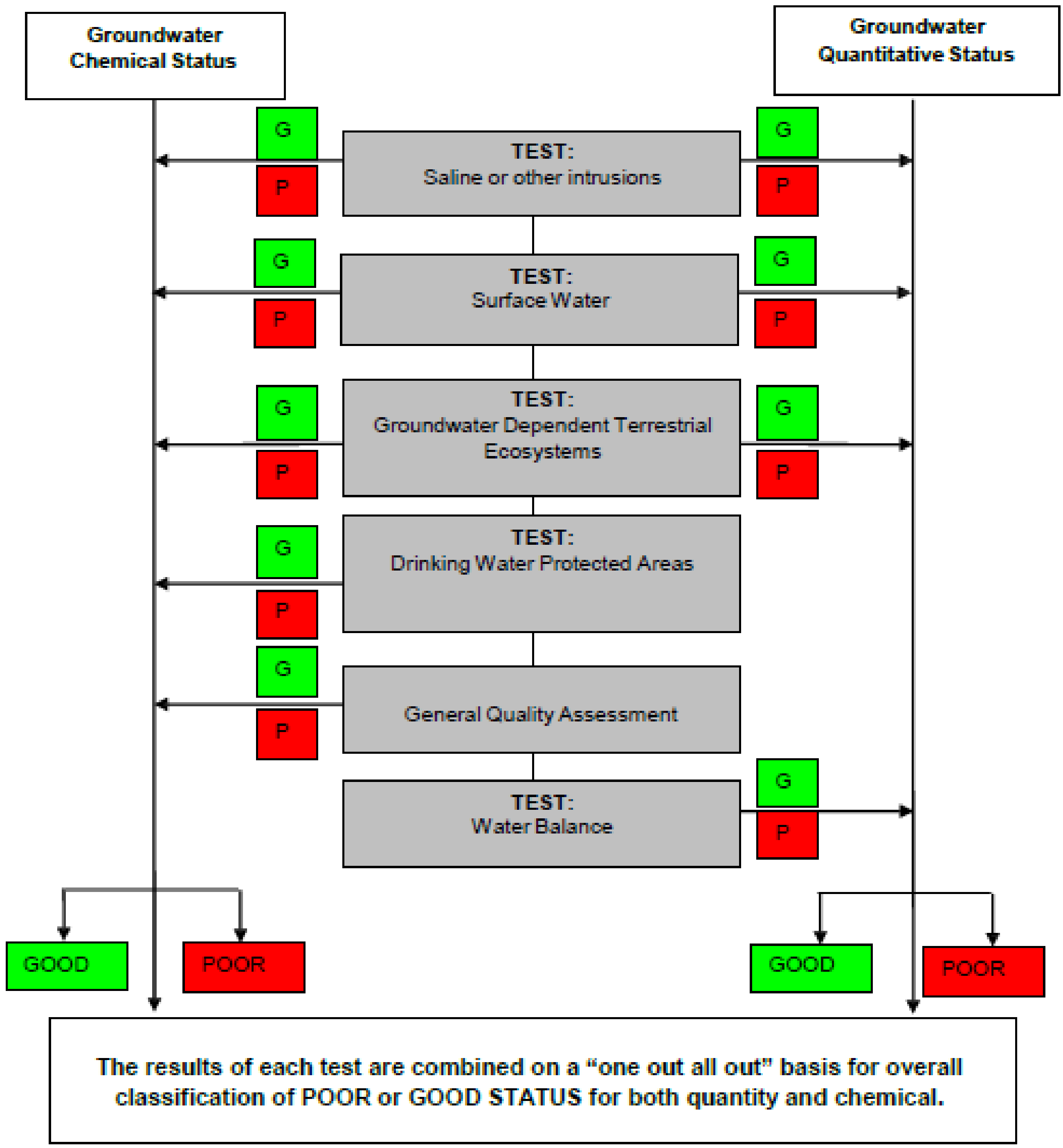

Figure 1: Overview of the groundwater classification process

Appendix 1 – Information on groundwater recharge as derived by the Geological Survey of Northern Ireland

Estimating recharge to groundwater is complex and difficult. It is dependent upon rates of rainfall, evaporation, transpiration, permeability and thickness of soil, and various hydrogeological properties of the saturated material that constitute the groundwater body.

There is no 100 % fail safe method to calculate recharge rates. The most accurate way of estimating or monitoring recharge is to have an entire groundwater body densely covered by observation boreholes that record accurate changes in groundwater levels, whilst having a very clear understanding of how the storage properties of the saturated groundwater body material vary both spatially and with depth. A groundwater level increase of 1 m in a sandstone aquifer with a storage coefficient of 20 % would equate to a recharge of 0.2 m^3 or 200 litres. Over 1 km^2 this would be 200,000 m^3. Most groundwater bodies tend to be heterogeneous and therefore the properties at one location may be very different than those somewhere else.

This ideal scenario is unrealistic and therefore different methods are required using spatial data to estimate groundwater recharge. It is important to note that any recharge values derived from spatial data are only estimates. Verification using groundwater levels can help to improve confidence in estimates but it is important to consider the level of confidence in the estimation methods when using them as part of a decision making tool.

A research project was undertaken by Gibson (2010) and Neary (2012) to study different methods of estimating groundwater recharge on a regional scale. This included a method adopted by the Republic of Ireland using groundwater vulnerability as a proxy for rates of groundwater recharge. This method involved that derivation of infiltration coefficients by targeted research on different sub-soil types. Slightly different groundwater vulnerability systems are applied in the Republic of Ireland and Northern Ireland. Expert judgment was used to link the Northern Ireland vulnerability categories to the Republic of Ireland infiltration coefficient system to derive a potential recharge map.

Evaluation of this potential recharge map showed that the average groundwater recharge per groundwater body was markedly different from the previous method applied for 2009 classification. This in itself does not conclude that one method is more accurate than the other but it did initiate a more detailed analysis of the two methods. It was found that the base flow index method previously used was likely to be more accurate as it relied upon the HOST dataset, which itself was derived from 1:50,000 scale soils mapping. The groundwater vulnerability mapping was derived from less accurate 1:250,000 scale superficial geology mapping. The application of infiltration coefficients to the groundwater vulnerability mapping was also thought to be a potential source of error.

The base flow indices method was applied to derive a secondary potential recharge map. It was recognised that all of the input datasets were spatially distributed and it was decided to apply the method on a 1 km^2 grid to allow the spatial distribution to remain. Upper limits of 200 and 100 mm/annum were placed on low and poorly productive aquifers grid squares respectively due to their likely inability to receive all of the groundwater recharge.

A multiplication factor of 0.82 was applied to actual evapotranspiration (AE). This was previously 0.95 from studies by Daly (1994) which suggested that annual AE for grassland in Ireland is typically about 95% of potential evapotranspiration (PE). However, more recent studies (Kennedy, 2010) indicated that this factor was more likely 0.82.

The equation used to derive recharge was:

Groundwater Recharge = Base Flow Index · (Rainfall – 0.82 · PE)

The 1 km^2 grid squares were then averaged to derive a single recharge rate for each groundwater body, which are given in the table below.

bedrock/ superficial groundwater body	name of groundwater body	recharge mm/ a
bedrock	Anierin- Cuilcagh East	141
	Antrim	193
	Ards Peninsula	148
	Artikelly	324
	Aughnacloy	193
	Ballinamore- Swanlinbar	181
	Ballintempo	203
	Ballybofey	169
	Ballycastle-Armoy	331
	Ballymena	332
	Ballyshannon East	132

	Ballyshannon South	549
	Belcoo-Boho	378
	Belfast mid (Belfast City)	173
	Belfast east (Scrabo)	104
	Belfast west (Lisburn)	185
	Belfast Hills-Islandmagee	210
	Bundoran	189
	Castlecaldwell Forest	185
	Castlederg	186
	Claddagh-Swanlibar	92
	Claudy	193
	Clones	107
	Coleraine-Kilrea	282
	Conagher Forest	386
	Cookstown	231
	Cooneen Water	178
	Creagh	346
	Crilly	188
	Crom Castle	125
	Derrygonnelly	332
	Derrylin	132
	Donagh	345
	Downpatrick	178
	Ederney	244
	Enniskillen	284
	Fairhead	240
	Florence Court-Drumgormley	182
	Glen Bridge	278
	Glenariff	398
	Gortin	198
	Irvinestown	205
	Keady	125

	Kilcoo	268
	Knockatallon	73
	Lough Swilly	200
	Louth	188
	Magheraveely	151
	Magilligan	273
	Marble Arch	320
	Monaghan Town	92
	Moneymore	323
	Moygashel	202
	Neagh	46
	Newry	183
	Newtown-Ballyconnell	208
	Omagh	232
	Pettigo	480
	Rathlin	325
	River Foyle	200
	Rossinver	177
	Slieve Rushen	294
	Slieve Rushen South	125
	Tandragee	171
	Tempo	319
	Tullaghan-Lough Melvin	221
superficial	Derrylin Complex	379
	Enler Valley	172
	Faughan	313
	Lagan Valley	195
	Magilligan Sands	371
	Main Valley	373
	Mourne Plain	318
	Murlough Sands	458
	Shanmoy	226

	Derrylin Complex	379

References

Daly, E. P. (1994) *Groundwater resources of the Nore River basin*. Geological Survey of Ireland, Unpublished draft GSI report.

Gibson, E. (2010) *A Review of Groundwater Recharge Estimation Methodologies for Northern Ireland.* MSc Thesis submitted to The Queen's University of Belfast

Kennedy, E. (2010) *An Analysis of Evapotranspiration Calculations in South East Ireland.* Dissertation Presented to The Department of the Civil, Structural and Environmental Engineering, Trinity College Dublin, in partial fulfilment of the Requirements for the Degree Masters of Science, Civil Engineering.

Neary, J.E. (2012). *Recalculation of Groundwater Recharge within Northern Ireland.* Internal report for The Geological Survey of Northern Ireland.

Appendix 2 – Assigning the main geological formation of the aquifer to each groundwater body

Aquifer classification in Northern Ireland is based on a methodology and associated report by the Geological Survey of Northern Ireland: *'Water Framework Directive: Aquifer classifications scheme for Northern Ireland'*, 2004.

The classification comprises eight classes of aquifers based upon geological strata type, relative resource productivity and flow type.

aquifer category	symbol	description	geological formation as per WFD reporting guidelines 2016
bedrock			
high productivity fracture flow	Bh (f)	High to moderate yields probable, however dependence on fracture flow makes poorer yields possible. Generally includes element of regional flow (km's).	fractured aquifers – highly productive
high productivity fracture/ intergranular flow	Bh (I-f)	High to moderate yields probable, however part dependence on fracture flow makes poorer yields possible. Dual porosity. Generally includes element of regional flow.	fractured aquifers – highly productive
high productivity fracture flow with karstic element	Bh (f-k)	High to moderate yields probable, however dependence on fracture flow makes poorer yields possible. Evidence of karstic flow. Generally	fissured aquifers including karst – highly productive

		includes element of regional flow.	
moderate productivity fracture flow	Bm (f)	High to moderate yields possible in places however dependence on fracture flow makes poorer yields possible. Potential element of regional flow, but local flow significant.	fractured aquifers – moderately productive
limited productivity fracture flow	Bl (f)	Moderate yields unusual. Low yields more common. Regional flow limited. Mainly shallow, local flow.	insignificant aquifers – local and limited groundwater
poor productivity fracture (flow)	Bp (f)	Small supplies may be possible but strata rarely exploited. Negligible regional flow. Limited local flow.	insignificant aquifers – local and limited groundwater
superficials			
high productivity intergranular flow	Sh (I)	High to moderate yields probable in most areas. Permeability high.	porous – highly productive
moderate productivity intergranular flow	Sm (I)	Moderate yields possible. Permeability moderate.	porous – moderately productive

Table A2:1 Northern Ireland aquifer classification and corresponding geological formation as per WFD reporting guidelines.

The aquifer classification layer was converted into a 1 km^2 raster file in ArcGIS. Then the percentage area of each aquifer type within every groundwater body was determined. The geological formation corresponding to the majority aquifer type as per Table A2.1 above was reported for each groundwater body.

Information on the geochemistry of Northern Irish aquifers is available from Robins (1996).

References:

Robins, N. S. (1996) *Hydrogeology of Northern Ireland*. London: HMSO for the British Geological Survey

McConvey, P. J. (2004) Water Framework Directive (2000/60/EC): *Aquifer classification scheme for Northern Ireland*. Commissioned report for Water Management Unit, Environment and Heritage Service, Department of Environment Northern Ireland

Northern Ireland Environment Agency
www.daera-ni.gov.uk

For further information:

Land and Groundwater Team, Regulation Unit
Klondyke Building
Cromac Avenue
Gasworks Business Park
Malone Lower
Belfast
BT7 2JA

Tel: 028 9056 9348
Email: LGWinfo@daera-ni.gov.uk
www.daera-ni.gov.uk

An Agency within the Department of
Agriculture, Environment and Rural Affairs
www.daera-ni.gov.uk