Galway County Council

Five years annual monitoring of Rahasane Turlough

2024 report (Year 4) on monitoring programme post works on Flood Relief Scheme

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1. Introduction

1.1. Background

The Dunkellin River and Aggard Stream flooded in November 2009, causing damage and disruption to life and properties in the Craughwell and Kilcolgan areas in Co. Galway. The Office of Public Works (OPW) commissioned a study of the flooding and its causes and effects, to identify a preferred flood relief scheme (FRS) to reduce frequency and/or impact of similar future flooding as a consequence. 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 appointed APEM to undertake the required field surveys and assessments for a period of five years, starting from July 2021. In each year to date, APEM has undertaken the agreed monitoring and submitted an annual findings report. A final report will be issued at the end of the 5-year monitoring period.

None of the FRS works implemented have directly impacted on Rahasane Turlough itself. Therefore, the main concerns with regard to the site relate to any possible change in the hydrological regime that 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 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 perceptible 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 fourth year of annual monitoring, conducted between July and August of 2024.

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 (Vegetation Survey) will report on the first part of Condition 4 part (c) '*monitoring of vegetation… at Rahasane Turlough'*.
- Chapter 4 (Macroinvertebrate Survey) will report on the second part of Condition 4 part (c) '*monitoring of … indicator species at Rahasane Turlough'*.
- Chapter 5 (Key Findings from Year 4) will summarise the findings of the surveys for this fourth 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 fourth 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 fourth of five annual aerial photography surveys of the Rahasane Turlough was conducted in August 2024 using a DJI Matrice 30T drone to assist with the ground-truthing and monitoring of karst features. The aerial photography is processed using Agisoft Metashape and can be viewed on ArcGIS. The geometrical resolution on the ground is approx. 3 cm/px with the drone flying at 80 m height, 6 m/s speed, 80% overlap and 70% sidelap. The drone was mounted with a dedicated RTK hardware module, increasing its positioning accuracy up to 1 cm on the horizontal plane and 2 cm on the vertical plane. The 2023 aerial imagery was provided by Bluesky specified to a resolution of 25 cm. Access to view and compare the processed and collated imagery for 2021 - 2024 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 2024:

- Craughwell 29007
- Aggard Bridge 29010
- Rahasane Turlough 29002

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

2.3.1. Craughwell 29007

Craughwell 29007, (Plate 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.

2.3.2. Aggard Bridge 29010

Aggard Bridge 29010 (Plates 2 and 3)) records the water level and temperature on a tributary of the Dunkellin River at 15-minute intervals, upstream of the turlough. Data are recorded using an OTT sensor and stored in an in-situ data logger (Plate 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 channelled under a bridge.

The vegetation at Aggard Bridge appears to have been cleared. However, some vegetation is still present on the riverbed.

2.3.3. Rahasane Turlough 29002

Rahasane Turlough 29002 (Plate 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.

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 2024. 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 April 2024 only).

Water level data for Q3 2021 through Q3 2024 for Craughwell 29007 are presented in Figure 2-1. During this period, water levels ranged between 17.11 m OD and 19.17 m OD (mean = 17.62 m OD). The highest recorded water level was on 21 October 2023. In 2024, water levels were at their lowest from July to the end of August, ranging from 17.17 to 17.22 m OD. Water levels during summer 2024 were low comparable to the summer of 2022. Water levels for the majority of June through to mid-August ranged from c. 17.2 – 17.3 mm. A rise to 17.5 mm was recorded at the end of August, however water levels did not reach the extent of August 2023 (18.1 m OD). Highest water levels were recorded in October 2023 at 19.17 m OD followed by flashy water levels associated with rainfall events with the lowest values recorded in the summer months of 2024. In comparison water levels were substantially higher in 2023 after heavy rainfall in August 2023.

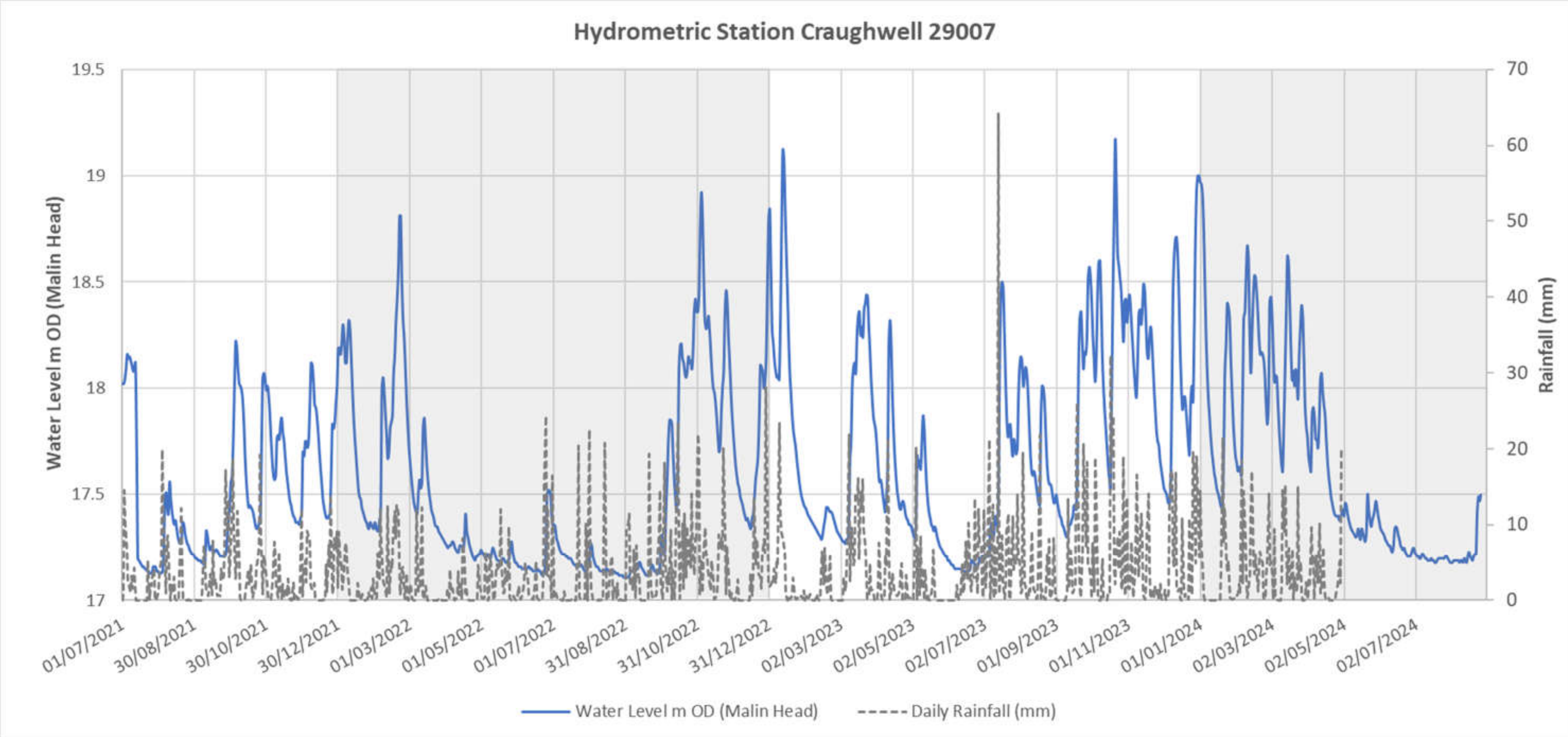

Figure 2-1: Craughwell 29007, Q3 2021 through Q3 2024 Water Level and Craughwell Rainfall Data.
Note: Met Éireann data is only available to the end of May 2024

Water level data for Q3 2021 through Q3 2024 from Aggard Bridge 29010 are presented in Figure 2-2. Water levels over this period ranged from 21.0 m OD to 21.9 m OD (mean = 21.34 m OD). The water level data follows similar trends to Station 29007. A steady decrease in water levels was recorded from June through to mid-August, similar to summer 2022. The 2024 summer was substantially drier than summer 2023. Winter water levels in 2023/2024 were higher than 2022/2023 and 2021/2022 winters. Rainfall in the 2023/2024 winter season was also higher than in previous years. Rainfall data is mirrored in groundwater levels with high rainfall recorded in winter and throughout spring and summer.

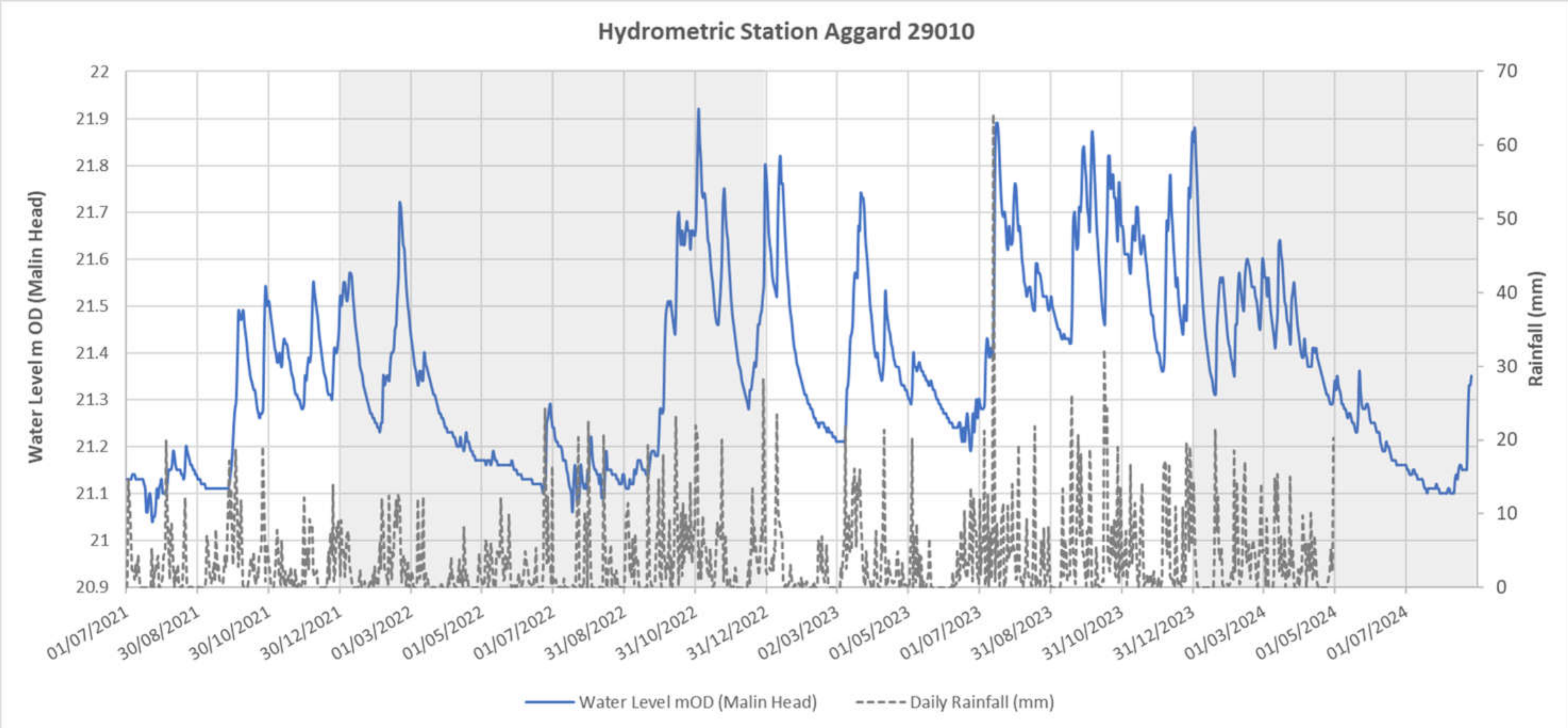

Figure 2-2: Aggard 29010, Q3 2021 through Q3 2024 Water Level and Rainfall (Craughwell) Data.
Note: Met Éireann data is only available to the end of May 2024

Water level data for Q3 2021 through Q3 2024 from Rahasane Turlough 29002 are presented in Figure 2-3. Water levels over this period ranged from 13.6 m OD to 16.8 m OD (mean = 14.3 m OD). Water levels at this location are very similar to 29010 and 29007. As with the other streams, June to mid-August were dry with low water levels similar to summer 2022. Summer 2023 was unusually wet. As with Craughwell 29007 and Aggard 29010, the high rainfall events in winter, spring and summer are all mirrored by increased stream water levels.

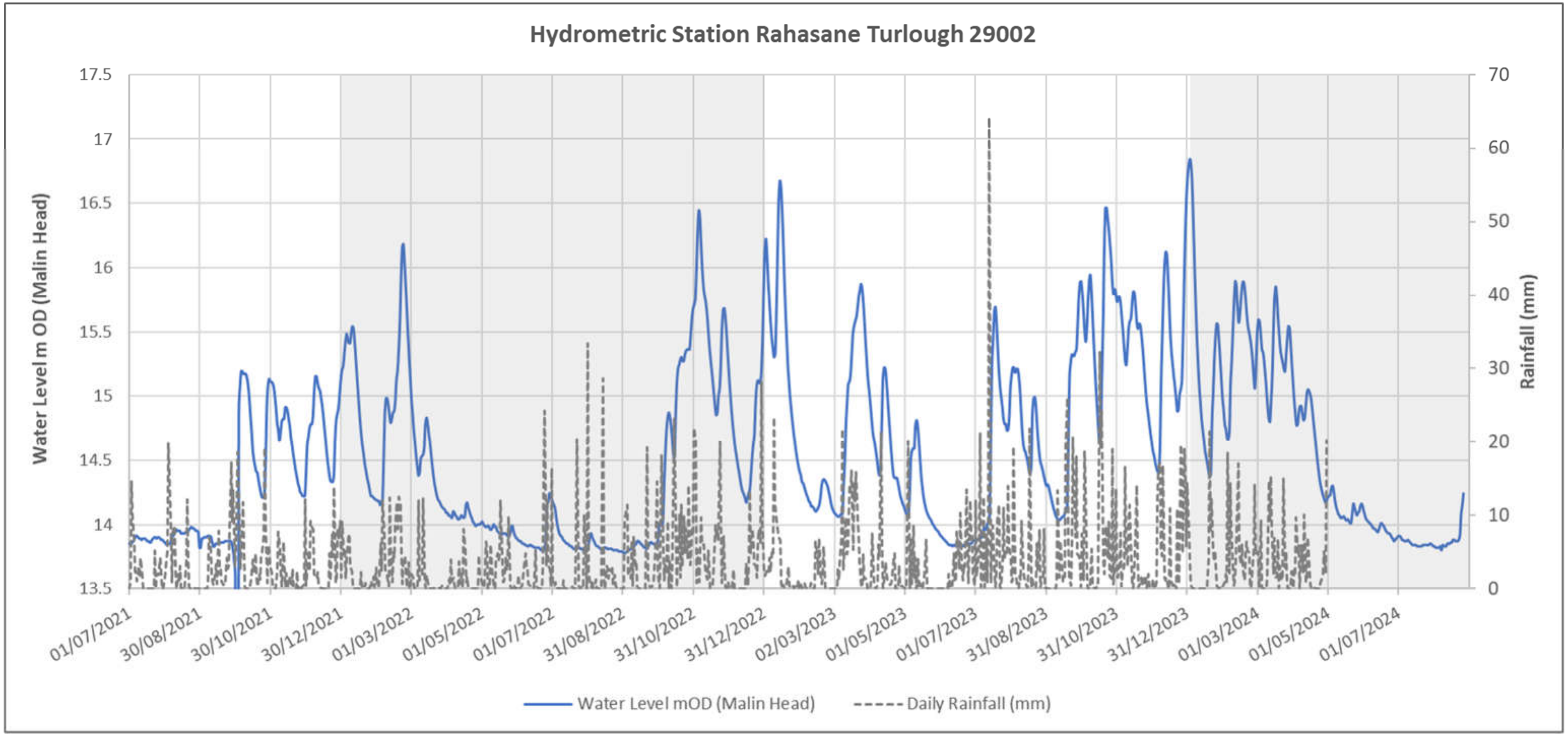

Figure 2-3: Rahasane Turlough 29002, Q3 2021 through Q3 2024 Water Level and Rainfall (Craughwell) Data.
Note: Met Éireann data is only available to the end of May 2024

2.5. Walkover survey – Rahasane Turlough

The fourth walkover survey to took place on 26 August 2024. The purpose of the walkover survey was two-fold:

a) to monitor the features recorded during the 2021/2022/2023 walkover; and
b) to record features exposed by the low turlough water level, where present.

Water levels in summer 2024 were lower than summer 2023, and were consistently low up until 24 August. However a sharp increase in water levels the weekend prior to the site walkover resulted in a 0.3 m water level increase, and the turlough was inundated on the day of the visit. Many of the features were therefore inaccessible or were waterlogged resulting in it being difficult to meaningfully assess whether any changes had occurred since the previous walkover survey.

The aerial photography was recorded on 7 – 8 August when water levels were substantially lower, and approximately 90 % 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 A) and listed in Table 2-4. 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 from 2021 - 2023.

Specific other features of interest noted on the site walkover survey are summarised in Table 2-4 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 - 2023 is provided in Figures 9 through 15, for comparison.

Table 2-1: Summary of hydrogeological and hydrological features at the Rahasane Turlough

ID*	X (ITM)	Y (ITM)	Feature	Comment	Change between 2021 & 2024
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
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

ID*	X (ITM)	Y (ITM)	Feature	Comment	Change between 2021 & 2024
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
C1	547145	718622	Estavelle	High water levels in estavelle	na
C2	547311	718809	Estavelle	Appears quite deep. Possibly a sinkhole	na
C3	545967	718122	Enclosed Depression	Small scale depressions c. 0.5m diameter	na
C4	545995	718203	Enclosed Depression	Large depression	na
C5	545974	718132	Enclosed Depression	Depression in c. 50m wide	na
C6	545900	717983	Monitoring well	Monitor for changes	na
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
GSI 7	550433	719748	Swallow hole	Monitor for changes	na

ID*	X (ITM)	Y (ITM)	Feature	Comment	Change between 2021 & 2024
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

*ID with prefix A: features identified by CDM Smith in 2021; ID with prefix B: features identified by CDM Smith in 2022; ID GSI 1-7: GSI features; ID RPS 1-16: RPS features

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 4 monitoring of the Rahasane Turlough. Aerial imagery was obtained on a day when approximately 10 % of the turlough SAC was submerged. OPW hydrometric station data and local rainfall data were collected and processed and presented.

Many of the karst features identified during the 2021 and 2022 surveys could not be accessed and monitored in 2024 due to the high-water levels following a period of heavy rainfall just prior of the walkover survey. Groundwater levels were high in the 2023/2024 winter season and dropped for the majority of June to mid-August.

There is no obvious change between 2023 and 2024, water levels were high in both walkover surveys and many features identified in 2021 and 2022 could not be monitored. 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. Vegetation Surveys

3.1. Review of previous datasets and reports

Monitoring of vegetation communities at Rahasane Turlough is being conducted to assess whether there are any patterns of change in the vegetation during the five years of the monitoring project. Following drainage works on the Dunkellin River (see Section 1.1), there is a requirement to monitor the turlough vegetation to find out if there is evidence that implementation of the flood relief scheme might lead to changes in water levels in the turlough, such as longer periods of drying out, lesser extent of inundation, or reduced frequency of flooding in the turlough. Such changes could be reflected in the composition of the turlough's vegetation communities.

The vegetation communities of turloughs are of high ecological interest and conservation importance for two reasons in particular:

1. Turloughs are extremely rare in a European and global context, with almost all examples found in Ireland;
2. The unusual and dynamic seasonal water regime facilitates a distinct range of plant species, some of which are not widely found outside of these habitats.

This ecological rarity and importance is emphasised by the fact that turloughs have been listed as priority habitats in the EU Habitats Directive (EU habitat code 3180). The vegetation of turloughs reflects their transitional nature, with a very dynamic water regime. The composition of the vegetation tends to change in accordance with the flooding gradient and the amount of time per year that each particular area is inundated.

A comprehensive study of turlough vegetation in Ireland was undertaken on behalf of the National Parks & Wildlife Service (NPWS) by Waldren (2015). In addition, NPWS commissioned a Conservation Objectives supporting document (O'Connor, 2017) to cover 45 Special Areas of Conservation (SACs) selected for the Annex I Priority habitat Turloughs (3180), for which individual Conservation Objectives Supporting documents had not been prepared. These documents were reviewed to inform the methodological approach to surveying.

The vegetation of Rahasane Turlough was surveyed in detail by Goodwillie (1992) as part of a study of 61 Irish Turloughs commissioned by NPWS. This survey focused on distinctive plant communities and specific indicator species, to ascertain the flora present and to examine any habitat variation, including variation between Rahasane and other turloughs.

A further study was undertaken by Sharkey (2012), documenting the vegetation communities of 22 turloughs within Counties Galway, Clare, Roscommon and Mayo. While this study did not include Rahasane Turlough, the categorisation of turlough vegetation communities was updated by Sharkey, and this updated classification was specified for use in the surveys carried out at Rahasane from 2021 to 2025.

Vegetation communities in Rahasane Turlough were surveyed by RPS environmental consultants during 2014-2015 in order to inform the planning submission for the Dunkellin River & Aggard Stream Flood Relief Scheme (RPS, 2016a). This study revisited Goodwillie's transects and examined 12 transects and 249 relevés in detail. The results of the surveys by RPS were reviewed and used to inform the site selection process for the current study.

3.2. Methods

Fieldwork methodology was adapted from Waldren (2015) in accordance with the scheduled and costed time available. This includes mapping of vegetation zones during the dry season (mid-summer to early autumn) using transects, and vegetation monitoring in fixed-position relevés. To select study areas for this 5-year monitoring project, the vegetation records from the transects and relevés in the RPS (2016a) survey were reviewed. A subset of 15 of these relevés, along three transects, were then selected for inclusion in the present study, with the intention being to achieve a geographic spread across the turlough and to focus on areas previously identified as being of botanical diversity and importance. These transects and relevés are shown in Appendix 1. They were the focus of the 2021 study and were again visited and surveyed in 2022 and 2024. Survey teams visited the site in summer 2023, but it was not possible to carry out surveys because all transects and relevés were inaccessible due to flooding.

The 2024 surveys were carried out on 24 and 25 July 2024, this being within both the optimum survey season for wetland habitats and the usual dry season for the turlough, and comparable with the timing of surveys in 2021 and 2022. Fieldwork was undertaken by Philip Doddy, Adrian Walsh and Ana Lencastre. All field surveyors are experienced ecologists with specialist skills in botanical field survey and habitat classification.

The vegetation communities along each transect were identified and mapped, using the updated vegetation community classification system of Sharkey (2012). This was done by examination and recording of vegetation along the selected transects, identifying the points of transition to different vegetation zones along each transect. The ArcGIS app Survey123 was used to record accurate locations along transects and to take geo-referenced photographs. Each of the selected 1 x 1 metre relevés was examined, where accessible. For each relevé this included an assessment of its physical characteristics, vegetation cover, vegetation type, plant species present and percentage cover of each species, as well as notes on management and any observed pressures or threats.

Due to the nature of the site, water levels fluctuate often and can impede access to survey areas. During the 2024 vegetation survey, there were a total of four relevés not accessible due to the water levels. A summary of relevé accessibility from 2021 – 2024 is given in Table 3-1.

Results from the vegetation zone mapping were processed on QGIS, and maps were produced showing the relevant vegetation zones.

Table 3-1: Relevés accessible in each survey year (2021 – 2024)

Year	T2 R2	T2 R4	T2 R6	T2 R12	T2 R16	T4 R5	T4 R10	T4 R16	T4 R18	T4 R22	T6 R2	T6 R6	T6 R12	T6 R16	T6 R18
2021							X	X	X	X	X	X			
2022								X	X		X	X			
2023	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2024								X	X		X	X			

Relevé completed (green)   X Relevé inaccessible due to flooding (orange)

3.3. Results and Discussion

This section presents the results of the vegetation surveys conducted at Rahasane Turlough in 2024. Summary tables are included to give a synopsis of the species present and vegetation cover in each relevé. Vegetation maps produced from these surveys are given in Appendix 2. In addition, comparisons between the results from the 2024 surveys and those conducted between 2014 and 2022 are given in Appendix 4. These are colour-coded according to their typical habitat (usually terrestrial, usually aquatic or intermediate).

As in previous survey years, the classification system of Sharkey (2012) corresponded only very approximately with the vegetation communities as recorded at Rahasane. This is not remarkable given that the set of turloughs studied by Sharkey did not include Rahasane, and such habitats, as with all natural systems, are naturally variable in character. It may be worthwhile considering the use of Goodwillie's (1992) classification system in future studies, as his study of Irish turloughs did include Rahasane. The high level of overgrazing at Rahasane Turlough also made the classification of vegetation challenging, as in many areas it was found that the vegetation was eaten down almost to soil level. Nonetheless, the information gathered for each relevé in the present study includes species records and percentage cover for each species, and could therefore be used in conjunction with improved or more closely-tailored classification systems in the future for the sake of comparison, if required.

3.3.1. Transect 2

The vegetation composition along parts of Transect 2 remained similar to what was observed in the previous survey seasons, in that it was mostly dominated by two species: silverweed (*Potentilla anserina*) and creeping bent (*Agrostis stolonifera),* with other significant species being white clover *(Trifolium repens),* creeping buttercup *(Ranunculus repens)* and water forget-me-not *(Myosotis scorpioides).* However, in this survey the dominance of *Potentilla anserina* was more pronounced than in previous years, with four of the five relevés showing an increase in the cover of this species. The main change noted between 2022 and 2024 was the reduction in the 5 (11) *Persicaria amphibia-Mentha aquatica* community. In 2022, this vegetation community occurred at three sections along the transect (see APEM, 2023). In 2024, the vegetation communities in these areas corresponded more to 3 (19) *Potentilla anserina – Potentilla reptans*. However, these areas were very heavily grazed by sheep in 2024, and it may be possible that some plant species had been eaten away or selectively preferred by grazers. Looking at the results from a relevé in this part of the transect (T2R4), there was an increase in creeping bent (*Agrostis stolonifera*) and silverweed (*Potentilla anserina*)*,* with a reduction in black sedge (*Carex nigra*)*,* water mint (*Mentha aquatica*)*,* water forget-me-not (*Myosotis scorpioides*)*,* greater plantain (*Plantago major*) and marsh bedstraw (*Galium palustre*). This could be indicative of a drier habitat if the trend continues.

There were five species recorded in small amounts in 2024 that had previously not been recorded in the relevés of Transect 2: meadow thistle (*Cirsium dissectum*), field horsetail (*Equisetum arvense*)*,* meadowsweet (*Filipendula ulmaria),* common bird's-foot trefoil (*Lotus corniculatus)* and creeping Jenny *(Lysimachia nummularia).* Species richness slightly declined in relevés 2 and 4, but increased or remained stable in relevés 6, 12 and 16.

Table 3-2: Summary vegetation results for relevés surveyed along Transect 2, Rahasane Turlough, July 2024. Species are colour-coded by typical habitat conditions as follows: yellow: usually terrestrial, blue: usually aquatic, grey: intermediate. Habitat classifications from Caffrey *et al*. (2023); for species not listed by Caffrey *et al*. (2023), typical habitat information is from Parnell & Curtis (2012) and Atherton *et al.* (2010).

Transect 2										
Relevé	**T2R2**		**T2R4**		**T2R6**		**T2R12**		**T2R16**	
Location (ITM)	X: 546294 Y: 719189		X: 546346 Y: 719102		X: 546424 Y: 718976		X: 546484 Y: 718877		X: 546547 Y: 718775	
Date	24/07/2024		24/07/2024		24/07/2024		24/07/2024		24/07/2024	
Water height (cm)	0		0		0		0		0	
Vegetation zone (Sharkey, 2012)	3 (19) *Potentilla anserina – Potentilla reptans*		3 (19) *Potentilla anserina – Potentilla reptans*		*Carex nigra – Scorzoneroides autumnalis*		3 (19) *Potentilla anserina – Potentilla reptans*		3 (19) *Potentilla anserina – Potentilla reptans*	
Vegetation height max (cm)	15		10		3		3		15	
% graminoids	10		50		30		30		10	
% forbs	90		65		50		70		80	
% shrubs	0		0		0		0		0	
% bryophytes	2		<1		0		0		0	
% bare ground	<1		<1		<1		20		5	
% poaching	0		0		0		5		0	
Botanical species richness	11		12		13		9		13	
Notes	Firm and dry underfoot. Tightly grazed by sheep. Animal dung present in area.		Tightly grazed by sheep.		Firm and dry underfoot. Heavily grazed by sheep. Animal dung present in area.		Firm and dry underfoot. Heavily grazed & nutrient-enriched by sheep. Animal dung present in area.		Firm and dry underfoot. Grazed by sheep. . Animal dung present in area Some rocky outcrops present in vicinity.	
Species	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**
Agrostis stolonifera	10	4	50	7	25	5	35	7	10	4
Calliergonella cuspidata							<1			
Cardamine pratensis	<1	1			<1	1				
Carex sp.			1		5	4				
Cerastium fontanum					1				1	

Transect 2										
Relevé	**T2R2**		**T2R4**		**T2R6**		**T2R12**		**T2R16**	
Cinclidotus fontinaloides	<1									
Cirsium sp.									1	
Equisetum arvensis			<1	1						
Filipendula ulmaria					<1					
Galium palustre			<1	1			<1	3	<1	1
Gnaphalium uliginosum							<1	1		
Hydrocotyle vulgaris					1					
Lotus corniculatus	<1	1								
Lysimachia nummularia							1			
Mentha aquatica			<1	1			<1	2		
Myosotis scorpioides	<1	1			<1		10	4	<1	1
Plantago major	<1	1	<1	1					<1	1
Plantago lanceolata					<1					
Potentilla anserina	75	8	60	8	35	7	25	5	70	8
Potentilla reptans			1		5	4			2	
Prunella vulgaris			<1	1			<1	1		
Ranunculus repens	1		<1	2	<1				<1	2
Rumex crispus	15	5	1						1	
Scorzoneroides autumnalis					<1				<1	2
Stellaria media	1								1	
Trifolium repens	20	5	2		10	4			10	4

3.3.2. Transect 4

As in the 2022 survey, it was not possible to access relevés 16 and 18 along Transect 4. The vegetation communities along the accessible parts of this transect were very similar to those recorded in 2022. One section of the transect that had previously been recorded in 2022 as 2 (18) *Agrostis stolonifera* – *Glyceria fluitans* was found in 2024 to correspond more to 2 (2) *Persicaria amphibia* – *Eleocharis palustris*. This area was very wet in 2024, with standing water over much of it. Sharkey (2012) noted that both of these communities occur in areas that retain shallow water during the summer months. Both vegetation communities have several of their most prevalent plant species in common. The relevé results from this area (T4R10) showed a decline in creeping bent grass *Agrostis stolonifera,* and an increase in common spike-rush (*Eleocharis palustris*) and amphibious bistort (*Persicaria amphibia*), thereby conforming more to the 2 (2) *Persicaria amphibia* – *Eleocharis palustris* community in 2024.

In all three relevés surveyed in 2024, there was an increase in the cover of silverweed (*Potentilla anserina*) since 2022. This was the dominant species in relevés 5 and 22, alongside creeping bent (*Agrostis stolonifera*). Between the two, relevé 5 showed higher species richness. In this relevé, other forbs made up a more significant component of the community, such as creeping cinquefoil (*Potentilla reptans*), creeping buttercup (*Ranunculus repens*) and curled dock (*Rumex crispus*).

Relevé 10 was wetter underfoot and displayed a distinct vegetation community in comparison to the above described relevés. The most abundant species was amphibious bistort (*Persicaria amphibia*). Other species were the common spike-rush (*Eleocharis palustris*), creeping bent (*Agrostis stolonifera*), floating sweet-grass (*Glyceria fluitans*) and *Sphagnum cuspidatum*.

Grazing pressure varied along this transect, as noted in Table 3-3, and poaching was noted at relevé T4R10.

Table 3-3: Summary vegetation results for relevés surveyed along Transect 4, Rahasane Turlough, July 2024. Some locations were inaccessible due to water levels. . Species are colour-coded by typical habitat conditions as follows: yellow: usually terrestrial, blue: usually aquatic, grey: intermediate. Habitat classifications from Caffrey *et al*. (2023); for species not listed by Caffrey *et al*. (2023), typical habitat information is from Parnell & Curtis (2012) and Atherton *et al.* (2010).

Transect 4										
Relevé	**T4R5**		**T4R10**		**T4R16**		**T4R18**		**T4R22**	
Location (ITM)	X: 547393 Y: 720048		X: 547437 Y: 719932		X: 547499 Y: 719770		X: 547597 Y: 719511		X: 547629 Y: 719427	
Date	25/07/2024		25/07/2024						24/07/2024	
Water height (cm)	0		0		Inaccessible		Inaccessible		0	
Vegetation zone (Sharkey, 2012)	3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*		*Persicaria amphibia – Eleocharis palustris*						3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*	
Vegetation height max (cm)	Max 40, mean 20		10						20	
% graminoids	75		20						42	
% forbs	35		60						55	
% shrubs	0		0						0	
% bryophytes	<1		10						0	
% bare ground	<1		5						1	
% poaching	0		4						0	
Botanical species richness	12		11						9	
Notes	Dry and firm underfoot. Lightly grazed by cattle & horses. Near a hedge. Several rocks in vicinity.		Wet but firm underfoot. Recent grazing and poaching by cattle. Animal dung present in area.						Dry and firm underfoot. Well grazed by sheep and donkeys.	
Species	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**
Agrostis stolonifera	35	7	10	4	Inaccessible		Inaccessible		30	6
Berula erecta			1							
Capsella bursa-pastoris	<1	1								
Carex sp.									10	4
Cinclidotus fontinaloides	<1	2								

Transect 4								
Relevé	**T4R5**		**T4R10**		**T4R16**	**T4R18**	**T4R22**	
Eleocharis palustris			15	5				
Filamentous green algae			5	4				
Galium palustre	<1	1	<1					
Glyceria fluitans			5	4				
Mentha aquatica			1					
Myosotis scorpioides	<1	2	1				1	
Persicaria amphibia			50	7				
Plantago major	<1	1					<1	2
Poa annua							2	
Potentilla anserina	70	8	<1				50	7
Potentilla reptans	<4	2					1	
Ranunculus repens	<3	2					<1	1
Rumex crispus	7	4					1	
Sphagnum cuspidatum			10	4				
Stellaria media	1	1						
Trifolium repens	<2	2						

3.3.3. Transect 6

As in the 2022 survey, it was not possible to access relevés 2 and 6 along Transect 6 due to high water levels. The vegetation communities along the accessible parts of the transect were almost the same as in 2022, with a long stretch of 3 (4) *Agrostis stolonifera – Potentilla anserina – Festuca rubra* community, as well as shorter lengths of 3A Tall herb, 2 (18) *Agrostis stolonifera – Glyceria fluitans* and others (Appendix 2).

Much of the vegetation along the transect was generally characterised by a dominance of creeping bent grass (*Agrostis stolonifera)* and silverweed (*Potentilla anserina)*. All three accessible relevés saw an increase in the cover of these two species compared to the most recent previous survey in 2022. White clover (*Trifolium repens)* and creeping buttercup (*Ranunculus repens)* were once again a notable component of the community, but occupied lower cover than in 2022 across all relevés.

All three completed surveys saw a decrease in species richness, most notably relevé 18. Grazing pressure along the transect was high, with the vegetation being grazed very short. Sheep, cattle and donkeys were present on the site at the time of the 2024 surveys. The only species recorded in transect 6 that had not been recorded in the previous surveys was common bird's-foot trefoil (*Lotus corniculatus)* in relevé 16.

Table 3-4: Summary vegetation results for relevés surveyed along Transect 6, Rahasane Turlough, July 2024. Some locations were inaccessible due to water levels. . Species are colour-coded by typical habitat conditions as follows: yellow: usually terrestrial, blue: usually aquatic, grey: intermediate. Habitat classifications from Caffrey *et al*. (2023); for species not listed by Caffrey *et al*. (2023), typical habitat information is from Parnell & Curtis (2012) and Atherton *et al.* (2010).

Transect 6										
Relevé	**T6R2**		**T6R6**		**T6R12**		**T6R16**		**T6R18**	
Location (ITM)	X: 548428 Y: 719865		X: 548378 Y: 719763		X: 548323 Y: 719656		X: 548285 Y: 719580		X: 548258 Y: 719526	
Date					24/07/2024		24/07/2024		24/07/2024	
Water height (cm)	Inaccessible		Inaccessible		0		0		0	
Vegetation zone (Sharkey, 2012)					3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*		3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*		3 (4) *Agrostis stolonifera – Potentilla anserina - Festuca rubra*	
Vegetation height max (cm)					6		3		15	
% graminoids					48		55		40	
% forbs					52		30		55	
% shrubs					0		0		0	
% bryophytes					0		0		0	
% bare ground					1		0		2	
% poaching					0		0		1	
Botanical species richness					10		11		12	
Notes					Dry and firm underfoot. Heavily grazed by sheep. Animal dung present in area.		Dry and firm underfoot. Heavily grazed by sheep and cattle. Animal dung present in area.		Dry and firm underfoot. Grazed by sheep, cattle and donkeys. Animal dung present in area.	
Species	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**	**% cover**	**DOMIN**
Agrostis stolonifera	Inaccessible		Inaccessible		22	5	50	7	40	7
Alopecurus geniculatus									1	
Cardamine pratensis					<1	1	<1			
Carex nigra					15	5				
Carex sp.					<4	3	2		1	
Cerastium fontanum									<1	2

Transect 6								
Relevé	**T6R2**	**T6R6**	**T6R12**		**T6R16**		**T6R18**	
Cirsium dissectum							<1	1
Galium palustre					<1			
Juncus sp.			<2	2				
Juncus bulbosus					<1	1	<1	1
Lotus corniculatus					2			
Myosotis scorpioides			<4	3	<1	2		
Plantago major							1	
Poa annua							<1	1
Potentilla anserina			38	7	27	6	50	7
Potentilla reptans			<2	1	<1	1		
Ranunculus repens					<1		<1	1
Rumex crispus							<1	1
Trifolium repens					3	3	3	3

4. Macroinvertebrate and Pond PSYM Surveys

4.1. Background

The annual monitoring of freshwater macroinvertebrate communities at Rahasane Turlough has been conducted to investigate whether any change in their composition has occurred that would indicate a transition from a habitat characteristic of being regularly flooded to one that is more frequently dry. Because turloughs are ephemeral, natural changes in the hydroperiod of the system occur year on year. Therefore, to establish whether a transition in habitat is occurring, it is important to look for changes in the community composition over a longer period.

The Predictive System for Multi-metrics (PSYM) is being used as a standard survey method for the turlough, allowing year on year comparison of the results. This system was developed by the Freshwater Habitats Trust and the Environment Agency in England to assess the biological quality of standing waters and provides a standardised method for surveying the turlough each year, combining macrophyte surveys with macroinvertebrate surveys (Howard, 2002).

In this fourth year of the survey, the presence of macrophyte species was assessed using the checklist provided by the PSYM method, and macroinvertebrates were sampled and identified to family level.

The water beetle community of Rahasane Turlough have been surveyed several times prior to this study: by Bilton (1989), O'Connor (2001), Waldron (2003/ 2004) and RPS (2016b). Foster *et al.* (1992) determined that aquatic Coleoptera as a group possess a range of attributes 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. 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). Water beetles were identified to species level, and were classified according to this system, to allow for comparison among years and with previous surveys conducted prior to the commencement of works at the site.

Standard metrics were calculated in addition to PSYM, and these were compared to the previous three years of results (APEM, 2021, 2023, 2024). The presence and abundance of ephemeral taxa were also examined, based on research conducted by Porst (2009). In this research, the presence of taxa such as Trichoptera,Heteroptera and Gastropoda was found to correlate with turloughs with longer hydroperiods, Gastropoda were also found to occur in higher abundances in turloughs with longer hydroperiods, probably owing to their limited mobility.

4.2. Review of previous datasets and reports

The following sources of site-specific data were reviewed:

- RPS (2014a). *Environmental Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme)*;
- RPS (2014b). *Natura Impact Statement (Dunkellin River and Aggard Stream Flood Relief Scheme)*;
- RPS, (2016b). 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).

4.3. Method

4.3.1. Physico-chemical measurements

Temperature, pH, conductivity and dissolved oxygen concentration and saturation were measured on-site on 14 August 2024 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.

4.3.2. Macroinvertebrate survey and analysis

Macroinvertebrate sampling was carried out at four locations at the Rahasane Turlough on 14 August 2024 (Figure 16). Most of the sites were in the same location as in previous years. In 2023, the turlough had exceptionally high water levels, and Sites 1 and 3 were moved owing to accessibility issues. However, in 2024, these sites reverted to their location in 2022. The substrate at each site was comprised of semi-permanent wetted areas with grazed grassland, with submerged, emerging and floating leaved aquatic plants present.

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 (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 in 2023, 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.

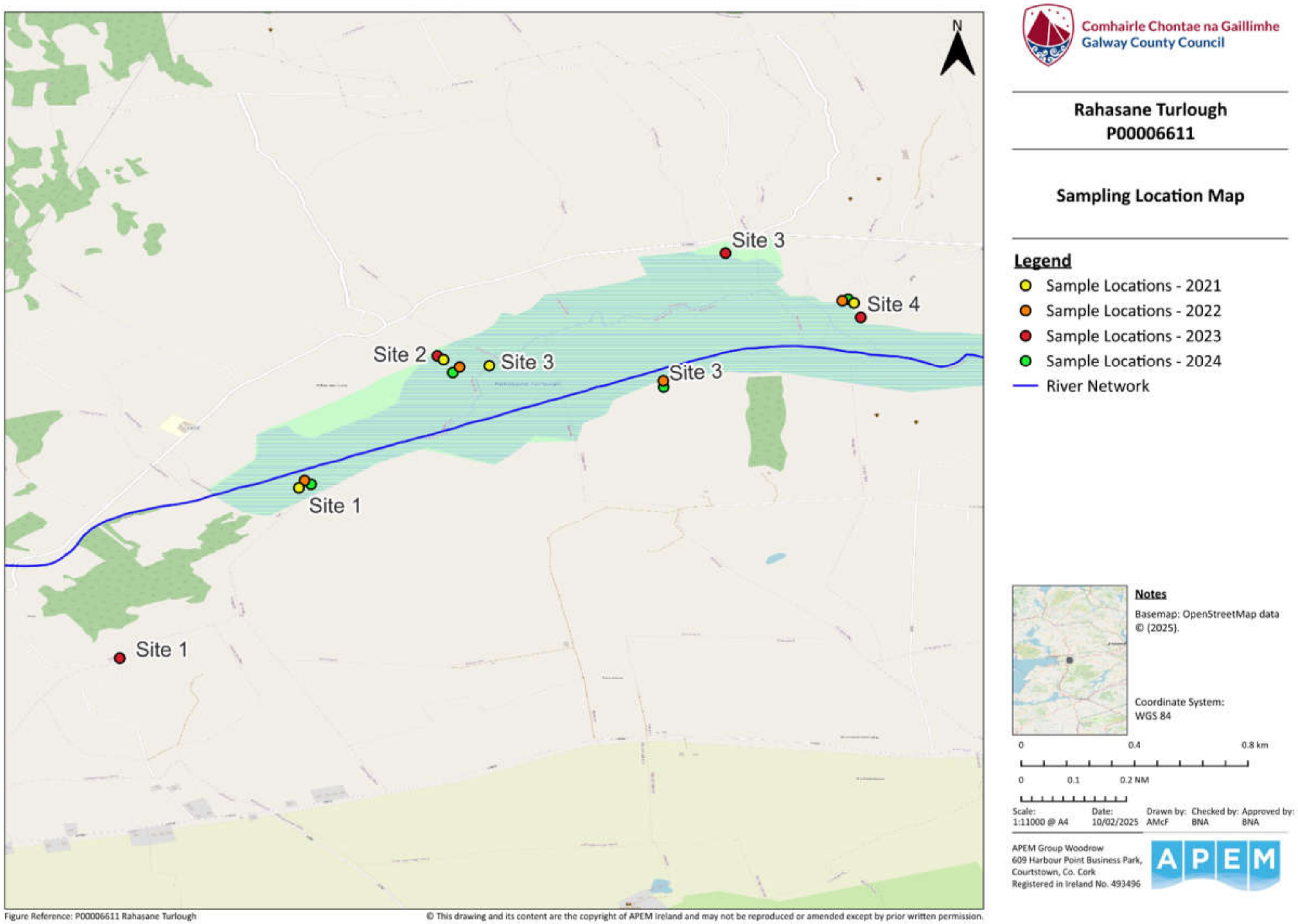

Figure 4-1: Locations of sample sites surveyed for macroinvertebrate and PSYM analysis in 2021, 2022, 2023 and 2024

4.3.3. Plant survey and analysis

Pond macrophytes were surveyed by wading the perimeter of the dry and shallow water areas at each of the four locations, with deeper areas sampled using the pond net. Species were recorded on the PSYM plant recording sheet as outlined in Howard (2002).

4.3.4. 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. Therefore, here the survey metrics are being compared to one another over the consecutive survey 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). The metrics calculated based on the macrophytes are: the number of submerged and emergent plant species and the Trophic ranking score (TRS) for aquatic and emergent plants. PSYM also includes a metric for uncommon species, assigning a rarity value, but as this is derived from species' status in small ponds in England, it was not considered valid and therefore not applied here.

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.

TRS is a measure of the average trophic rank for the pond, calculated by assigning each plant species with a trophic score based on its affinity to waters of a particular nutrient status. Plant scores in this system vary between 2.5 (dystrophic i.e., very nutrient poor conditions) and 10 (eutrophic, i.e., nutrient rich conditions)

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 determined, given that this metric not appropriate for still waters.

4.3.5. Assessment using water beetles

Aquatic beetles were identified to species level and classified using the system outlined in 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. The MQS was calculated for each of the surveys conducted by APEM in 2021, 2022, 2023 and 2024. The MQS was also calculated for each of the pre-construction surveys, using the species list provided from all previous surveys conducted at Rahasane Turlough presented in the report by RPS (RPS, 2016b) was. This enabled a comparison in MQS to be made over time. .

4.4. Results and discussion

4.4.1. Site description

All sampling sites were inundated grazed pastures, with emergent vegetation abundant (approximately 50% cover) at most sites, with the exception of Site 3 where the algae *Cladophora* sp. was abundant, with 10% cover from emergent vegetation. All sites were grazed intensively, and heavily silted.

4.4.2. Water quality

Key water chemical parameters are summarised in Table 4-1. Water temperature was higher than the 14-15°C recorded in 2023 but slightly cooler than the 21-24°C recorded in 2021 and 2022. Dissolved Oxygen (DO) saturation % were supersaturated at three of four sites, similar to the high levels were observed in 2022 (162-192%) In 2023 DO saturation, in contrast was around 100% (84-105%), while in 2021 it was low (29-51%). Submerged plants and algae were noted as present at all sites, and photosynthesis from these groups is likely to be the cause of the supersaturation of DO. Conductivity was slightly lower at all sites than those recorded in other years. Turbidity was also low at most sites, with the exception of Site 3.The pH of all sites was alkaline, as would be expected in a turlough, given its Karst nature and given the likelihood of photosynthesis, known to increase the pH. This result was similar to previous years, except in 2021 when it was slightly acid.

Table 4-1: Summary of *in situ* physicochemical data at Rahasane Turlough, August 2024

Parameter	Unit	Site 1	Site 2	Site 3	Site 4
Temperature	°C	20.4	19.7	20.9	21.5
Dissolved Oxygen	% Saturation	163.0	103.5	134.1	185.4
Dissolved Oxygen	Mg/L	14.7	9.46	11.98	16.4
Conductivity	µS/cm	301	349	338	372
pH		8.97	8.52	8.09	9.10
Turbidity	NTU	3.21	4.63	12.42	1.03

4.4.1. Taxonomic richness

Among the four sites surveyed, 32 families from 12 orders of macroinvertebrate taxa were identified (Table 4-2). This was the highest level of diversity recorded to date at the turlough, and considerably higher than that recorded in 2023, likely owing to summer water levels being low, similar to levels in 2021 and 2022 and contrasting with 2023 when water levels were exceptionally high, and where samples were collected in areas far from where the more permanent pools are situated. Similar to all previous years, the sample was dominated by aquatic gastropod snails, with very high numbers of Bithyniidae and Planorbiidae in particular. Lymnaeidae numbers were much lower than recorded in previous years. Overall, gastropods comprised of over 50% of the sample, which was slightly higher than in 2023, but lower than in 2021 and 2022 when gastropods comprised ≥80% of the sample. High abundances of gastropods in turloughs have been associated with longer hydroperiods (Follner and Henle, 2006). It has been suggested that this relates to their limited mobility (Follner and Henle, 2006). This limited ability to move seems to permit greater survival in sites inundated for longer periods, despite possessing adaptations to drought (Williams, 2006).

There were also high numbers of the freshwater louse Asellidae (*Asellus aquaticus*) and the non-native shrimp *Crangonyx pseudogracilis* (Crangonyctidae). These were also recorded in high numbers in 2023, but were not recorded in previous years. These crustaceans combined comprised 35% of the sample in 2024 and 29% of the sample in 2023, compared with 1% of the sample in 2021 and 2022. This shift from gastropods to crustaceans, is of interest. It is possible that *C. pseudogracilis* has recently colonised Rahasane Turlough. , Both *C. pseudogracilis* and *A. aquaticus* are tolerant of low oxygen conditions - the supersaturation of oxygen detected at most sites detected this year would be matched by a corresponding dip in oxygen levels at night owing to respiration, which may limit some of the gastropod taxa, and provide a competitive advantage to both species. ,. Both species are also generally found in detritus rich water with high levels of decomposition. Heavy siltation was reported at each site, and Gastropod taxa, generally scrapers, would have more difficulty feeding in heavily silted environments than crustaceans, who feed on decaying organic matter. It is possible that the increase in this species in the samples represents an increase in organic matter in the system.

In a study of Irish turloughs, caddisflies (Trichoptera) and true bugs (Hemiptera) abundances were found to have a significant positive correlation with the hydroperiod of the turlough (Porst, 2009). Despite being ephemeral residents of temporary waters, these macroinvertebrate groups need more permanent habitats to complete their life cycles (Lahr, 1997; Lahr *et al.*, 1999). A greater diversity of Hemiptera were recorded (6 families) compared to previous years, but fewer water bugs (Corixidae) were recorded in 2024 than in all previous years. Corixidae are known to colonise new habitats rapidly and the higher numbers of them in 2023 and 2021 might reflect inclusion of recently flooded areas in the survey in these years with higher water levels in these years, over areas which are not permanently flooded (APEM, 2021 and 2023). No consistent trends in the presence and abundance of Heteroptera is apparent among years, and they represented a small proportion of the sample in each year. A small number of cased caddis flies (Leptoceridae) were recorded, which were absent in 2023 and 2022. Their presence potentially reflects how the sampling included more permanently wetted areas.

Non-biting midge Chironomidae were also recorded in greater numbers than in previous years. The smaller numbers of predators such as Corixidae and aquatic adult beetles may have allowed them to proliferate in this year. There was a greater diversity of aquatic beetle taxa recorded than in previous years, and despite the numbers being much smaller than the exceptional numbers recorded in 2023, these largely represented the larvae (*Haliplu*s sp.) and the number of adults recorded were similar to those recorded in 2021 and 2022. Numbers of damselflies (Coenagrioniidae) were similar to previous years and much higher than in 2023, and dragonflies (Aeshnidae) were also recorded for the first time among years.

Porst (2009) hypothesized that turloughs with longer habitat permanence have higher abundances of ephemeral taxa, because 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 similar to previous years (<10%), with the exception of 2023 (when it was 26% of the sample). The higher water levels in that year likely explain this greater proportion as these colonisers dominated the sample.

Thirty nine taxa of aquatic plants were recorded among sites, identified to species, based on presence/absence, using the taxa list form provided by the PSYM method (Appendix 5). Macrophytes were not surveyed in 2023 owing to exceptionally high water levels, as the permanent and semi-permanent pools previously surveyed where macrophytes would be observed were inaccessible and the accessible survey points were inundated grassland, where no macrophytes would be expected to occur. Forty seven taxa were observed in 2022 and twenty four in 2021, although a specialist botanist was not available in 2021, and it is possible that this result may be an underestimate.

Table 4-2: List of macroinvertebrate taxa and their abundance recorded at Rahasane Turlough in 2021, 2022, 2023 and 2024

Colour codes for where proportional abundance of a taxa is high:
Yellow: 10-20% of sample; orange: 20-30% of sample; red: 30-40% of sample.

Order/Class	Family	Abundance			
		2021	2022	2023	2024
Planaria	Planariidae	4			
	Dendrocoeliidae	1			
Oligochaeta	Lumbricidae	22		2	
	Lumbriculidae				1
	Naididae				17
Hirudinea	Glossiphoniidae	1	3		17
	Erpobdellidae	2			6
Gastropoda	Valvatidae		85	10	3
	Bithyniidae	945	355		420
	Lymnaeidae	991	499	306	30
	Planorbidae	413	410	795	834
	Physidae	79	69	93	53
	Hydrobiidae				26
Bivalvia	Sphaeriidae	18	111		30
Isopoda	Asellidae	24	13	474	510
Amphipoda	Crangonyctidae			309	420
	Gammaridae	8	10		
Ephemeroptera	Baetidae	1	4	9	
Odonata	Coenagrioniidae	60	60	10	51
	Aeshnidae				6
Hemiptera	Gerridae	1			3
	Veliidae		5		14
	Notonectidae		2		9
	Nepidae				9
	Hebridae				1
	Corixidae	200	38	108	6
Trichoptera	Limnephilidae	2			
	Leptoceridae	4			5
Diptera	Chironomidae	32	5	17	118
	Simuliidae				2
	Culicidae	3			3
	Sciomyzidae			1	
	Tabanini		1		
Lepidoptera	Pyralidae				9
Coleoptera	Haliplidae	220	9	38	25
	Dytiscidae	1	8	568	12
	Helophoridae		6	1	2
	Hydrophilidae		1		
	Chrysomelidae				1
	Hydraenidae				2
	Elmidae				1
	Curculionidae	1			
Total order/class		14	10	9	12
Total Families		24	20	15	32

4.4.2. PSYM Results

The Pond SYM metrics are presented in Tables 4-3 and 4-4. There were 27 PSYM macroinvertebrate taxa recorded in 2024, higher than any previous year and almost double the number recorded in 2023. The BMWP and corresponding ASPT were slightly higher than in previous years. However, the ASPT scores are relatively low overall, typical of standing waters, and reflecting the presence of very few taxa sensitive to organic pollution. Two Odonata and Megaloptera (OM) taxa were present (Coenagrioniidae and Aeshnidae), compared with one found in each previous year. Biggs *et al*. (2000) found that the OM metric had a strong correlation with environmental degradation in ponds, and was a good indicator of water quality in British ponds. The presence of Aeshnidae which had not been detected to date in the turlough, increased the score of this metric, and suggests an improvement in ecological condition, but should be examined in the context of all the metrics together. The number of Coleoptera taxa (registering as PSYM scoring) also increased, with the highest score to date. Overall, all scores improved and were at their highest value in 2024, suggesting an improvement in ecological condition at the turlough.

Table 4-3: Pond SYM macroinvertebrate metrics calculated at Rahasane Turlough

Metric	2021	2022	2023	2024
BMWP	78	62	54	116
No of PSYM Taxa (NTAXA)	19	16	14	27
ASPT	4.11	3.88	3.6	4.29
No. of Odonata & Megaloptera Taxa (OM)	1	1	1	2
No. of Coleoptera Taxa (PSYM scoring)	2	2	3	4

The aquatic plant metrics are shown in Table 4-4, and the PSYM aquatic plan species recorded at the turlough are documented in Appendix 5. Biggs *et al*. (2000) found that emergent and submerged plant richness had strong correlations with environmental degradation. Taxa richness of these species varied over time, with less diversity in 2024 than in 2022, but more than in 2021. However, as previously stated, it is likely that species richness in 2021 was underestimated. The Trophic Ranking Score was slightly higher in 2024 than in previous years. Plants are scored based on their affinity to waters of a particular nutrient status, with higher scores associated with more nutrient rich conditions. Therefore, the slightly higher score in 2024 indicates the presence of more nutrient tolerant plant species than in previous years.

Table 4-4: Pond PSYM aquatic plant metrics calculated at Rahasane Turlough

Metric	2021	2022	2024
No. of Emergent & Submerged species	21	44	33
Trophic Ranking Score	8.35	7.97	8.62

4.4.1. Standard Macroinvertebrate Metric Results

The standard macroinvertebrate metrics are presented in Table 4-5 below. The number of families and the WHPT NTAXA were notably higher than in previous years, reflecting greater taxonomic diversity at the site. The Q value score was the same as previous years. The WHPT and WHPT-ASPT were slightly higher than other years, albeit with low scoring overall, and indicating little change at the site in terms of ecological quality.

Table 4-5: Standard macroinvertebrate metrics calculated at Rahasane Turlough

Metric	2021	2022	2023	2024
Total no. Families	24	20	15	36
Q Value	Q3	Q3	Q3	Q3
WHPT	81.6	64.8	46.5	102.7
WHPT ASPT	3.4	3.6	3.1	3.7
WHPT NTAXA	24	18	15	28

4.4.2. Beetle Survey Comparison

Aquatic beetle species recorded at the site since 2021 are presented in Table 4-7 and changes in the Mean Quality Score (MQS) over time are recorded in Table 4-8. Twelve species of aquatic beetle were recorded at the site in 2024. Three of these species had not been recorded at the site to date in any previous surveys since 1989: *Haliplus immaculatus, Colymbetes fuscus* and *Ochthebius minimus*. Since APEM surveys began in 2021, eight new aquatic beetle species have been recorded at the site. These species did not have particularly high Species Quality Scores (SQS), with all relatively commonly distributed in Ireland. 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).

Rhantus frontalis, newly recoded in 2023, was again found in 2024. This species has a moderately high SQS of 16. However, *R. frontalis* is not restricted to undisturbed habitats, and its score is based on its rarity in Ireland.

Table 4-6: Aquatic beetle species recorded in the 2021-2024 surveys of the Rahasane Turlough

Family	Species / Species group	2021	2022	2023	2024
Curculionidae		1			
Chrysomelidae	Larvae				1
Haliplidae	*Haliplus* sp. (larvae)	199			3
	Haliplus ruficollis group	20	6	23	11
	Haliplus immaculatus				7
	Haliplus lineolatus	1	1	7	
	Haliplus ruficollis		2	8	2
	Haliplus sibericus				2
Dytiscidae	Larvae			2	
	Hygrotus inaequalis		3	14	1
	Hygrotus quinquelineatus			17	
	Hygrotus impressopunctatus			316	
	Hydroporus palustris		5	199	8
	Agabus nebulosus			17	
	Colymbetus fuscus				2
	Ilybius fuliginosus	1			
	Rhantus exsoletus			1	
	Rhantus frontalis			2	1
Helophoridae (Hydrophilidae)	*Helophorus aequalis*			1	
	Helophorus brevipalpis				1

Family	Species / Species group	2021	2022	2023	2024
	Helophorus longitarsis/griseus/minutus		3		
	Helophorus minutus		3		1
	Laccobius colon		1		
Elmidae	*Elmis aenea*				1
Hydraenidae	*Octhebius minimus*				2

The species in grey are noted in the Environmental Impact Statement as sensitive to hydrological alterations.

Beetle diversity was higher than in previous recent years, and similar to that documented in older studies (Table 4-7). The Mean Quality Score (MQS) however was the lowest recorded in over 20 years, and was at the lower end of the range recorded overall in previous surveys, despite more species having been found at the turlough. This indicated that the species recorded in 2024 were more commonly occurring than those recorded in recent years. This score was even lower than that recorded in 2023, which was hypothesized to have been low owing to a lack of representative habitats being surveyed in 2023 due to the level of flooding at the turlough. In 2024, representative habitats were certainly surveyed, but the quality score of the species recorded was on average lower. Nevertheless, the metric is likely out of date given that the metric was developed in the early 1990s and the rarity of each species was determined based on surveys conducted over thirty years ago.

Records of several aquatic beetle species sensitive to hydrological alterations were noted in the Environmental Impact Statement (EIS). 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). None of these four species were found in the 2024, despite the considerable numbers of three of these species (with the exception of *G. bilineatus*) recorded in 2023 (Table 4-7). *G. bilineatus* has only been found once at the turlough, recorded in 2004. None of these species were recorded in the 2021 or 2022 surveys. It is possible that high water levels in 2023 flooded very small isolated wetland pools where these species are more likely to occur, and that these species were encompassed into the shallower edges of the main body of water in the turlough, and thus were captured more easily. 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 4-7: Mean Quality Score (MQS) calculated 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
2024	**5.5**	**12**	**APEM**
2023	6.0	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	3.0	11	Foster
1989	3.3	11	Bilton

5. Key Findings from Year 4

Hydrogeology and Hydrology Survey:

- As part of the fourth 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.
- Hydrometric data indicated that winter water levels in 2023/2024 were higher than in the previous two winters, but that summer 2024 was substantially drier than 2023, and similar to summer 2022.
- Many of the karst features identified during the 2021 and 2022 surveys could not be accessed and monitored during the walkover survey 2024 due to the high-water levels, also experienced in 2023. The water levels in the turlough during the 2021 & 2022 survey were much lower due to prolonged dry periods in those years. Nevertheless, there is no obvious change between 2023 and 2024 in the features that were assessed.
- Aerial imagery shows no evident change in karst features at the Rahasane Turlough.

Vegetation Surveys:

- The turlough's water was lower than in the summer of 2023, allowing access to eleven out of fifteen relevés, similar to 2022.
- Grazing pressure was generally very high, with vegetation eaten down almost to soil level in some areas.
- There was also a notable prevalence of animal dung in many areas, which is likely to contribute to enrichment of the water. Sheep, cattle, horses and donkeys were present in different parts of the site.
- Poaching of the substrate was noted in some areas, particularly where the substrate was soft or wet.
- The classification system of Sharkey (2012) was found to correspond only very approximately with the vegetation communities present at Rahasane, making it difficult to compare vegetation community cover over time. In future studies, it may be worth considering an alternative classification system.
- One notable result was the decline of the 5 (11) *Persicaria amphibia-Mentha aquatica* community along Transect 2. If this trend continues, it may indicate a drying of the habitat, although the heavy grazing and animal enrichment may also be affecting the vegetation composition here.

Macroinvertebrate and PSYM Survey:

- Water quality readings suggest high levels of photosynthesis with emergent vegetation and algal cover high at all sites. The pH of the site was alkaline, similar to previous years, and heavy siltation and intensive grazing was evident at all sites.
- A greater diversity of macroinvertebrate taxa were recorded at the site, with 32 families present, distinctly higher than recorded in previous years, dominated by >50% aquatic gastropods, principally Bithyniidae and Planorbiidae. Nevertheless, this represents a decrease from >80% gastropods in the sample in 2021 and 2022 with a shift to increasing crustaceans within the turlough occurring, seen in a sharp rise in the proportion of crustaceans (Asellidae and Cragonyctidae) recorded in 2023 and 2024, rising to 35% of this year's sample.
- Despite an increase in overall macroinvertebrate, Odonata and beetle diversity, Pond SYM macroinvertebrate metrics were consistent with previous results, with samples dominated by pollution tolerant taxa, indicating likely nutrient impact at the site. Aquatic plant Pond SYM

metrics were relatively consistent with the macroinvertebrate results, showing a similar Trophic Ranking Score among years, although slightly higher than previous years indicating an increased presence of nutrient tolerant plant species. Overall, the ecological condition appears to be similar to previous years. The proportion of ephemeral taxa was also similar to earlier years.

- Aquatic beetle diversity was higher than in previous recent years, but with the lowest Mean Quality Score recorded in over 20 years, indicating rare species were less common at the site.
- To date, based on four years of surveys, comparing PSYM scores, community structure, abundance of ephemeral taxa, gastropod community and beetle MQS scores among years, despite considerable interannual variation, no evidence of more frequent drying of the turlough has been detected.
- The final survey under the planning conditions will be conducted in 2025. This will aim to establish if a transition has occurred from a habitat characteristic of being regularly flooded to one that is more frequently dry.

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Plates

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

Plate 2: Vegetation at Aggard Bridge

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

Plate 4: Rahasane Turlough 29002 Hydrometric Station

Plate 5: Aggard Bridge 29010 Data Logger

Plate 6: ID: B10 Estavelle (left: 2023, right: 2024)

Plate 7: ID: C3 Small scale depressions

Plate 8: ID: A10 Existing well (left: 2021, right: 2024)

Plate 9: ID: A1 Enclosed depression (left: 2022, right: 2024)

Plate 10: View of Rahasane Turlough looking SW from N shore

Plate 11: Feature C9 Estavelle

Plate 12: Feature C10 Estavelle

Plate 13: Relevé T2R2

Plate 14: Relevé T2R6

Plate 15: Relevé T2R12

Plate 16: Relevé T2R16

Plate 17: Relevé T4R5

Plate 18: Relevé T4R10

Plate 19: Relevé T4R22

Plate 20:: Relevé T6R12

Plate 21:: Relevé T6R16

Plate 22:: Relevé T6R18

Plate 23: Photo of Site 1 (macroinvertebrate survey, 18.08.24)

Plate 24: Photo of Site 2 (macroinvertebrate survey, 14.08.24)

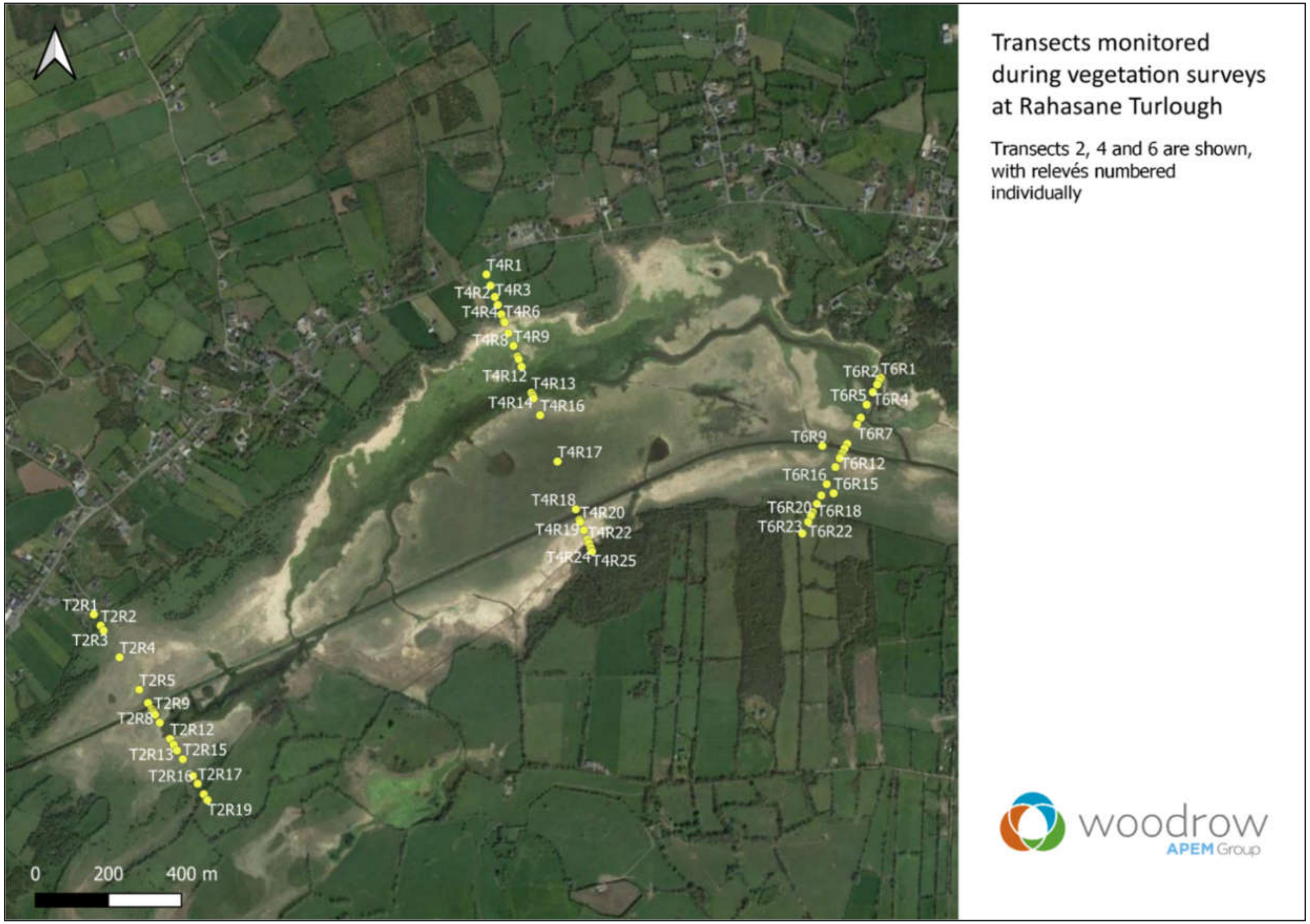
Plate 25: Photo of Site 3 (macroinvertebrate survey, 18.08.24)

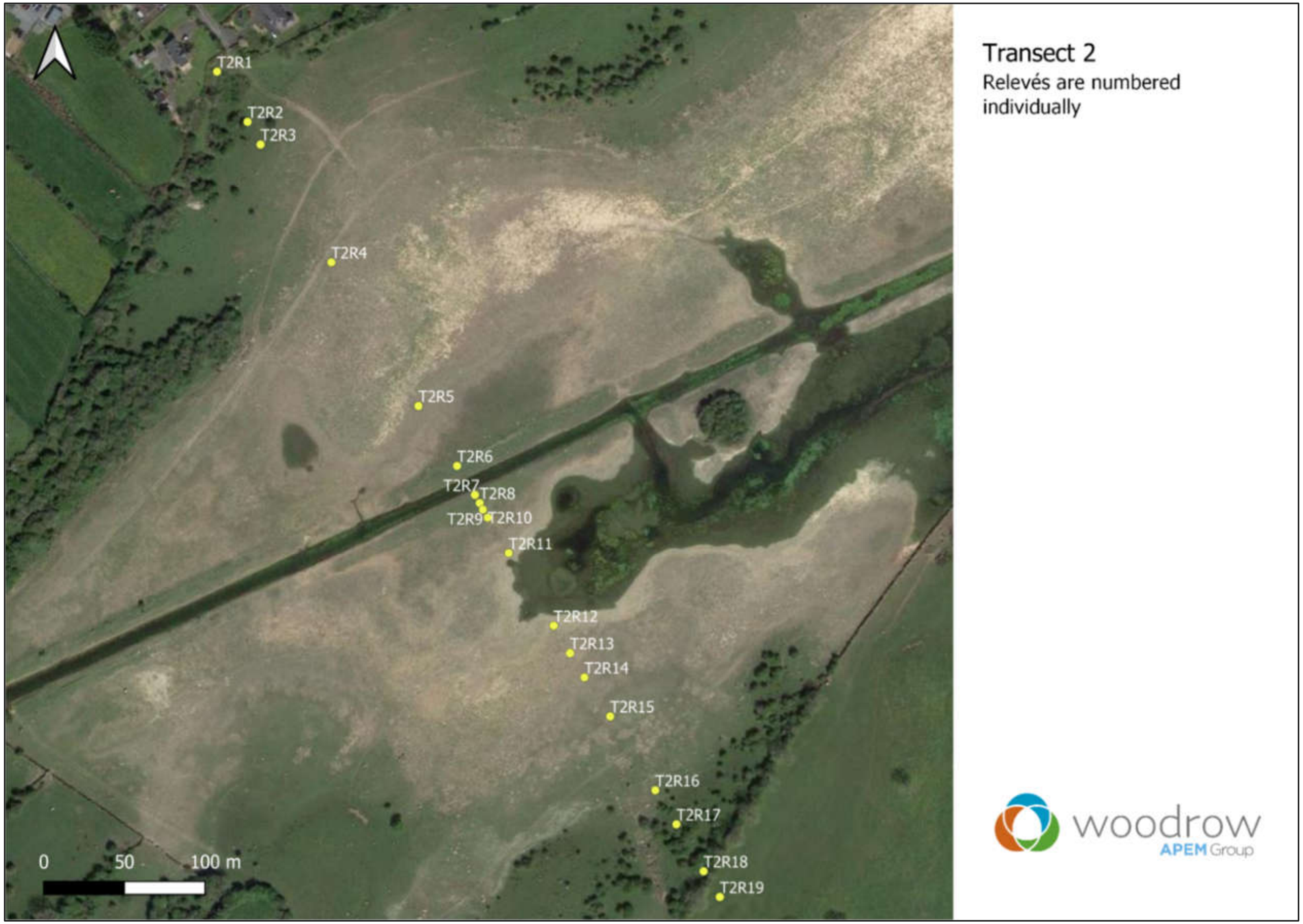
Plate 26: Photo of Site 4 (macroinvertebrate survey, 18.08.24)

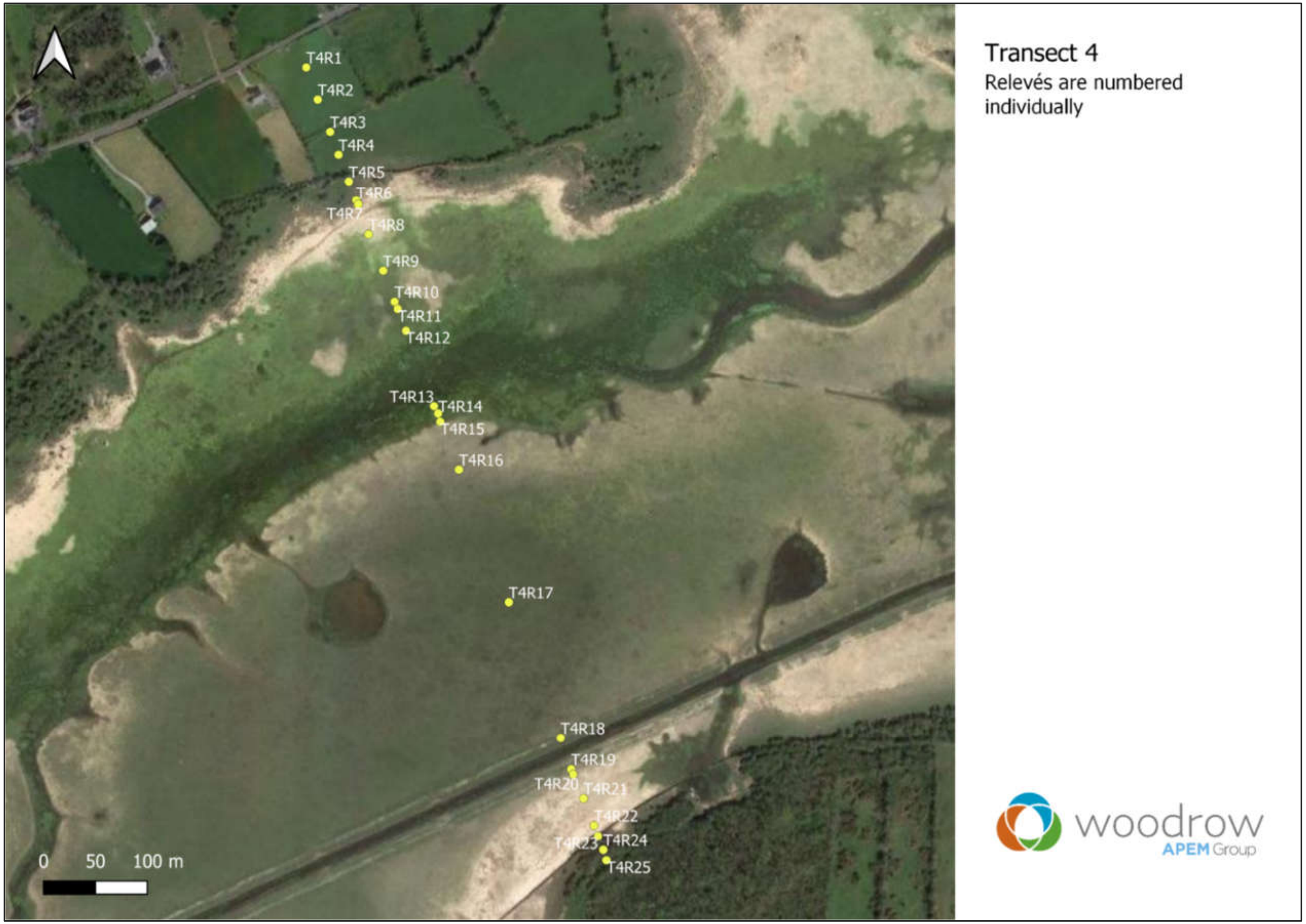
Appendix 1: Drawing 1 Hydrology and Hydrogeology Walkover Monitoring Locations

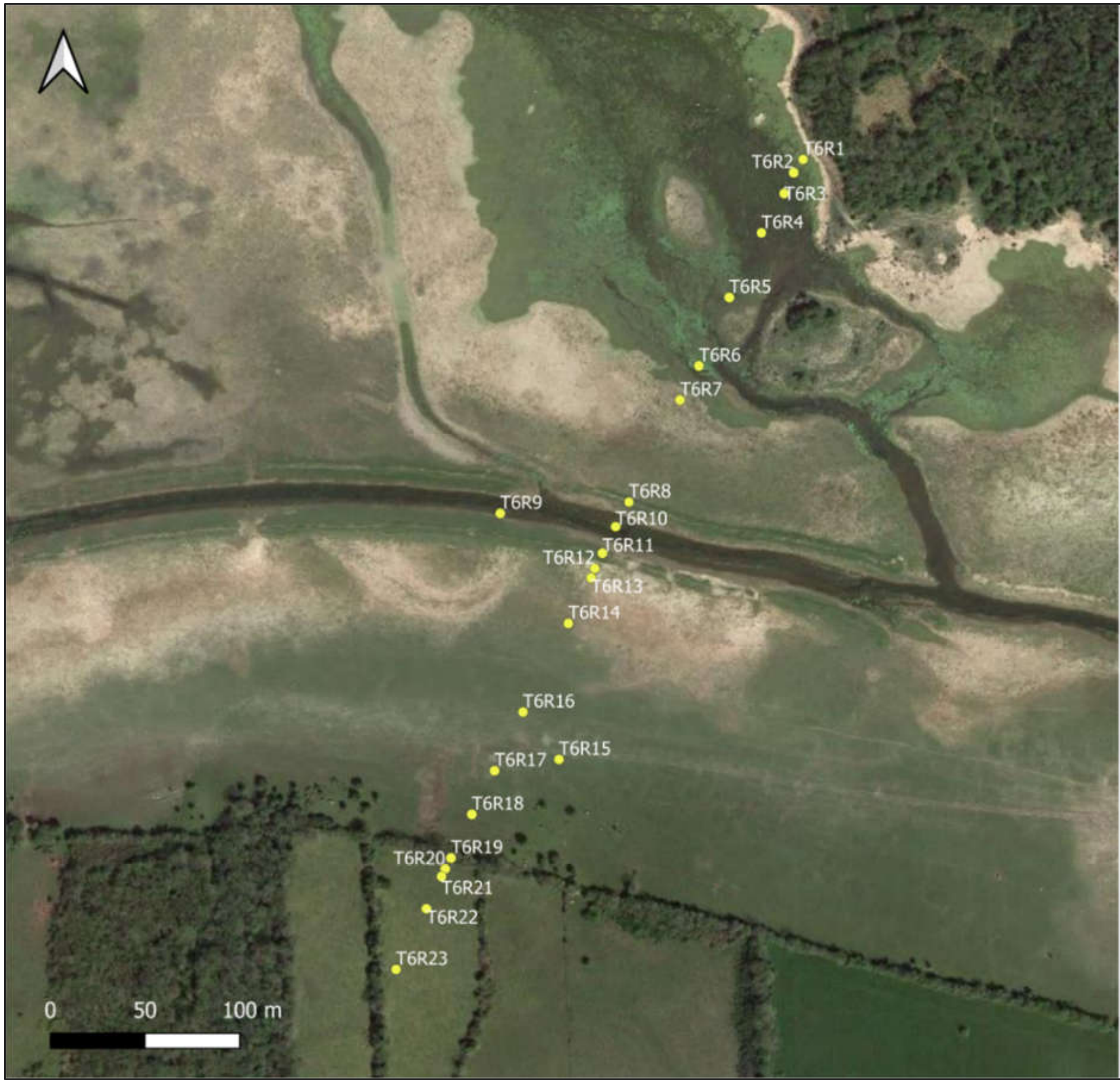
N
Killeeneenmore
RAHASANE TURLOUGH
29002
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
A12
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
B11
C1
C2
C3
C4
C5
C6
0
0.25
0.5 km
Map Legend
2021
2022
2024
Hydrometric Guage
Enclosed Depression
Spring
Swallow Hole
Turlough
Spatial Reference
Datum: IRENET95
Projection: Transverse Mercator
N
SITE LOCATION - NOT TO SCALE
Drawing Title
2024 Monitoring Locations
Project Title
Rahasane Turlough Monitoring
Project No.
240257
Drawing No.
1
Scale
1:10,425
Drawn By
BP
Checked By
BA
Date
12/09/2024
Email: info@mkoireland.ie/ Website: www.mkoireland.ie

Appendix 2: Vegetation Transects & Relevé Locations




Transect 2
Relevés are numbered individually
T2R1
T2R2
T2R3
T2R4
T2R5
T2R6
T2R7
T2R8
T2R9
T2R10
T2R11
T2R12
T2R13
T2R14
T2R15
T2R16
T2R17
T2R18
T2R19
0
50
100 m
woodrow
APEM Group

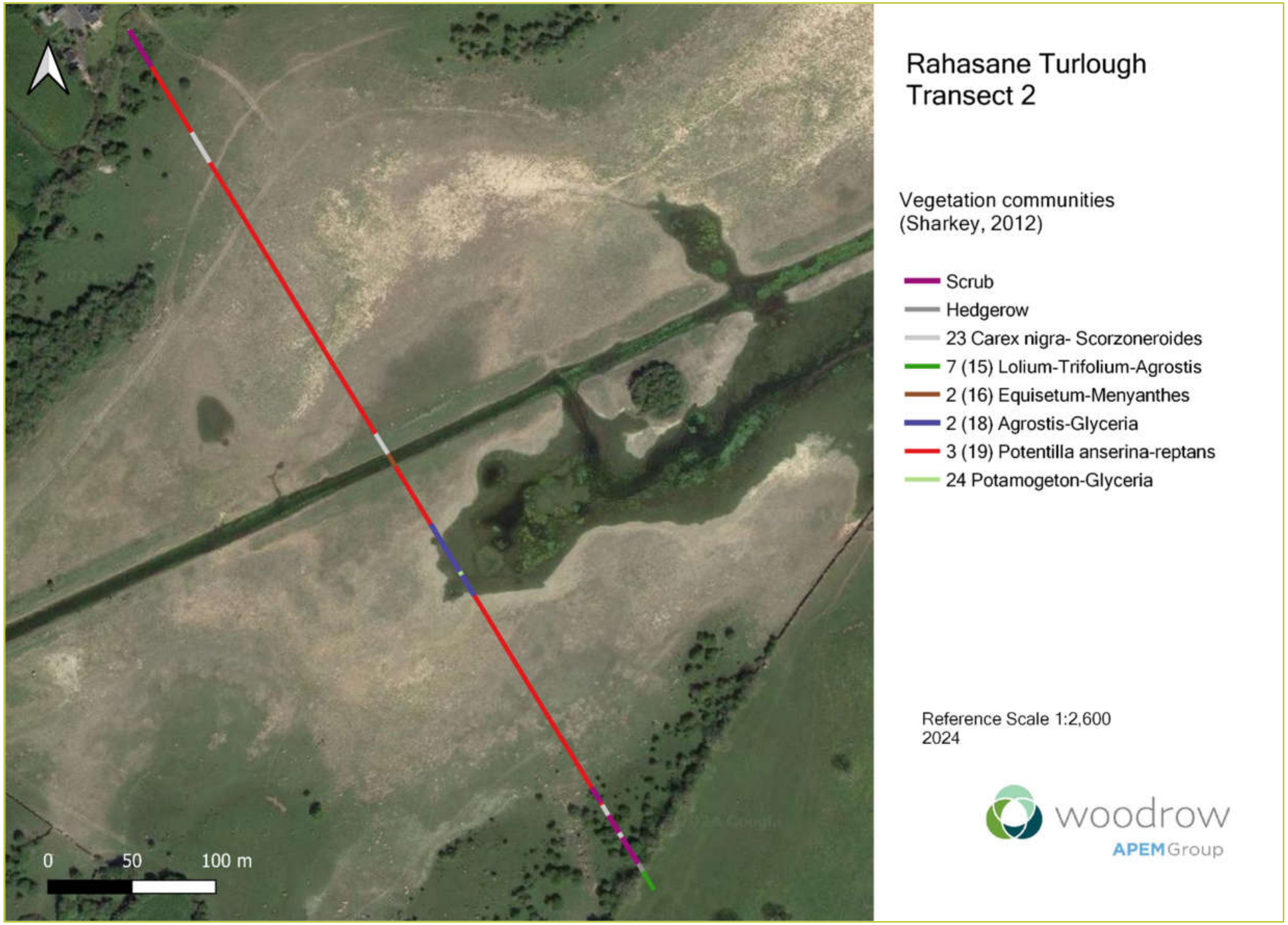

T4R1
T4R2
T4R3
T4R4
T4R5
T4R6
T4R7
T4R8
T4R9
T4R10
T4R11
T4R12
T4R13
T4R14
T4R15
T4R16
T4R17
T4R18
T4R19
T4R20
T4R21
T4R22
T4R23
T4R24
T4R25
0 50 100 m
Transect 4
Relevés are numbered individually
woodrow
APEM Group



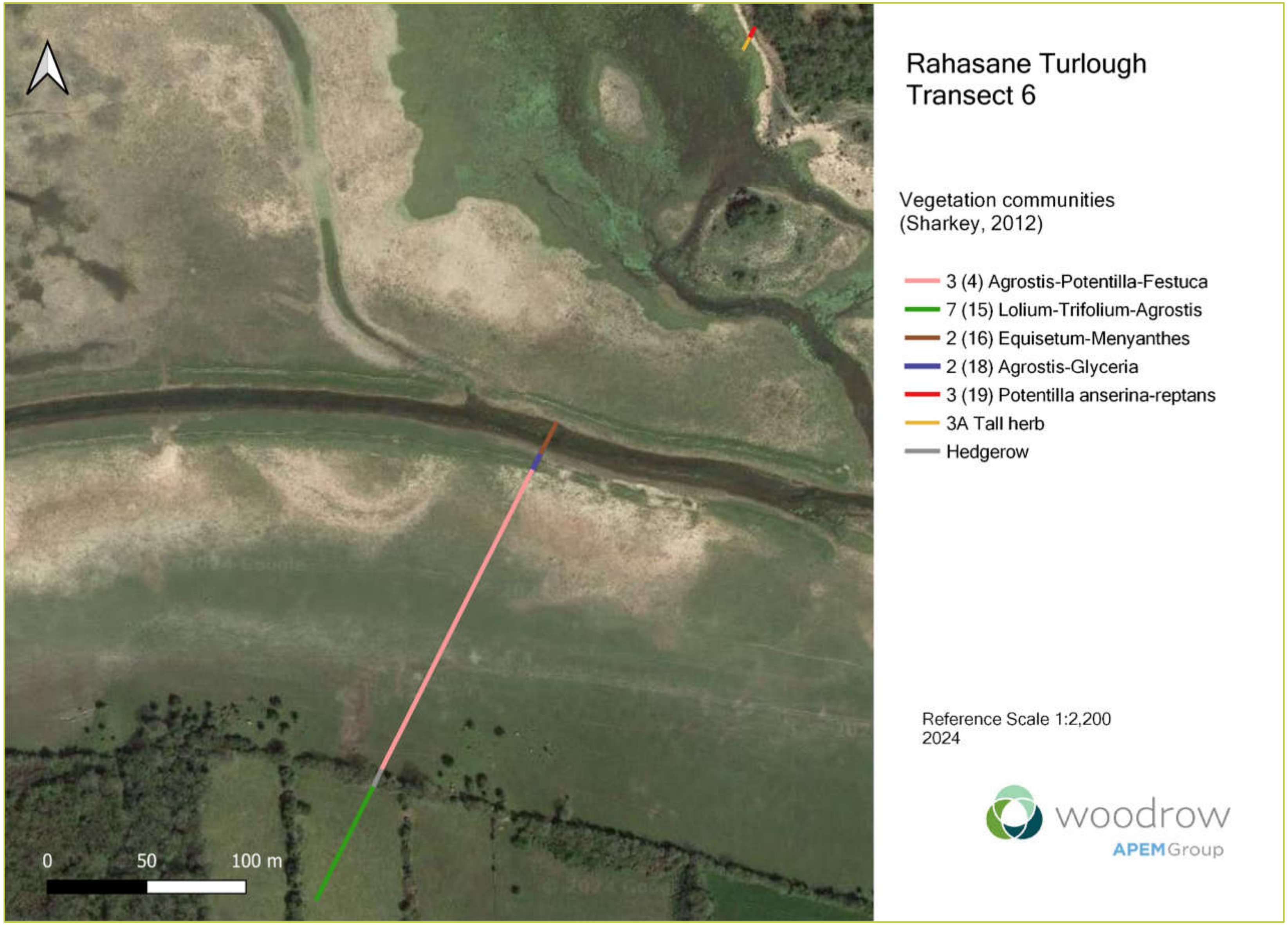
Transect 6

Relevés are numbered individually

Appendix 3: Vegetation Communities




Rahasane Turlough
Transect 4
Vegetation communities
(Sharkey, 2012)
3 (4) Agrostis-Potentilla-Festuca
7 (15) Lolium-Trifolium-Agrostis
2 (16) Equisetum-Menyanthes
2 (18) Agrostis-Glyceria
1 (10) Lolium-Trifolium
2 Persicaria-Eleocharis
Scrub
Reference Scale 1:3,800
2024
0 50 100 m
woodrow
APEM Group


Rahasane Turlough
Transect 6
Vegetation communities
(Sharkey, 2012)
3 (4) Agrostis-Potentilla-Festuca
7 (15) Lolium-Trifolium-Agrostis
2 (16) Equisetum-Menyanthes
2 (18) Agrostis-Glyceria
3 (19) Potentilla anserina-reptans
3A Tall herb
Hedgerow
Reference Scale 1:2,200
2024
0
50
100 m
woodrow
APEM Group

Appendix 4: Vegetation Comparison Tables

Figure 0-1: Comparison between plant species recorded from 2014-2015 to 2024 at Transect 2, Rahasane Turlough. Figures show percentage cover for each plant species. Species are colour-coded by typical habitat conditions as follows: yellow: usually terrestrial, blue: usually aquatic, grey: intermediate. Habitat classifications from Caffrey *et al*. (2023); for species not listed by Caffrey *et al*. (2023), typical habitat information is from Parnell & Curtis (2012) and Atherton *et al.* (2010).

Transect 2	Relevé T2R2				Relevé T2R4				Relevé T2R6				Relevé T2R12				Relevé T2R16			
Species \ Date	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024
Achillea millefolium		6	12																	
Agrostis stolonifera	60	23	5	10	40	40	40	50	50	33	25	25	55	65	52	35	35	38	20	10
Alopecurus geniculatus													2							
Bellis perennis	+	<4	5						1	<1	2									
Brachythecium rutabulum						<4				<1				2				<4		
Bryum sp.						<1														
Calliergonella cuspidata			1													<1				
Cardamine pratensis	+			<1		<1	1			<1		<1	3		<1		0.5	<4		
Carex hirta	+								20											
Carex nigra	6	5	<1				5				3									
Carex panicea											2									
Carex sp.								1				5								
Cerastium fontanum									1	<1	<1	1								1
Cinclidotus fontinaloides		<4	<1	<1					5											
Cirsium arvense	4				+															
Cirsium sp.																				1
Equisetum arvensis								<1												
Festuca rubra		<4									<1									
Filipendula ulmaria												<1								

Transect 2	Relevé T2R2				Relevé T2R4				Relevé T2R6				Relevé T2R12				Relevé T2R16			
Species / Date	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024
Fontinalis antipyretica															4					
Galium palustre					+	10	5	<1		5			3		<1	<1	1	<4	1	<1
Gnaphalium uliginosum						<1									<1	<1				
Hydrocotyle vulgaris		<4										1						<4		
Juncus articulates					2															
Juncus sp.										<1										
Lolium perenne			5																	
Lotus corniculatus				<1																
Lysimachia nummularia																1				
Mentha aquatica					3	5	2	<1					6	<4	4	<1				
Myosotis scorpioides				<1	10	10	10		+	2		<1	10	12	8	10	5	<4	<1	<1
Nasturtium officinale														<4						
Persicaria amphibia						<4														
Persicaria minus																	0.5			
Plagiochila sp.	+																			
Plantago lanceolata		<4	2							4	6	<1								
Plantago major	+		1	<1		2	4	<1	+				1				2		<1	<1
Poa annua			15																	
Poa pratensis							10													
Potentilla anserina	35	32	28	75	65	15	30	60	70	25	28	35		16	34	25	40	30	70	70
Potentilla reptans		4					2	1		<4	2	5						<4	<1	2
Prunella vulgaris						<1		<1								<1				
Ranunculus repens	10		1	1	5	<4	3	<1	10	<1	<1	<1					15	<4	1	<1
Ranunculus trichophyllus													1							
Rorippa sp.						<1								<4						
Rumex crispus	10	7	2	15		<4	1	1	5	1	2		0.5					<4		1

Transcect 2	Relevé T2R2				Relevé T2R4				Relevé T2R6				Relevé T2R12				Relevé T2R16			
Date / Species	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024
Taraxacum officinale			1																	
Scorzoneroides autumnalis	1	<4	<1						4	<4	<1	<1					15	<4	<1	<1
Stellaria media				1															<1	1
Trifolium repens	30	18	70	20			5	2	15	30	28	10					30	26	20	10
Viola persicifolia						<4														
Species richness	**12**	**13**	**16**	**11**	**9**	**16**	**13**	**12**	**12**	**15**	**13**	**13**	**9**	**7**	**8**	**9**	**10**	**12**	**10**	**13**

Figure 0-2: Comparison between plant species recorded from 2014-2015 to 2024 at Transect 4, Rahasane Turlough. Figures show percentage cover for each plant species. Species are colour-coded by typical habitat conditions as follows: yellow: usually terrestrial, blue: usually aquatic, grey: intermediate. Habitat classifications from Caffrey *et al*. (2023); for species not listed by Caffrey *et al*. (2023), typical habitat information is from Parnell & Curtis (2012) and Atherton *et al.* (2010).

Transect 4	Relevé T4R5				Relevé T4R10				Relevé T4R16				Relevé T4R18				Relevé T4R22			
Species / Date	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024
Agrostis stolonifera		25	28	35		Inaccessible	50	10	75	Inaccessible	Inaccessible	Inaccessible	50	Inaccessible	Inaccessible	Inaccessible	90	Inaccessible	30	30
Alopecurus geniculatus						Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible	1	Inaccessible		
Berula erecta						Inaccessible	2	1		Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		
Capsella bursa-pastoris				<1		Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		
Cardamine pratensis						Inaccessible	<1			Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible	3	Inaccessible		
Carex hirta						Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible	10	
Carex nigra						Inaccessible				Inaccessible	Inaccessible	Inaccessible	3	Inaccessible	Inaccessible	Inaccessible		Inaccessible		
Carex sp.						Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		10
Cerastium fontanum		<1	1			Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible	1	
Cinclidotus fontinaloides		<1	1	<1		Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		
Eleocharis palustris						Inaccessible	6	15		Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		
Festuca rubra	60				40	Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		
Filamentous green algae						Inaccessible	<1	5		Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		
Fontinalis antipyretica						Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible	0.5	Inaccessible		
Galium palustre				<1		Inaccessible	<1	<1	5	Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible	3	Inaccessible	1	
Glyceria fluitans						Inaccessible	4	5		Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		
Juncus bulbosus						Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible	<1	
Mentha aquatica						Inaccessible	3	1	10	Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible	2	
Myosotis scorpioides	+	5	1	<1	5	Inaccessible	23	1	5	Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible	5	Inaccessible	5	1
Persicaria amphibia		<4				Inaccessible	15	50		Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		
Persicaria minus						Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible	1	Inaccessible		
Plantago lanceolata						Inaccessible				Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		Inaccessible		

Transect 4	Relevé T4R5				Relevé T4R10				Relevé T4R16				Relevé T4R18				Relevé T4R22			
Species / Date	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024
Plantago major		2		<1									15							<1
Poa annua																				2
Potentilla anserina	50	50	55	70				<1	5				15				7		23	50
Potentilla reptans	10	2	2	<4															7	1
Ranunculus repens	20	10	6	<3					5				5						1	<1
Rorippa sp.																	2			
Rumex acetosa													5							
Rumex crispus	+	5	3	7																1
Scorzoneroides autumnalis	+		<1										5							
Sphagnum cuspidatum								10												
Stellaria media		<1		1									2							
Trifolium repens			4	<2									5							
Viola persicifolia	+																			
Species richness	**8**	**11**	**10**	**12**	**2**		**10**	**11**	**6**				**9**				**9**		**10**	**9**

Figure 0-3: Comparison between plant species recorded from 2014-2015 to 2024 at Transect 6, Rahasane Turlough. Figures show percentage cover for each plant species. Species are colour-coded by typical habitat conditions as follows: yellow: usually terrestrial, blue: usually aquatic, grey: intermediate. Habitat classifications from Caffrey *et al*. (2023); for species not listed by Caffrey *et al*. (2023), typical habitat information is from Parnell & Curtis (2012) and Atherton *et al.* (2010).

Transect 6	Relevé T6R2				Relevé T6R6				Relevé T6R12				Relevé T6R16				Relevé T6R18			
Species / Date	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024
Agrostis stolonifera									15	50	20	22	10	48	43	50	20	20	22	40
Alopecurus geniculatus										<4										1
Bellis perennis																		<1	1	
Cardamine pratensis					1					<1		<1		<4		<1		<1		
Carex hirta		Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible			<1									
Carex nigra										3	20	15	20	4	4		10		3	
Carex sp.												<4				5				1
Cerastium fontanum																			1	<1
Cirsium sp.																				<1
Festuca rubra									15	<4				4	2				6	
Filipendula ulmaria													20		<1					
Galium palustre		Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible		<1	3	<4		<4	<1	<1	5	2	1	
Glyceria fluitans					50															
Juncus articulatus																			2	
Juncus bulbosus															1	<1				<1
Juncus sp.											<1	<2								
Lolium perenne																			2	
Lotus corniculatus		Inaccessible	Inaccessible	Inaccessible		Inaccessible	Inaccessible	Inaccessible								2				
Myosotis scorpioides					3				1	3	3	<4		<4	<1	<1				
Phleum pratense																			2	
Plantago major															<1				1	1
Poa annua																				<1
Potentilla anserina									50	30	35	38	30	32	25	27	15		36	50

Transect 6	Relevé T6R2				Relevé T6R6				Relevé T6R12				Relevé T6R16				Relevé T6R18			
Date / Species	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024	2014-2015	2021	2022	2024
Potentilla reptans											<1	<2		<4	<1	<1		<1	2	
Prunella vulgaris																		<4	2	
Ranunculus repens									20	10	15	10	5		3	<1		<4	3	<1
Rumex acetosa																		<1		
Rumex crispus					2					<4										<1
Scorzoneroides autumnalis									+				5				5	2	<1	
Sparganium erectum					1															
Stellaria media																	5			
Taraxacum officinale											<1				<1					
Trifolium repens					1						3		10		20	3	45		25	3
Veronica catenata					1															
Veronica chamaedrys														<4						
Veronica serpyllifolia																			<1	
Species richness					**7**				**6**	**10**	**11**	**10**	**7**	**9**	**13**	**11**	**7**	**9**	**17**	**12**

Appendix 5: Aquatic Plant Taxa Lists

Figure 0-2: Aquatic plant species recorded at the Rahasane Turlough, August 2024

Type of Macrophyte	Species	Rarity Score	Trophic Ranking Score	No. of Sites present
Emergent Plants	*Agrostis stolonifera*	1	LP	4
	Alisma plantago-aquatica	1	9	4
	Apium nodiflorum	1	10	1
	Berula erecta	2	10	2
	Caltha palustris	1	7	1
	Cardamine pretensis	1		2
	Eleocharis palustris	1	LP	3
	Equisetum fluviatile	1	LP	2
	Galium palustre	1		2
	Glyceria fluitans	1	LP	2
	Hydrocotyle vulgaris	1	LP	1
	Juncus bulbosus	1	5.3	1
	Mentha aquatica	1	7.3	3
	Myosotis scorpioides	1	9	4
	Oenanthe fluviatilis	2		1
	Persicaria hydropiper	1	10	1
	Phalaris arundinacea	1	8.5	2
	Ranunculus flammula	1	LP	1
	Rorippa islandica	8		2
	Rorippa nasturtium-aquaticum	1	10	1
	Solanum dulcamara	1	10	2
	Sparganium erectum	1	8.5	2
	Typha angustifolia	2	10	1
	Veronica sp. (undertemined)	1		1
Floating Leaved Plants	*Lemna trisulca*	1	10	2
	Nuphar lutea	2	8.5	1
	Persicaria amphibia	1	9	3
	Potamogeton natans	1	LP	4
Submerged Plants	*Apium inundatum*	2	6.3	3
	Callitriche sp (undertermined)	1		4
	Chara sp	2	7.3	3
	Elodea canadensis	1	7.3	2
	Hippuris vulgaris	2	7.7	4
	Myriophyllum verticillatum	4		2
	Oenanthe fluviatilis	2		1
	Potamogeton pusillus	2	9	3
	Sparganium emersum	1	10	3
	Total Number of Species	37		

LP= Species exhibiting little nutrient preference

Appendix 6: 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.