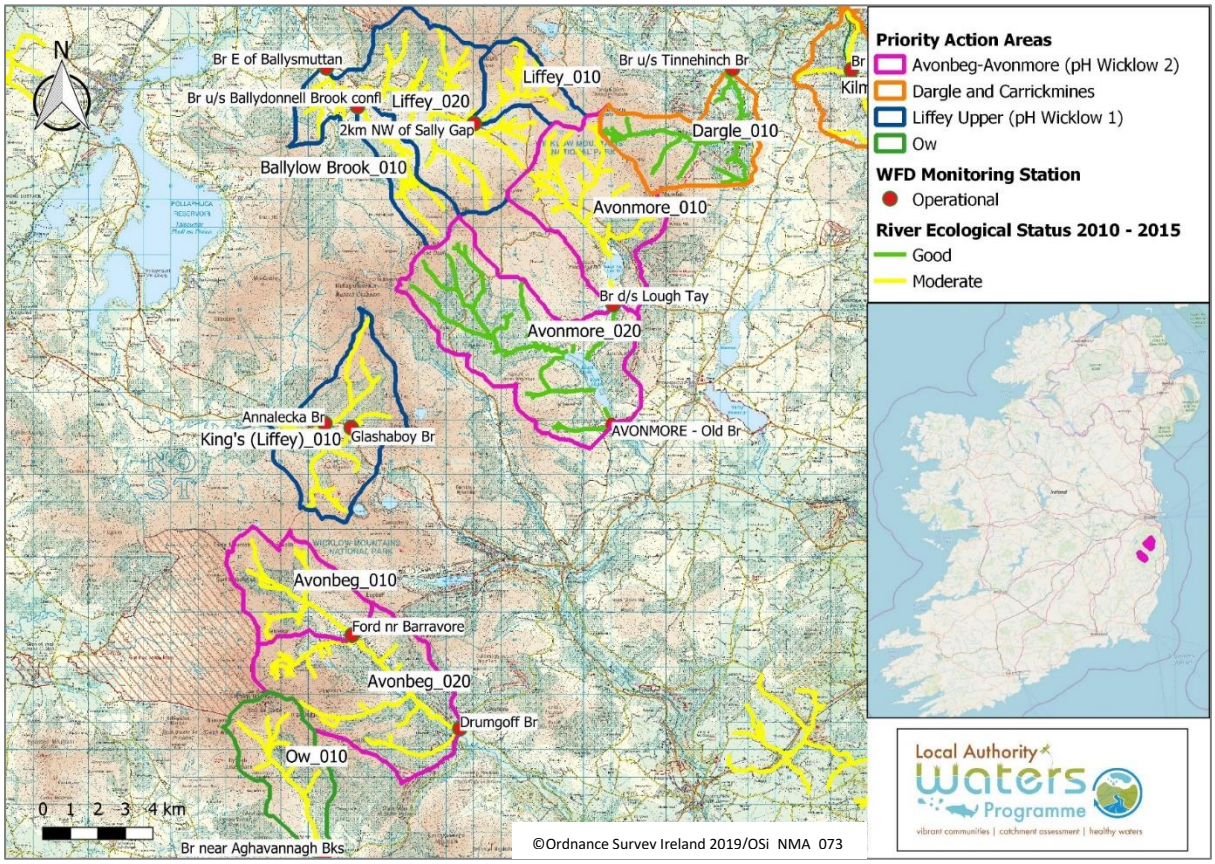

Avonbeg – Avonmore (AFA0012) Priority Area for Action

Desk Study Report

March 2020

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Acknowledgements

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1 Non-technical Summary

Avonbeg-Avonmore Priority Area for Action (PAA) consists of four waterbodies located in the east part of the Wicklow Mountains. Avonbeg_010 and Avonbeg_020 form the headwaters to Avonbeg River; and Avonmore_010 and Avonmore_020 form Cloghoge River being headwaters to Avonmore River. All four waterbodies are *At Risk* of achieving their Water Framework Directive (WFD) environmental objectives by 2021. Avonmore_010 and Avonmore_020 are High status objective waterbodies (Blue Dot Catchments) and their recent biological conditions indicate Good biological status. Avonbeg_010 and Avonbeg_020 (both having environmental objective of Good ecological status) achieve good or high biological conditions. Despite Good biological conditions, physico-chemical measurements taken at the three waterbodies (Avonmore_010, Avonbeg_010, Avonbeg_020) indicate failing acidification conditions, which is the main driver for Moderate 2010-2015 ecological status for these sites. Most recent 2013-2018 Ecological Status improved to Good at these three waterbodies (Avonmore_010, Avonbeg_010, Avonbeg_020). This is due to satisfactory acidification conditions during those years. Waterbodies are however still *At Risk*, due to possible failure of acidification conditions in the future cycles.

Review of the physico-chemical data from the Environmental Protection Agency (EPA) confirms that significant issue for these waterbodies is low pH values, which occasionally fall below 4.5 pH Ecological Quality Standard (EQS) threshold failing WFD acidification conditions. Additionally, biological assessment data indicate that peat siltation is a significant issue potentially affecting biological conditions (moderate siltation was identified at Avonmore_020 during 2015 biological survey, with slight to moderate siltation reported for Avonmore_010 and Avonbeg_020). 50% filamentous algae cover was recorded in 2018 Q-value assessments in Avonmore_020 indicating potential nutrient enrichment at this site.

Low alkalinity values measured across three waterbodies (Avonmore_010, Avonbeg_010 and Avonbeg_020) indicate that this area naturally shows very little buffering capacity for pH fluctuations. This is because of siliceous nature of the surrounding geology, where Igneous lithological groups dominate, which usually show lowest pH values in groundwater in Ireland. With shallow aquifers, low permeability rocks, poorly drained and peaty soils and steep topography these waterbodies are rather 'flashy' in nature with potential of higher drainage density and low buffering capacity. Surface runoff through peaty soils can increase levels of naturally occurring Dissolved Organic Carbon (DOC), which can further contribute to lower pH in the aquatic system.

Natural sensitivity to acidification of this area is enhanced by the presence of forestry, which was identified as a main pressure for the Avonbeg_010 and Avonbeg_020 waterbodies. Historically, acidification has been caused by the anthropogenic emissions and the ability of tree canopies to capture more sulphur and nitrogen pollutants from the atmosphere than other types of vegetation, leading to increased deposition of sulphur and nitrogen oxides at the conifer forests and their release to surface waters. With significant reductions in acid deposition since the 1980s, organic acids such as increased DOC content are now believed to be the main driver for the current acidification conditions. Increased DOC levels may be associated with the hydrological changes to the catchments (drainage associated with forestry establishment) leading to an increased surface runoff and less water contact time thereby reducing the chance of natural buffering reactions to occur. Increased DOC levels can be also a result of drying of the peaty soils leading to the oxidation and mineralisation of organic matter and therefore increased release of DOC. In Avonmore_010 (with reduced forest cover), EPA identified atmospheric deposition as the main pressure affecting acidification. Agriculture and forestry were also identified as significant pressures here that could affect river habitat, which may be the cause of

siltation issues. In Avonmore_020 forestry clearfelling operations were identified as a significant pressure.

Biological surveys are planned for Avonmore_010 and Avonmore_020 (High status objective waterbodies) to identify locations of potential change between High and Good biological conditions. This will include assessment of siltation issue. Furthermore, planned clearfell activities will be reviewed with the recommendations on increased awareness and measures to assure maintaining good biological conditions. Acidification impacts will be reviewed by the EPA pH Review Programme, which focuses on the assessment of the impacts of pH on Ecological Status in Wicklow acid sensitive waterbodies. Avonbeg-Avonmore, Liffey Upper and Ow PAAs are included in the EPA pH Review Programme. LAWPRO will assist the EPA pH Review Programme through the Local Catchment Assessment in selected waterbodies of the programme.

2 Introduction

2.1 Background to the Priority Area for Action (PAA)

Avonbeg-Avonmore is one of the 29 areas recommended for action in the Midlands and Eastern Region. It was selected during regional catchment assessment workshop in May 2017 based on the draft River Basin Management Plan priorities, a set of agreed principles and the local priorities. Workshop attendees included representatives of Local Authority staff, Local Authority Waters and Communities Office (LAWCO) (now part of the Local Authority Waters Programme LAWPRO), Irish Water, Inland Fisheries Ireland, Forest Service, Coillte, National Parks and Wildlife Service, Teagasc, Department of Housing Planning and Local Government, Geological Survey Ireland, National Federation of Group Water Schemes, Department of Agriculture, Food and Marine, Bord na Mona, Waterways Ireland and Environmental Protection Agency. The Avonbeg-Avonmore PAA was selected as a priority area for action in the 2nd cycle. The EPA report includes the following reasons:

• 2nd pH project to link to the other Wicklow pH project (Liffey Upper PAA). Four deteriorated water bodies.
• Two High Ecological Status objective water bodies. Headwaters to the Avonbeg and Avonmore rivers.

Avonbeg – Avonmore Priority Area for Action (PAA) is located within Wicklow County and consists of four waterbodies all being *At Risk* of achieving Water Framework Directive (WFD) environmental objectives: Avonmore_010, Avonmore_020, Avonbeg_010 and Avonbeg_020 (Figure 1), all being headwaters to Avonmore and Avonbeg Rivers.

Avonmore_010 (waterbody size 21.7km^2), also known as Cloghoge River, rises in the Wicklow Mountains north west of Roundwood. It flows south through Lough Tay and into Lough Dan located in Avonmore_020 waterbody. Cloghoge Brook_010 tributary (not included in the PAA) joins Avonmore_010 between the two lakes. Avonmore_020 waterbody (waterbody size of 34.4 km^2) includes Inchavore River west of the Lough Dan and Cloghoge River both of which flow into Lough Dan to form Avonmore River. WFD status objectives for both waterbodies (Avonmore_010 and Avonmore_020) is to achieve High ecological status by 2021.

Avonbeg _010 (waterbody size 13.9 km^2) and Avonbeg_020 (waterbody size 27.2 km^2) both form headwaters of Avonbeg River, which also rises in Wicklow Mountains but further south (at Camenabologue Mountain) in the area south west from Glendalough. Avonbeg flows south east and joins Avonmore at the Meeting of the Waters to form Avoca River which discharges to the Irish Sea at Arklow.

2.2 Information Sources Consulted

Several information sources were consulted during the preparation of the desk study for the Avonbeg-Avonmore PAA including:

- WFD web application – EPA characterisation data and water quality data,
- Mobile Monitoring Unit (MMU) assessments (CDM Smith, 2015; O'Keeffe and Barrett, 2013; Ryan and Jordan, 2010),
- Research data (Aquafor Literature Review (Johnson *et al*., 2008); Hydrofor Project (Kelly-Quinn *et al*., 2016); and long-term monitoring data of rainfall and throughfall in Wicklow Mountains (Johnson *et al*., 2013),

- Forest Service data,
- Coillte information,
- Geological Survey Ireland (GSI) information (Tedd *et al*., 2017 and personal communication),
- EPA information.

2.3 PAA Summary Information

A summary of risk, ecological status, known pressures and associated significance for the Avonbeg – Avonmore PAA are presented in Table 1.

The initial characterisation recommended that the following actions be undertaken:

Avonbeg_010:

- IA1 Provision of Information (FC003194, Environmental Protection Agency):
  Water body to be included in the pH review.

Avonbeg_020:

- IA1 Provision of Information (FC003195, Environmental Protection Agency):
  Water body to be included in the pH review.

Avonmore_010:

- IA1 Provision of Information (FC001546, Environmental Protection Agency):
  The EPA will include this assessment as part of a pH review.
- IA8 High status RWB pressures (FC001545, LAWPRO):
  Focus local catchment assessment on forestry and sediment sources and transport and, in particular, areas which have been recently clearfelled. Locations where animal access is occurring should also be identified. Overall with the exception of pH, acidification and sediment, water quality is considered to be good and this is corroborated by external water quality and SSRS data.

Avonmore_020:

- IA8 High status RWB pressures (FC001549, LAWPRO):
  To undertake this local catchment assessment in conjunction with the assessment of forestry activities in AVONMORE_20. Focus assessment on forestry and sediment sources and transport and, in particular, areas which have been recently clearfelled.

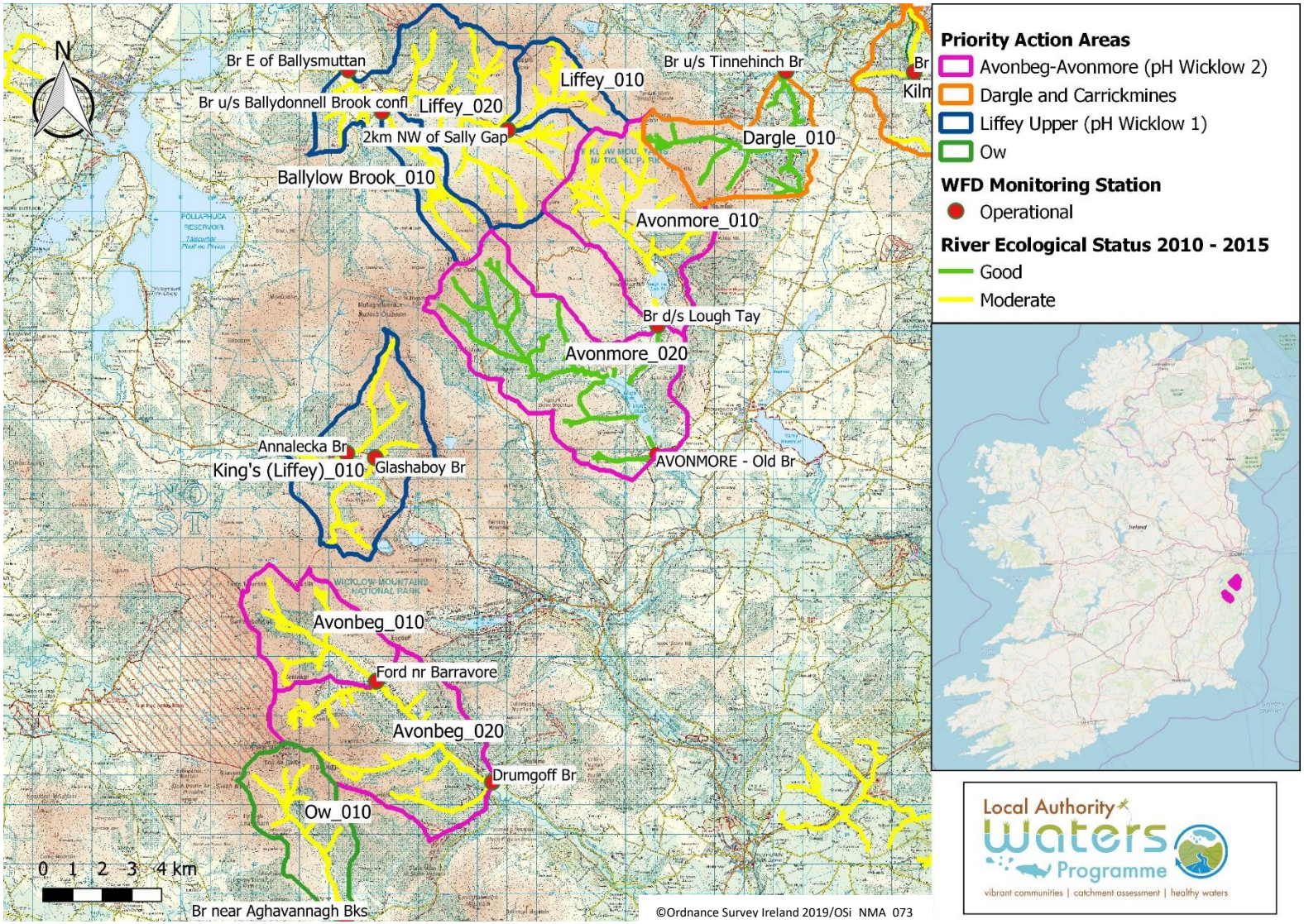

Figure 1 Waterbody catchment areas within the Avonbeg-Avonmore PAA and their neighbouring PAAs. Also shown are the assigned 2010-2015 Ecological Status at each waterbody & the location of EPA monitoring points.

Table 1 Summary of status and pressures for Avonbeg – Avonmore PAA.

WB Code	WB name	WB Type	Risk	High status obj.	Env. Objective date	Ecological Status				No of pressures	Pressure category	Pressure subcategory	Significant pressure (Y/N)
						2009	2012	2015	2018				
IE_EA_10A040100	AVONBEG_010	River	*At Risk*	No	2021	G	G	M	G	1	Forestry	Forestry	Yes
IE_EA_10A040400	AVONBEG_020	River	*At Risk*	No	2021	G	M	M	G	1	Forestry	Forestry	Yes
IE_EA_10A050010	AVONMORE_010	River	*At Risk*	Yes	2021	H	M	M	G	3	Atmospheric	Atmospheric	Yes
											Agriculture	Agriculture	Yes
											Forestry	Clearfelling	Yes
IE_EA_10A050020	AVONMORE_020	River	*At Risk*	Yes	2021	H	H	G	G	1	Forestry	Clearfelling	Yes

WB – Waterbody; H – High; G – Good; M – Moderate.

3 Receptor information & assessment

3.1 Context and Setting

Avonbeg – Avonmore PAA consists of four waterbodies (Avonbeg_010, Avonbeg_020, Avonmore_010 and Avonmore_020), all of which are *At Risk* of achieving their WFD environmental objectives by 2021. Two of these waterbodies, Avonmore_010 and Avonmore_020 are High status objective waterbodies. 2010-2015 Ecological Status deteriorated to Moderate due to failing acidification conditions for Avonbeg_010, Avonbeg_020 and Avonmore_010. There was no physico-chemical data being collected in Avonmore_020 and 2010 – 2015 Ecological Status for this waterbody (which is of High status objective) was Good. In addition to acidification impact, deteriorated Ecological Status was driven by declined biological conditions (High biological conditions dropped to Good in 2015) for both Avonmore_010 and Avonmore_020. Most recent 2013 – 2018 Ecological Status improved to Good for Avonbeg_010, Avonbeg_020 and Avonmore_010 (with satisfactory acidification conditions).

All four waterbodies form headwaters to Avonmore and Avonbeg rivers. They are located in Wicklow Mountains Special Area of Conservation (SAC) and Special Protection Area (SPA). Avonmore_010 and Avonmore_020 are also *Margaritifera* sensitive area (catchments of other extant populations, not designated sites).

3.2 WFD Information

EPA Biological Quality Rating (Q-values) is conducted at the 'Br d/s Lough Tay' monitoring station (RS10A050010) and 'AVONMORE – Old Br' monitoring station (RS10A050020) for Avonmore_010 and Avonmore_020 respectively. Avonbeg biological surveys are conducted at 'Ford nr Barravore' (RS10A040100, Avonbeg_010) and 'Drumgoff Br' (RS10A040400, Avonbeg_020). For the locations of the EPA monitoring stations, see Figure 1.

Q-Value, nutrient sampling and selected supporting elements results (in case of this PAA it is pH) for active EPA monitoring stations are summarised in Table 2 and relevant plots are presented thereafter. Table 3 summarises status information for two lakes, Lough Tay and Lough Dan which are located in Avonmore_010 and Avonmore_020 waterbodies. Lake outlets are c. 0.7 – 1 km above EPA monitoring locations for these waterbodies.

Review of biological and physico chemical data (Table 2) indicate acidification is a significant issue for Avonmore_010, Avonbeg_010 and Avonbeg_020. While pH is not measured within Avonmore_020 waterbody it is expected to have similar acidification issues. Peat siltation and possible nutrient enrichment may be additional issues affecting Avonmore_020.

Both, Lough Tay and Lough Dan are *in Review* (Table 3). Moderate Ecological Status of Lough Tay is driven by both biological conditions (macrophytes) and specific pollutant (zinc). Lough Tay also failed to achieve Good Chemical Surface Water Status (not included in the Ecological Status), failing mercury and Polycyclic Aromatic Hydrocarbons (PAHs), both of which are considered ubiquitous chemicals (derived from atmospheric deposition) being the main causes for failures of chemical status throughout Europe. Moderate Ecological Status of Lough Dan is driven by Moderate specific pollutants (zinc).

Toxicity of zinc is related to its bioavailability which is dependent on physicochemical parameters, such as pH (affecting metals solubility, and/or competing with zinc for absorption), hardness and the content of DOC. DOC can bind zinc into non-labile form. Calcium content (but also H^+) can compete with metals affecting its bioavailability at the biological receptors (Maycock, 2010).

It is assumed that zinc may originate from underlying geology in the PAA. In both lakes, the annual average of zinc is approximately 10 ug/l which is above the EQS of less or equal to 8ug/l for low hardness waters (< 10 mg/l CaCO3). Considering co-dependence of zinc bioavailability (and therefore its toxicity) on pH, DOC and calcium content, some other states incorporate Bioavailability Models to estimate zinc which is bioavailable. Preliminary assessment of such modelling for Lough Tay and Lough Dan indicates low zinc bioavailability suggesting it is unlikely to be an issue to the lake biology (EPA, pers. comm.). River data were not assessed for zinc, but it is unlikely it is affecting ecological conditions of Avonmore_010 and Avonmore_020 considering potentially no impact in the upstream lakes.

Table 2 Summary of Q-Value, physico-chemical data for Avonbeg – Avonmore PAA (including inputting tributary – Cloghoge Brook, which is not included in the PAA).

Waterbody		**Avonbeg_010**	**Avonbeg_020**	**Avonmore_010**	**Cloghoge Brook_010 (inputting to Avonmore_020)**	**Avonmore_020**
Risk Category		***At Risk***	***At Risk***	***At Risk***	***Review***	***At Risk***
Monitoring station		Ford nr Barravore (RS10A040100)	Drumgoff Br (RS10A040400)	Br d/s Lough Tay (RS10A050010)	Br u/s Annamoe R confl (RS10C010100)	AVONMORE - Old Br (RS10A050020)
Monitoring station type		Operational	Operational	Operational	Operational	PreWfd
Biological Status						
Q - values	*2009*	4-5	4	4-5	4-5	4-5
	2012	4	4-5	4-5	4-5	4-5
	2015	4	4	4	4-5	4*
	2018	4-5	4	4	4-5	4
Water chemistry						
Baseline PO4+ (2016 – 2018)		0.005	0.005	0.005	0.033*	n/a
Baseline NH4+ (2016 – 2018)		0.011	0.014	0.011	0.01	n/a
Baseline NO3- (2016 – 2018)		0.16	0.14	0.18	0.1	n/a
pH measurement range for the year, and number of pH measurements falling below 4.5 pH EQS (for soft water)						
		min	max	fail	min	max	fail	min	max	fail	min	max	fail	
pH	*2012*	4.5	5.89	0	4.49	6.02	1	4.45	5.67	1	4.3	6.27	1	n/a
	2013	4.44	6.26	1	4.24	6.06	1	4.47	6.07	1	3.94	6.6	3	n/a
	2014	4.84	6.48	0	4.75	5.18	0	4.36	4.8	1	4.11	5.34	2	n/a
	2015	4.36	6.22	1	4.2	5.94	3	4.93	6.13	0	4.1	5.47	2	n/a
	2016	5	6.4	0	4.7	5.9	0	5	6.2	0	4.4	6.3	1	n/a
	2017	5.1	6.7	0	4.9	6.4	0	5.8	7	0	4.6	7	0	n/a
	2018	5.8	6.8	0	5.5	6.9	0	5.3	6.4	0	4.6	7.1	0	n/a

Waterbody	**Avonbeg_010**	**Avonbeg_020**	**Avonmore_010**	**Cloghoge Brook_010** (inputting to Avonmore_020)	**Avonmore_020**
HYMO (2015 EPA ecology information)		Slight to moderate siltation, cattle access, mild bank erosion	Slight to moderate siltation		Moderate siltation, Noted siltation (*) at the 2015 Q-value survey
HYMO (2018 EPA ecology information)	substrate siltation - not visible	slight siltation	clean substrate		slight siltation
HYMO – RHAT 2009 survey (from the bridge)	HYMO class: Good		HYMO class: High		HYMO class: High
Comments	No issues with P/N chemistry or ecology. Moderate status due to failing acidification conditions	No issues with P/N chemistry or ecology. Moderate status due to failing acidification conditions	No issues with P/N chemistry. Status driven by failing acidification conditions and Good biological conditions (High status objective)	No issues with P/N chemistry or ecology. Moderate status due to failing acidification conditions	- No chemistry data available, **but suspected pH issues** based on inputting waterbodies. - Possible siltation. Status driven by Good biological conditions (High status objective)
Ecological Status (2010 – 2015)	Moderate	Moderate	Moderate	Moderate	Good
acidification conditions (status 2010 - 2015)	Fail	Fail	Fail	Fail	n/a
Ecological Status (2013 – 2018)	Good	Good	Good	Good	Good
Environmental Objective	Good	Good	High	Good	High
EPA Biologist comments	**Avonbeg notes 2015:** Satisfactory ecological conditions were evident at three of the four stations surveyed on the Avonbeg river in late July 2015. The macroinvertebrate fauna indicated a decline from high to good ecological conditions at Drumgoff Bridge (0400). **Avonbeg notes 2018:** Satisfactory ecological conditions were evident at three of the four stations surveyed		**Avonmore notes 2015:** The Avonmore River remains in a satisfactory ecological condition in July 2015 however the macroinvertebrate fauna indicated a decline from high to good ecological conditions at five of the six sites classified as high in the 2012 survey. **Peat siltation of the instream substrata was most notable in the upper reaches (0010 and 0020)** and may be contributing to the decline observed. **Avonmore notes 2018:** The Avonmore river was in a satisfactory ecological condition at six of the seven stations surveyed in June 2018. The macroinvertebrate		

Waterbody	Avonbeg_010	Avonbeg_020	Avonmore_010	Cloghoge Brook_010 (inputting to Avonmore_020)	Avonmore_020
	on the Avonbeg river in June 2018. The diversity of pollution sensitive macroinvertebrate species indicated a return to high ecological conditions in the upper reaches (0100). The paucity of pollution sensitive macroinvertebrate species coupled with excessive instream filamentous algal growth indicated unsatisfactory ecological conditions at Grennan Bridge (0600).		fauna continues to indicate satisfactory good ecological conditions in the upper reaches however **excessive instream filamentous algal growth was noted at Old Bridge (0020) indicating some signs of enrichment.** High ecological conditions continue at Rathdrum (0300). The paucity of pollution sensitive macroinvertebrate fauna and dominance of pollution tolerant species indicated an unwelcome decline in the lower reaches at Lions Bridge (0500). 2018 Q-value survey noted 50% filamentous algae cover in Avonmore_020 (AVONMORE - Old Br monitoring station).		
Protected Areas	Wicklow Mountains Special Area of Conservation (SAC) and Special Protection Area (SPA) Wicklow groundwater IEPA1_EA_G_076 Historic Mine (Glenmalure) groundwater IEPA1_EA_G_079		Wicklow Mountains SAC and SPA *Margaritifera* sensitive area - catchment of other extant populations** Wicklow groundwater IEPA1_EA_G_076		
Groundwater body information	Historic Mines (Glenmalure) groundwater body is located within Avonbeg_010 and Avonbeg_020. Overall Groundwater status (2010-2015 and 2013-2018) is Poor due to Poor Chemical Groundwater Status (mainly historic pollution (Pb and Zn) from mines)				
Significant issue: monitoring point / waterbody	pH fluctuations	pH fluctuations slight/moderate siltation	pH fluctuations, slight/moderate siltation biological conditions (high status objective)	pH fluctuations	peat siltation, nutrient enrichment (algal growth) biological conditions (high status objective)

*single high value (0.44 P mg/l in 2017; rest of the data on average at 0.005 P mg/l range.

** 'Margaritifera sensitive area - Catchments of other extant populations. These mussel populations may lie (in part) within SAC, other nature conservation sites or in the wider countryside. Those populations within SAC were not considered of sufficient quality to warrant designation for the species and detailed restoration objectives, targets, plans or measures are unlikely to be developed. However, the potential effects of any plans, developments or activities on the populations, including the potential to cause 'environmental damage' as per the Environmental Liability Directive and Regulations, must be determined through SEA, EIA or other ecological assessment. The NPWS holds some detailed information on the distribution and abundance of freshwater pearl mussels in a small number of these catchment.'

n/a – not available.

Table 3 Summary of Ecological Status or Potential for Lough Tay and Lough Dan located in Avonmore_010 and Avonmore_020 waterbodies (source: EPA).

Waterbody name	**Tay (Lake)**	**Dan (Lake)**
Waterbody code	IE_EA_10_25	IE_EA_10_29
inputting & receiving WB	Avonmore_010	Avonmore_020
Risk Category	***Review***	***Review***
Ecological Status or Potential SW 2010-2015 and 2013-2018	Moderate	Moderate
• Biological Status or Potential	Moderate Moderate Macrophyte Status or Potential	Good
• Supporting Chemistry Conditions	Moderate - Failed Specific Pollutant Conditions – Zinc (2010-2015) - Moderate Specific Pollutant Conditions – Zinc (2013-2018)	Moderate - Failed Specific Pollutant Conditions – Zinc (2010-2015) - Moderate Specific Pollutant Conditions – Zinc (2013-2018)
Chemical Surface Water Status 2010-2015 and 2013-2018	Failing to achieve good – Mercury and PAH	Good

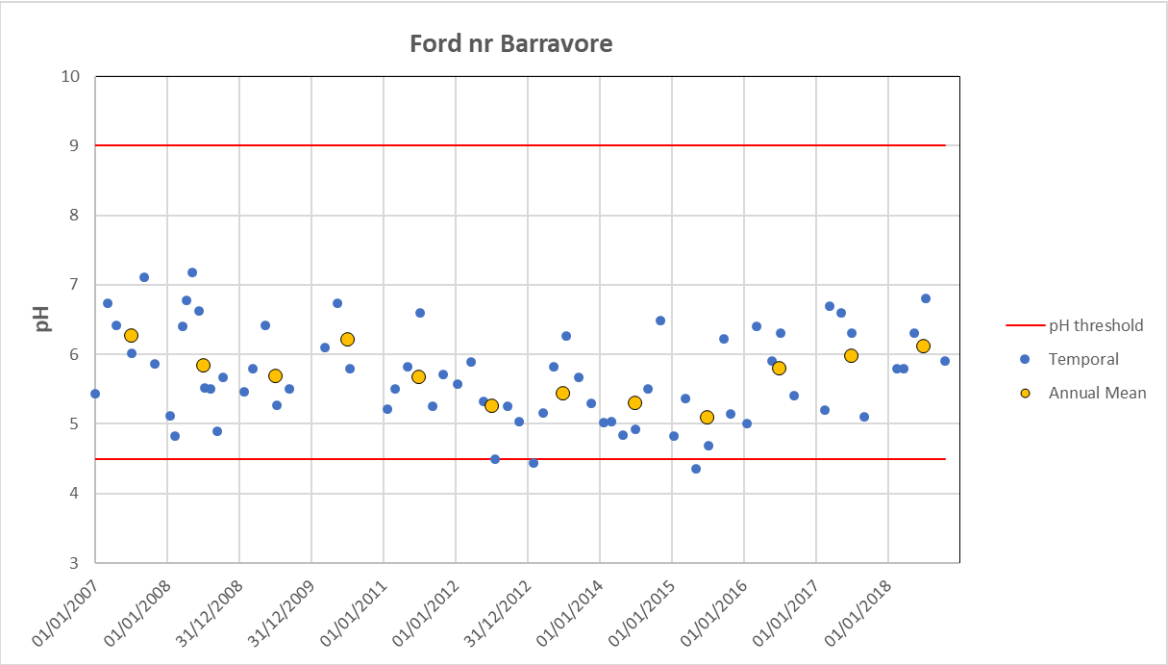

Figure 2 Temporal variations and annual mean values for pH at Avonbeg_010 at Ford nr Barravore monitoring station.

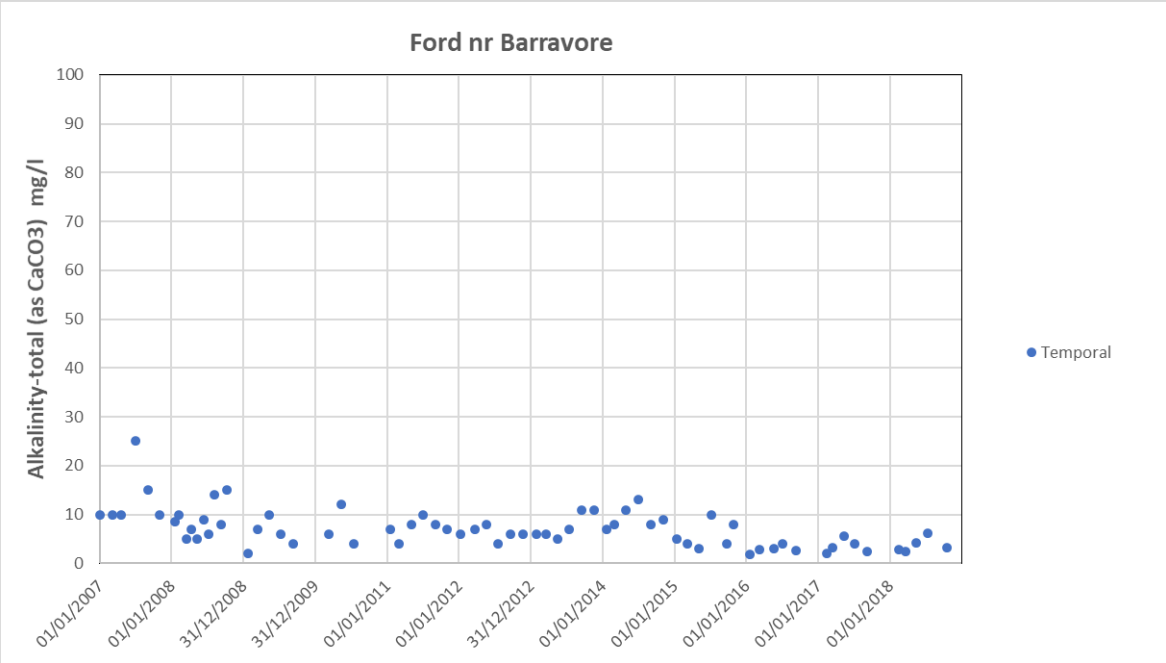

Figure 3 Temporal variations values for alkalinity as CaCO3 (mg/l) at Avonbeg_010 at Ford nr Barravore monitoring station.

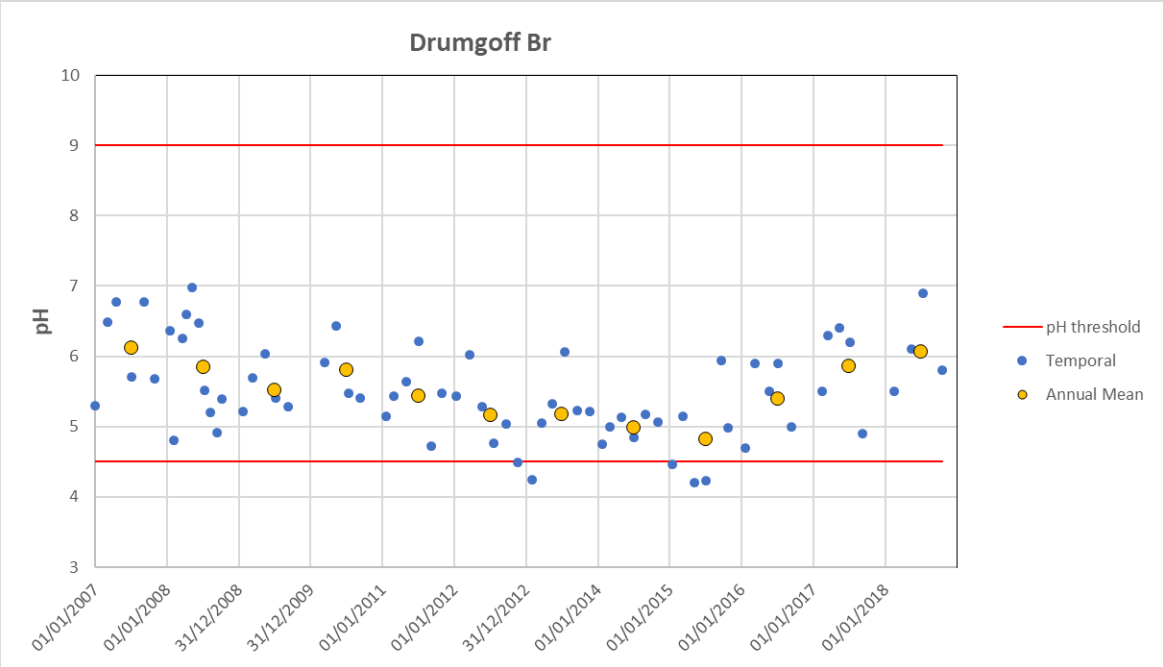

Figure 4 Temporal variations and annual mean values for pH at Avonbeg_020 at Drumgoff Br monitoring station.

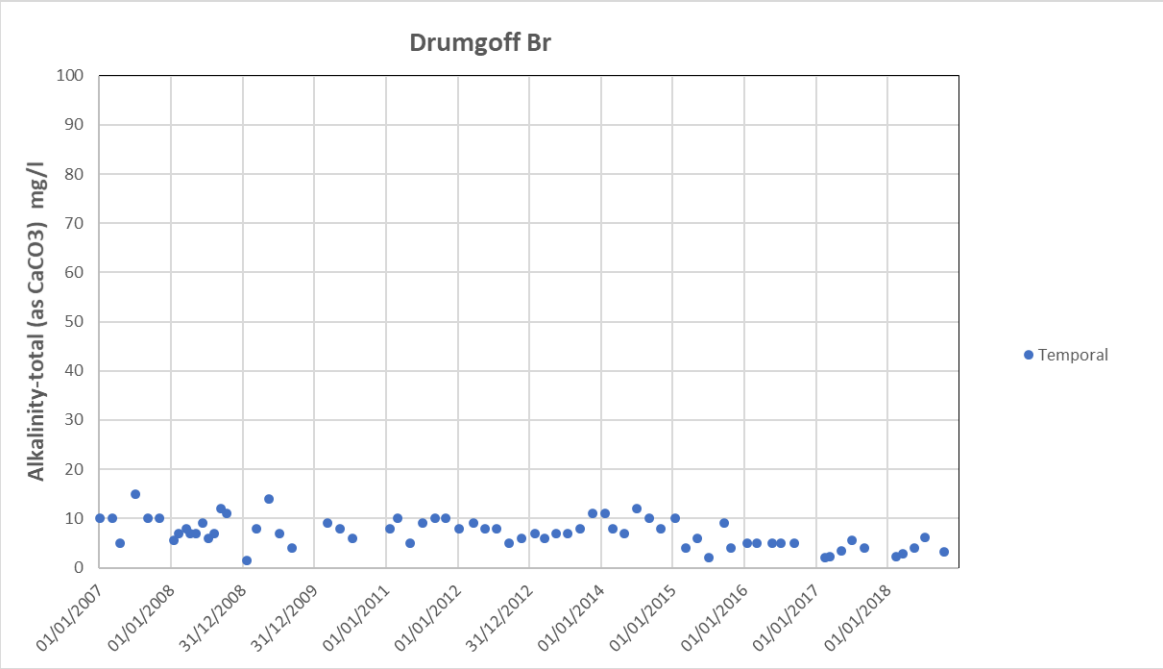

Figure 5 Temporal variations values for alkalinity as (CaCO3 mg/l) at Avonbeg_020 at Drumgoff Br monitoring station.

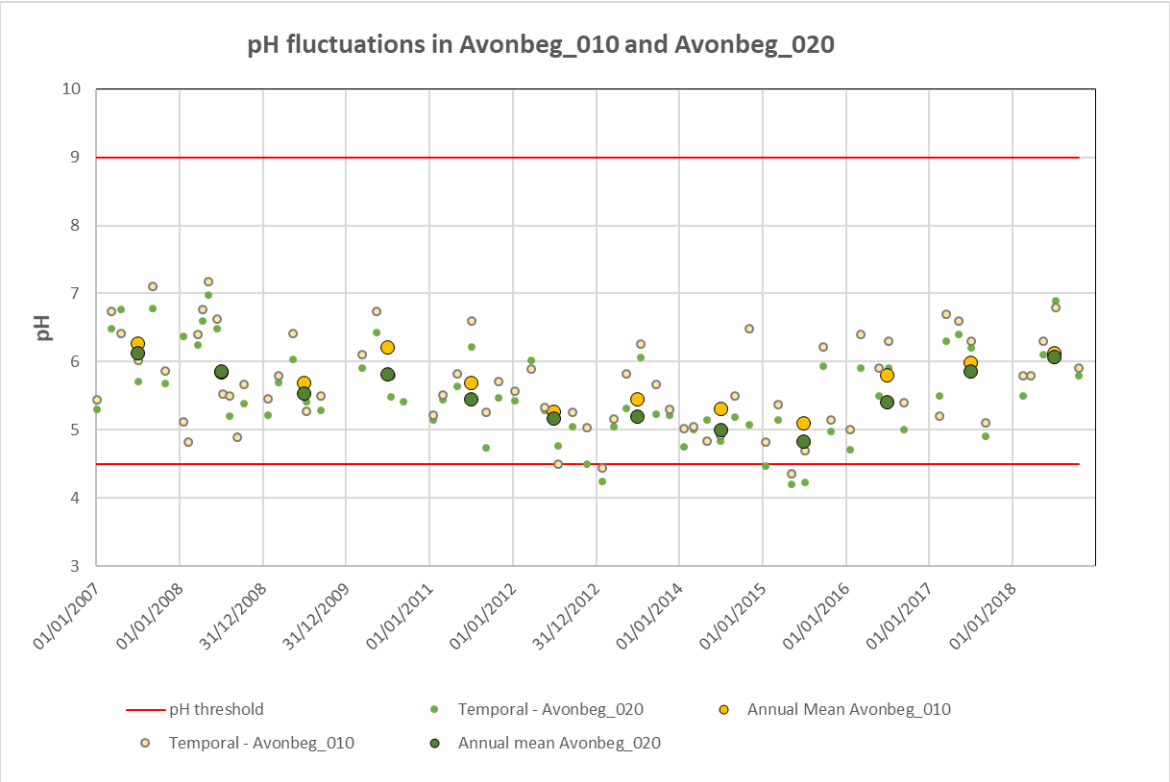

Figure 6 Temporal variations and annual mean values for pH at Avonbeg_010 and Avonbeg_020.

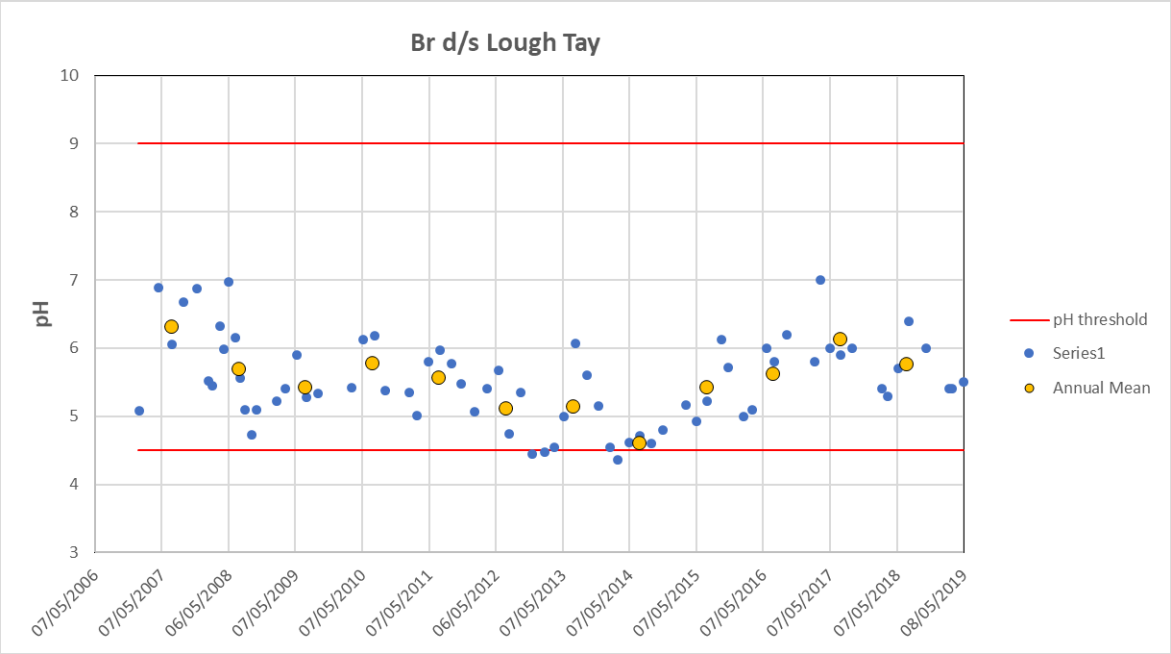

Figure 7 Temporal variations and annual mean values for pH at Avonmore_010 at Br d/s Lough Tay monitoring station.

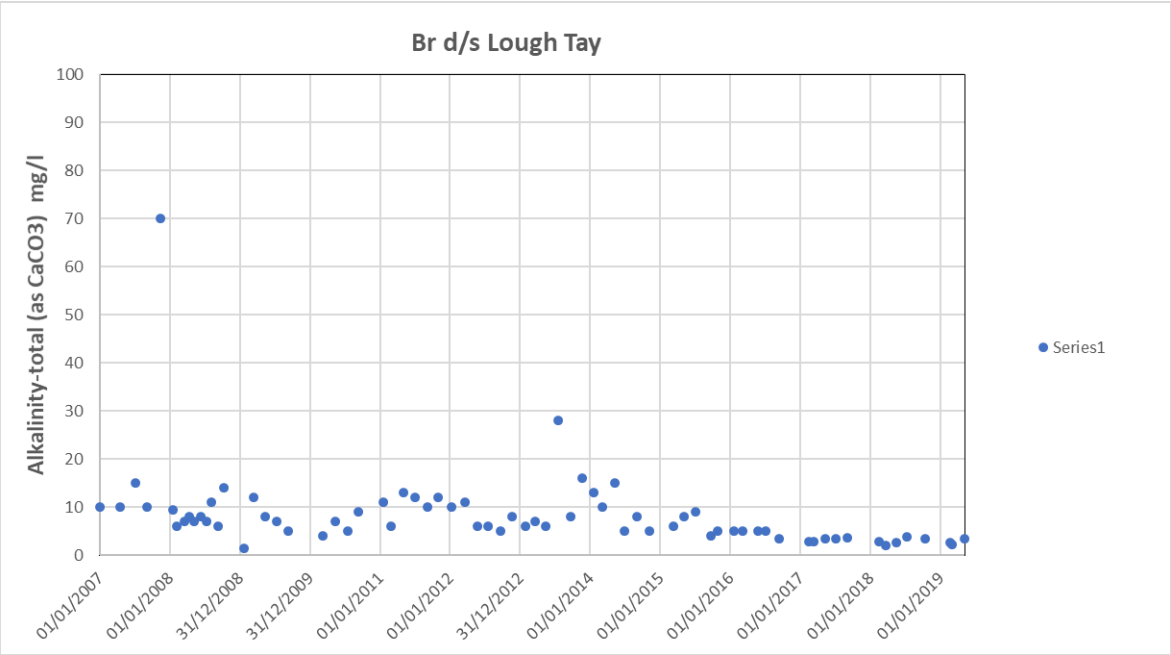

Figure 8 Temporal variations values for alkalinity as CaCO3 (mg/l) at Avonmore_010 at Br d/s Lough Tay monitoring station.

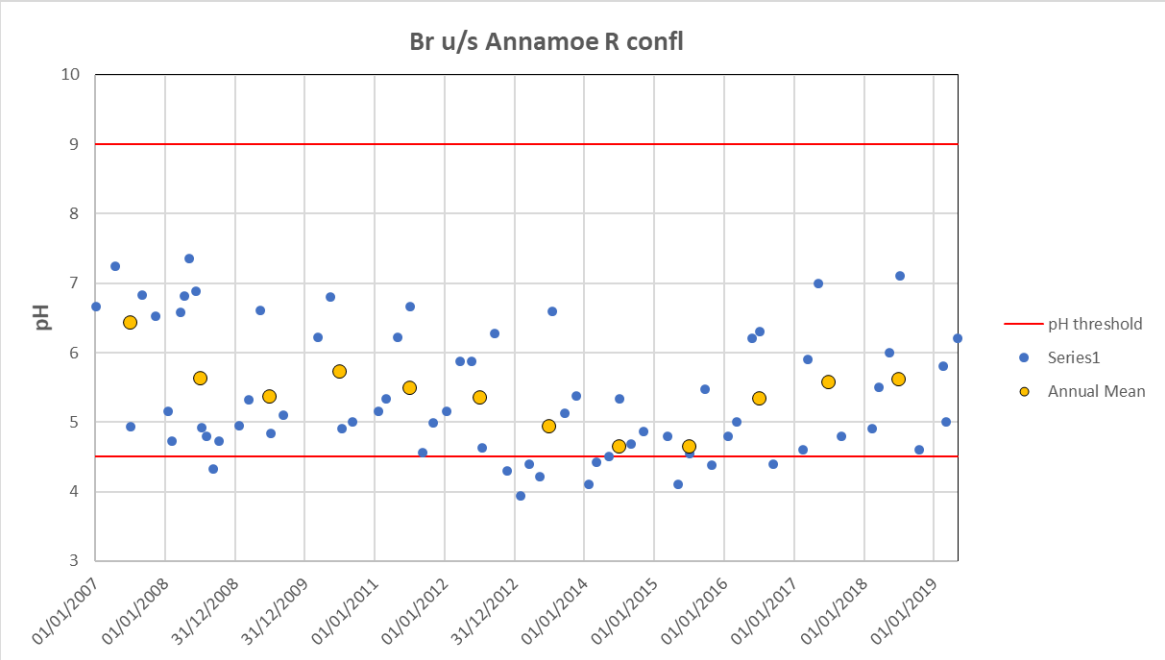

Figure 9 Temporal variations and annual mean values for pH at Cloghoge Brook_010 at Br u/s Annamoe R confl monitoring station.

3.3 Supplementary Information – Mobile Monitoring Unit investigative assessment

As part of Water Framework Directive implementation process, the Eastern River Basin District established Mobile Monitoring Unit (MMU) to gather monitoring data and identify local pressures. Investigative assessment undertaken by the MMU in the Avonbeg – Avonmore PAA is summarised below. For more detailed information please refer to the full MMU reports (CDM Smith, 2015; O'Keeffe and Barrett, 2014; Ryan and Jordan, 2010).

- Avonmore_020

MMU assessment of Inchavore River was carried out in 2010. Inchavore River flows into Lough Dan and is located in Avonmore_020. Assessment indicated that the river was found to be probably not at risk at the upstream reaches with lower macroinvertebrate diversity and probably impact found further downstream (closer to the lake). Low risk scores were attributed to surrounding peat land (Ryan and Jordan, 2010).

- Avonmore_010 and Avonmore_020

Further assessments of the rivers and stream inflowing into Lough Tay and Lough Dan have been carried out in 2013 (O'Keeffe and Barrett, 2013). Q-Values at the EPA monitoring stations indicated High biological conditions at both waterbodies at the time of assessment (2012 Q-Value of 4-5).

Biological assessments (Small Stream Risk Score, SSRS) were carried out at five locations on three occasions (May/June, September and November). Results indicated that sites 1 – 4 were 'Probably not at risk' at all occasions, while site 5 fluctuated between being 'possibly at risk' in June, 'at risk' in September and 'probably not at risk' in November sampling. Site 5 was located on the main channel of Inchavore River flowing into the Lough Dan (Figure 10).

High status generally requires at least 3 Class A taxa to be well represented with few tolerant taxa, and few or absent very tolerant taxa (McGarrigle *et al*., 2002). Review of the SSRS field sheets from

May/ June sampling indicates that sites 1 – 4 were well represented by the sensitive (class A) taxa with tolerant taxa being in few numbers. Site 5 was represented by lower macroinvertebrate diversity with *Protonemura* being the only sensitive taxa present indicating less than High biological conditions at that location.

Nutrient sampling carried out in dry conditions did not show major exceedances of the EQS of High status (see Figure 10 for the sampling locations). One sample showed higher ammonia levels (0.139 mg/l N) at the Cloghoge River downstream of the confluence with Cloghoge Brook attributed to unrestricted deer access to the river network. Higher phosphate level (0.035 mg/l P) was also found just downstream of Lough Tay in September (although June sampling at this location did not show any exceedance).

Field observations indicated presence of filamentous algae in selected locations which can be an indication of nutrient enrichment. Most prevalent aquatic plant growth was noted upstream of Lough Dan on the Cloghoge River. Summer SSRS field sheets indicate that filamentous algae were 'present' at all sites but site 4. Sewage odour was recorded at site 4 (May sampling) however no source was found.

Additionally, widespread bank erosion was noted with most prominent bank erosion recorded for Cloghoge Brook tributary. Unrestricted deer access to the streams was present throughout all the area and sheep access point was noted downstream of Lough Tay. Some sediment deposition was also noted throughout field observations.

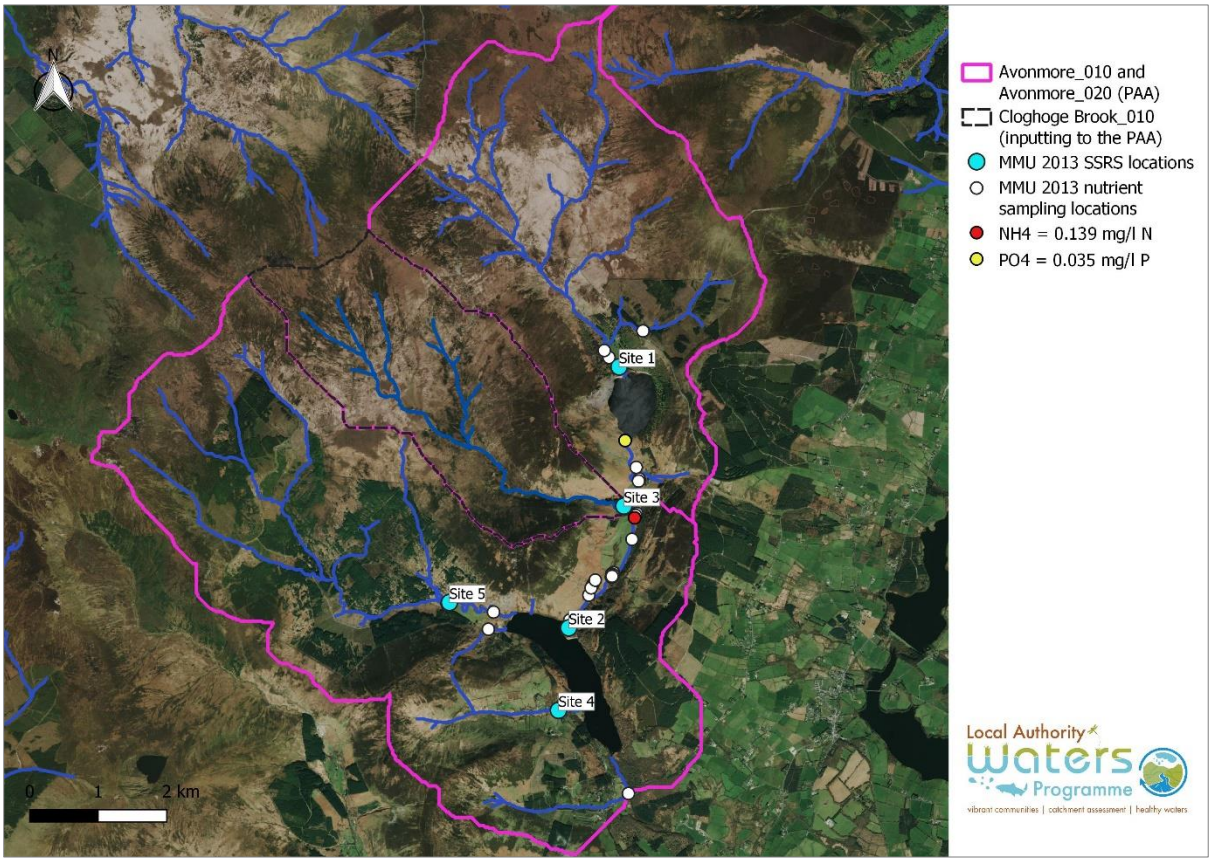

Figure 10 Location of the 2013 MMU assessment in Avonmore_010 and Avonmore_020.

- Avonbeg_010

MMU assessment was carried out in Avonbeg Upper catchment in 2014 following deterioration of biological conditions from High to Good. Nutrient sampling conducted in dry conditions did not show

exceedance of 95%ile EQS for High status (with one sample being above annual mean EQS for High status). Forestry has been recognised as a significant pressure in the catchment. Large tree felling operations located on high slopes close to the main channel and major tributaries were observed in the catchment. As the harvested sites were established prior to Forest Service guidance, trees were planted to the stream edge and therefore an established and a well vegetated riparian area was not present between river network and recent clearfelling activities. These activities and bank erosion were attributed to the siltation issues noted in selected locations (CDM Smith, 2015).

3.4 Supplementary Information – forestry research

There is huge body of research investigating forest-water interactions in Ireland including acidification impacts from mature forests and nutrient and sediment loss during harvesting and planting stage of the forestry. This section does not intend to provide a literature review of available information but rather summarise selected available information, which is relevant to the significant issues recognised in this PAA.

Acidification is a complex issue and understanding of the issue and drivers for acidity have changed for the last 30 years. Section below provides information on all the drivers for acidification as explained by earlier literature review (Johnson at el., 2008), followed by more recent understanding of the issue (Kelly-Quinn et al., 2016).

Forestry role in increased acidity

Acidification has been recognised as a significant issue for the waterbodies in this PAA. Changes in land use can affect acidification conditions in the acid sensitive catchments and presence of conifer forest in acid sensitive catchment can enhance acidity in the surface water. There is number of processes suggested that could explain forest role in the increased acidity as summarised in Aquafor Literature Review (Johnson *et al*., 2008):

- Interception of atmospheric pollutants (sulphur and nitrogen compounds) and sea salts (mainly in Atlantic coastal areas) by the mature canopy cover resulting in the increased transfer of mineral acids to the catchment. There is an increased interception at high altitudes but also for conifer rather than deciduous forests with higher concentrations of pollutants found at the forest edges and historically in the eastern parts of the country.
- Uptake of base cations by trees and their removal through clear felling may lead to soil acidification.
- Increased drainage of forested peaty catchments can result in oxidation and mineralization of organic matter resulting in increased production of organic acids draining to the surface waters. Organic acids may contribute to the acidity. Organic acids, however, form complexes with inorganic aluminium in the non-labile form mitigating in this way aluminium toxicity to biota. Historically, site preparation for the conifer forest plantation could additionally result in mineralisation of organic matter and additional release of nitrogen compounds and sulphates to surface waters.
- Alterations to the hydrology of a forested catchment may result in increased run-off therefore reduced residence time of water and less chance for buffering reactions to occur.
- Short-term increase in nitrate leaching may follow large-scale felling operations in acid-sensitive catchments. Impacts depend on size of the harvested sites, use of protective measures, nitrate uptake by other forested sites and site characteristics.

Acidification and aluminium toxicity

Acidification can result in reduced or eliminated fish population and elimination of acid-sensitive of macroinvertebrate community (particularly mayflies, some caddisflies, crustaceans and molluscs are affected). Toxicity arises due to low pH values (acidity) or the presence of labile inorganic aluminium. In acid mineral soils (pH < 4.2) aluminium constitutes the main buffering capacity. With increased inputs of acidic anions (sulphates and nitrates) labile inorganic aluminium becomes available in the soil solution which can be mobilised to the drainage network. High aluminium concentrations are linked to the toxicity affecting fish and macroinvertebrate communities. Dissolved humic substances naturally occurring in peaty and unimpacted catchments can mitigate toxicity of inorganic aluminium to biological community as they can bind inorganic aluminium into the non-labile form. Calcium content (Ca^{2+} values in excess of 1.0 mg l^{-1}) is also important in terms of buffering capacity but also ability to ameliorate aluminium toxicity (see more details in Aquafor Literature Review, Johnson *et al*., 2008).

Drivers of acidification and Hydrofor Project findings for east region

Historically, acidification has been caused by the anthropogenic emissions and deposition of sulphur and nitrogen oxides. Most recent research project – Hydrofor (Kelly-Quinn *et al*., 2016), which was an EPA funded research project (2008-2014) assessing impacts of forest operations on ecological quality of both rivers and lakes, highlighted that despite significant reductions in atmospheric pollution (since 1990s), higher episodic acidity or greater alkalinity loss is still found in catchments that drain closed canopy conifer forest. Drivers for the acidity were shown to be high losses of Dissolved Organic Carbon (DOC) from peaty soils. Organic acidity (DOC, but also inorganic aluminium) was shown to be higher in stream draining forested catchments. Impacts were showing lower numbers of acid-sensitive macroinvertebrate taxa in catchments with extensive forest cover. The impacts could be seasonal with shown recovery of macroinvertebrate community during summer in comparison to winter/ spring most likely due to more frequent storm events in winter season. The greatest impact on biological community was found within and downstream of the forest plantation (0.5 – 1.5km). There was no recommendation from the Hydrofor Project in relation to a safe threshold of forestry cover for the acidification impacts from the project.

Hydrofor project also investigated forestry operations were higher episodic phosphorus (main issue on peaty soils) and sediment inputs were shown to result from the forestry operations. Lake studies showed higher levels of plant nutrients, heavy metals, DOC, lower DO in lakes located within forested catchments. Conifer forests were exerting a trophic, rather than an acidic or toxic effect on lake ecosystems. Biological community changes were recorded after forest clearfelling operations (Kelly-Quinn *et al*., 2016).

- PAA relevant information

Hydrofor project studied acidification impacts in forested catchments of varying forestry cover in three geological settings: east (granite/ felsite), west (metamorphic), south (Old Red Sandstone). Number of sites were investigated in the Wicklow Mountains (sampled during the period October 2009 to November 2010) and selected sites were located in Avonmore-Avonbeg and Liffey Upper PAAs (Figure 11 and Table 4).

There was no data available for the individual study site in the project report, however mean values of collected physico-chemical parameters were summaries based on the forestry cover and base and storm conditions for the region. These results are summarised for the east region in the Table 5. For more detailed data analysis please refer to the project report (Kelly-Quinn *et al*., 2016).

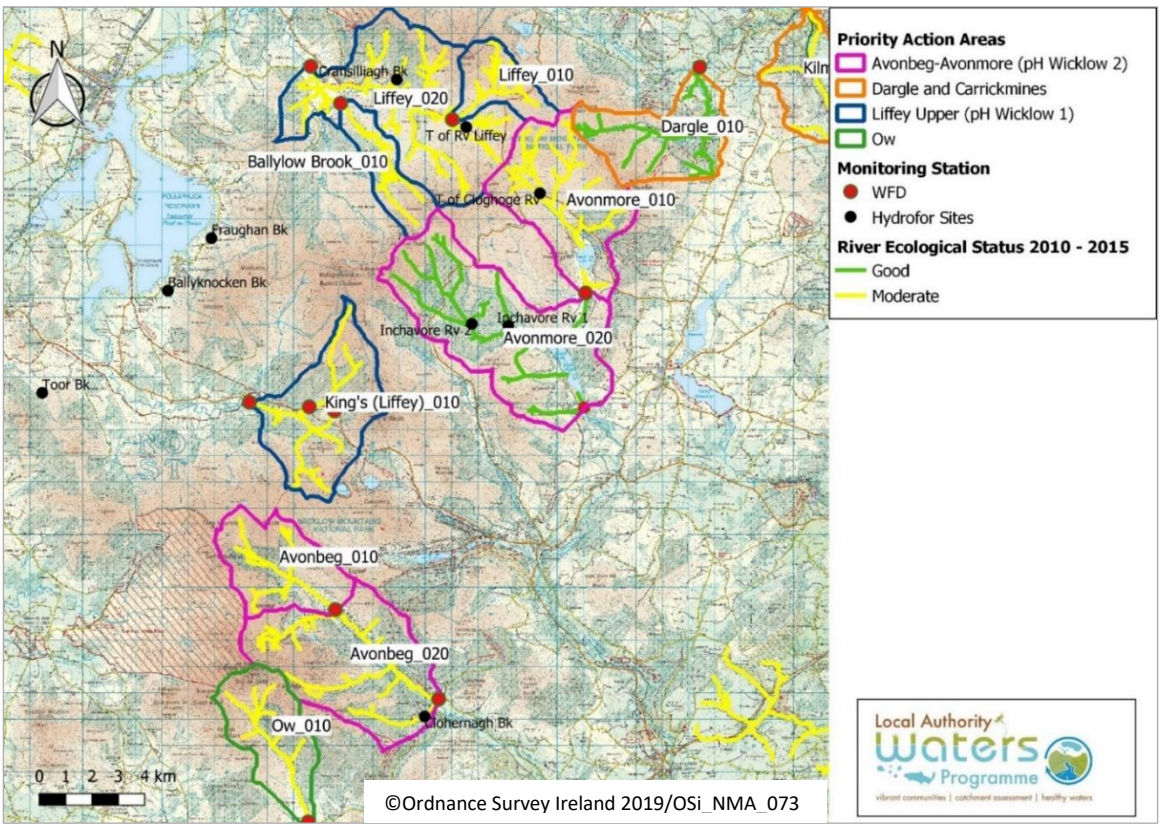

Figure 11 Location of the eastern Hydrofor sites in relation to the PAAs.

Table 4 Hydrofor sites with the forestry characteristics and their location in relation to Priority Areas for Action.

Hydrofor Site Name	PAA	Waterbody Name	Forest Cover % (Hydrofor timeline)	Forest Band
Cransilliagh Bk	Liffey Upper	Liffey_020	31.1	Low
T of Rv Liffey	Liffey Upper	Liffey_020	0	No
T of Cloghoge Rv	Avonbeg - Avonmore	Avonmore_010	0	No
Inchavore Rv 1	Avonbeg - Avonmore	Avonmore_020	23.6	Low
Inchavore Rv 2	Avonbeg - Avonmore	Avonmore_020	38.1	Low
Clohernagh Bk	Avonbeg - Avonmore	Avonbeg_020	61.2	High
Ballyknocken Bk			36.1	Low
Fraughan Bk			0	No
Toor Bk			33	Low

Table 5 pH, Acid Neutralising Capacity (ANC), Dissolved Organic Carbon (DOC) and aluminium concentrations recorded for east region across forest cover bands during Hydrofor Project (Kelly-Quinn *et al.*, 2016).

Forest Cover	Flow	pH – mean (range)	pH – BT	ANC (µeq l^{-1}), mean (range)	Al^{n+} (µg l^{-1}) mean (range)	DOC (mg l^{-1}) mean (range)
All sites	Base	6.12 (5.03-6.94)	9	106.84 (8-254)	135.76 (43-278)	7.65 (2-25)
	Storm	4.66 (3.93 – 6.09)	52	73.59 (-49-204)	287.29 (63-581)	18.61 (9-34)
No forest	Base	6.05 (5.12 – 6.94)	3	111.44 (37-219)	139.79 (43-268)	10.13 (3-25)
	Storm	4.63 (4.09 – 6.09)	20	78.36 (-1-128)	180.81 (63-348)	19.04 (9-34)
Forest	Base	6.16 (5.03 – 6.91)	6	104.4 (8-254)	133.60 (43-348)	6.32 (2-34)
	Storm	4.68 (3.93 – 5.59)	32	70.35 (-49-167)	359.54 (118-581)	18.32 (10-30)

pH – BT - the number of pH ≤ the biological threshold of 5.5.

No statistically significant effect of forest was found on base flow pH values. As opposed to other regions, in the east sampling also did not show different pH values during storm flow between forested and non-forested catchments. The number of pH values that dropped below the biological threshold of 5.5 increased however with forest cover in the east region. Loss in Acid Neutralising Capacity (ANC) indicates episodic acidity and there were significant reductions found in ANC between base-flow and storm-flow conditions. Slightly lower ANC values were found in forested versus non forested sites, but the results were not statistically significant. DOC levels showed to increase with the level of forest cover during storm-flow conditions for west and south regions. In the eastern region (in contrast to the results found in other regions) moorland sites had significantly higher DOC levels than forested sites at the base flow. This was due to one site – tributary of River Liffey (located in Liffey_020, Liffey Upper PAA), which is impacted by the previous peat extraction. Hydrofor results also show an increase in aluminium concentrations for the forested sites compared to no forest sites during storm events (Kelly-Quinn *et al*., 2016).

The key drivers of the episodic acidity were shown to be organic acids together with base cation dilution in all three regions. Base-cation dilution was significantly greater in non-forested streams in west and south, while in the east forested streams showed greater base-cation dilution. No forest effect on organic acids was detected in east region (as opposed to south and west). The contributions of NO_3 to episodic acidity in storm water (in contrast to other regions) has increased with the presence of forestry in the catchments in the east. For mean values of metals, anions and alkalinity for the east region sites please refer to the Hydrofor report (Kelly-Quinn *et al*., 2016, p.15-16).

Increased DOC levels were shown to be the driver of the episodic acidity in Hydrofor project. Data for the east region sites did not however show effect of forest on organic acids. High DOC values found in one non-forested site, which is impacted due to peat extraction (Liffey Upper PAA) suggests that not only forestry but also other land use changes that can affect hydrology of a catchment and in this way enhance release of DOC levels can contribute to the acidification issues.

Reductions in atmospheric deposition

Sulphur emissions declined substantially in Europe in response to EU National Emissions Ceiling Directive leading to reductions in sulphur deposition. In Roundwood (located in close proximity to Avonmore_010 waterbody) and Ballinastoe (site used after Roundwood site was felled in 2003) in Wicklow, long term monitoring data at the forested sites, show decreasing trends in non-marine sulphates and pH recovery in bulk precipitation and throughfall. Data show an increase from average precipitation pH of 4.57 (1991-1995) to average 5.04 (2005 – 2010) at the sites. Average throughfall pH (which represents total deposition as it includes both wet and dry fractions) recovered from 4.17 (1991 – 1995) to 4.71 (1998 – 2003). Little difference between pH of bulk precipitation and throughfall was shown for 2009 – 2010 for Ballinastoe site. Reductions in ammonia in bulk precipitation were also recorded (however similar trends were not evident in the throughfall data). Reductions in non-marine sulphate were shown to be related to the reductions in European sulphate emissions. (Johnson *et al*., 2013).

The same research data show increase in humus water acidity and DOC levels confirming that organic acids are important factors in this layer. Increases in DOC were also recorded in the soil water. Improvements in the chemistry of deposition are related to a recovery of soil acidification as decreasing trends of total aluminium and acidity in soil water were recorded. However, N deposition continues to contribute to soil acidification and the mobilisation of Al in soil leachate in Wicklow sites (Johnson *et al*., 2013).

Considering reductions in atmospheric deposition as shown in the research forestry site in Wicklow Mountains, it can be concluded that atmospheric deposition is not a significant issue in this area.

3.5 Conclusion on Significant issues

- Acidification

Failing acidification conditions (driving Moderate ecological status 2010-2015) were identified as significant issue for Avonmore_010, Avonbeg_010 and Avonbeg_020. While pH is not measured within Avonmore_020 waterbody it is expected to have similar acidification issues. pH values measured since 2017 did not fell below EQS of 4.5 (Table 2), that resulted in improved acidification conditions and consequently improved 2013-2018 Ecological Status.

Measurements of pH in this PAA are still low with some readings below pH of 5.5, which is considered a biological threshold where impacts on ecology may occur (Figure 2, Figure 4, Figure 7). Longitudinal comparison of the pH values (between Avonbeg_010 and Avonbeg_020 (Figure 6) typically show lower pH at the downstream site. Low alkalinity values for all the sites indicate little natural buffer capacity for the pH fluctuations. Available research data confirm low pH values, increased DOC and high aluminium concentrations for the sites located in this PAA. Therefore, despite recent improvements there is still a risk of future failing of the WFD EQS threshold for acidification conditions.

- Siltation

Peat siltation was identified as a significant issue at Avonmore_020 waterbody (moderate), which was noted at the 2015 EPA Q-value survey. Siltation was also noted (slight to moderate) for Avonmore_010 and Avonbeg_020 in 2015 assessment. Although relatively low levels were recorded, organic siltation can be potentially more detrimental to biological community. Moreover, Avonmore sites are of High environmental objective, therefore lower levels of siltation can potentially affect these sites. 2018 EPA assessment surveys indicate however an improved situation with clean substrate in Avonmore_010 and only slight siltation in Avonmore_020 suggesting sites could have recovered from this impact. Considering annual variability of sediment transport and widespread bank erosion, access points (as noted in MMU assessments) and forestry activities as potential pressures in the waterbodies siltation can be still a significant issue and should be considered during Local Catchment Assessment.

- Nutrient enrichment

2018 Q-value survey noted 50% filamentous algae cover in Avonmore_020 (AVONMORE - Old Br monitoring station) indicating potential nutrient enrichment at this waterbody.

4 Significant pressure information

4.1 Initial EPA Characterisation

Summary of the pressures identified during the WFD characterisation process is shown in Table 6. Main pressure identified for this PAA is forestry impacting both morphological and acidification conditions of the waterbodies. Additionally, atmospheric deposition (affecting acidification conditions) and agriculture were identified as pressures for Avonmore_010.

Table 6 Pressures identified during the WFD characterisation process.

Waterbody Name	Id	Category	Sub Category	Significant ?	Pressure & Impact details	Significant (desk study confirmed)
Avonbeg_010	WBP0006094	Forestry	Forestry	Yes	Acidification	
Avonbeg_020	WBP0006095	Forestry	Forestry	Yes	Acidification	
Avonmore_010	WBP0004193	Atmospheric	Atmospheric	Yes	Acidification	No
	WBP0004181	Agriculture	Agriculture	Yes	Altered habitats due to morphological changes	
	WBP0004180	Forestry	Clearfelling	Yes	Altered habitats due to morphological changes	
Avonmore_020	WBP0004207	Forestry	Clearfelling	Yes	Altered habitats due to morphological changes	

4.2 Forestry

Both private and Coillte forest plantations are present in all four waterbodies. Forestry land types are shown in Figure 12 for Avonmore_010 and Avonmore_020 and in Figure 13 for Avonbeg_010 and Avonbeg_020.

In Avonmore_010, 12% of the waterbody is forested. Private forests constitute 36% and mainly include mixed and broadleaf high forests at the private estate surrounding Lough Tay. Remaining forest belongs to Coillte and majority of the land is felled (not replanted) with small area of conifer high forest. In Avonmore_020 majority of the forest (82%) belongs to Coillte and dominant land use (60% of the forest) constitutes conifer high forest. There is no forest land use in Cloghoge Brook_010, which is a waterbody feeding into Avonmore_020 (between the two lakes).

In Avonbeg_010 and Avonbeg_020 nearly all forest land use belongs to Coillte (99% in Avonbeg_010 and 100% in Avonbeg_020). In Avonbeg_010, the forest constitutes 30% of a land use in this waterbody and forestry includes a mixture of high conifer forest, felled (not replanted) areas and areas

never planted. In Avonbeg_020, 40% of the land is under forest cover with high conifer forest being the predominant type of forest present (i.e., 65% of the forest land use).

Forest operations can contribute to the siltation and nutrient release potentially affecting biological conditions. To maintain Good or High biological conditions, all future forest operations require appropriate measures protecting water quality in this PAA. Further information on future forestry activities in the PAA was sought from Coillte and Forest Service. Information on these activities together with recommendation of protective measures formed a referral to Forest Service for a protect function in this PAA.

Waterbodies in this PAA are also considered naturally acid sensitive due to their physical characteristics providing very little buffering capacity. Research data show increased acidity in the acid sensitive and forested catchments. Main driver of episodic acidity was shown to be increased levels of DOC, which may be associated with land use changes altering hydrological regimes (lowering of a water table) due to drainage of the peaty soils for the forest plantations. There are however waterbodies in this area (e.g., Cloghoge Brook) with no forestry cover which also show failing acidification conditions.

4.3 Atmospheric

Atmospheric deposition was identified as a significant pressure impacting acidification conditions in Avonmore_010 during EPA characterisation process. Research data show however recovery in precipitation and throughfall acidity for Wicklow Mountains area due to significantly reduced atmospheric deposition from non-marine sulphur. Therefore, atmospheric deposition is an unlikely pressure in this case.

4.4 Agriculture

Agriculture was identified as a significant pressure in Avonmore_010 during EPA characterisation process. Peat bogs, mainly located in headwaters, are the main land cover type in this waterbody. This area, together with moors, heather and grassland (south and west from the Lough Tay) form agriculture commonage area. Two commonage areas are identified in this waterbody (located in Ballinastoe and Cloghoge townlands), however Commonage Framework Plans for these areas is not available. Considering siltation (slight to moderate) being identified as an issue, overgrazing, peat erosion, water drinking access points or peat extraction may be potential sediment sources in this waterbody.

4.5 Conclusion on Significant Pressures

Main pressure identified for this PAA is forestry, which can affect both morphological and acidification conditions of the waterbodies. Additionally, atmospheric deposition affecting acidification conditions was identified as a significant pressure in Avonmore_010. With the significant reductions in atmospheric pollution this pressure is however unlikely to cause the impact. Agriculture that can contribute to morphological changes was also identified as a significant pressure for Avonmore_010 and this needs to be further investigated.

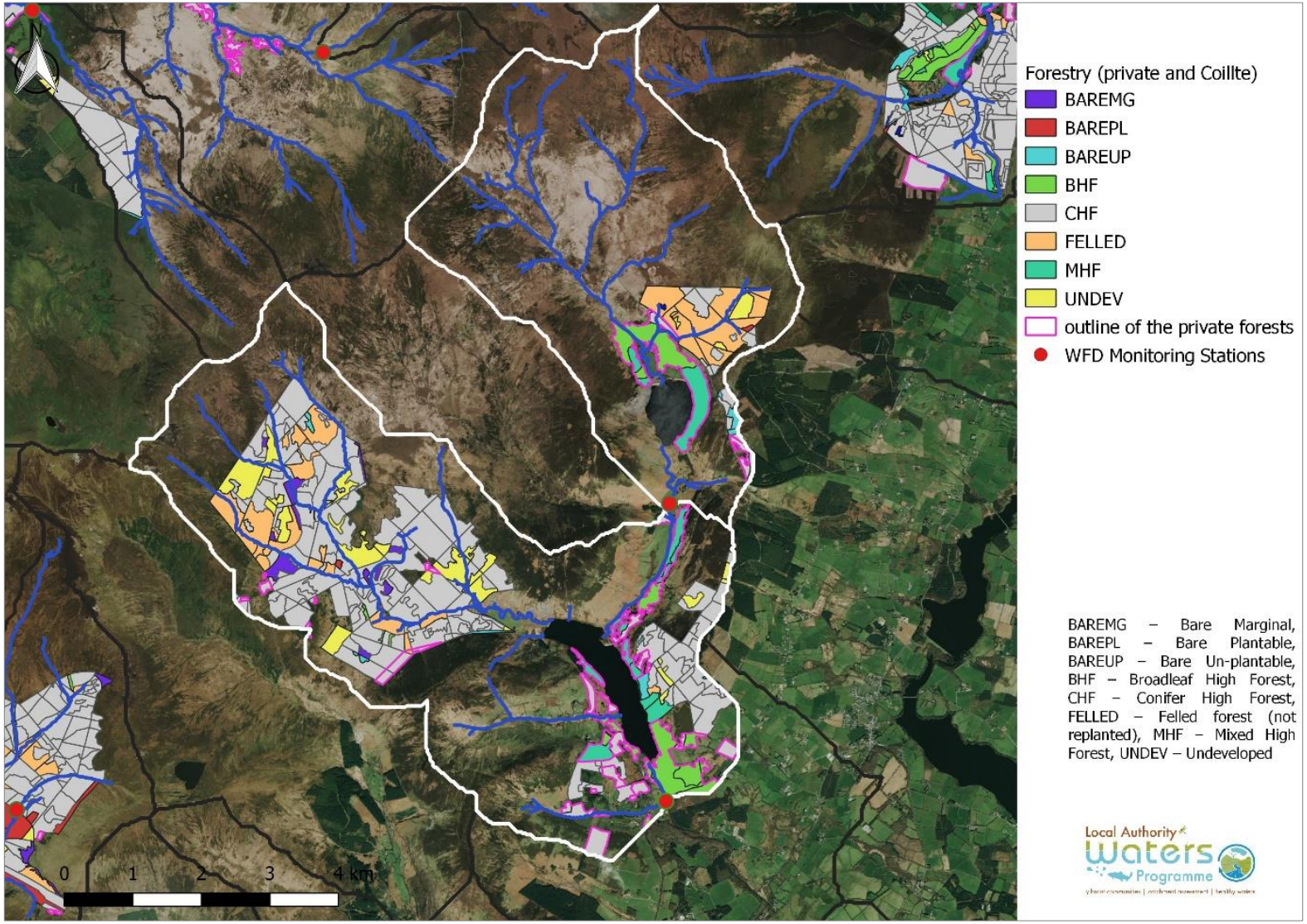

Figure 12 Forestry land use types in Avonmore_010 and Avonmore_020.

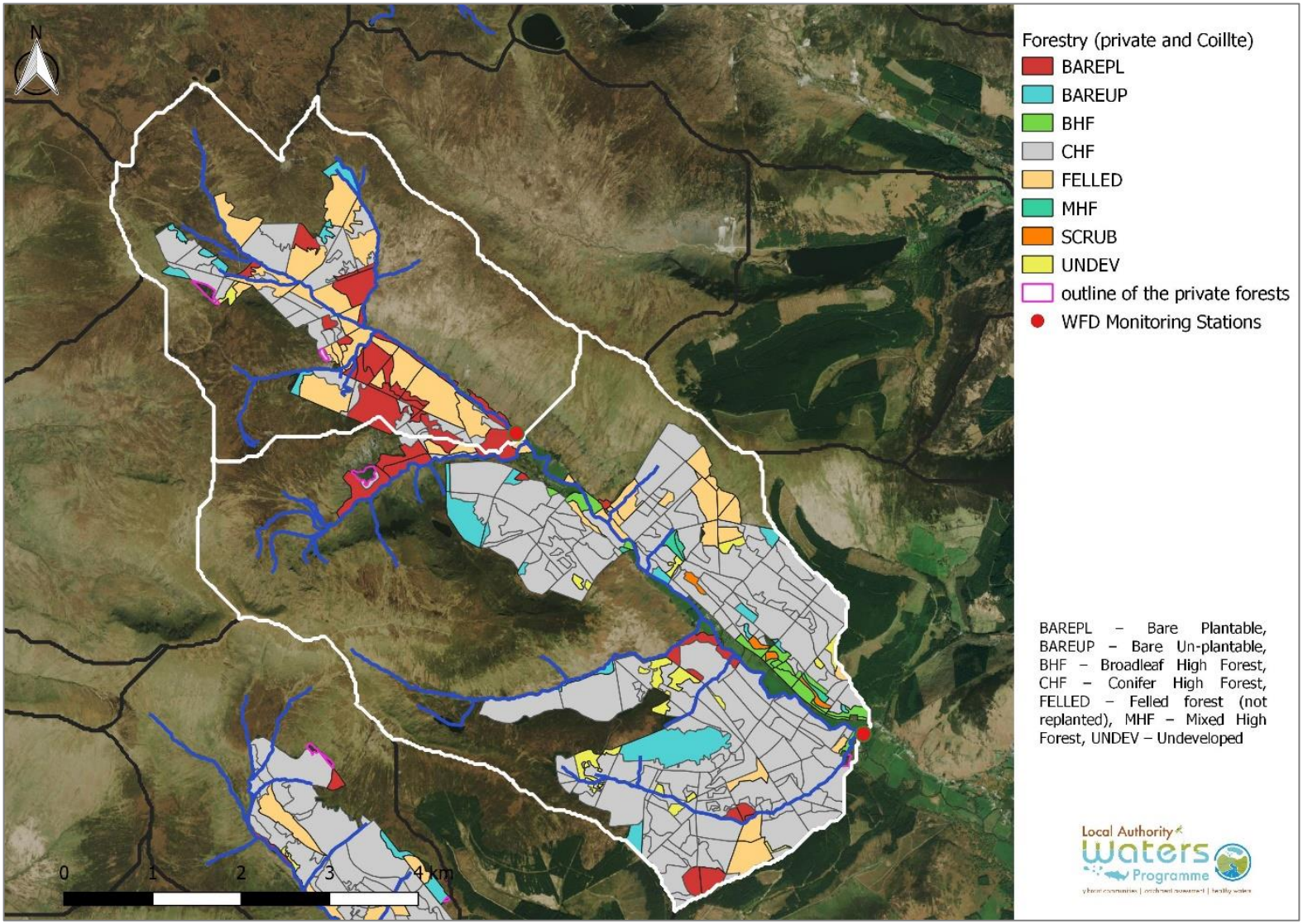

Figure 13 Forest land use types in Avonbeg_010 and Avonbeg_020.

5 Pathway information & analysis

This part of the report usually contains information that allows for the conceptual understanding of catchment pathways mainly related to transport of nitrate and phosphate within the catchment. Nutrients are not identified as being a significant issue in these waterbodies, however, considering acidification issues recognised it was considered relevant to describe underlying geology and soils within the catchment providing background information and context to the issue. These are summarised in the Table 7 in this section and shown in Figures 16 – 19 in Appendix I of this report. Physical characteristics indicate natural acid-sensitivity of this PAA.

Table 7 Avonbeg and Avonmore PAA physical characteristics.

Factor	Description & relevance
Land Cover/ Land Use	• **Avonbeg** Peatland is the dominant land use. Forest cover for both waterbodies is mainly located along the main river channel (30% of land use for Avonbeg_010 and 41% for Avonbeg_020) with high proportion of conifer plantations. • **Avonmore** In Avonmore_010 dominant land cover are peat bogs with some moors and heather forming agriculture commonage area. 11% of the land use is forestry with some felled site upstream of Lough Tay, mixed and broad-leaved forest surrounding the lake and mainly grassland downstream of the lake (with small area of conifer forest). In Avonmore_020, 23% of the land draining to the outlet is under forest (mainly Coillte land), with majority of conifer forest is located upstream of Lough Dan (Inchavore River). Rest of the land is mainly peat bog and moorland area.
Soil (Figure 16)	• **Avonbeg** Peaty (blanket peat) and poorly drained soils (shallow soils (podzols (peaty), lithosols, peats, with/or without a peaty/organic horizon) derived from mainly acidic parent material) with free-draining soils north of the catchment and partly along the rivercourse (mainly scree).. • **Avonmore** Mainly peaty soils (blanket peat) in the upper parts of the catchment with poorly drained soils (shallow soils (podzols (peaty), lithosols, peats, with/or without a peaty/organic horizon, derived from mainly acidic parent material) with small areas of mineral alluvium) surrounding lakes, small proportion of free-draining soils towards Avonmore_020 catchment outlet. Peaty soils are usually wet and acidic by nature. Acidity in peatlands results from microbial decay processes, cation exchange (when not

	disturbed as abundant sphagnum acidifies its surroundings by cation exchange), and input of acids from the atmosphere.
Bedrock (Figure 17)	Ordovician Metasediment and Granites and other Igneous Intrusive rocks for all four waterbodies. **pH background:** • pH natural groundwater background: Groundwater in the non-calcareous sedimentary and igneous lithological groups has the lowest pH values with medians of 6.03 and 6.07 respectively. Igneous rocks pH data show 5th %ile of 5.35, 95%ile of 7.53 and median of 6.07 (Tedd *et al*., 2017). • Groundwater pH data available for Avonmore_010 show pH of 6.6 for Sraghmore Wicklow Visitor Centre and one sample from a private well in the Avonbeg_030 catchment of 7 pH units on 03/02/1997 (GSI, pers. comm.). • pH data available for Askinagap Group Water Scheme located in Ow_020 waterbody in Wicklow Mountains of similar geology and characteristics (Ordovician Metasediments and poorly drained soils with forestry/ grassland as land use) show pH from 5.1 to 6.8 pH units with a mean of 6.0 pH.
Topography	• Headwaters located in Wicklow Mountains. High topography may influence flashiness of the flows. If land is overgrazed, it may also affect slope erosion. • **Avonbeg_010 and Avonbeg_020**: rises at Conavalla Mountain (734m) and Camenabologue Mountain and surrounded by multiple hills North and South of the river course. • **Avonmore_010**: west - Carrigvore Mountain (682m), north west – 570m; North East – Djouce Mountain (750m), South East – Luggala Mountain (595m); • **Avonmore_020**: West (headwater) ~720m; just upstream of the Lough Dan – 534m (North) and 640m (South)
Subsoil	• **Avonbeg:** Blanket peat, Rock, Scree, Granite till • **Avonmore:** Blanket peat, Rock, Sandstone till
Subsoil permeability	Moderate (mainly in the areas of peat soils in Avonmore waterbodies and small parts in Avonbeg), with depth to bedrock <3m in other areas.
Aquifer (Figure 18)	Ll – Locally Important Aquifer – Bedrock which is moderately productive only in local zones; Pl – Poor aquifer – bedrock which is generally unproductive except for local zones;
Groundwater vulnerability (Figure 19)	Extreme and X-Extreme dominant with bedrock outcrop in places

6 Interim story of the Priority Area for Action

6.1 Avonbeg_010

Avonbeg_010 is one of four waterbodies in Avonbeg-Avonmore Priority Area for Action (PAA). It is the headwater to Avonbeg River. This waterbody is *At Risk* of achieving Water Framework Directive (WFD) environmental objective of Good Ecological Status by 2021. Historically biological conditions were Good or High and most recent biological survey indicate High biological conditions (2018 Q-value of 4.5). Failing acidification conditions is the main driver for Moderate 2010-2015 ecological status. The 2013-2018 Ecological Status improved to Good, however pH measurements at this waterbody are low (pH values between 4.36 and 6.8, 2012-2018) and there is still a risk that acidification conditions could fail in the future cycles. This waterbody is naturally acid sensitive due its physical characteristics such as steep topography, igneous (low permeability) lithology, shallow aquifer, very thin subsoils and soils, and presence of poorly drained or peaty soils which provide limited buffering capacity for pH fluctuations. Natural sensitivity to acidification of this area is enhanced by the presence of forestry, which was identified as a single significant pressure for this waterbody. With significant reductions in acid deposition (derived from air pollution), organic acids such as increased Dissolved Organic Carbon (DOC) content is believed to be the main driver for the failing acidification conditions. Increased DOC levels may be associated with the hydrological changes to the catchments such as increased surface runoff, increased discharge and or mineralisation of peaty soils associated with the land drainage at the forestry plantations. Exact drivers are however not known. This waterbody (and whole Avonbeg-Avonmore Priority Area for Action) is included in the EPA pH Review Programme, which focuses on the assessment of the acidification drivers and ecology impacts in Wicklow catchments for further characterisation process. With forestry plantations occupying significant area of the waterbody (30% of the land use, with approximately third of this being conifer high forest), there is a risk of potential nutrient and sediment release during future forestry operations. To maintain Good or High biological conditions all future forestry operations should adhere to appropriate measures protecting water quality in the waterbody.

6.2 Avonbeg_020

Avonbeg_020 waterbody is part of the Avonbeg-Avonmore Priority Area for Action. It is *At Risk* of achieving Water Framework Directive (WFD) environmental objective of Good Ecological Status by 2021. Although it achieves Good biological conditions (Q-Value of 4 in 2015 and 2018), failure of acidification conditions was the main driver for the Moderate 2010-2015 Ecological Status. Despite improvements of the 2013-2018 Ecological Status to Good, there is still a risk of failure of the pH measurements in the future cycles. Range of pH measurements in this waterbody is quite low (pH measurements between 4.2 and 6.9, 2012-2018), and pH values decrease here in comparison to the inputting Avonbeg_010 waterbody. Natural settings of a catchments (steep topography, igneous (low permeability) lithology, shallow aquifer, very thin subsoils and soils, and presence of poorly drained or peaty soils) provide limited buffering capacity for pH fluctuations. Natural acid sensitivity of this area is enhanced by the presence of the forest, which was identified as a single significant pressure for this waterbody. With significant reductions in acid deposition (derived from air pollution), organic acids such as increased Dissolved Organic Carbon (DOC) content is believed to be the main driver for the failing acidification conditions. Increased DOC levels may be associated with the hydrological

changes to the catchments such as increased surface runoff, increased discharge and or mineralisation of peaty soils associated with the land drainage at the forestry plantations. Exact drivers are however not known. This waterbody (and whole Avonbeg-Avonmore Priority Area for Action) is included in the EPA pH Review Programme, which focuses on the assessment of the acidification drivers and ecology impacts in Wicklow catchments for further characterisation process. With forestry plantations occupying significant area of the waterbody (41% of the land use of the catchment area upstream including inputting Avonbeg_010 waterbody), there is a risk of potential nutrient and sediment release during future forestry operations. To maintain Good or High biological conditions all future forestry operations should adhere to appropriate measures protecting water quality in the waterbody.

6.3 Avonmore_010

Avonmore_010 is one of four waterbodies in Avonbeg-Avonmore Priority Area for Action (PAA). It is the headwater to Avonmore River, and it is a High Status objective waterbody (Blue Dot Catchment). It is *At Risk* of achieving its Water Framework Directive (WFD) environmental objectives by 2021. Lough Tay, which is located in this waterbody (approximately 1km upstream of the monitoring location) is at Moderate Ecological Status. Historically, Avonmore_010 achieved High biological conditions (1990-2012) and these conditions declined to Good in 2015 and 2018 assessments. The 2010-2015 Ecological status was further downgraded to Moderate due to failing acidification conditions. Although pH measurements did not fail WFD threshold of 4.5 in the 2013-2018 cycle (improving Ecological Status to Good), there is still a risk of failure of the pH conditions in the future cycles due to very low pH values at this waterbody (pH measurements range of 4.36 to 7 between 2012 and 2018). Additionally, EPA biological assessment data indicate slight to moderate peat siltation at the site (2015 data), which could be affecting biological conditions, although 2018 assessments indicate clean substrate.

EPA characterisation process identified three significant pressures for this waterbody: (i) atmospheric pressure (impacting acidification conditions), (i) forestry and (iii) agriculture (that could impact river habitats due to morphological changes).

Siliceous nature of the surrounding geology, shallow aquifers, low permeability rocks, poorly drained and peaty soils and steep topography affect sensitivity of this catchment to acidity. Low alkalinity values confirm limited buffering capacity to pH fluctuations. This could be further enhanced by the anthropogenic changes. Although atmospheric deposition was recognised as a significant pressure there has been an air quality improvement in the area therefore exact drivers for the failing acidification conditions are not known. This impact will be further investigated with the EPA pH Review Programme (supported by LAWPRO Local Catchment Assessment) which focuses on the assessment of the acidification drivers and ecology impacts in Wicklow catchments for further characterisation process.

Local Catchment Assessment is planned at this waterbody to identify locations of potential change between High and Good biological conditions. This work will be coordinated with the Blue Dot Catchment Programme. Commonage practices and felled forest areas require further assessment for potential source of peat sediment. Any future forestry operations should adhere to appropriate measures protecting water quality. Additional measures may be required considering High Status objective of this waterbody. Guidance for the High Status objective waterbodies (Blue Dot sites) will be developed by the Blue Dot Catchments Programme and may be considered for this waterbody.

6.4 Avonmore_020

Avonmore_020 is one of four waterbodies in Avonbeg-Avonmore Priority Area for Action (PAA). Avonmore_010 (which includes Lough Tay) and Cloghoge Brook_010 (which is not part of the PAA) are two inputting waterbodies to Avonmore_020.

Avonmore_020 is a High Status objective waterbody (Blue Dot Catchment). It is *At Risk* of achieving its Water Framework Directive (WFD) environmental objective by 2021. Lough Dan located in the middle of Avonmore_020 waterbody (approximately 700 m upstream of the monitoring location) is at Moderate Ecological Status. Historically, Avonmore_020 achieved High biological conditions (1990-2012) and these conditions declined to Good in 2015 and 2018. 2015 EPA monitoring data indicated moderate siltation of the river substrate, which improved to slight in 2018 assessment. No physico - chemical measurements are taken at this waterbody. 2018 ecological assessment indicated some nutrient enrichment due to algal growth at the monitoring location (50% filamentous algae cover was recorded at the monitoring station). EPA characterisation process identified Forestry as a single pressure impacting river habitats (due to morphological changes) at this waterbody.

Local Catchment Assessment (LCA) is planned at this waterbody to identify locations of potential change between High and Good biological conditions and assess potential siltation and nutrient issues. This work will be coordinated with the Blue Dot Catchment Programme. Any future forestry operations in this waterbody should adhere to appropriate measures protecting water quality. Additional measures may be required considering High Status objective of this waterbody. Guidance for the High Status objective waterbodies (Blue Dot sites) will be developed by the Blue Dot Catchments Programme and may be considered for this waterbody.

While no pH measurements are available for this waterbody, considering natural acid sensitivity of this area and failing acidification conditions of two inputting waterbodies (Avonmore_010 and Cloghoge Brook_010) this waterbody is included in the EPA pH review Programme (supported by LAWPRO LCA) for further assessment of the acidification drivers and ecology impacts in the acid sensitive Wicklow catchments.

7 Workplan

The summary of assigned WFD actions to each waterbody is presented below. Proposed plan for the Local Catchment Assessment is also included.

7.1 Avonbeg_010

- IA1 Provision of Information (EPA):

Water body to be included in the pH review.

7.2 Avonbeg_020

- IA1 Provision of Information (EPA):

Water body to be included in the pH review.

7.3 Avonmore_010

- WFD further characterisation action: IA1 Provision of Information (EPA)

The EPA will include this assessment as part of a pH review.

- WFD further characterisation action: IA8 High status RWB pressures (LAWPRO)

Focus local catchment assessment on forestry and sediment sources and transport and areas which have been recently clearfelled. Locations where animal access is occurring should also be identified. Overall with the exception of pH, acidification and sediment water quality is considered to be good and this is corroborated by external water quality and SSRS data.

- Proposed Local Catchment Assessment

Local Catchment Assessment is planned in summer months in number of locations to assess biological conditions, siltation levels and pH to identify impacts in the area as indicated in Figure 14 and Table 8. Visual assessments of the felled forestry are also required. Catchment walk may be required between monitoring location and outlet of the lake to identify any potential pressure sources. Outcomes of the assessments will be discussed with the Blue Dot Catchment Programme coordinator.

Table 8 Proposed locations of LCA for Avonmore_010.

Location	Description	Reason
1	EPA monitoring station Br D/s Lough Tay	confirming good/ high status
2	200m u/s of the mon station, upstream of the tributary	close to monitoring station but upstream of the small tributary (ruling out impacts from the tributary)
3a	Luggala Lodge - u/s of lake (u/s of tributary with forestry)	check biological conditions of the stream flowing into the lake
3b	Luggala Lodge - u/s of lake (d/s of trib with forestry)	Check forest impacts. Depending on results here assessments of the tributaries in headwaters may be required (locations 5, 6, 7)

Location	Description	Reason
4	d/s of felling (Boleyhorrigan Br)	check felling impacts (Coillte) Visual assessment depending on 3a and 3b results. According to Coillte layer area upstream of this point is felled and not replanted.
5	SE of Sally Gap	check if high status in headwaters
6	trib d/s of SE Sally Gap	checking if impact between Sally gap and Luggala
7	Sheepbank Br	check if impact between Sally gap and Luggala

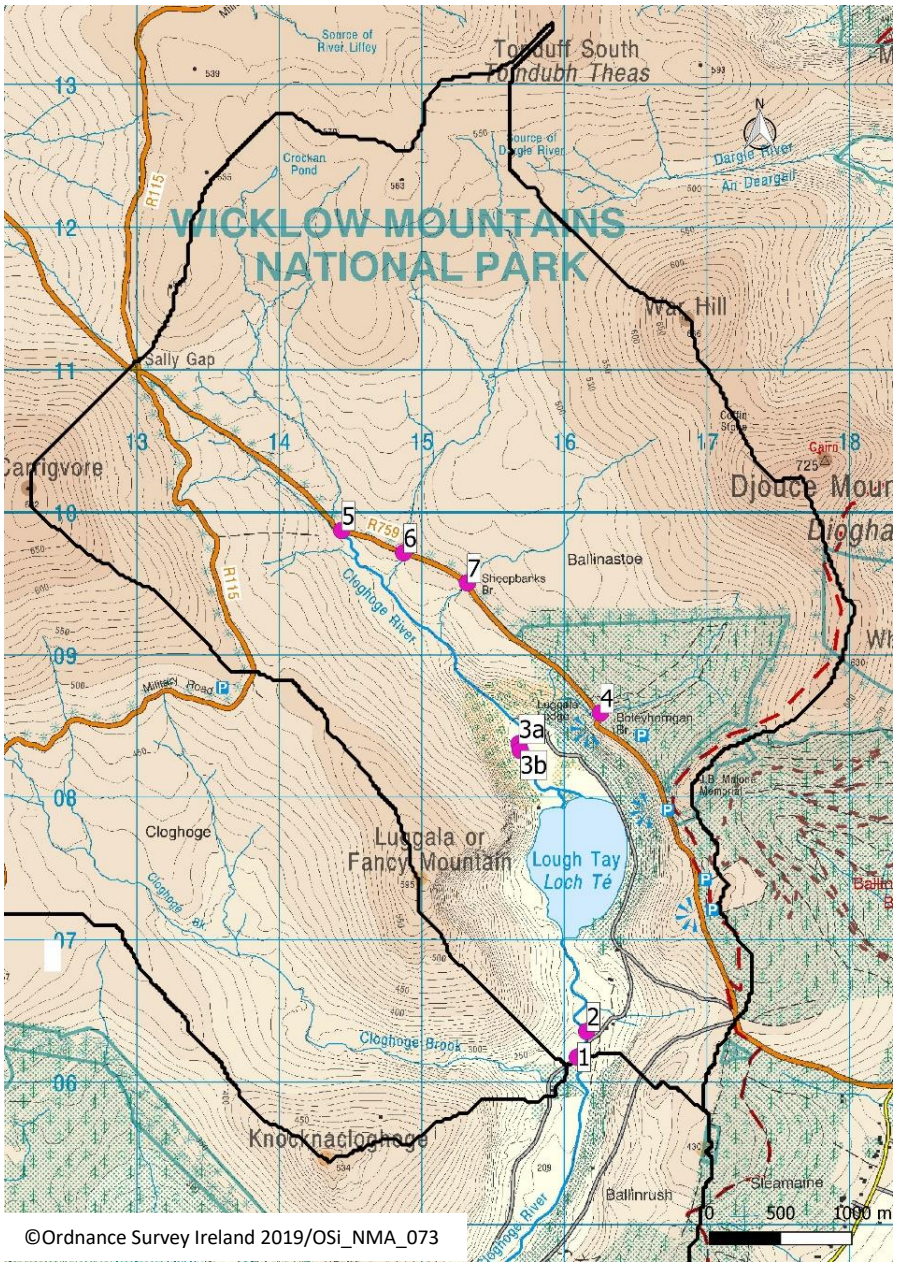

Figure 14 Proposed locations of LCA for Avonmore_010.

7.4 Avonmore_020

- WFD further characterisation action: IA8 High status RWB pressures

To undertake this local catchment assessment in conjunction with the assessment of forestry activities in AVONMORE_20. Focus assessment on forestry and sediment sources and transport and, in particular, areas which have been recently clearfelled.

- Proposed Local Catchment Assessment

Local Catchment Assessment is planned in number of locations to assess biological conditions, siltation levels, visual assessments of macroalgae and macrophytes for the potential nutrient issue, and pH at the reach downstream of the lake and inputting tributaries as indicated in the Figure 15 and Table 9. Visual assessments of the felled areas are also required depending on the results of the ecological assessments and site access. Outcomes of the assessments will be discussed with the Blue Dot Catchment Programme coordinator.

Table 9 Proposed locations of LCA for Avonmore_020.

Label	Description	Reason
1	Avonmore – Old Br – EPA monitoring station	Confirming good/ high status
1a	Tributary just u/s of Old Br	Ruling out impacts from the tributary
1b	U/s of tributary – u/s of Old br	Ruling out impacts from the tributary
2	Ttributary 1 to lake - U/S of Lough Dan	Ruling out impacts from the tributary
3	Tributary 2 - Carrigeenshinnagh tributary (west of Lough Dan)	Ruling out impacts from the tributary
4	Tributary 3 (Ichavore) - West North of Lough Dan	Ruling out impacts from the tributary - no road access – possibly walk from location 2
In1	Inchavore tributary - capturing parts of it on the main road	Depending on the location 4 assessment, these are possible locations for further assessment upstream with road access.
In2	Inchavore tributary - capturing parts of it on the main road	Depending on the location 4 assessment, these are possible locations for further assessment upstream with road access.
In3	Inchavore triibutary - capturing parts of it on the main road	Depending on the location 4 assessment, these are possible locations for further assessment upstream with road access.

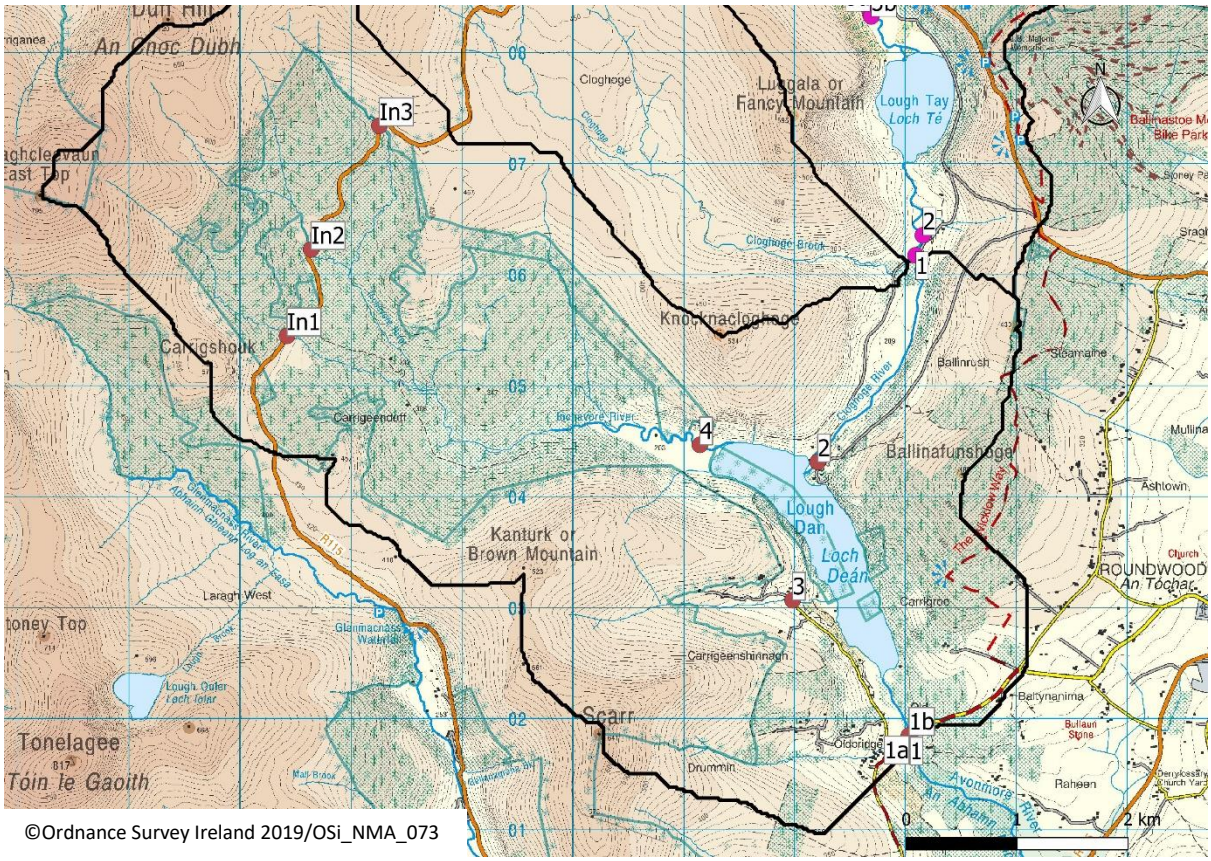

Figure 15 Proposed locations of LCA for Avonmore_020.

7.5 EPA pH review Programme

EPA pH Review Programme focuses on the assessment of the acidification drivers and ecology impacts in waterbodies in Wicklow Mountains area where waterbodies are at risk of failing acidification conditions. Waterbodies in this PAA but also Liffey Upper and Ow PAAs are included in this Review Programme. LAWPRO will assist EPA in the review process through Local Catchment Assessment. Installation of in-situ pH probes for continuous and high-resolution measurements in selected sites included in the EPA pH Review Programme (which may be outside Avonbeg-Avonmore PAA) is proposed. This data will help refine conceptual understanding of the pH impact helping further EPA characterisation process for the acid-sensitive catchments in Wicklow area.

8 Review of mitigation options

8.1 Acidification

Implementing measures for acidification require confidence in pressure drivers and acidification impacts on the ecology. Ecological impacts and acidity drivers (chemistry) will be assessed through the EPA pH review project.

8.2 Siltation

Number of measures exist that can prevent release of fine sediments during forest operations. These include use of silt traps, silt fencing, soil and log dams, settlement areas, in-stream straw bales, use of brash mats, appropriate timing of operations and appropriate use of machinery, no machinery use when felling at the water bank or introducing buffers. Agriculture measures may be required depending on local pressures and these may include livestock exclusion from drinking access points, introducing buffer areas, restoration of possibly eroded (or overgrazed) peat, destocking.

8.3 Nutrients

Potential nutrient enrichment was noted in one of the waterbodies and this will have to be further assessed. Choice of measures depends on the pressure type affecting nutrient conditions and this is yet to be investigated.

9 Communications

Stakeholder meeting was held on 13th May 2019 in the form of a field visit in Ow catchment in Wicklow. Attendees included Forest Service, Coillte, LAWPRO, Wicklow Co Co and EPA. Challenges of the forestry legacy issues, examples of measures and future co-operation were discussed.

No community information meeting was planned for this PAA considering forestry being a dominant pressure. Although agriculture was recognised as a significant pressure in one waterbody (Avonmore_010), with one private estate and two commonage areas in this waterbody there was no need for such meeting. Further need for the community meeting will be evaluated if agriculture is confirmed as a significant pressure after Local Catchment Assessment.

Date of completion of Desk Study: March 2020

10 References

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Appendix I – Maps

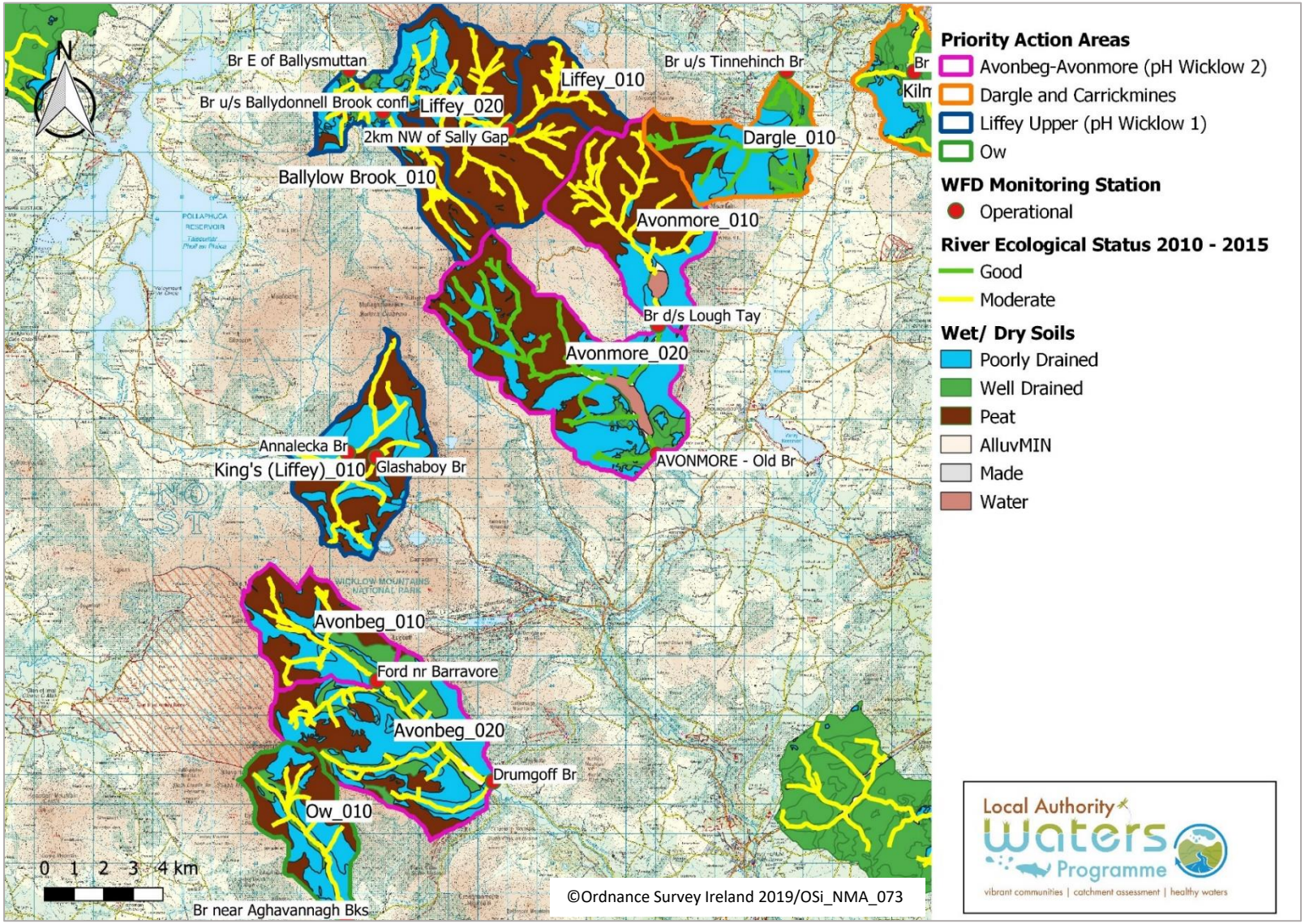

Figure 16 Wet and Dry Soils within Avonbeg – Avonmore PAA.

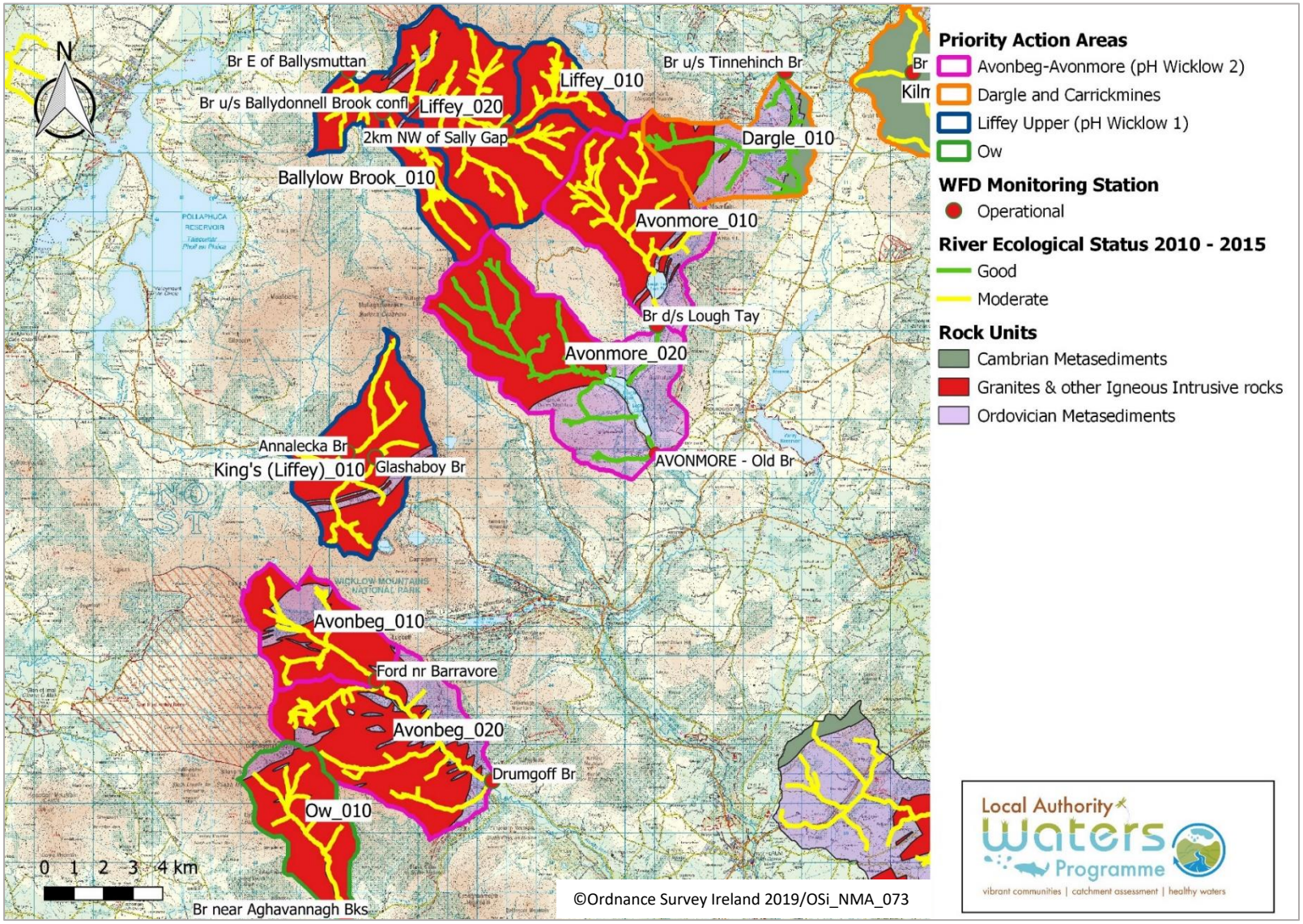

Figure 17 Rock Units within Avonbeg – Avonmore PAA.

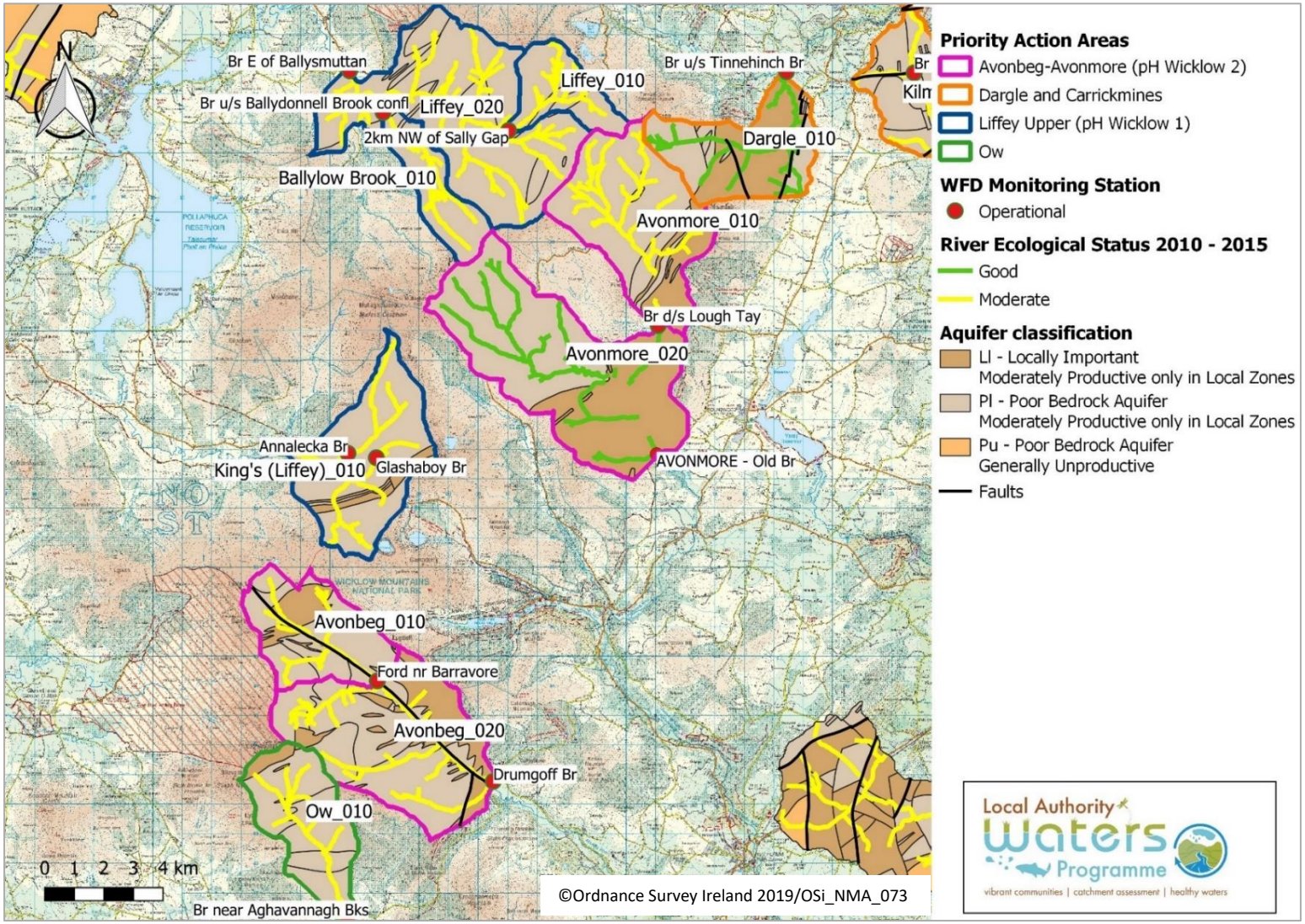

Figure 18 Aquifer type within Avonbeg – Avonmore PAA.

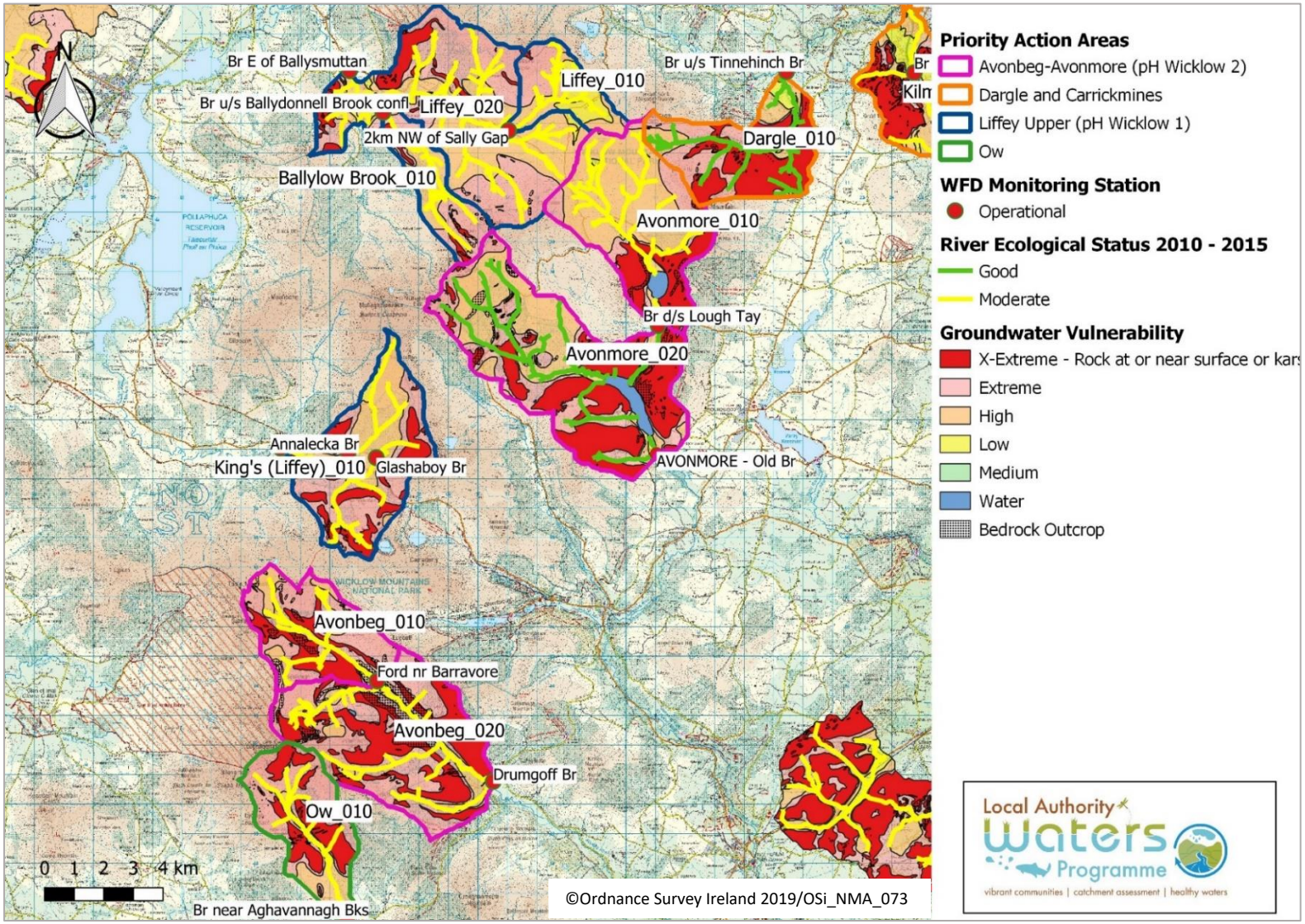

Figure 19 Groundwater Vulnerability within Avonbeg – Avonmore PAA.