Galway County Council

Five years annual monitoring of Rahasane Turlough

2023 report (Year 3) on monitoring programme post works on Flood Relief Scheme

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1. Introduction

1.1. Background

In November 2009, the flooding of the Dunkellin River and Aggard Stream caused damage and disruption to life and properties in the Craughwell and Kilcolgan areas in Co. Galway. As a result, the Office of Public Works (OPW) commissioned a study of the flooding, its causes and effects, to identify a preferred flood relief scheme (FRS) to reduce frequency and/or impact of similar future flooding. In 2011, Galway County Council commissioned an assessment of the likely environmental impacts of the proposed scheme. An agreed scheme was developed, including flood relief works (a combination of river widening, deepening, culvert upgrade and replacement, bridge improvement and replacement, and general channel maintenance). The scheme was designed to provide optimum flood relief with minimum environmental impact, whilst also satisfying cost-benefit criteria. The planning application for the scheme (07.JA0035) submitted by Galway County Council, was granted with seven associated conditions. Of these, Condition No. 4 states:

'For a period of five years following completion of all works, the local authority shall undertake annual monitoring at Rahasane Turlough, to include:

(a) field assessment of swallow holes and recording of natural collapse of conduits or infilling of swallow holes
(b) monitoring of water level at existing river gauges up and down gradient of Rahasane Turlough, and
(c) monitoring of vegetation and indicator species at Rahasane Turlough

Reason: In the interest of the protection of the environment and to broaden scientific knowledge.'

Works on the FRS are complete and Galway County Council, wishing to fulfil its commitments under Condition 4 of the issuance of planning permission, have therefore, appointed APEM Ireland (APEM) to undertake the required field surveys and assessments for a period of five years, starting from July 2021. In each year, APEM will undertake the agreed monitoring and submit an annual findings report, followed by a final report at the end of the 5-year monitoring period.

As no works implemented have directly impacted on Rahasane Turlough itself, the main concerns with regard to the site relate to any possible change in the hydrological regime that pertained/pertains to and within it on an annual basis, and in particular, whether implementation of the FRS might lead to any drying out/reduction in the extent and/or frequency of flooding. The proposed alterations to the Dunkellin River and its bridges have been designed to have virtually no impact on the hydrological regime of Rahasane Turlough, according to the Environmental Impact Assessment. Turlough water levels are predicted to change slightly, but these are not predicted to be significant under flood conditions. Maximum flood levels are predicted to remain unchanged and predicted surface water profiles for various flow scenarios (e.g., 5th percentile, 10th percentile) show no, or, at most, imperceptible changes between the pre- and post-works situations. However, the impact of a possible change in the hydrological regime of the turlough may be detected through the monitoring proposed by An Bord Pleanála (ABP), as follows:

1. Reduction in number, or complete cessation, of changes to the physical structure of the Karst below the turlough, e.g. reduced/zero new incidences of collapse or infilling of swallow holes;
2. Lower water levels and reduced flow volumes and velocity into / out of the turlough as compared to those recorded in the past;
3. Changes in composition of the vegetation, e.g. a shift away from wetland species to more dryland species, and;

4. Changes in the composition of freshwater macroinvertebrate fauna from one characteristic of a regularly flooded habitat to one of a more frequently dry habitat.

This report covers the third year of annual monitoring, conducted between July and September of 2023. There was exceptionally high levels of rainfall in the summer period of 2023 - the rainfall in each month was significantly higher than the previous years of monitoring, particularly in July of 2023, when the levels were over three times higher than those of previous years (Table 1). This meant that the water level of the turlough was flooded to winter levels throughout the summer months when each of the surveys were planned.

Table 1. Total rainfall in millimetres recorded at the Athenry Met Éireann weather station

Year	June	July	August	September
2021	29.8	58.5	84.8	91.1
2022	79.4	66.0	79.6	114.2
2023	93.8	224.1	129.1	148.2

This affected how each of the surveys was conducted in turn. Hydrogeological and hydrological walkover surveys were limited, as the majority of sites previously surveyed were not accessible (and the features to be ground-truthed not visible) owing to inundation. Vegetation surveys were not possible to conduct at all, as all of the transects were under water. As a result, no vegetation chapter is included in this year's report.

Macroinvertebrate surveys were conducted, but it was not possible to conduct the full Pond PSYM method used in previous years, which involves a macrophyte survey. This was because water levels were far beyond the permanent and semi-permanent pools previously surveyed where macrophytes would be observed, and accessible survey points on the turlough were inundated grassland, where no macrophytes would be expected.

1.2. Report Structure

The report is structured to meet the requirements of Condition No. 4 under which An Bord Pleanála granted the application (07.JA0035). Therefore, the remaining structure of the report is as follows:

- Chapter 2 (Hydrogeology and Hydrology Surveys) will report on Condition 4 part (a) '*field assessment of swallow holes and recording of natural collapse of conduits or infilling of swallow holes*' and on Condition 4 part (b) '*monitoring of water level at existing river gauges up-gradient and down gradient of Rahasane Turlough'*.
- Chapter 3 (Macroinvertebrate Survey) will report on the second part of Condition 4 part (c) *monitoring of … indicator species at Rahasane Turlough'*.
- Chapter 4 (Key Findings from Year 3) will summarise the findings of the surveys for this third year.

2. Hydrogeology and Hydrology Surveys

The ecosystem associated with the Rahasane Turlough SAC is highly dependent on the hydrological flow regime at the site. The hydrological flow regime is, in turn, defined by the karst system that underlies the turlough catchment. The surface expression of the karst system is manifested by karst features such as caves, swallow holes, estavelles (ground features that can act as a sink or supply of water depending on surrounding hydrological and hydrogeological conditions) and springs. The key challenge is differentiating natural changes in hydrological behaviour from those which may be attributed to the flood scheme. To meet this challenge, we have undertaken the following:

- Review of previous datasets and reports;
- The third of five annual drone surveys;
- Visited and conducted a brief assessment of the four OPW hydrometric stations associated with the Rahasane Turlough;
- Collected and assessed relevant hydrometric station data; and
- Conducted a site walkover of the turlough to ground-truth and observe karst features for annual monitoring purposes.

2.1. Review of previous datasets and reports

The following sources of site-specific data were reviewed:

- OPW – 2018 Flood Risk Management Plan – Galway Bay South East;
- OPW – 2019 Strategic Environmental Assessment Statement - Galway Bay South East;
- OPW – 2010 Preliminary Flood Risk assessments – Groundwater Flooding;
- RPS - 2014 Environmental Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme);
- RPS – 2014 Natura Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme);
- RPS – 2016 Preconstruction Assessment Geology and Hydrogeology; and
- OPW – Water level and flow data at gauging stations deemed relevant to the FRS, notably on the Dunkellin River near the Rahasane SAC.

The following additional sources of publicly available data and information were checked and used as appropriate:

- Geological Survey Ireland (GSI) web-based groundwater data viewer, specifically the GSI karst database;
- Ordnance Survey Ireland (Geohive) – Historic maps and aerial photography;
- Environmental Protection Agency (EPA web-based data viewer “EPA map viewer”); and
- National Parks and Wildlife Service (NPWS) web-based data viewer (Special Areas of Conservation; Special Protection Areas).

2.2. Annual Drone Survey

The third of five annual aerial photography surveys of the Rahasane Turlough was conducted in June 2023 by Bluesky using a low flying airplane to assist with the ground-truthing and monitoring of karst features. The aerial photography is specified to a resolution of 25 cm. The imagery captured in 2021 – 2022 was conducted using a DJI Mavic 2 Pro drone flown at a height of 125 m and processed using the software programme DroneDeploy. Access to view and compare the processed and collated imagery for 2021 - 2023 has been provided to Mr Enda Gallagher of Galway County Council.

2.3. OPW Hydrometric Stations

OPW Hydrometric Stations (gauging stations) are measurement stations installed on rivers and lakes to record water levels, temperature and/or flow, mainly for flood risk management purposes. In the context of the FRS and the Rahasane Turlough SAC, three existing hydrometric stations on the Dunkellin River were visited in August 2023:

- Craughwell 29007
- Aggard Bridge 29010
- Rahasane Turlough 29002

These stations measure water levels upstream (29007, 29010) and downstream (29002) of Rahasane Turlough. Their locations are shown on Drawing 1 in Appendix 1.

2.3.1. Craughwell 29007

Craughwell 29007 (Figure 1) is a relatively new hydrometric station on the Dunkellin River. It is approximately 230 m downstream of former monitoring station 29007. The latter was replaced with the new station following the construction of the FRS through Craughwell village. The new station 29007 is located upstream of a bridge and is positioned to measure the river levels where the natural river course and the FRS are combined. It records the water level and temperature at 15-minute intervals using an OTT PLS sensor. The data are stored in a data logger and automatically loaded to a server via solar-powered telemetry.

The riverbed at the hydrometric station appears relatively clean (i.e. free of vegetation or other obstacles). The riverbanks are built up with rocks for stability purposes, to a level of approx. 2.7 m above the stream bed. There is a concrete structure which slopes 45° towards the stream at the base of the nearby bridge.

Figure 1: OPW Hydrometric Station Craughwell 29007 (facing west)

2.3.2. Aggard Bridge 29010

Aggard Bridge 29010 (Figure 2; Figure 3) records the water level and temperature on a tributary of the Dunkellin River at 15-minute intervals. Data are recorded using an OTT sensor and stored in an in-situ data logger (Figure 4). The data are automatically transmitted to a server via solar-powered telemetry. The stream banks are heavily vegetated and the profile of the tributary changes over short distances. Downstream, the flow is channeled under a bridge.

There is extensive vegetation within the stream at Aggard.

Figure 2: Overgrowth at Aggard Bridge

Figure 3: Aggard Bridge 29010 Hydrometric Station (facing downstream)

Figure 4: Aggard Bridge 29010 Data Logger

2.3.3. Rahasane Turlough 29002

Rahasane Turlough 29002 (Figure 5) records the water level and temperature of the Dunkellin River downstream of the Rahasane Turlough SAC. Data are recorded at 15-minute intervals using an OTT sensor and stored in a data logger. The data are automatically loaded to a server via solar-powered telemetry. The riverbanks at and upstream of the monitoring station are heavily vegetated.

Figure 5: Rahasane Turlough 29002 Hydrometric Station

2.4. Hydrometric Station Data

Water level data for each of the hydrometric stations are graphed below for the period from the inception of this project (third quarter (Q3) of 2021, i.e. July, August, September) through the third quarter (Q3) of 2023. The data were obtained by the OPW Hydro-Data website (www.waterlevel.ie). Daily rainfall data from the Craughwell weather station (www.met.ie) were added to the graphs for illustration purposes (note, this data runs through end of June 2023 only).

2.4.1. Craughwell 29007

Water level data for Q3 2021 through Q3 2023 for Craughwell 29007 are presented in Figure 6. During this period, water levels ranged between 17.1 mOD and 19.1 mOD (mean = 17.4 mOD). The highest recorded water level was on 12 January 2023. In 2023, water levels were at their lowest from June to mid-July, ranging from 17.1 to 17.4 mOD. An unusually wet summer resulted in a sharp water level rise to 18.1 mOD in August, higher than Q4 levels in 2021. Water levels remained high through to September. Notably, high rainfall events in July and August 2022 (up to 22.5 mm) were not mirrored by increased stream water levels. Highest water levels were recorded in February 2022 at 18.87 mOD followed by decreasing water levels with the lowest values recorded in the summer months of 2022. In comparison water levels increased substantially in 2023 after heavy rainfall in August.

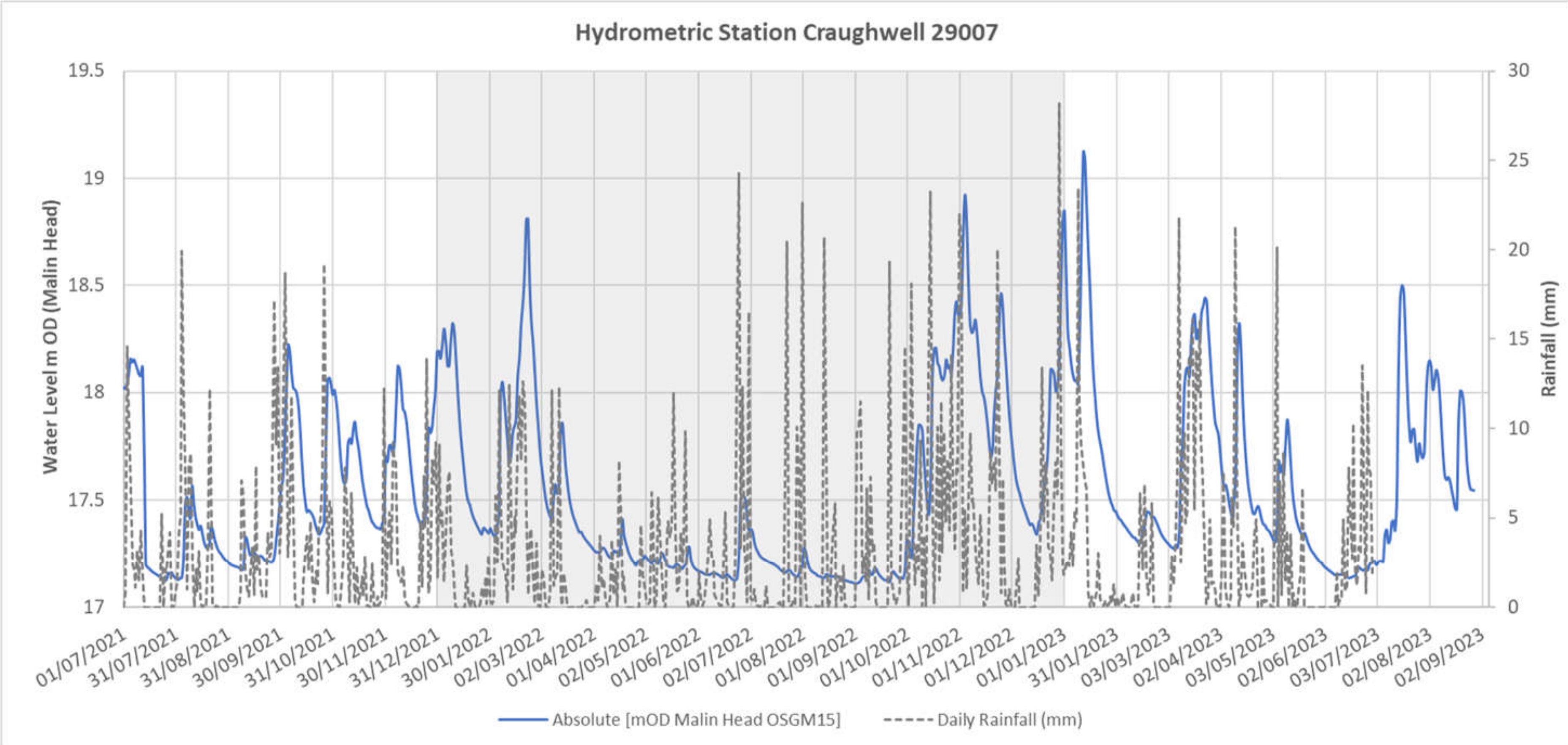

Figure 6: Craughwell 29007, Q3 2021 through Q3 2023 Water Level and Craughwell Rainfall Data .

2.4.2. Aggard Bridge 29010

Water level data for Q3 2021 through Q3 2023 from Aggard Bridge 29010 are presented in Figure 7. Water levels over this period ranged from 21.0 mOD to 21.9 mOD (mean = 21.3 mOD). The water level data follows similar trends to Station 29007. Notably the summer months June to August recorded higher water levels in 2023 than previous years. The period from end of July through to September saw a sharp increase in water level, to 21.9 mOD, higher than winter water levels in 2021 and as high as those in 2022. Rainfall data from 2023 is mirrored in groundwater levels with high rainfall recorded in winter and throughout spring and summer.

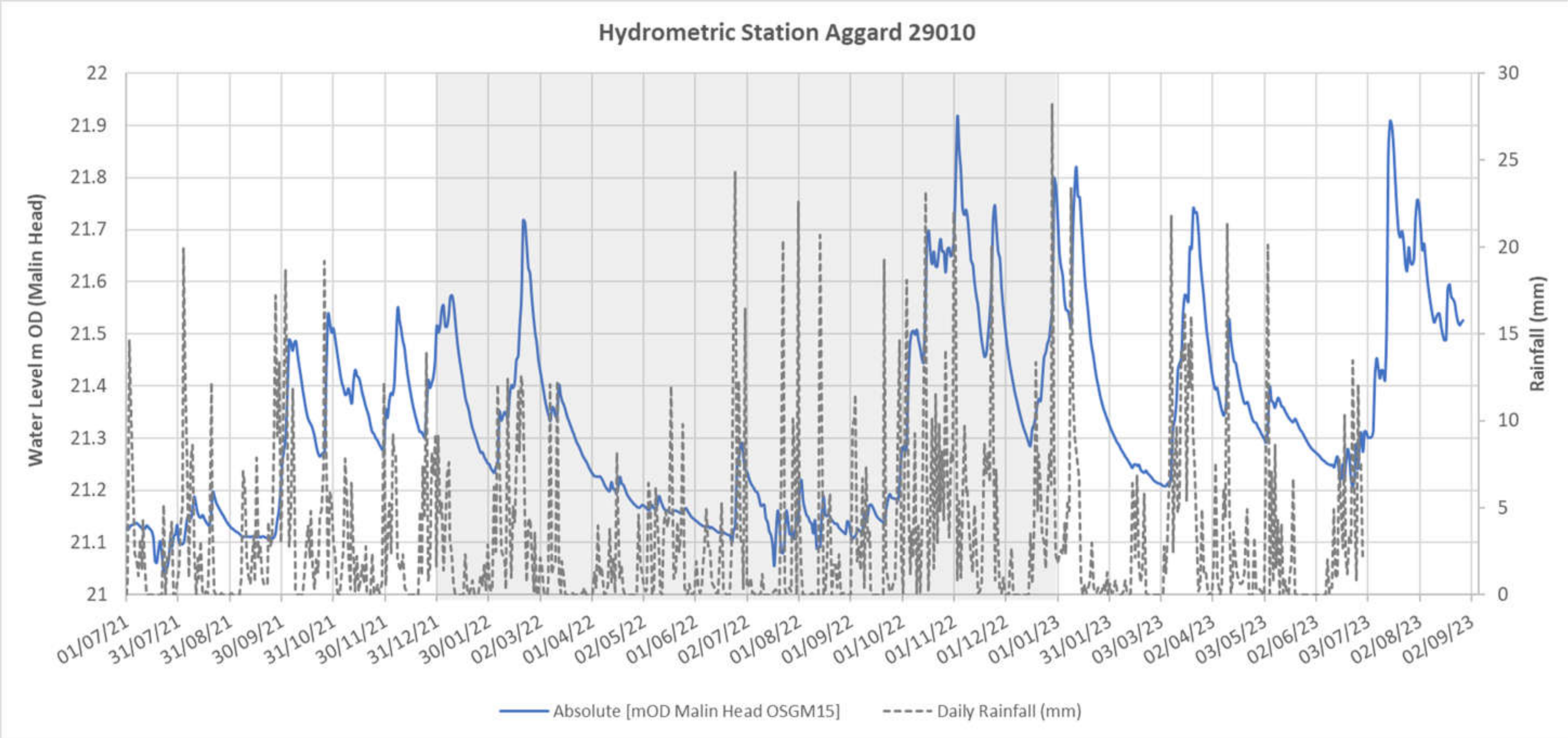

Figure 7: Aggard 29010, Q3 2021 through Q2 2023 Water Level and Rainfall (Craughwell) Data

2.4.3. Rahasane Turlough 29002

Water level data for Q3 2021 through Q3 2023 from Rahasane Turlough 29002 are presented in Figure 8. Water levels over this period ranged from 13.6 mOD to 16.7 mOD (mean = 14.4 mOD). As with the other streams, a large rainfall event in the middle of July through August resulted in a sharp water level rise to 15.7 mOD, which as high as winter levels. As with Craughwell 29007 and Aggard 29010, the high rainfall events in winter, spring and summer are all mirrored by increased stream water levels.

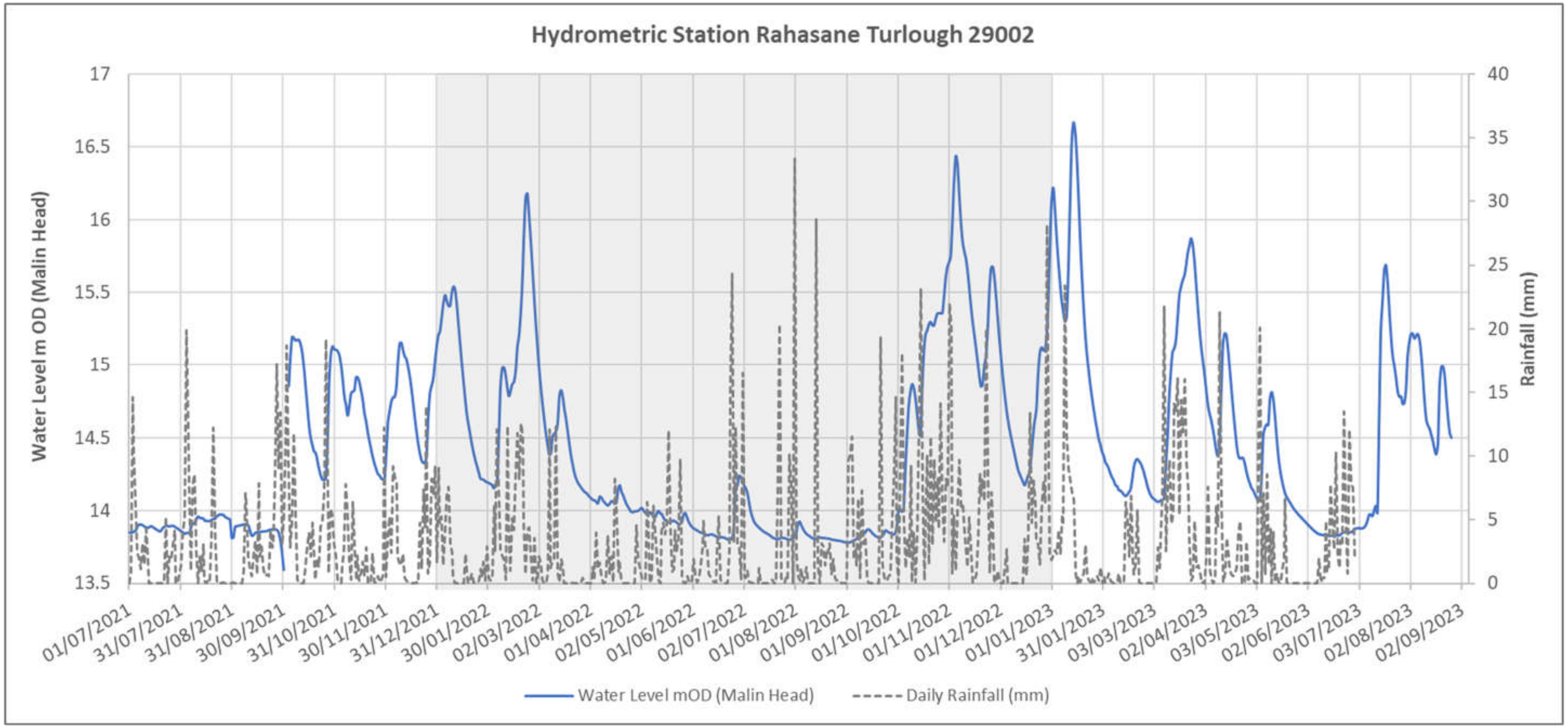

Figure 8: Rahasane Turlough 29002, Q3 2021 through Q3 2023 Water Level and Rainfall (Craughwell) Data

2.5. Walkover survey – Rahasane Turlough

The third walkover survey took place on 15 August 2023. The purpose of the walkover survey was two-fold:

a) to monitor the features recorded during the 2021/2022 walkover; and
b) to record features exposed by the low turlough water level, where present.

During the 2023 walkover, the turlough was inundated on the day of the visit. 2023 was the wettest year since the monitoring programme begin, with high winter, spring and summer water levels and rainfall. This resulted in only a short dry period in June followed by an unusually wet summer. Many of the features were inaccessible on the day of the walkover or were waterlogged, resulting in it being difficult to meaningfully assess whether any changes had occurred since the previous walkover survey. The high water levels are not interpreted to have any association with the flood relief scheme.

The aerial photography was recorded in June when water levels were substantially lower. Approximately 95% of an estimated total turlough area of 3.27 km^2 (NPWS) was above water.

Known karst features in the Rahasane Turlough SAC are shown on Drawing 1 (Appendix 1) and listed in Table 2. These incorporate those features in the GSI database, those mapped by RPS from Lidar data during the FRS project and those that were ground-truthed or identified during the site walkover survey in 2022.

Specific other features of interest noted on the site walkover survey are summarised in Table 2 and include monitoring wells. The team checked with GSI and other researchers of turlough hydrology, but the purpose or circumstances around the presence of monitoring wells are not known.

A selection of images of features during both this year and 2021/2022 is provided in Plates 1 to 6, for comparison.

Table 2: Summary of hydrogeological and hydrological features at the Rahasane Turlough

*Key to ID prefixes –

A: features identified by CDM Smith in 2021;
B: features identified by CDM Smith in 2022;
GSI: features in the GSI database;
RPS: features previously identified by RPS.

ID*	X (ITM)	Y (ITM)	Feature	Comment	Change between 2021 & 2023
A1	546108	718854	Enclosed depression	Monitor for changes.	No change
A2	546310	718914	Dunkellin River	Hydrological reference feature – observation point within turlough.	Some debris at base of bridge
A3	546327	718940	10+ small scale depressions	Possible near surface expression of epikarst. Monitor for changes.	na
A4	546325	718991	Enclosed depression	Monitor for changes.	na
A5	546570	719115	Area receiving inflow from river	Possible nearby swallow hole.	na
A6	546653	719086	Wetland vegetation	Monitor for changes – ecologist	
A7	546681	719110	50+ small depressions of Approx. 200 mm diameter	Possible near surface expression of epikarst. Monitor for changes.	na
A8	546689	719158	Enclosed depression	Possible location for groundwater recharge/discharge (estavelle). Monitor for changes	na
A9	546912	719483	Monitoring well	Condition unknown. Consider condition survey for possible monitoring.	No change
A10	547683	718724	Existing well	Condition unknown. Consider condition survey for possible monitoring.	No change
A11	547408	718725	Enclosed depression	Possible location for groundwater recharge/discharge (estavelle). Monitor for changes.	No change
A12	547411	718730	Enclosed depression	Possible location for groundwater recharge/discharge (estavelle). Monitor for changes.	No change

ID*	X (ITM)	Y (ITM)	Feature	Comment	Change between 2021 & 2023
B1	546551	718960	Small scale depression	Monitor for changes.	na
B2	546629	719112	Estavelle (?) Low water levels (<200mm)	Possible location for groundwater recharge/discharge. Monitor for changes.	na
B3	546839	719313	Estavelle/spring	Feeds steam that flows SW to main channel. Monitor for changes.	na
B4	547006	719548	Turlough water	-	na
B5	547308	719874	Estavelle	Location of groundwater recharge/discharge. Monitor for changes.	na
B6	547310	719876	Estavelle	Location of groundwater recharge/discharge. Monitor for changes.	na
B7	547320	719912	Localised depression	Small scale depression. Monitor for changes.	na
B8	547857	720058	Pond	Appears to drain to main channel. Source unknown. Monitor for changes.	na
B9	547998	720015	Old Dunkellin channel	Monitor for changes.	na
B10	548042	720136	Estavelle	Location of groundwater recharge/discharge. Monitor for changes	No change
B11	548090	720139	GW in depression	Small scale depression. Monitor for changes.	No change
GSI 1	547409	718761	Spring	Monitor for estimated flow	na
GSI 2	547732	718806	Enclosed depression	Monitor for changes	na
GSI 3	546483	718930	Swallow hole	Monitor for changes	na
GSI 4	548512	719832	Enclosed depression	Monitor for changes	na
GSI 5	548647	719790	Enclosed depression	Monitor for changes	na
GSI 6	549994	719655	Swallow hole	Monitor for changes	na

ID*	X (ITM)	Y (ITM)	Feature	Comment	Change between 2021 & 2023
GSI 7	550433	719748	Swallow hole	Monitor for changes	na
RPS 1	550577	719824	Enclosed depression	Monitor for changes	na
RPS 2	547982	719853	Enclosed depression	Monitor for changes	na
RPS 3	548582	719523	Enclosed depression	Monitor for changes	na
RPS 4	548744	719523	Enclosed depression	Monitor for changes	na
RPS 5	547832	719589	Enclosed depression	Monitor for changes	na
RPS 6	547473	719282	10+ small scale depressions	Possible near surface expression of epikarst. Monitor for changes.	na
RPS 7	547372	718848	Enclosed depression	Monitor for changes	na
RPS 8	547041	718867	Enclosed depression	Monitor for changes	na
RPS 9	546943	718755	Enclosed depression	Monitor for changes	na
RPS 10	546994	718861	Enclosed depression	Monitor for changes	na
RPS 11	546920	719065	Enclosed depression	Monitor for changes	na
RPS 12	546509	718456	Enclosed depression	Monitor for changes	na
RPS 13	546205	718203	Enclosed depression	Monitor for changes	na
RPS 14	545843	717986	Enclosed depression	Monitor for changes	na
RPS 15	546277	718983	Enclosed depression	Monitor for changes	na
RPS 16	546459	719099	Enclosed depression	Monitor for changes	na

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2.6. Results and Discussion

An aerial photography survey, review of hydrometric data and walkover survey of Rahasane Turlough were conducted as part of Year 3 monitoring of the Rahasane Turlough. Aerial imagery was obtained on a day when approximately 5% of the turlough SAC was submerged. OPW hydrometric station data and local rainfall data were collected and processed and presented.

Karst features identified during the 2021 and 2022 surveys could not be accessed and monitored in 2023 due to the high water levels following heavy rainfall over the summer of 2023. Groundwater levels remained high all through the summer months and into autumn due to the unusually wet 2023 year. These high water levels are a direct response to heavy and prolonged rainfall without substantial dry periods.

The main difference between 2022 and 2023 is the amount of water in the turlough (notably more in 2023 compared to 2022 and 2021). This was due to the extended wet period during the summer months of 2023. The water levels in the turlough during the 2021 & 2022 survey were much lower due to prolonged dry periods in those years. Aerial imagery shows no evident change in karst features at Rahasane Turlough.

3. Macroinvertebrate and Pond PSYM Surveys

3.1. Background

Annual monitoring of freshwater macroinvertebrate communities has been conducted at Rahasane Turlough to establish if changes in their composition has occurred that would suggest a transition from a habitat characteristic of being regularly flooded to one that is more frequently dry. Turloughs are ephemeral, and natural changes in the hydroperiod occur on an annual basis. It is therefore important to look for changes in the community composition over a longer period, to establish whether a transition in habitat, and consequently in the macroinvertebrate community composition, is occurring.

The Predictive System for Multi-metrics (PSYM) was designed for habitat survey and the assessment of standing waters (Howard, 2002). This method was used as a standard survey method for the turlough, allowing year on year comparison of the results. It was developed by the Freshwater Habitats Trust and the Environment Agency in England and provides a standardised method for surveying and assessing the biological quality of standing waters.

However, the full PSYM method for ponds, which involves a macrophyte survey, could not be conducted this year, as water levels were very high, making the permanent and semi-permanent pools previously surveyed where macrophytes would be observed inaccessible. Accessible survey points on the turlough were inundated grassland, where no macrophytes would be expected to occur.

In this third year of the survey, macroinvertebrate samples were identified to family level, although some were identified to a genus/species level. Water beetles were identified to species level to allow for comparison among years and with previous surveys conducted prior to the commencement of works at the site.

The presence and abundance of ephemeral taxa were also examined, based on research conducted by Porst (2009). Presence of taxa such as Trichoptera and Heteroptera are correlated with turloughs with longer hydroperiods and Gastropoda also occur in higher abundances in turloughs with longer hydroperiods, probably owing to their limited mobility. Standard metrics were calculated in addition to the calculation of the PSYM, which were compared to the first two years of results, to examine if any changes in macroinvertebrate communities present have occurred.

3.2. Review of previous datasets and reports

The following sources of site-specific data were reviewed:

- RPS, 2014. Environmental Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme);
- RPS, 2014. Natura Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme);
- RPS, 2016. Dunkellin River and Aggard Stream Flood Relief Scheme: Pre-construction Aquatic Beetle Survey

The following additional sources of relevant publicly available data and information were also reviewed:

- Environmental Protection Agency (EPA web-based data viewer (EPA map viewer; Water))
- National Parks and Wildlife Service (NPWS) web-based data viewer (Special Areas of Conservation; Special Protection Areas).
- National Biodiversity Data Centre Database

- Porst, 2009. *The Effects of Season, Habitat, Hydroperiod and Water Chemistry on the Distribution of Turlough Aquatic Invertebrate Communities.* PhD Thesis, Trinity College Dublin.
- Relevant published peer reviewed papers associated with turlough macroinvertebrate community composition (Foster *et al.*, 1992; Lahr, 1997; Lahr *et al.*, 1999; Follner and Henle, 2006 and Williams, 2006

3.3. Method

3.3.1. Physico-chemical measurements

Temperature, pH, conductivity and dissolved oxygen concentration and saturation were measured on-site at each sample location using a multiparameter probe. Additional information on the local environment, substrate, shading, level of grazing and emergent plan cover was also recorded.

3.3.2. Macroinvertebrate survey and analysis

Macroinvertebrate sampling was carried out at four locations at the Rahasane Turlough on 26 September 2023 (Figure 9). Owing to the high water levels, some of the previous sites were inaccessible (Sites 1 and 3) and thus these sites were moved to more accessible points. Site 1 was southwest of the original sampling point. The southern bank of the turlough was completely inaccessible and thus Site 3 was moved to the northern shore, halfway between Sites 2 and 4. The substrate at each site was comprised of inundated grazed grassland, with submerged, emerging and floating leaved aquatic plants absent, as water levels were so high and the habitats present lacked heterogeneity.

The survey was conducted by sweep netting through the submerged vegetation at all mesohabitats present at each location, using a standard pond net with 1 mm mesh size for a period of 45 seconds at each site (bringing the total to a 3-minute sample), as outlined in the PSYM method by Howard (2002). The samples were preserved in > 90% Isopropyl alcohol on-site and returned to the laboratory for further analysis, where they were combined into a single composite sample. An additional targeted aquatic beetle combined sample was selectively collected from a number of isolated pools around the turlough by sweep netting through submerged vegetation at all mesohabitats present using a small handheld pond net with 1 mm mesh size for a period of 30 seconds at each site, in order to maximise the number of species encountered; this method was also used in 2022, and was a slight adjustment to the 2021 method, following an external review of the first year's sampling programme. This sample was preserved in > 90% Isopropyl alcohol on-site and returned to the laboratory for further analysis.

Specimens were identified under a binocular microscope to family level in the laboratory using the standard range of identification keys published by the Freshwater Biological Association, AIDGAP and others, with the exception of water beetles, which were identified to the finest resolution possible (species level where possible). A list of the macroinvertebrate taxa recorded can be found in Appendix 2 of this report. This list informed the calculation of all macroinvertebrate indices.

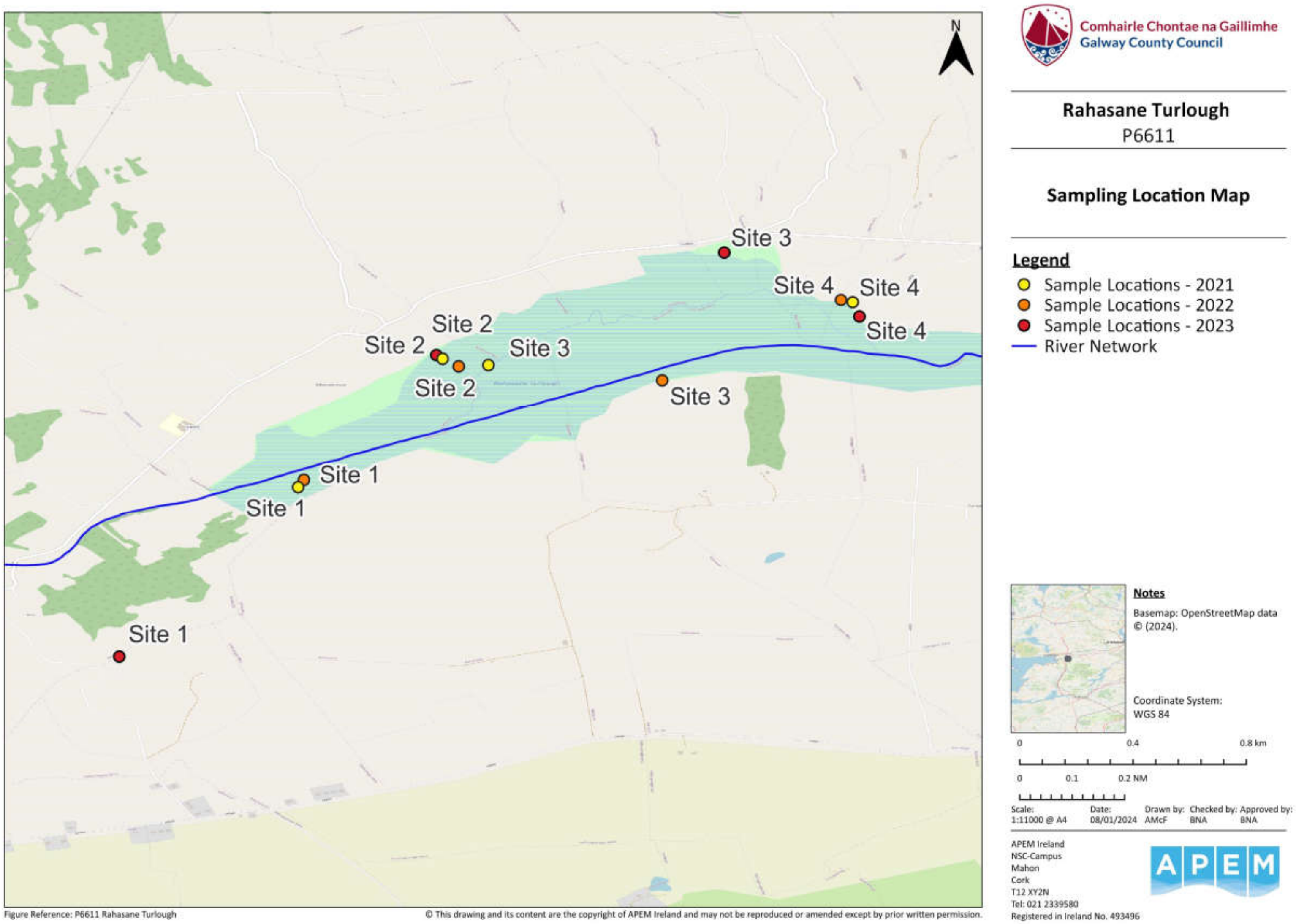


Figure 9: Locations of sample sites surveyed for macroinvertebrate and PSYM analysis in 2021, 2022 and 2023

3.3.3. Metrics calculation

PSYM was calculated for Rahasane Turlough based on the assessment of macroinvertebrate assemblages present as well as environmental data. PSYM is a predictive tool, comparing observed species assemblages with expected composition based on the type and location of the water body, and metric scores are then combined to provide a single value which summarises the overall ecological quality of the water body. However, the reference data used to enable the prediction is currently only available for England and Wales. Instead, the survey metrics will be compared to one another over five consecutive years, to identify any changes over this time.

For the macroinvertebrate samples the metrics calculated for invertebrates in PSYM are Biological Monitoring Working Party (BMWP) score, Average Score Per Taxon (ASPT), the number of dragonfly and alderfly (Odonata and Megaloptera) families (OM) and the number of beetle families (Coleoptera). As macrophytes could not be surveyed on this occasion, these metrics could not be calculated.

The BMWP and ASPT scores exploit the natural sensitivity of each taxon to organic pollution. Macroinvertebrate families which are sensitive to pollution are assigned high BMWP scores, while pollution-tolerant taxa score low. BMWP index may be altered significantly depending on whether the sampling process captures species found in some habitats but not in others. Standardisation of the BMWP score is therefore provided by the ASPT, allowing robust comparisons among sites. BMWP was developed in the UK and has since been adapted for a range of locations globally, including Iberia (BMWP-I) and Costa Rica (BMWP-CR); the original version works well in Ireland.

Although the PSYM method recommends that pond quality should assessed using both plant and invertebrate assemblages, it is stated that a partial assessment can be made using just one assemblage if necessary, and that macroinvertebrates are likely to be the best choice of organisms for assessing overall water body quality (Howard, 2002).

An EPA Q value classification was assigned to each site. The Q-values were assigned based on the presence and relative abundance of sensitive groups and the consideration of additional qualifying criteria, as described by Toner *et al.* (2005), and in Feeley *et al.* (2020), outlined in more detail in Appendix 2. The Whalley Hawkes Paisley Trigg (WHPT) NTAXA (number of taxa) and WHPT-ASPT were also calculated. The WHPT is an enhancement of BMWP, now used in the UK for monitoring, assessing and classifying rivers in accordance with the requirements of WFD.

The Q-value and WHPT metrics are designed for use on samples collected from rivers, and so have limitations when applied to samples from standing waters, particularly as these are often naturally subject to low oxygen concentrations and have different assemblages of taxa to rivers. Many of the metrics incorporating macroinvertebrates as bioindicators use a species or overall community's response to levels of dissolved oxygen to assess impact. This makes their use in standing waters less robust, so other measures of ecological health or value are needed, such as the presence/absence of particular species. In addition, given that much of Rahasane Turlough is ephemeral, the samples collected are likely have quite distinct assemblages. However, the metrics can still be useful as a means of comparison of samples taken from the same water body over time and were calculated here on that basis. In the case of the Q value assigned, a corresponding WFD Ecological Status was not assigned, given that this metric is being used as a means of comparison among years, and is not designed for use in still waters.

3.3.4. Assessment using water beetles

Foster *et al.* (1992) identified that aquatic Coleoptera as a group possess a range of attributes required to evaluate the conservation status of wetlands. They identified ten distinct assemblage types of Irish water beetles and developed a classification system for habitats typical of these assemblages. The

Rahasane Turlough was identified as Community Type F, described as 'turloughs and more permanent, large, shallow, water bodies on base-rich substrata' (Foster *et al*., 1992).

This research also devised a classification system to assess water beetle assemblages, ranking sites by community significance using a simple metric that can demonstrate the quality of different wetland habitat types and identify sites of highest ecological value (Foster *et al*., 1992). This involves calculating Individual Species Quality Scores (SQS), assigned based on how commonly or rarely the species occurs in certain habitat types, and is based on an initial study that looked at their frequency within 10 km squares across Ireland. The scores of elusive species are downgraded, as are those associated with tidal water or confined to habitats of man-made origin. The scores of species restricted to undisturbed natural habitats are upgraded within the system. Then a Mean Quality Score (MQS) for a site is calculated by dividing the total of individual SQS by total number of scoring species. This method was followed here.

The water beetle community of the Rahasane Turlough has been surveyed several times prior to this study: by Bilton (1989), O'Connor (2001), Waldron (2003/ 2004) and RPS (2016). A summary of the results from the previous surveys was presented in the report by RPS (2016). Using the MQS from each of these studies enables a comparison to be made over time.

3.4. Results and discussion

3.4.1. Water quality

Key water chemical parameters were recorded on-site and are summarised in Table 3. Water temperature was significantly lower at all sites than recorded in previous years (more than 6°C lower at all sites), likely as a result of the much wetter summer preceding the survey. Dissolved Oxygen (DO) was also significantly different than it was other years. In 2021, all sites had quite low DO saturation levels (29-51%) and in 2022 all sites were supersaturated (162-192%). In contrast, DO levels in 2023 were at healthy levels (84-105%) as defined in the Surface Water Regulations (2009). Conductivity levels were slightly higher on average than those recorded in other years. The oxygen concentrations are probably a consequence of sampling this year being in parts of a much larger water body, which may have less fluctuation in physicochemistry, This could have resulted in the dilution of nutrients and lead to less algal growth observed than in previous years. In 2022 there were extensive growths of algae, whose photosynthesis during the day is likely to lead to supersaturation of oxygen (and, conversely, low concentrations overnight); these were not present in 2023.

Table 3. Summary of *in situ* physicochemical data at Rahasane Turlough, August 2023

Parameter	Unit	Site 1	Site 2	Site 3	Site 4
Temperature	°C	14.9	15.0	15.0	14.1
Dissolved Oxygen	% Saturation	94	105	105	84
Dissolved Oxygen	Mg/L	9.46	10.50	10.50	8.63
Conductivity	µS/cm	481	552	552	554

3.4.2. Taxonomic richness

All sampling sites were flooded grasslands, with no macrophytes present at any site (owing to elevated water levels). Among the four sites surveyed, 15 families of macroinvertebrates from 9 groups were identified (Table 4). This is a decrease in diversity compared with 2022, when 20 families from 10 groups were recorded, and 2021 when 24 families from 14 groups were recorded.

Key taxa not found in 2023 were the gastropod snail Bithyniidae and the pea mussel Sphaeriidae. However, high numbers of the gastropod snails Planorbidae, Physidae and Lymnaeidae were recorded, similar to previous years. Higher abundances of Gastropoda in turloughs have been associated with longer hydroperiods and it has been suggested that this relates to their limited mobility (Follner and Henle, 2006). The limited mobility of molluscs seems to permit greater survival in sites inundated for longer periods, despite possessing adaptations to drought (Williams, 2006).

In contrast to previous years, there were high numbers of freshwater louse Asellidae (*Asellus aquaticus*) and shrimp Crangonyctidae (*Crangonyx* sp.); there were also large numbers of water bugs (Corixidae). Most interesting of all were the exceptionally high numbers of aquatic beetles, particularly the diving beetles Dytiscidae, in the sample (more than 20% of the sample). Fewer beetles were found in samples in 2022 (1.4%, 24 individuals) and 2021 (6.5% of the sample, 222 individuals); most of the beetles in 2021 were larvae of the family Haliplidae, which have low dispersal ability, whereas in 2023 almost no larvae were recorded. There was a decrease in the number of damselflies (Coenagrioniidae) in the sample, when compared with the previous years.

Porst (2009) showed that Trichoptera (caddisflies) and Heteroptera (true bugs) abundances have a significant positive correlation with the hydroperiod of the turlough in her study of Irish turloughs. Although these macroinvertebrate groups are ephemeral residents of temporary waters, they need more permanent habitats to complete their life cycles (Lahr, 1997; Lahr *et al.*, 1999). No consistent trends in the presence and abundance of Heteroptera were apparent among years, they represented a small (<10%) proportion of the sample in each year, and were most diverse in 2022 (3 families present) and least diverse in 2023 (1 family present). Trichopterans were absent from the 2023 and 2022 surveys and present only in small numbers in 2021.

The differences in 2023 may reflect the flooded nature of the turlough in 2023 (in contrast with the particularly dry summer in 2022) and the fact that permanently flooded sites could not be surveyed. Sphaeriidae are unable to disperse as adults, whereas Corixidae and Dytiscidae have strong powers of dispersal and are able to colonise new habitats rapidly. Gastropod snails and Asellidae are examples of taxa that can thrive in heavily vegetated wetland areas and will benefit from the availability of detritus and biofilm created by the flooding and decomposition of more terrestrial summer vegetation; other groups that have large numbers of detritus feeders, including caddisflies (Trichoptera), are confined to permanently wet areas and so are unlikely to be present in large numbers to colonise recently flooded areas; they, along with mayflies (Baetidae) are also less likely to be present in the aquatic larval stage during the summer. Chironomidae is a family of true flies with many species, several of which are adapted to rapid colonisation of new habitats; however, the large numbers of Corixidae and Dytiscidae probably exert a heavy predation pressure on these species, keeping their numbers low.

Porst (2009) hypothesized that turloughs with longer habitat permanence have higher abundances of ephemeral taxa, because in there is a greater possibility of colonisation. The proportional abundance of ephemeral taxa with high dispersal ability such as Odonata, Hemiptera, some Diptera, and some Coleoptera families (e.g. Dytiscidae) was higher in 2023 than in previous years (quarter of the sample, instead <10%), perhaps reflecting the longer hydroperiod, although the total abundance of these taxa varied among years, with no consistent trend.

The summer flooding in 2023 is likely to have masked any underlying patterns. However, the long term nature of this survey means that any compositional change in the invertebrate community is likely to be picked up despite unusual years such as this.

Table 4: List of macroinvertebrate taxa and their abundance recorded at Rahasane Turlough in 2021, 2022 and 2023

Order/Class	Family	Abundance		
		2021	2022	2023
Planaria	Planariidae	4		
	Dendrocoeliidae	1		
Oligochaeta	Lumbricidae	22		2
Hirudinea	Glossiphoniidae	1	3	
	Erpobdellidae	2		
Gastropoda	Valvatidae		85	10
	Bithyniidae	945	355	
	Lymnaeidae	991	499	306
	Planorbidae	413	410	795
	Physidae	79	69	93
Bivalvia	Sphaeriidae	18	111	
Ostracoda		1		
Isopoda	Asellidae	24	13	474
Amphipoda	Crangonyctidae			309
	Gammaridae	8	10	
Ephemeroptera	Baetidae	1	4	9
Odonata	Coenagrioniidae	60	60	10
Hemiptera	Gerridae	1		
	Veliidae		5	
	Notonectidae		2	
	Corixidae	200	38	108
Trichoptera	Limnephilidae	2		
	Leptoceridae	4		
Diptera	Chironomidae	32	5	17
	Culicidae	3		
	Sciomyzidae			1
	Tabanini		1	
Coleoptera	Haliplidae	220	9	38
	Dytiscidae	1	8	568
	Helophoridae		6	1
	Hydrophilidae		1	
	Curculionidae	1		
Total order/class		14	10	9
Total families		24	20	15

3.4.3. PSYM Results

The Pond PSYM metrics are displayed in Table 4. There were 14 PSYM macroinvertebrate taxa recorded, representing limited diversity at the site, and a reduction year on year since 2021. Both the BMWP and the corresponding ASPT scores were lower at the site in 2023, than in previous years, and scores declined over time. The declining score may indicate a decline in ecological quality. It must be noted however, that the sampling was conducted over flooded grassland, as the various mesohabitats of the lake were flooded and could not be sampled safely. The 2023 results may therefore be a consequence of this: the fauna at the accessible sites is limited to the more opportunistic and adaptable ones that can take advantage of the recently flooded habitat. As in previous years, only a single OM taxon was present, the damselfly Coenagrioniidae, which is the same as found in the previous two years. The OM number can be a good indicator of water quality in British ponds (Biggs *et al*., 2000), so the continued low diversity may suggest a potential negative impact at the turlough; conversely, Odonata and Megaloptera, which are large-bodied may not be well adapted for living in a turlough with a direct river connection and therefore potential for fish predation during periods of flooding.

Table 5. Pond PSYM macroinvertebrate metrics calculated at Rahasane Turlough

Metric	2021	2022	2023
BMWP	78	62	54
No of PSYM Taxa (NTAXA)	19	16	14
ASPT	4.11	3.88	3.6
No. of Odonata & Megaloptera Taxa (OM)	1	1	1
No. of Coleoptera Taxa	2	2	3

3.4.1. Standard Macroinvertebrate Metric Results

The standard metrics for freshwater macroinvertebrate surveys are recorded below in Table 5. The Q-value score was the same as previous years. The values of the WHPT,WHPT-ASPT and WHPT NTAXA scores were all lower than previous years, with a low baseline score recorded in 2021. Although all scores are lower in 2023, this is likely to be explained more by the high water levels, and lack of access to all mesohabitats (which were flooded) rather than a true decline in ecological quality.

Table 6. Standard macroinvertebrate metrics calculated at Rahasane Turlough

Metric	2021	2022	2023
Total no. Families	24	20	15
Q-Value	Q3	Q3	Q3
WHPT	81.6	64.8	46.5
WHPT ASPT	3.4	3.6	3.1
WHPT NTAXA	24	18	15

3.4.2. Beetle Survey Comparison

Ten species of aquatic beetle were recorded at the site, including a number of specimens that could only be identified to a grouping of species (Table 6). Three species that were not recorded in any of the previous surveys since 1989 were newly recorded: *Haliplus lineatocollis*, *Rhantus exsoletus* and *Rhantus frontalis*. Since APEM surveys began in 2021, five new aquatic beetle species have been recorded at the site.

Of interest, is that *Rhantus frontalis* (newly recorded in 2023) has a moderately high Species Quality Score (SQS) of 16. A high SQS represents aquatic species that are rare, with a higher score for rarer species or those restricted to undisturbed, natural habitats (Foster *et al*., 1992). However, *R. frontalis* is not restricted to undisturbed habitats, and its score is based on its rarity in Ireland.

Beetle diversity in the 2023 samples was much higher than 2022 and 2021, and only slightly lower than that documented in older studies (Table 7). However, the MQS score was lower than that documented in the past five previous studies (since 2002) indicating that the species present had a lower SQS than those previously recorded. Again, the lower MQS could possibly be attributed to the lack of representative habitats sampled in 2023 owing to the level of flooding. Many beetles, especially Dytiscidae, are highly mobile and can colonise new habitat quickly, so the 2023 results may be a consequence of more adaptable species (with low MQS) taking advantage of the summer flooding.

The Environmental Impact Statement (EIS) noted that several beetle species which are sensitive to hydrological alterations had been identified in the turlough previously. These were the turlough species *Agabus nebulosus, Hygrotus quinquelineatus* and *Hygrotus impressopunctatus*; and the moss dwelling species *Graptodytes bilineatus. G. bilineatus* is listed as Near Threatened on the Irish Water Beetle Red List (Foster *et al.*, 2009) and is considered likely to be vulnerable to disturbance and sensitive to alterations in flooding (Sheehy Skeffington *et al.*, 2006). Three of the four species named were found in the 2023 survey, with very high numbers of *H. impressopunctatus* and considerable numbers of *A. nebulosus* and *H. quinquelineatus* recorded. However, *G. bilineatus* was not found at the site on this occasion. This species has only been found once at the site, in 2004. None of these species were recorded in the 2021 or 2022 surveys. The fact that these species were found in considerable numbers at the site suggests that the flood relief scheme has not caused a hydrological change at the turlough. However, continued monitoring in the coming years should maintain a focus on the beetle communities, to continue to assess the aquatic beetle community, given their sensitivity to hydrological change.

Table 7. Aquatic Beetle species recorded in the 2021, 2022 and 2023 surveys of the Rahasane Turlough

Family	Species / Species group	2021	2022	2023
Curculionidae		1		
Haliplidae	*Haliplus* sp. (larvae)	199		
	Haliplus ruficollis group	20	6	23
	Haliplus lineolatus	1	1	7
	Haliplus ruficollis		2	8
Dytiscidae	Larvae			2
	Hygrotus inaequalis		3	14
	Hygrotus quinquelineatus			17
	Hygrotus impressopunctatus			316
	Hydroporus palustris		5	199
	Agabus nebulosus			17
	Ilybius fuliginosus	1		
	Rhantus exsoletus			1
	Rhantus frontalis			2
Helophoridae (Hydrophilidae)	*Helophorus aequalis*			1
	Helophorus longitarsis/griseus/minutus		3	
	Helophorus minutus		3	
	Laccobius colon		1	

Table 8. Mean Quality Score (MQS) calculated for the water beetle community and number of aquatic beetle species surveyed at the Rahasane Turlough, in this survey (bold) compared with previous years

Year	MQS Score	No. of species	Surveyor
2023	**6**	**10**	**APEM**
2022	7.7	6	APEM
2021	6.7	3	APEM
2016	6.5	17	RPS
2004	10.4	13	Waldron
2003	7.5	12	Waldron
2002	5.7	10	O'Connor
1992	3	11	Foster
1989	3.3	11	Bilton

4. Key Findings from Year 3

Hydrogeology and Hydrology Survey:

- As part of the third year of monitoring the Rahasane Turlough, a drone survey and walkover survey of Rahasane Turlough were conducted and hydrometric data (OPW hydrometric station data and local rainfall data) was collected and reviewed.
- The walkover survey was conducted in August, and the turlough was inundated, due to sustained heavy rainfall over the summer of 2023, with most of the features inaccessible or inundated, making it difficult to assess whether changes had occurred since the last survey in 2022. In contrast, approximately 5% of the turlough SAC was submerged when the aerial imagery was obtained in June, when water levels were substantially lower.
- No change was noted on any of the Karst features identified during the 2021 survey that were possible to monitor, aside from debris at the base of the Dunkellin Bridge.
- The main difference recorded between the 2022 and 2023 surveys was the amount of water in the turlough (notably more in 2023 compared to 2022 and 2021). This was due to the extended wet period during the summer months of 2023. The water levels in the turlough during the 2021 and 2022 survey were much lower owing to prolonged dry periods in those years. Aerial imagery from 2023 shows no evident change in karst features at the turlough.

Macroinvertebrate and PSYM Survey:

- Water levels at the turlough were at winter levels owing to exceptionally high levels of rainfall in the summer of 2023. This meant that permanent and semi-permanent ponds within the turlough that had been previously surveyed were inaccessible. Accessible survey points were all on inundated grassland, and as a result no macrophyte survey was conducted (as macrophytes were not present).
- Water quality readings differed from previous years. A much lower temperature was recorded, likely as a result of sustained rainfall lowering water temperature. Much healthier levels of Dissolved Oxygen were recorded, possibly as a result of greater water levels resulting in the dilution of nutrients and less algal growth.
- A total of 15 macroinvertebrate families were recorded, principally gastropods, but with higher numbers of freshwater louse, shrimp and aquatic beetles than recorded in previous years. Pond PSYM metrics supported a conclusion of nutrient impact at the site.
- A high abundance (>1200 specimens) of gastropods was found at the site. There was a lower diversity of gastropods recorded at the turlough than in the previous 2 years (4 families). However, it is unlikely that some families were absent owing to drought pressure given the high water levels, and more likely that the homogeneity of habitats surveyed didn't encompass those previously sampled where a richer diversity could be found.
- The abundance and diversity of beetles in the samples collected was higher than recorded in 2021 and 2022. Nevertheless the Mean Quality Score was lower than previous years. However, three of the four species noted in the EIS which are sensitive to hydrological alterations were found at the site, not previously recorded in 2022 or 2021.
- Although high water levels meant that this years results were not directly comparable with other years, a diverse aquatic community was recorded even at inundated sites without typical aquatic habitats.
- Future surveys will continue to compare results such as the PSYM scores, community structure, abundance of ephemeral taxa (positively correlated with more permanent turloughs), gastropod community and beetle MQS scores, among years, to establish if a transition has occurred from a habitat characteristic of being regularly flooded to one that is more frequently dry.

5. References

Biggs J, Williams P, Whitfield M, Fox G and Nicolet P (2000). *Biological techniques of still water quality assessment. Phase 3. Method development.* Environment Agency R&D Technical Report E110. Environment Agency, Bristol.

Feeley HB, Bradley C, Free G, Kennedy B, Little R, McDonnell N, Plant C, Trodd W, Wynne C and O'Boyle S (2020). A national macroinvertebrate dataset collected for the biomonitoring of Ireland's river network, 2007–2018. *Scientific Data* 7: 280.

Follner K and Henle K (2006). The performance of plants, molluscs, and carabid beetles as indicators of hydrological conditions in floodplain grasslands. *International Review of Hydrobiology* 91: 364-379.

Foster GN, Nelson BH, Bilton DT, Lott DA, Merritt R, Weyl RS and Eyre MD (1992). A classification and evaluation of Irish water beetle assemblages. *Aquatic Conservation: Marine and Freshwater Ecosystems* 2: 185-208.

Howard S (2002). *A guide to monitoring the ecological quality of ponds and canals using PSYM.* Environment Agency, West Midlands and Freshwater Habitats Trust.

Lahr J (1997). Ecotoxicology of Organisms Adapted to Life in Temporary Freshwater Ponds in Arid and Semi-Arid Regions. *Archives of Environmental Contamination and Toxicology* 32: 50-57.

Lahr J, Diallo A, Ndour K, Badji A and Diouf P (1999). Phenology of invertebrates living in a sahelian temporary pond. *Hydrobiologia* 405: 189-205.

O'Connor Á (2017). *Turloughs and Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation.* Conservation objectives supporting document series. National Parks & Wildlife Service, Dublin.

Porst, G (2009). *The Effects of Season, Habitat, Hydroperiod and Water Chemistry on the Distribution of Turlough Aquatic Invertebrate Communities.* PhD Thesis, Trinity College Dublin.

RPS (2016a). *Dunkellin River and Aggard Stream Flood Relief Scheme Pre-construction Aquatic Beetle Survey.* Prepared on behalf of Galway County Council.

RPS (2016b). *Dunkellin River and Aggard Stream Flood Relief Scheme Turlough Vegetation Community Surveys.* Prepared on behalf of Galway County Council.

Toner P, Bowman J, Clabby K, Lucey J, McGarrigle M, Concannon C, Clenaghan C, Cunningham P, Delaney J, O'Boyle S, MacCarthaigh M, Craig M and Quinn R (2005). *Water Quality in Ireland: 2001–2003.* Environmental Protection Agency, Johnstown Castle Estate, Wexford, Ireland.

Plates

Plate 1 ID: B10 Estavelle (left: 2021, right: 2023)

Plate 2 ID: A10 Depressions (left: 2022, right: 2023)

Plate 3 Existing well (condition unknown) (left: 2021, right: 2023)

Plate 4 ID: A1 Enclosed depression (left: 2022, right: 2023)

Plate 5 View of Rahasane Turlough looking SE from NW shore

Plate 6 Debris at base of Dunkellin Bridge

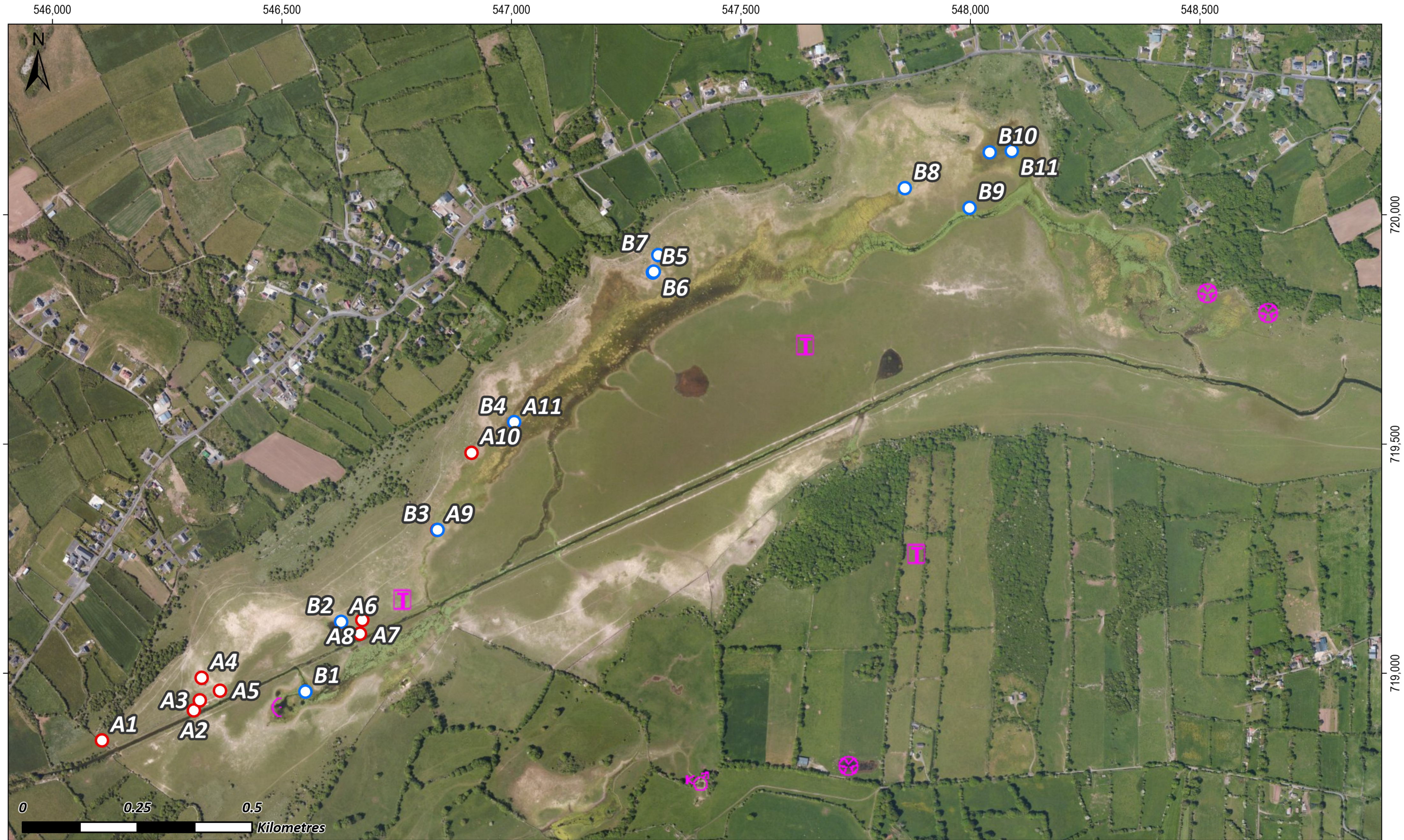
Plate 7 Photo of Site 1 (macroinvertebrate survey, 26.09.23)

Plate 8 Photo of Site 2 (macroinvertebrate survey, 26.09.23)

Plate 9 Photo of Site 3 (macroinvertebrate survey, 26.09.23)

Plate 10 Photo of Site 4 (macroinvertebrate survey, 26.09.23)

Appendix 1: Drawing 1 Hydrometric Stations



Client:	Consultant:	Drawing Title:	Project Name:	Karst Landforms (GSI)	Site Walkover Location - see report for details	Drawn: BP	Checked: LF	Approved: JH
APEM Ireland Ltd	15 Wentworth, Eblana Villas, Dublin 2, D02 A611, Dublin (Ireland) CDM Smith Tel: +353 1 232 1044 Web: www.cdmsmith.com	Hydrogeological Features	RAHASANE TURLOUGH MONITORING Project Code: 264298	Enclosed Depression Spring Swallow Hole Turlough	2021 2022	Date: 18/11/2022 Drawing Number: 1	Scale: 1:10,500 @ A4 Revision: D	

Spatial Reference
Name: IRENET95 Irish Transverse Mercator

Document Path: C:\Users\pittsb\OneDrive - CDM Smith\Teams - GIS Team Europe - Ireland\Drone Operations\Rahasane\Rahasane.aprx

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Appendix 2: Macroinvertebrate metrics

Q-Value Assessment

The EPA Q-value classification is assigned based on the assessment of the macroinvertebrate sample, which involves recording the taxa present at a suitable and attainable (under field conditions) taxonomic resolution and their categorical relative abundance determined using approximate counts (as described in Feeley *et al.*, 2020). From this, the number of taxa present and categorical relative abundance of sensitive (Group A), less sensitive (Group B), tolerant (Group C), very tolerant (Group D) and most tolerant (Group E) taxa to organic pollution is examined. Additional Qualifying Criteria are also considered, consisting of recording the abundance of *Cladophora* spp, Macrophytes, and slime growths / sewage fungus, as well as the Dissolved Oxygen Saturation % and the level of substratum siltation. Then, based on the combination of number of taxa and relative abundance of the sensitive or tolerant groups present a Q-value is assigned. Details on the assignment of the scores can be found in Toner *et al.*, (2005).

BMWP and ASPT

The Biological Monitoring Working Party (BMWP) index was designed to identify the degree of organic pollution based on the natural sensitivity of taxon to the pollution. Aquatic organisms respond to chemical changes in water, in particular to the changes in dissolved oxygen concentrations. As pollution levels increase, the microbial oxygen demand rises, resulting in a decline in available oxygen concentrations. Many stream organisms require high dissolved oxygen concentration and are therefore not found in water bodies with lower oxygen concentrations. Macroinvertebrate families which are sensitive to pollution are assigned high BMWP scores, while pollution-tolerant taxa score low. In the BMWP system, benthic invertebrate taxa are assigned a score between 1 (tolerant to organic pollution) and 10 (intolerant to organic pollution). The BMWP score is the sum of the values for all families present in the sample. The number of BMWP-scoring families is typically recorded alongside the BMWP score, as is the Average Score Per Taxon (ASPT), which can be determined by dividing the BMWP score by the number of scoring taxa present. The BMWP score may vary significantly depending on whether the sampling process captures species found in some habitats but not in others. Standardisation of the BMWP score is therefore provided by the ASPT, with the average BMWP score per taxon allowing robust comparisons among sites.

BMWP was designed for assessing river quality, but has been successfully incorporated into the PSYM method for pond quality assessment.

WHPT and WHPT-ASPT

The Whalley Hawkes Paisley Trigg (WHPT) metric is used in the UK for monitoring, assessing and classifying rivers in accordance with the requirements of WFD based on assessing the ecological quality of the macroinvertebrates present when sampled. It is a revised version of the original BMWP index. Empirical data was used in the development of the WHPT index to assign abundance related sensitivity weights to taxa. The taxa included in the index are modified from those used for the BMWP index and a number of taxa were removed due to insufficient data; some additional families were included where sufficient data were available, and some existing BMWP composite taxa were split into their constituent families. The WHPT-ASPT values typically range from 1 (indicative of sites with high organic matter concentration, typically associated in rivers with pollution and degradation) to 13 (indicative of sites with very low organic matter concentration, associated in rivers and lakes with low pollution and degradation). The WHPT-ASPT score standardises the WHPT score to an average per taxa to allow a robust comparison among sites.