Lough Gur Priority Area for Action

Desk Study AFA0117

View looking northwest across Red Bog towards Lough Gur, September 2021

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Disclaimer:

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Acknowledgements

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Data attribution

The following data sources were consulted in the preparation of this report:

- EPA WFD App
- Land use: Corine 2018
- Subsoils Maps: Teagasc-EPA (2015)
- P and N Susceptibility Maps: EPA (2018)
- Aquifer Category: GSI (2017)
- Groundwater Vulnerability: GSI (2017)
- WFD Waterbody Status: EPA (2018)
- Pollution Impact Potential Maps: EPA (2021)
- Macrophyte report 2016-2018, Lough Gur, EPA Ecology
- National Research Survey Programme Lakes 2018, Lough Gur. IFI 2019 1-4458 IFI_2018.pdf
- Central Statistics Office (CSO), 2016. CSO Statistical Databases. http://www.cso.ie/en/databases/ [accessed on 24th March 2022].
- Catchment boundaries, waterbodies and Areas for Action, EPA 2018
- EPA SLAM, February 2022
- Group scheme preliminary source protection area, Lough Gur Geological Survey Ireland Spatial Resources (arcgis.com)
- Failte Ireland report, Visitors to Tourist Attractions 2007-2011-(Revised-Oct-2012).pdf (failteireland.ie). [accessed 5th January 2022]

Other sources/publications consulted:

- Ball, D.M., 2004. "Lough Gur Hydrological Assessment" – Draft Report (unpublished).
- Dalton, Walsh, Viane, Allott, 2019. "Lough Gur Palaeolimnology".
- De Eyto E, Irvine K, 2007. "Assessing the status of shallow lakes using an additive model of biomass size spectra". Aquatic Conservation: Marine and Freshwater Ecosystems. 17(7): 724–736.
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- Walsh, N., 2017. "Using lake sediment records to examine recent productivity in Lough Gur, Co. Limerick" (M.A. Thesis). Mary Immaculate College.

Date of completion of this desk study

Desk study completed on 1st July 2022. Document conclusions are based on data collated on or before 30th March 2022.

Summary

Lough Gur priority area for action (PAA) is located in the Maigue subcatchment (24_13), approximately 20km south of Limerick city. The PAA comprises two waterbodies, Lough Gur itself and the Ballycullane (Limerick)_010 river waterbody in which sub basin the lake is situated.

Lough Gur

Lough Gur is a shallow horseshoe-shaped lake (79ha approximately, Type 10), largely enclosed by five hills. There are two bogs in the catchment, Lake Bog to the east of the lake and Red Bog to the south.

There are no natural surface watercourses flowing into Lough Gur. It is fed by groundwater springs and surface runoff from adjacent lands. A man-made channel links Lake Bog to Lough Gur but this channel is only active during wetter winter periods or after sustained heavy rainfall (Langford and Gill, 2016).

There are two outflows from the lake, Pollavaddra swallow hole to the northeast which emerges at two springs to the north of Knockfennel and an artificial channel to the northwest which connects the lake to the Ballycullane (Limerick)_010 main river channel.

The lake's contributing catchment was mapped by Ball in 2004 and more recently by Langford and Gill in 2016. The catchment boundary aligns with the EPA Ballycullane (Limerick)_010 subbasin boundary to the north, east and north east, as expected. To the south, the boundaries don't align because Red Bog doesn't discharge to Lough Gur; the Langford and Gill study found that direction of flow is from the lake towards Red Bog.

Lough Gur is at moderate WFD status and *At Risk*. Status has improved here over the course of the EPA WFD lakes monitoring programme, from bad status in 2007-2009 to poor in 2010-2015, improving to moderate in 2013-2018.

Total phosphorus (TP) is the primary significant issue impacting on lake water quality. Chlorophyll α and pH are also periodically elevated (linked to TP and reduced alkalinity due to photosynthesis). Ammonium has been elevated on occasion.

Lands in the catchment are mainly under agriculture and residential use.

The significant pressures on Lough Gur were identified in the EPA initial characterisation as Domestic Wastewater (Single House Discharges) and Agriculture (Pasture). Other studies have referred to tourism as a potential pressure on lake water quality (Viaene, 2015. Walsh, 2017).

The desk study confirms that Agriculture and Domestic Wastewater are significant pressures on lake water quality. The impact of tourism on lake water quality was assessed specifically in relation to the visitor centre. The desk study concludes that this is not a pressure on lake water quality.

The EPA SLAM (Feb 2022) identified atmospheric deposition as a potential significant TP source, linked to local pasture but with contribution also likely from further afield. Recycling from lake sediment is also a potential TP source.

Considering the significant land-based sources of lake total phosphorus (Agriculture and Domestic Wastewater), pathways will be via overland and shallow subsurface flow in the poorly draining soils and groundwater flow in the well-drained areas where groundwater vulnerability is extreme with rock at or near surface.

Specialist monitoring may be required for Lough Gur in the future (e.g. groundwater monitoring and/or dust deposition sampling to validate the SLAM estimate of atmospheric TP contribution) but very limited local catchment assessment is proposed here for the present. This is because the lake has already been

extensively studied and monitored so there is a reasonable degree of certainty around the desk study significant issue and pressure conclusions. Also the only surface water stream for assessment is the man made channel which periodically delivers flow to Lough Gur from Lake Bog. Instead it is proposed to refer agriculture and DWWTS as pressures directly from the desk study.

For agricultural pressures, two referral types are proposed, based on the following:

i) phosphate referrals focused on pathway interception measures in poorly draining areas with surface and shallow sub surface flowpaths and
ii) phosphate referrals focused on groundwater flowpaths where well drained soils overly areas of extreme groundwater vulnerability with rock at or near surface. Risk here will be driven by land use/agricultural activity in these areas.

For domestic wastewater (single house systems) pressures, LAWPROs approach is to issue letters to relevant landowners advising of their eligibility to apply for a grant to repair or upgrade their systems (where certain conditions are met relating to registration etc). These letters will be issued to the high and very high risk residences in the lake contributing catchment, as identified from EPA Sanicose risk maps.

Ballycullane (Limerick)_010

Ballycullane (Limerick)_010 rises in the south of the sub basin near Tullabracky, flowing north and west to discharge to the Camoge_020 river waterbody (part of the Camoge PAA) upstream of Meanus. OSi 50k and Prime 2 maps show the discharge to be via three tributary channels.

Ballycullane (Limerick)_010 is not monitored under WFD. Its extrapolated WFD status is moderate, based on expert judgement. Its risk is in *review*.

Natural sediment accumulation maps indicate areas of high to extensive sediment deposition close to the waterbody outlet. The main river channel and tributaries are in the Maigue Arterial Drainage scheme. This information suggests that sediment is a likely significant issue in the waterbody.

Results of limited nutrient monitoring undertaken to date showed elevated levels of all three nutrients in high river flows (based on one high flow sample only). Further investigation is needed to confirm.

Twenty one percent of the sub-basin is high risk for surface phosphate loss (PIP Rank 1 to 3). These critical source areas are mainly located close to the waterbody outlet. Phosphate may be an issue here.

From EPA initial characterisation information in the WFD app, the significant pressure is listed as Anthropogenic Pressures-Unknown.

If sediment is confirmed to be a significant issue in Ballycullane (Limerick)_010, hydromorphology is a significant pressure.

If further monitoring indicates that phosphate or ammonium are significant issues, then agriculture is a likely significant pressure which will need to be investigated in the field, particularly focusing on the critical source areas close to the waterbody outlet.

Phosphate (and ammonium) contribution from Lough Gur will also need to be assessed by nutrient and flow monitoring.

1 Background

Table 1-1. Background information on Lough Gur PAA

Priority Area for Action	Catchment Number	Catchment Name	Subcatchment	Region	Local Authority
Lough Gur	24	Shannon Estuary South	24_13 Maigue SC_050	Southwest	Limerick City and County Council

Priority Area for Action	No. of *At Risk* WBs	No. of *Review* WBs	No. of dRBMP Prioritised WBs	No of WBs for Status Improvement:		
				2021	2027	Beyond 2027
Lough Gur	2	0	0	0	2	0
Reasons for selection	• Opportunity to work with a strong group water scheme here. Many farmers in the area are members of the scheme • Active community and angling groups. • High recreational and amenity value. • Important for biodiversity and heritage.					

Table 1-2: Summary of individual waterbodies in Lough Gur PAA

Waterbody Code	Waterbody Name	Risk	Obj.	Ecological Status				Pressures		
				2007-2009	2010-2012	2010-2015	2013-2018	Category	Sub-category	Sig? (Y/N)
IE_SH_24_99	Lough Gur	*At Risk*	Good	Bad	Poor	Poor	Mod	Domestic wastewater	Single house discharges	Yes
								Anthropo-genic pressures	Unknown	No
								Agriculture	Pasture	Yes
IE_SH_24B900440	Ballycullane (Limerick) _010	*Review*	Good	Unassigned up to 2022. Extrapolated status is now moderate, based on expert judgement.				Anthropo-genic pressures	Unknown	Yes

Source: Summary information from WFD App

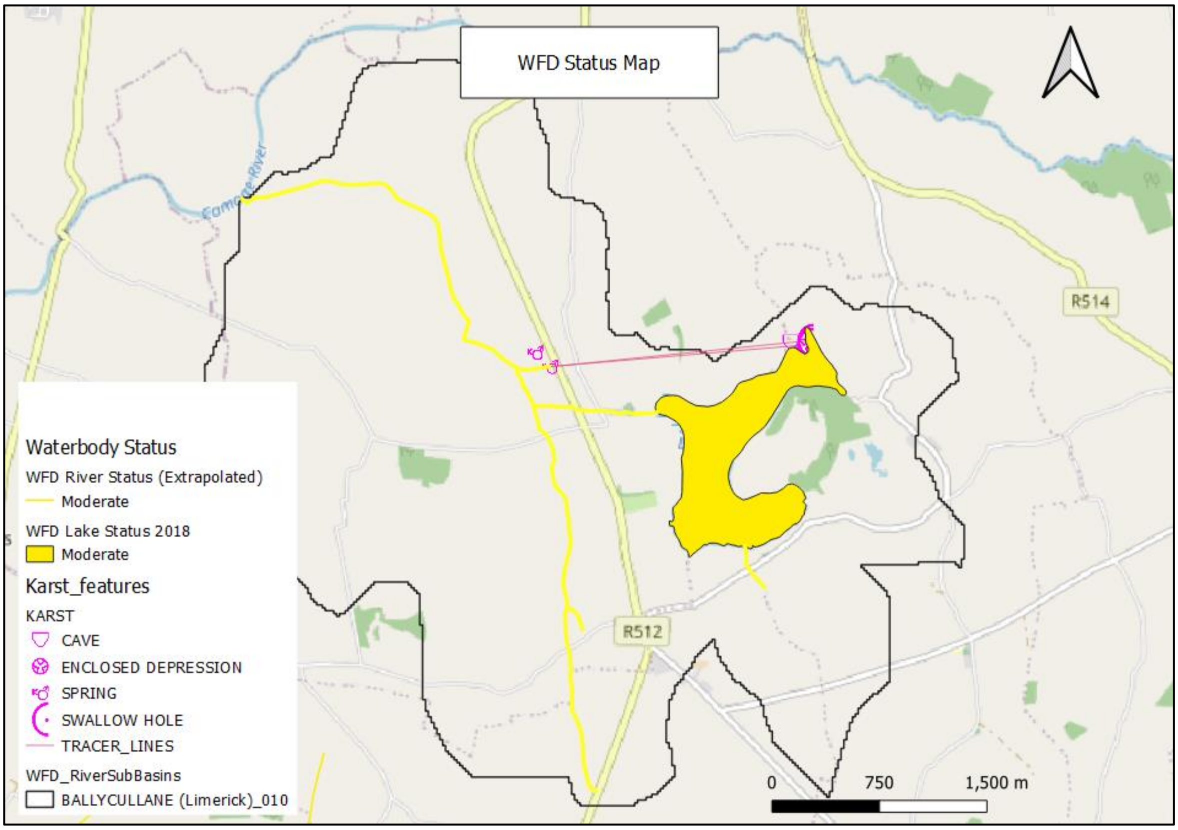


Figure 1-1. Waterbody status map. Note river status shown is 2022 updated (extrapolated) status for Ballycullane (Limk)_010.

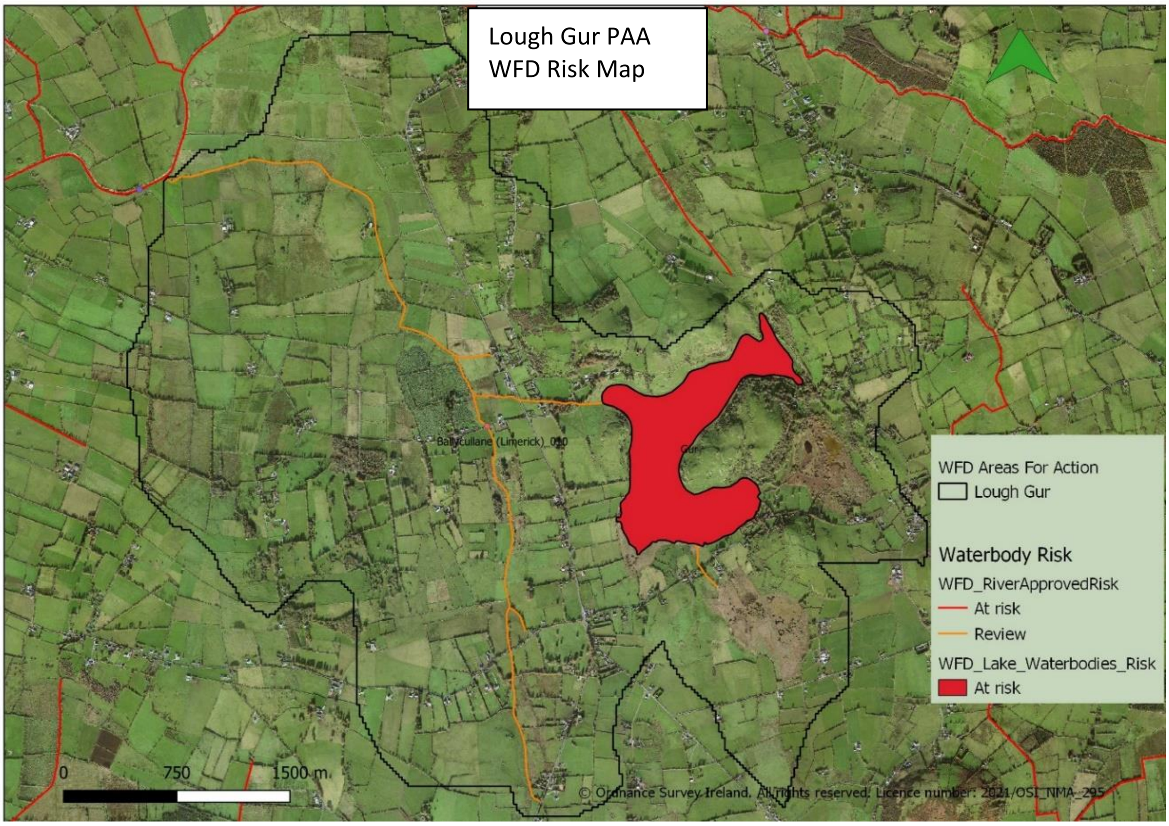


Figure 1-2. Waterbody risk map

2 Receptor information

2.1 Context and Setting

Lough Gur priority area for action (PAA) is located in the Maigue subcatchment (24_13), approximately 20km south of Limerick city. The PAA comprises two waterbodies, Lough Gur itself and the Ballycullane (Limerick)_010 river waterbody, in which sub basin the lake is situated.

Lough Gur (Moderate status and *At Risk*)

Lough Gur is a shallow horseshoe-shaped lake, 79ha approximately with mean depth 1.59m (Layden, 1993). The lake is largely enclosed by five hills, Knockadoon to the immediate east, Knockfennell and Knockroe to the north and north east respectively, Grange Hill to the northwest and Knocksrahir to the south east. Hills slope steeply to the shore particularly along the lake's northern and eastern boundaries. The area is a proposed National Heritage Area (pNHA, 437).

There are no natural watercourses flowing into Lough Gur. It is fed by groundwater springs and surface runoff from adjacent lands. A man-made channel links the lake and the adjacent Lake Bog to the east but according to the Lough Gur Catchment Study final report (Langford and Gill, 2016), this channel is only active during wetter winter periods or after sustained heavy rainfall.

There are two outflows from the lake, Pollavaddra swallow hole at the northeast end which emerges at two springs to the north of Knockfennel (see appendix VI) and an artificial channel to the northwest which connects the lake to the Ballycullane_010 main river channel. The Lough Gur Catchment Study determined that a significant volume of water leaves the lake system via this channel, approximately half of its total outflow during the study period (Langford and Gill, 2016). An Irish Fisheries Investigations report (King and O'Grady, 1994) states that this drainage channel was constructed in the 19th century and may have been designed to drain the reed-swamp area immediately to the east. These drainage works resulted in the lake level being lowered by an average of 2.1m (Langford and Gill, 2016. Dalton et al, 2019).

The lake's contributing catchment was mapped in a project undertaken on behalf of Limerick City and County Council in 2004 (Ball, 2004). This study estimated the surface catchment at 3.7km^2. The estimate for the groundwater catchment was larger, at 4.68km^2. In a more recent study, the contributing catchment area was mapped at 3.68km^2 for surface water and 3.48km^2 for groundwater (Langford and Gill, 2016, see map in appendix I). The lake contributing catchment boundary follows the Ballycullane (Limerick)_010 sub basin boundary to the north, north east and east but to the south it is much smaller and closer to the lake, with Red Bog to the south outside the boundary. A channel connects the lake and Red Bog but the Langford and Gill catchment study concluded that the direction of flow is from the lake towards Red Bog.

The Lough Gur Group Water Scheme groundwater abstraction well (in Fedamore groundwater body) is close to the lake, to the east. The source protection area has been mapped by GSI and is outside the lake catchment and also outside the Ballycullane (Limerick)_010 sub basin (see fig 2-2 below).

Ballycullane (Limerick)_010 (unassigned up to March 2022. Now moderate extrapolated status. In *Review*)

The Ballycullane (Limerick)_010 rises in the south of its sub basin, near Tullabracky, flowing north and then west to discharge to the Camoge_020 river waterbody approximately 4km upstream of Meanus. The river receives the outflow from Lough Gur mainly via a man-made channel to the north west but also via the spring discharge to the north of Knockfennel.

Ballycullane (Limerick)_010 is part of the Maigue Arterial Drainage scheme with maintenance works last undertaken here in 2021, according to OPW maps (Appendix IX).

2.2 Receptor Overview

2.2.1 Lough Gur

Water quality data for the lake are summarised in table 2.1. Monitoring locations are shown in figure 2.1.

Figure 2-1. WFD monitoring sites, Lough Gur

Table 2-1. Receptor information for Lough Gur

Waterbody		**Lough Gur**	
Risk Category		***At Risk***	
Environmental Objective		**Good**	
Environmental Objective Date		2027	
Monitoring Type		Surveillance	
Monitoring stations (Figure xx)		Littoral	LIT_0010 and LIT_0020
		Macrophytes	M_1 to M_4
		Phytobenthos	PB_0010 and LIT_0010
		Chemistry	Site 1, Site 2, L Gur Station 1 amenity centre, L Gur Station 2 old church
		Fish	Fish/Biota dummy site
		Investigative	PRF_010
Lake type		Type 10: altitude 75.4m depth <4m , high alkalinity, area 0.78km2	
Biological Status			
Phytoplankton	*2007-2009*	Moderate	
	2010-2012	Good	
	2010-2015	Good	
	2013-2018	Good	
Other Aquatic Flora			
Macrophytes	*2007-2009*	Moderate	
	2010-2012	Moderate	
	2010-2015	Moderate	
	2013-2018	Moderate	
Phytobenthos	*2007-2009*	Moderate	
	2010-2012	Good	
	2010-2015	High	
	2013-2018	Good	
Invertebrate Status	Monitored but no standard has been developed and/ or the quality element is not used for status assessment.		
Fish Status			
	2007-2009	Bad	
	2010-2012	Poor	
	2010-2015	Poor	
	2013-2018	Moderate	
Hydromorphological Conditions			
Hydro-morphology	*2007-2009*	No data	
	2010-2012	High	
	2010-2015	High	
	2013-2018	Moderate	
Evidence of drainage		See text. Artificial channel constructed to the northwest in the 1840s, connecting the lake to Ballycullane (Limerick)_010	
Comments		Status is driven by macrophytes and fish and hydromorphology?	
Conceptual model required (Y/N)		Yes, for referral areas. Not required for LCA	

Waterbody	Lough Gur
Risk Category	***At Risk***
Environmental Objective	**Good**
Environmental Objective Date	2027
Monitoring Type	Surveillance
Ecological Status	
2013-2018	Moderate
Observations from EPA Macrophyte Report	Moderate status is an accurate reflection of the state of the plant community within Lough Gur. Ideally a Charophyte lake should have a percentage relative frequency of Chara species of sixty percent or more with a good diversity of macrophytes from all other groupings at low abundances. This is not the case here where the relative frequency of Chara sp. is very low. Total phosphorus levels are consistently above the good/moderate class boundary and this is reflected in the dominance of nutrient tolerant macrophyte taxa. Total phosphorus levels will need to be permanently reduced below the high/good class boundary to re-establish a low nutrient regime in the lake which will give Charophytes a competitive advantage over nutrient tolerant taxa.
Estimated residence time	0.21 years (De Eyto and Irvine, 2007)
Protected Areas	pNHA. L Gur is a charophyte lake (high alkalinity lakes with a lake bed of marl (lime rich mud or mudstone) and a plant community of mostly Chara). Fedamore GW supply and L Gur GWS (note that GWS source protection area is outside the lake catchment, see fig 2-2 below)
Significant issue	Elevated nutrients (total phosphorus and ammonium), pH and elevated chlorophyll.

Figure 2-2. Group water scheme Source Protection Area

2.2.2 Ballycullane (Limerick)_010

Ballycullane (Limerick)_010 is not monitored for either biology or chemistry under WFD. Its status was unassigned up to March 2022 when EPA assigned an extrapolated status of moderate here, based on expert judgement. Available receptor data are summarised in Table 2-2:

Table 2-2. Receptor information for Ballycullane (Limerick)_010

Ballycullane (Limerick)_010		**Figs Tables**	**Results**
Risk Category		Y	***Review***
Biological Status	**2013-2015**	NA	Unassigned
	2016-2018		Unassigned
	trends in Q values **2016-2018 Q value data** **Fish status**		NA.
Hydrochemistry Data			
Ortho-P (mg/l P)	**Baseline**	NA	Not monitored under WFD. Limited sampling undertaken for the Camoge LCA suggests low phosphate in low flows. One high flow sample result = 0.192ppm
	indicative quality		No data
	Trends - significant?		No data
	Distance to threshold		No data
NH4-N (mg/l N)	**Baseline**	NA	Not monitored under WFD. Limited sampling undertaken for the Camoge LCA suggests low ammonium in low flows. One high flow sample result = 0.16ppm
	indicative quality		No data
	Trends - significant?		No data
	Distance to threshold		No data
TON (mg/l N)	**Baseline**	NA	Not monitored under WFD. Limited sampling undertaken for the Camoge LCA suggests low nitrate in low flows. One high flow sample result = 5.16ppm
	indicative quality		No data
	Trends - significant?		No data
	Distance to threshold		No data
Supporting Conditions	**Chemical conditions** **Oxygenation Conditions** **Acidification Conditions**	NA	No data
Hydromorphology			
RHAT score		N	Not assessed for WFD. MQI condition moderate for most of the channel
Evidence of Arterial drainage		Y	Yes
Ecological Status (2013–2018)		N	Unassigned up to 2022. Extrapolated status now Moderate, based on expert judgment
Elements driving status		N	NA
Protected Areas			Lough Gur, situated within the sub basin, is a pNHA.
WFD Objective			Good
EPA biologist's notes (if any)			NA
Significant issue/impact for receptor			Sediment. Nutrients ammonium and phosphate may also be elevated

2.3 Biological Monitoring Results

2.3.1 Lough Gur

Macrophyte status

Lake macrophytes were surveyed by the EPA on four occasions (2009, 2012, 2015 and 2018). Macrophyte status was moderate in all survey years. The EPA 2016-2018 macrophyte report for Lough Gur concluded that:

- The 2018 plant status of Lough Gur is moderate and has been since the baseline survey.
- The lake plant community is characterised by:
  - nutrient tolerant and elodeid taxa
  - low numbers of nutrient sensitive taxa
  - low abundance of Chara species

The report goes on to state 'Moderate status is an accurate reflection of the state of the plant community within Lough Gur. Ideally a Charophyte lake should have a percentage relative frequency of Chara species of sixty percent or more with a good diversity of macrophytes from all other groupings at low abundances. This is not the case here where the relative frequency of Chara sp. is very low'.

Fish status

Fish surveys were undertaken in Lough Gur under the WFD surveillance monitoring programme in 2009, 2012, 2015 and 2018. Results are shown in **Error! Reference source not found.**

Table 2-3. WFD fish status Lough Gur

Survey year	**2009**	**2012**	**2015**	**2018**
Status	Bad	Poor	Poor	Moderate

The most recent fish survey was undertaken in September 2018 at locations shown in the map in **Error! Reference source not found.**The IFI survey report summary states that a total of four fish species were recorded on the lake in September 2018, out of 331 fish captured. Perch was the dominant fish species in terms of abundance and Rudd was the dominant fish species in terms of biomass. Perch captured during the 2018 survey ranged in length from 5.5cm to 28.0cm, with seven age classes present, ranging from 0+ to 6+, indicating reproductive success in each of the previous seven years. Roach captured during the 2018 survey ranged in length from 8.6cm to 26.7cm, with six age classes present, ranging from 1+ to 6+, indicating reproductive success in six of the previous seven years. Using the multimetric fish ecological classification tool (Fish in Lakes – 'FIL2'), Lough Gur has been assigned an ecological status of Moderate for 2018 based on the fish populations present.

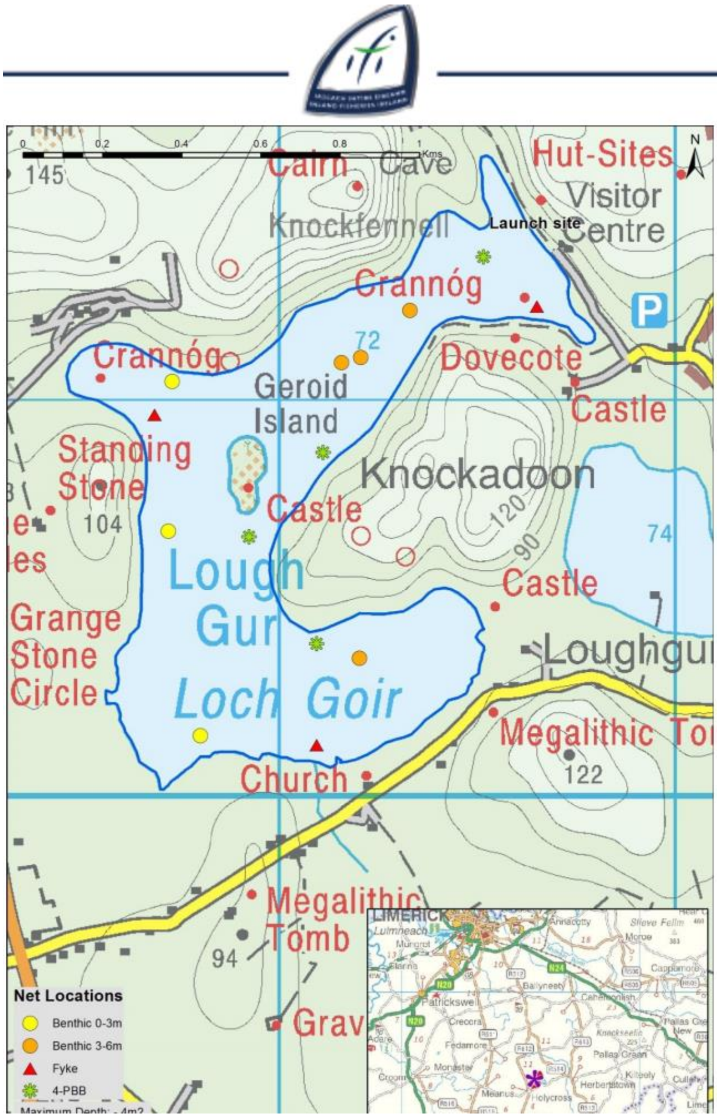


Figure 2-3. Fish monitoring sites, Lough Gur.
Source: IFI report Lough Gur IFI/2019/1-4458

2.3.2 Ballycullane_010

There are no biological monitoring data available for Ballycullane (Limerick)_010.

2.4 Hydrochemistry Data

2.4.1 Lough Gur

Annual average total phosphorus, ammonium and chlorophyll α results are shown below in table 2-4. Prior to 2015, four lake sites were assessed for these parameters (Site 1, Site 2, L Gur Station 1 amenity centre and L Gur station 2 old church). Monitoring has not been undertaken at the old church station since 2014. The amenity centre location was not assessed in 2016 to 2018 although samples were taken here in 2020 and 2021.

Table 2-4. Lake monitoring results, Lough Gur

Waterbody		Lough Gur				
Risk Category		*At Risk*				
Environmental Objective		Good				
Monitoring Station		Site 1	Site 2	L Gur Station 1 amenity centre	L Gur station 2 old church	Mean
Water chemistry						
Total Phosphorus (mg P/l)	*2007*	0.036	0.061	0.036	0.026	0.040
	2008	0.046	0.052	0.032	0.023	0.038
	2009	0.025	0.020	0.104	0.023	0.043
	2010	0.021	0.019	0.032	0.026	0.025
	2011	0.017	0.013	0.033	0.022	0.021
Good status ≤ 0.025 (mean)	*2012*	0.029	0.036	0.045	0.016	0.031
	2013	0.059	0.022	0.024	0.030	0.034
	2014	0.022	0.019	0.026	0.023	0.022
	2015	0.022	0.021	0.097	ND	0.047
	2016	0.020	0.025	ND	ND	0.022
	2017	0.027	0.025	ND	ND	0.026
	2018	0.037	0.030	ND	ND	0.034
	2019	0.020 (n=4)	0.019 (n=4)	0.031 (n=4)	ND	0.023
	2020	0.041 (n=4)	0.039 (n=4)	0.020 (n=1)	ND	0.038
	2021	0.030 (n=12)	0.028 (n=12)	ND	ND	0.029
Mean TP (2020 baseline)		**0.035**	**0.030**	**0.029**	**ND**	**0.029**
Total ammonium (mg N/l)	*2007*	0.035	0.024	0.173	0.101	0.083
	2008	0.081	0.036	0.102	0.050	0.067
	2009	0.218	0.106	0.115	0.098	0.134
	2010	0.035	0.026	0.070	0.047	0.045
Good status ≤ 0.065 (mean) and ≤ 0.140 (95%ile)	*2011*	0.033	0.035	0.109	0.107	0.071
	2012	0.071	0.063	0.063	0.041	0.060
	2013	0.030	0.020	0.065		0.038
	2014	0.010	0.010	0.113		0.044
	2015	0.216	0.223	0.183		0.207
	2016	0.037	0.060	ND	ND	0.048
	2017	0.108	0.116	ND	ND	0.112
	2018	0.059	0.051	ND	ND	0.055
	2019	0.039 (n=4)	0.035 (n=4)	0.040 (n=4)		0.038
	2020	0.059 (n=4)	0.060 (n=4)	0.010 (n=1)		0.054
	2021	0.065 (n=12)	0.075 (n=12)	ND	ND	0.070
Mean ammonia N (2020 baseline)		**0.059**	**0.064**	**0.034**	**ND**	**0.058**
Chlorophyll α (µg/l)	*2007*	5.1	7.7	18.2	5.8	9.2
	2008	24.8	51.9	13.1	10.0	24.9
	2009	23.5	19.7	26.0	17.6	21.7

Waterbody		Lough Gur				
Risk Category		*At Risk*				
Environmental Objective		Good				
Monitoring Station		Site 1	Site 2	L Gur Station 1 amenity centre	L Gur station 2 old church	Mean
Lake type 10 HG: 6.4 GM: 10.9 MP: 21.8 PB: 43.6	*2010*	6.5	7.2	8.7	12.3	8.7
	2011	2.2	2.0	9.8	7.6	5.4
	2012	6.7	5.5	10.9	11.8	8.7
	2013	18.1	11.3	3.8	11.0	11.1
	2014	7.3	4.0	4.2	11.0	6.6
	2015	5.0	5.0	3.2		4.4
	2016	3.3	3.5			3.4
	2017	15.3	10.0			12.6
	2018	7.5	8.2			7.9
	2019	4.4 (n=4)	6.3 (n=4)	3.7 (n=4)		4.8
	2020	19.1 (n=3)	9.4 (n=3)	4.7 (n=1)		12.9
	2021	12.5 (n=11)	11.0 (n=11)	ND		11.7
Mean Chlorophyll α (2020 baseline)		**11.8**	**9.7**	**3.9**	**ND**	**9.9**
Significant issue: monitoring point		TP. Recent Chlα issues also	TP. Recent ammonium & Chlα issues also	Recent data indicates TP	No recent data	
Significant issue: waterbody		Total phosphorus. Periodic spikes also observed in ammonium and chlorophyll α				

As the table shows, total phosphorus is the most consistently elevated parameter with the 2020 baseline exceeding the good status EQS at all monitored stations. Ammonium and chlorophyll α have also been elevated on occasion. Mean results for 2021 exceeded the chlorophyll α EQS at Sites 1 and 2 and the ammonium EQS at Site 2.

Individual ammonium, total phosphorus, chlorophyll α and pH results for the four monitoring stations are discussed below for the period January 2012 to December 2021. Results for Station 2 are included here but data are more limited for this station with only twelve samples analysed during this period, all prior to November 2014.

Results are compared against the relevant lake good status EQS (mean and 95%ile where relevant) from EU Environmental Objectives (Surface Waters) Amendment Regulations, 2019.

Ammonium

Ammonium concentrations are graphed in Figures 2-4 and 2-5. There have been a number of significant ammonium spikes at all four stations, all during winter months. Over 80% of Site 1 and Site 2 results between February 2018 and September 2021 were below the mean good status EQS, suggestive of improvement during this period but ammonium levels spiked again at both sites between October and December 2021, rising to 0.3ppm in December.

These results confirm that although annual average ammonium levels have dropped below the EQS in the last four years, ammonium remains a potential issue in this waterbody.

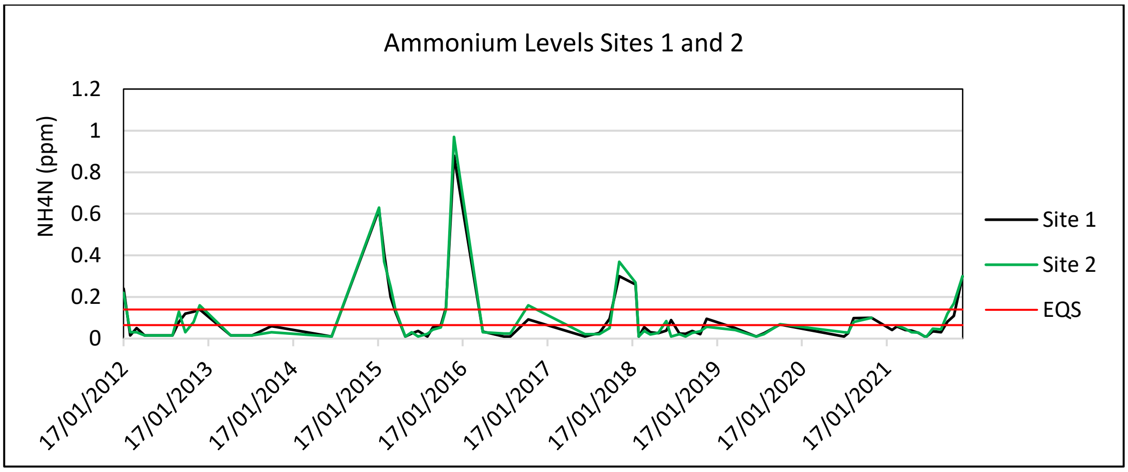


Figure 2-4. Ammonium levels, Sites 1 and 2

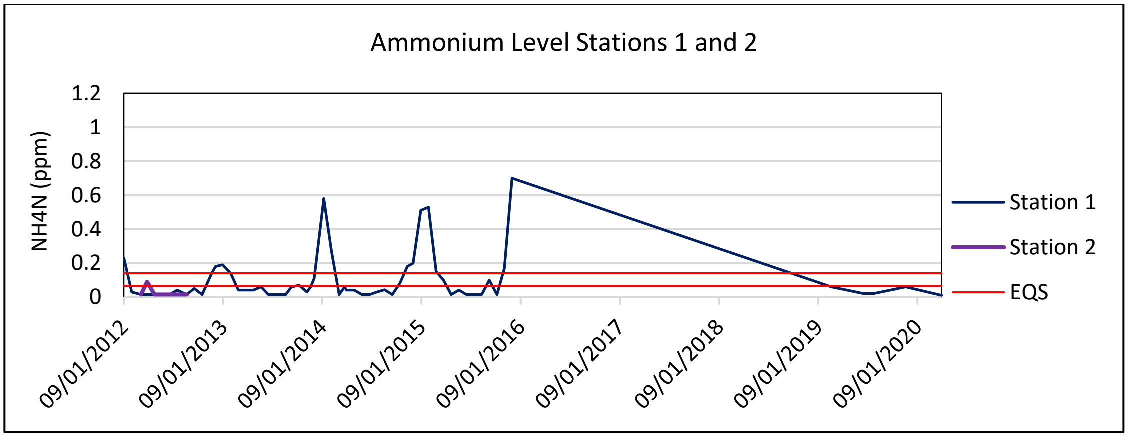


Figure 2-5. Ammonium levels, Stations 1 and 2

Total Phosphorus

Total phosphorus (TP) results are graphed in figures2-6 and 2-7. Between January 2018 and December 2021, 40% of results for Site 1, 35% of results for Site 2 and 55% of results for Station 1 were at or above the lake good status EQS. There were also a number of significant TP spikes observed at Sites 1, 2 and Station 1 during this period, mainly occurring in spring and summer months.

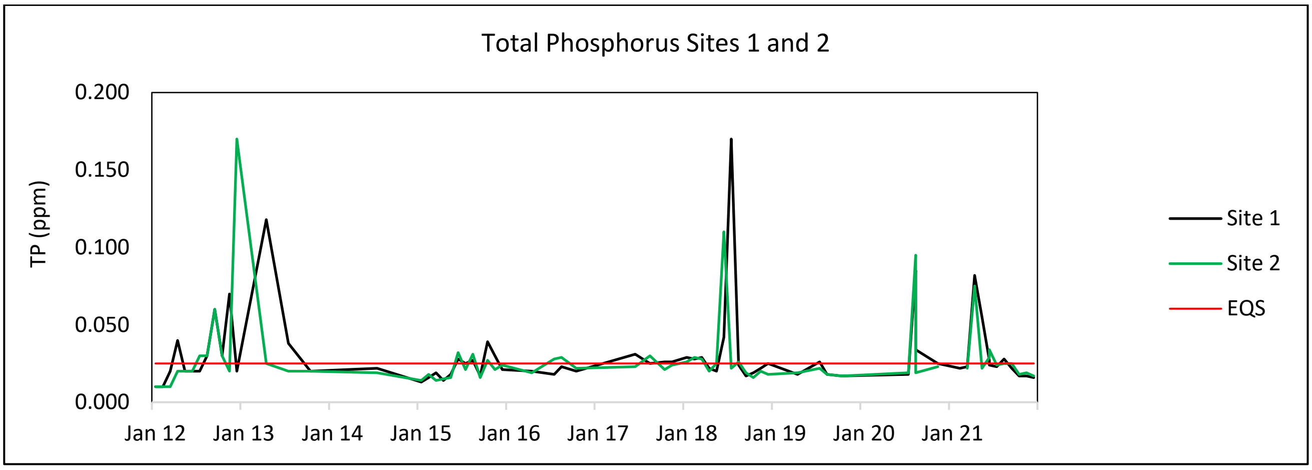


Figure 2-6. TP levels, Sites 1 and 2

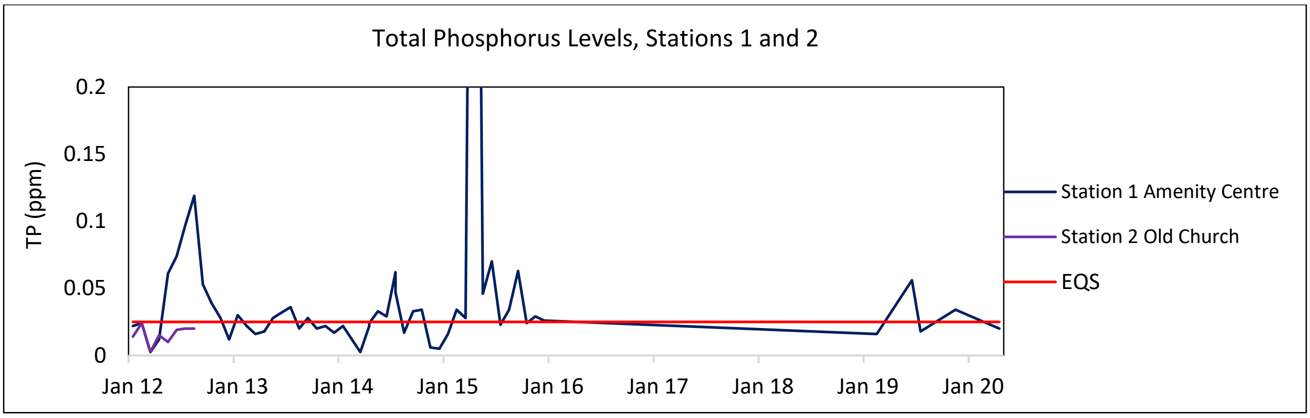


Figure 2-7. TP levels, Stations 1 and 2

Chlorophyll α

Chlorophyll α results are graphed in figures 2-8 and 2-9. Periodic spikes are apparent at both Sites 1 and 2. Peaks are generally associated with spring/summer months, as would be expected. Data for Stations 1 and 2 are more limited but exceedences here were all pre-2013.

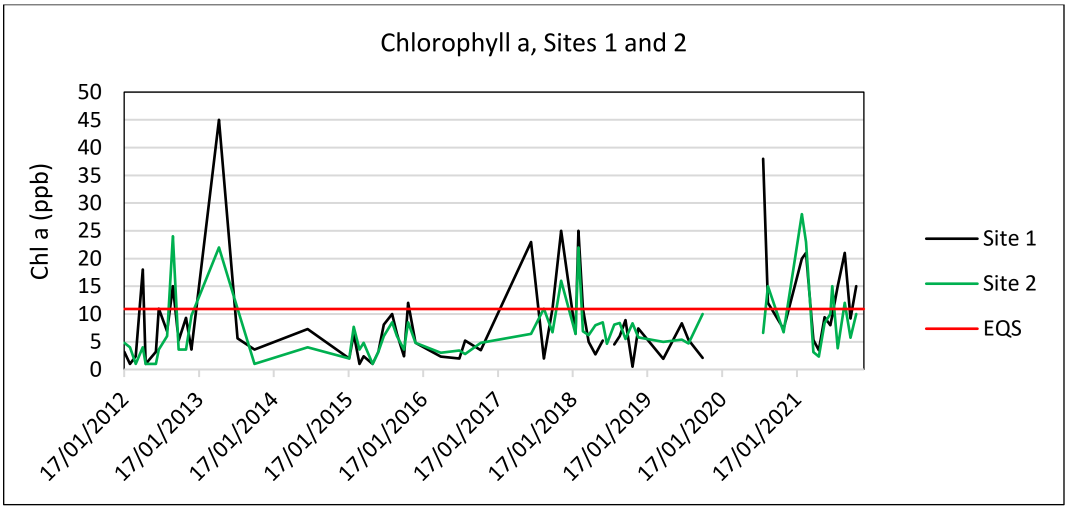


Figure 2-8. Chl α Sites 1 and 2

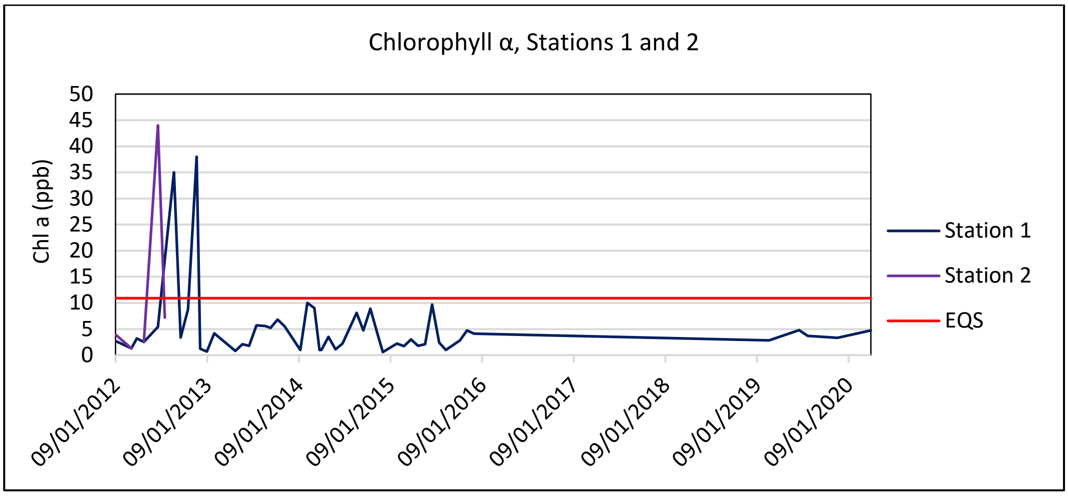


Figure 2-9. Chl α Stations 1 and 2

pH

pH levels are graphed in figures 2-10 and 2-11. All results met the lower limit of 6.0 pH units but the upper pH limit of 9.0 was exceeded periodically, mainly in summer months.

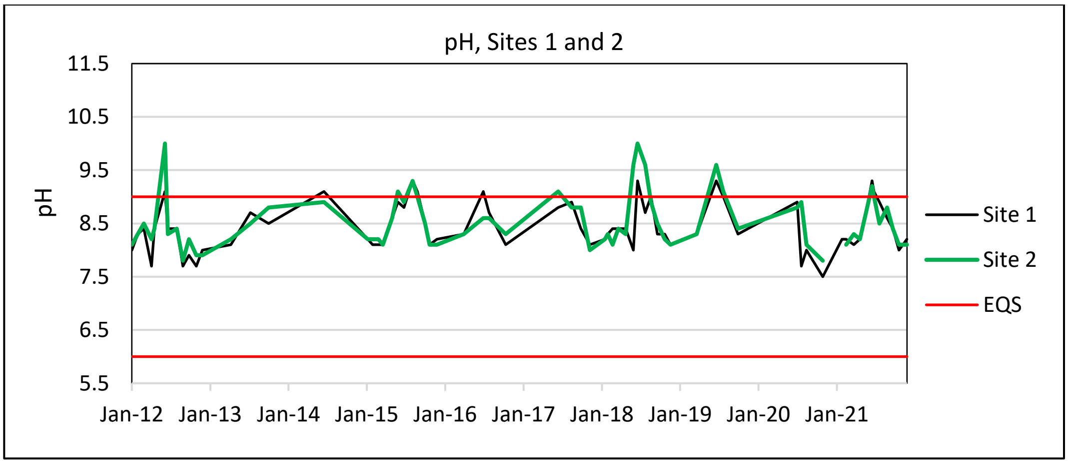


Figure 2-10. pH Sites 1 and 2

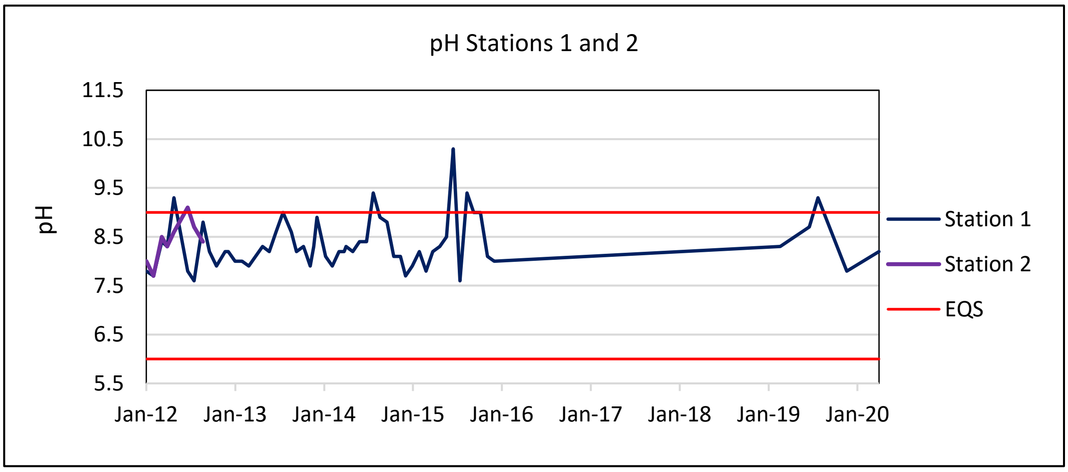


Figure 2-11. pH, Stations 1 and 2

2.4.2 Ballycullane (Limerick)_010

There are no WFD hydrochemistry monitoring data for Ballycullane_010 but three rounds of nutrient monitoring were undertaken at the waterbody outlet in 2021, as part of the Camoge PAA local catchment assessment. Results are summarised below in table 2-5.

Table 2-5. LCA monitoring results, outlet of Ballycullane (Limerick)_010

	NH4N mg/l	**TON mg/l**	**MRP mg/l**	**Comments**
02/02/2021	0.16	5.16	0.192	High flow (Q5)
20/04/2021	< 0.04	<1	0.019	Low flow (Q90)
01/07/2021	< 0.04	<1	0.030	Low flow (Q95)
Mean Good Status EQS *from SW Regs*	0.065	NA	0.035	

As can be seen from the table, nutrient levels in low river flows were below the mean EQS for ammonium and phosphate and below detection limits in the case of nitrate. Levels of all three nutrients were elevated in the single high flow sample (Feb 21). Data are too limited and results too variable to allow conclusions to be drawn however. Groundwater contribution would be higher in the low flow samples. Lake contribution would be expected to be higher in high flows and there have been periodic spikes in lake ammonium and total phosphorus levels. These could possibly account for the elevated river ammonium and orthophosphate levels in the single high flow sample except that river nitrate levels were also high in that sample; lake nitrate levels have never been greater than 2ppm.

Additional nutrient monitoring is needed to confirm which, if any, nutrients are an issue in this waterbody and if so, to what extent. Twenty one percent of the sub basin is high risk for P loss to surface waters (PIP rank 1 to 3), with critical source areas mainly located close to the waterbody outlet. Thirty percent is high risk for N loss. Chemistry samples should be taken at different locations on the Ballycullane (Limerick)_010, including at the lake outlet, and in different river flow conditions.

Sediment is a likely significant issue in Ballycullane (Limerick)_010. The main channel and tributaries are part of the Maigue Arterial Drainage Scheme. Natural sediment accumulation maps indicate large areas likely to have high to extensive levels of natural sediment deposition towards the waterbody outlet. Pathways would be overground, from the poorly draining soils close to the waterbody outlet. There may also be natural sediment loss due to bank erosion along the river channel.

2.5 Conclusion on Significant Issues

2.5.1 Lough Gur

Total phosphorus, pH, ammonium and chlorophyll α are all elevated to varying degrees at different sample locations on Lough Gur but total phosphorus is the most frequently and consistently elevated parameter across all monitored sites. It is also the most useful parameter in relation to identifying likely pressures on the lake. This is because ammonium levels will reduce with oxidation, chlorophyll α levels are linked to plant and algal growth (and to TP) and the pH changes may be linked to changes in buffering capacity (in turn linked to photosynthesis).

To determine whether local pressures could be contributing TP to the lake, particularly at the shoreline sampling locations (Stations 1 and 2), graphs of annual average total phosphorus levels are included in figure 12 below for each of the four monitoring stations. As the map shows, the only site exhibiting possible local impact was Station 1 (Visitor Centre) in 2015. Previous studies suggested that permanent and migratory birds may be a source of nutrients to the lake (Ball, 2004) particularly where feeding is concentrated, such as along the lake shore near the civic amenity centre (Langford and Gill, 2016). This could possibly account for the 2015 TP spike at station 1.

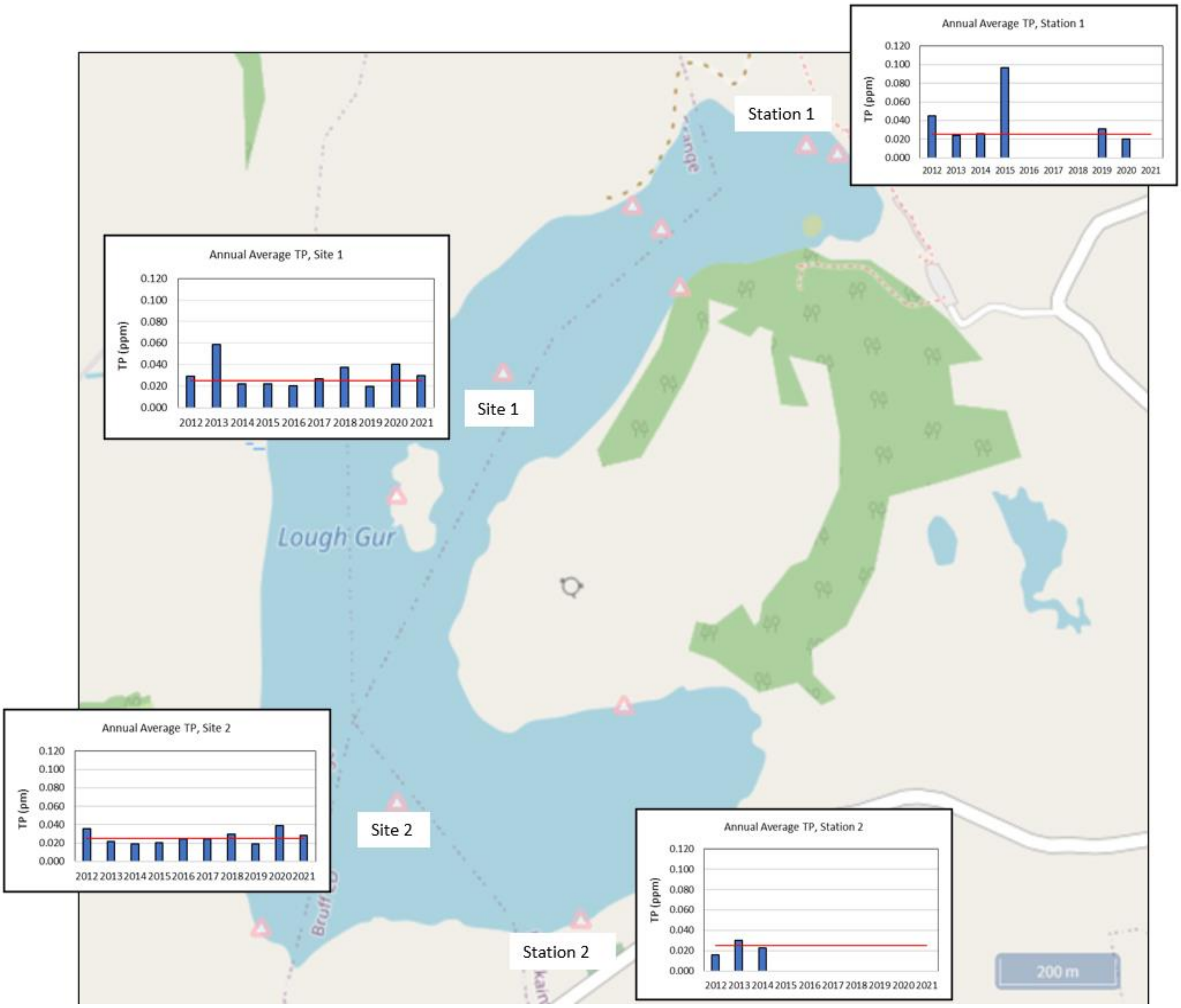


Figure 2-12. AAV TP, Lough Gur monitoring stations

The estimated total annual phosphorus load in the lake water column and the required reduction to meet the good status TP EQS were estimated using the average TP results for all stations from January 2012 to December 2021, multiplied by the lake volume and residence time in years. The TP reduction required to meet the high status EQS of 0.01mg/l (as recommended by the EPA lakes team for charophyte lakes) was also determined. These estimates are provided in table 2-6. Note that the annual figure of 190 kg per annum may be a significant overestimate as it assumes that all of the phosphorus in the water column leaves the lake rather than becoming re-bound in lake sediment or taken up by lake macrophytes.

Table 2-6. Estimated TP load and required reduction, Lough Gur

	TP (mg/l)	Lake Volume *(from Layden, 1993)* (m3)	Lake TP (Kg)	Lake Turnover *(from De Eyto and Irvine, 2007)* (years)	Lake P (Kg per annum)
Mean 2012 to 2021, all sites	0.033	1,207,620	39.85	0.21	190
Required Reduction to meet Good status EQS	0.008	1,207,620	9.66	0.21	46
EPA recommended reduction for L Gur as a charophyte lake	0.023	1,207,620	27.78	0.21	132

Ballycullane (Limerick)_010

Sediment is a likely significant issue in Ballycullane (Limerick)_010, considering that the main channel and tributaries are part of the Maigue arterial drainage scheme and that sediment settings maps indicate high to extensive areas of natural sediment deposition close to the waterbody outlet.

Results of one high flow river sample indicate that nutrients ammonium, phosphate and nitrogen may all be *potential* significant issues in this waterbody but a significant amount of additional monitoring is required to confirm whether this is the case and if so, what are the likely nutrient sources. See section 6 for an outline of the proposed approach to local catchment assessment.

3 Significant Pressures

3.1 Initial characterisation

Significant pressures from the EPA initial characterisation are shown in table 3.1. Table includes WFD Cycle 3 update information.

Table 3-1. EPA initial characterisation information

Water body Name	Id	Category	Subcategory	Name	Sig?	Pressure & Impact details
Ballycullane _010	WBP0006267	Anthropogenic pressures	unknown	NA		The assessment of the pressures in this water body cannot be undertaken until the completion of an Investigative Assessment. Not extractive industry as such - at the Limerick workshop it was noted that there is phosphorus input to the water body from Lough Gur which is on its way to becoming a bog. Outflow from Lough Gur comes to here (swallow hole discharges to the west), agreed that the water body is probably At Risk. The swallow hole that was there previously stopped it from progressing to become a bog. Lough Gur itself has nutrient inputs, it is always at best mesotrophic. Additional details in WFD app
Lough Gur	WBP0004822	Domestic wastewater	Single house discharges	NA	Yes	Nutrient pollution (direct discharges from septic tanks)
	WBP0004824	Anthropogenic pressures	unknown	NA	No	During the workshop it was noted that there are extensive areas of animal grazing around the lake shore and this may be contributing nutrients to the lake. It was also noted that the surface water catchment to the lake is small and that the GW input is less than expected. Since channel was cut to reduce the level, the annual fluctuations have decreased significantly by about a metre. (Channel) and anthropogenic inputs means it is accelerating move towards bog. Potential to be classed as HMWB. 2013-18. 3rd Cycle update: no longer deemed significant pressure based on further pressure identification in 3rd cycle. Unknown impact type unchecked.
	WBP008108	Agriculture	pasture	NA	Yes	Nutrient pollution. Corine: Predominately pasture – with some peatlands PIP: High PIP for P/SW surrounding lake TP elevated and following upward trend.

3.2 Additional Pressure Information

3.2.1 Lough Gur

Ball (2004) suggested that in addition to anthropogenic impacts, permanent and migratory birds may be contributing to lake nutrients. He also discussed the possibility that the volcanic tuff rocks within the lake contributing catchment may contain the phosphate rich mineral apatite that could be released to the groundwater system through weathering. Langford and Gill didn't identify a significant potential source of naturally occurring phosphorus either in the local limestone or volcanic bedrock so they concluded that the elevated groundwater P is more likely to be from anthropogenic sources (Langford and Gill, 2016).

A study of lake sediment cores to examine recent productivity concluded that the supply of P and N to Lough Gur increased notably starting in the period 1988-1992, also attributed to (diffuse) anthropogenic sources (Walsh, 2017).

A study of the trophic history of Lough Gur which assessed sediment nutrient concentrations over time, found an almost stable concentration of TP and TN from 1900 until 1950, a progressive increase between 1950 and 1990 and a steep upward trend from 1990 on, with the dominant driver for the recent changes attributed to intensification of human settlement around the lake combined with tourism development and agricultural practices (Viaene, 2015). This supports the EPA initial characterisation of agriculture and domestic wastewater as significant pressures on lake water quality. Tourism as a pressure on Lough Gur could potentially be associated with discharges from the visitor centre (if these exist) and bird feeding at the lake shore.

Total phosphorus is the significant issue impacting on lake water quality but ammonium, chlorophyll α and pH are also potential issues here; ammonium is periodically elevated as is chlorophyll (linked to the elevated TP) and there have been spikes observed in pH over the upper limit of 9.0 pH units. However this section looks only at potential TP contribution from different sources in the lake catchment to identify the likely significant (land based) pressures here. TP is more useful than ammonium, chlorophyll α and pH for this purpose because:

- chlorophyll levels are linked to algal growth (linked to TP).
- pH spikes are linked to biological processes within the lake (linked to chlorophyll).
- while the pressures under consideration are likely to contribute ammonium as well as phosphorus to the lake, ammonium is not stable in the environment so it is not as useful for tracking load contribution.

Note that contribution of lake sediment to water column phosphorus levels may be significant in Lough Gur. Langford and Gill (2016) and Layden (1993) concluded that there is weak thermal stratification in the lake and strong dissolved oxygen stratification in summer, with near anoxic conditions observed at depth. Phosphorus will be released into the water column from lake sediment in these conditions. However for the purpose of determining current significant pressures on lake water quality, only land based contributions are examined in this desk study.

As outlined in table 2-6, a total annual reduction of **46**kg P is required from all sources to bring TP levels down to below the Good/Moderate boundary (0.025mg/l). The EPA lakes team has advised that as L Gur is/should be a charophyte lake, lake total phosphorus levels would need to be permanently reduced below the high/good class boundary (0.01mg/l). This would mean a required reduction of **132**kg P per annum, a significant TP load for such a small catchment.

To identify the significant pressures impacting on lake water quality, the visitor centre, domestic wastewater treatment system and agriculture are examined below in relation to their total estimated annual TP load to the lake and also their contribution to the required reduction. DWWTS and agriculture were identified in the cycle 3 initial characterisation as the likely significant pressures on the lake.

The EPA ran their Source Load Apportionment Model (SLAM) for the lake contributing catchment in February 2022. The model output is summarised in table 3-2.

Table 3-2. SLAM v 303 L Gur, February 2022

	Agriculture	Atmospheric deposition	DWWTS	Total
P (kg per year)	31	47	5	84

The SLAM output identified atmospheric deposition as the largest contributor to lake TP, with agriculture contributing 31kg per annum and DWWTS contributing only 5kg per annum (see sections 3.2.1.2 and 3.2.1.3 for further discussion on these pressures). The model did not consider significant point sources as there are no licensed discharges to the lake. However, the potential of the visitor centre to impact on lake water quality is assessed in section 3.2.1.1.

3.2.1.1 Lough Gur Visitor Centre

There are public toilet facilities at two locations at the Lough Gur visitor and interpretive centre:

i) within the interpretive centre building, discharging to a septic tank located approximately 50m to the south south east of the centre and

ii) a newer multi-unit system located in the car park, which discharges to a holding tank. There is no discharge to ground or to waters at the site from this second facility; the holding tank is emptied by Limerick City and County Council staff as required.

In relation to i) above, additional information is needed to confirm that there is no onsite discharge from this unit. Lough Gur development company received a grant of planning in May 2012 to upgrade the interpretive centre at Lough Gur (planning reference P12/95). One of the conditions in the final grant of planning was that no works commence until the applicant submits information to demonstrate that the outlet pipe from the existing septic tank is blocked and the existing septic tank is watertight. A proposal was to be submitted to the PA for the proper and safe management of effluent generated from the development. In a follow up investigation and report from the LCCC environment section, recommendations were made for further investigation of the system with a proposal to be submitted to pump effluent from the septic tank to the existing holding tank on site that Limerick County Council empties.

No further information has been obtained to date on the current status of the discharge from this system. A precautionary and conservative approach has been taken in this desk study to determine whether, **IF** the system discharges to the lake, the discharge could act as a significant pressure on lake water quality. For this purpose, an estimated load has been determined from total visitor numbers, assuming that 10% of visitors use the centre toilets.

Visitor numbers to Lough Gur centre were last publicly reported by Failte Ireland in their report on the numbers of visitors to tourist attractions in Ireland between 2007 and 2011 (see table 3-3) (Failte Ireland, 2012).

Table 3-3. Extract from Failte Ireland report

Name of Attraction	2007	2008	2009	2010	2011
Lough Gur Visitor Centre	3,010	2,019	1,912	1,779	1,624

Visitor numbers have increased significantly since 2011 with references to visitor numbers of 45,000 in 2018 (Walsh, 2017 and Failte Ireland).

The treatment system soakaway/percolation area is approximately 30m from the lake shore. Groundwater vulnerability is extreme here so potential pathways exist from the soakaway/percolation area to the lake. Therefore if the actions required under planning have not yet been carried out, sewage effluent from the public toilets within the visitor centre could discharge to the lake with very little attenuation. A conservative estimate of the potential phosphorus contribution from the facility is provided in table 3-4 below, based on the assumption that 10% of the 45,000 visitors in 2018 would have used the toilet facilities within the centre. This is likely to be a significant over-estimate of actual numbers considering the multi-unit facility in the car park.

Table 3-4. Estimated BOD and nutrient load from visitor centre toilets

	Volume (litres)	BOD	Ammonium as N [1]	Total phosphorus[1]
Load per visitor (in grammes for all parameters except volume)	5*	10*	1.33	0.363
Total load per annum based on 45,000 visitors in 2018 and assuming that 10% use the centre facilities (Kg)	22,500	45	6	1.6

Note [1]: The estimated BOD load from amenity toilets is 10g per person per day from amenity toilets (EPA, 1999). This is 1/6th of the generally accepted daily BOD load of 60 grammes per person. Estimates are not provided for ammonium or phosphate load from amenity toilets so the approach taken in table 3-4 was to use the same fraction as for BOD load (i.e. 1/6th of the accepted daily load of 8 grammes of nitrogen and 2.18 grammes of phosphorus per person respectively).

The estimated maximum total TP contribution of 1.6 kg per annum is less than 1% of the total lake load and less than 4% of the required reduction. These calculations indicate that while it is important for reasons of public health that planning conditions are complied with and that effluent from the visitor centre toilets is all held for offsite disposal, the visitor centre toilets are not a significant pressure in terms of the total phosphorus (or ammonium) load to the lake. It must be emphasised that the calculations in Table 3.4 are speculative as no information could be obtained on the current status of the system discharge.

3.2.1.2 DWWTS

The potential impact of onsite treatment systems on Lough Gur lake water quality was previously investigated as part of a study undertaken by Corós Environmental Engineering on behalf of Limerick County Council (see Lough Gur Environmental Management Study report for further details). All systems assessed were located to the south of the lake, within the catchment boundary. In brief, the assessment included an inspection of the septic tanks (12 dwellings) for capacity, integrity and number of chambers. Effluent samples were collected for analysis and a total P load from twelve dwellings was then estimated, assuming a flow rate of 100 litres per person per day (99g/d average load from the 12 dwellings). The assessors carried out soil auguring to establish depth to bedrock in the vicinity of percolation areas. They found shallow soils with very limited phosphorus attenuation capacity. The Corós report concluded that none of the 12 septic tank systems complied with either SR6 or EPA 2000.

The EPA SLAM output (February 2022) estimated a load from DWWTS of only **5**kg P per annum for the catchment but this may not take into account the low level of attenuation which is likely considering the Corós report findings.

Twenty four high and very high risk dwellings are located in the lake contributing catchment (from EPA Sanicose P risk maps). Assuming that the P losses from these residences are similar to those found in the Corós investigation, this suggests that the total P loss from DWWTS is 198 grammes per day (**72** kg per annum).

An alternative approach to estimating the DWWTS TP load is to consider occupancy and estimated maximum P loss per capita for the 24 high and very high risk dwellings (table 3-5).

Table 3-5. TP contribution from DWWTS, based on occupancy and estimated P load per person

Average occupancy rate per dwelling	2.8	*From CSO 2016 statistics for L Gur townland*
No. of high and very high risk dwellings	24	*From sanicose maps*
Total estimated PE	67.2	
Phosphorus load per PE (gpppd)	2.18	*based on estimates for raw domestic sewage*
Total P load (g per day) to treatment systems	146	
Total P load (g per day) discharged, assuming 50% P removal via sludge and soil	73	*Arbitrary removal rate applied here. No data is available on actual removal through the systems in this catchment, although Corós report suggests generally poor removal efficiencies*
Total P load discharged to the lake (kg per annum)	**27**	

The estimate of **27**kg per annum from table 3-5 is significantly lower than the extrapolated Corós figure of **72**kg per annum but significantly higher than the SLAM output figure of **5**kg per annum. The real P loss from DWWTS is likely to be somewhere between **5** and **27**kg per annum. For the purposes of comparing against required lake TP reduction, a mid-range estimate of **16**kg per annum is used in this desk study.

3.2.1.3 Agriculture

Agriculture is the main land use in the Lough Gur contributing catchment (appendix IV). Lands are a mix of poorly draining and well drained but the well drained soils are thin, with Extreme X groundwater vulnerability (appendix VI). Therefore phosphorus can be lost to the lake from agricultural lands via two diffuse pathways i) surface and shallow subsurface flow from poorly draining (high P susceptibility) areas and ii) groundwater pathways where groundwater vulnerability is extreme with rock near surface and soils are too thin to allow for significant attenuation.

The EPA SLAM model output estimated **31**kg diffuse P loss per annum from pasture, taking both surface and groundwater pathways into consideration. This loss represents 67% of the required reduction in catchment P losses for the good status TP EQS to be achieved (**46**kg, table 2-6).

We can conclude from this that agriculture is a significant pressure on Lough Gur, with risk of diffuse P loss via surface and groundwater flow paths. Considering the depositional nature of the lake environment, there is also a possibility that a small number of episodic events each year (such as inappropriate slurry application) may potentially contribute a significant additional P load to the lake.

3.2.1.4 Atmospheric Deposition

EPA SLAM output estimates an annual P contribution of **47**kg from atmospheric deposition (likely to be mainly from pasture). From the SLAM report: '*Atmospheric deposition map of TN (Henry & Aherne, 2014) & uniform rates of TP deposition are estimated as 0.5 kg ha-1 yr-1 (Jordan, 1997). Open water is defined by the lake segment dataset*'.

This is a more significant P contribution than any of the individual pressures assessed above but it is a model output which would need to be validated by physical measurement in the field. This could potentially be done by collecting dust deposition samples for TP analysis on a monthly basis over twelve months, at strategic locations around the lake. However the value of such monitoring is questionable for the present considering that while atmospheric losses may be linked to pasture in the local environment, contribution is also likely from further afield. Agricultural referrals within the catchment may be of benefit in terms of local atmospheric losses but atmospheric deposition from pasture in the wider environment can't be addressed via Lough Gur PAA referrals.

3.2.1.5 Pressures Summary, Lough Gur

P losses from each of the potential pressures are assessed against the lake required TP reduction in table 3-6.

Table 3-6. Estimated lake TP contribution from each pressure type

Pressure	Est. annual TP load Kg	Potential cont. to required TP reduction for good status (%)	Potential cont. to required TP reduction for charophyte lake (%)	Comments
Visitor Centre	1.6	3.5	1.2	*Not significant even taking the precautionary approach that 10% of 2018 visitor numbers use the visitor centre toilet facilities and that discharge is to the lake, which has not been confirmed*
DWWTS	16	35	12	*Midway between SLAM output (5kpa) and desk study estimate (27 kpa)*
Agriculture	31	67	23	*SLAM output, Feb 2022*
Atmospheric deposition	47	102	36	*SLAM output, Feb 2022. Would need to be verified by field measurement*
Total	96	208	72	*Agriculture and atmospheric deposition are the main significant pressures but DWWTS is also a pressure here.*

As the table shows, atmospheric deposition appears to be the greatest contributor to lake TP, based on the SLAM output but this would need to be verified by field measurement. Also, as outlined earlier, while the atmospheric TP burden may in part arise from within the PAA itself, contributions will also arise from further afield.

Agriculture and DWWTS are the two main pressures delivering TP to Lough Gur via surface and groundwater flowpaths. The visitor centre is not a pressure here.

3.2.2 Ballycullane (Limerick)_010

EPA initial characterisation listed anthropogenic/unknown as the significant pressure on Ballycullane (Limerick)_010. The WFD App pressure/impact section states that investigative assessment is needed here in order to refine the significant pressure.

As outlined earlier, this waterbody is not monitored under WFD. Sediment is a likely significant issue here. Limited nutrient monitoring results suggest that phosphate, ammonium and nitrate are all potential issues in high flow but further assessments are needed before conclusions can be made.

SLAM v204 output for Ballycullane (Limerick)_010 was 73% for pasture, 7% for arable and 6% for septic tanks.

3.2.2.1 Agriculture

Agriculture is a potential pressure on Ballycullane (Limerick)_010. The SLAM output was very high for agriculture, at 79% for pasture and arable combined. Land use is mainly under agriculture (pasture) here (appendix IV). PIP v3 maps show that high risk areas for surface phosphate loss cover twenty one percent of the sub basin (appendix II). These areas are also high risk for sediment loss. There are large areas of the sub basin with well drained soils (appendix V), particularly towards the south and north east but groundwater vulnerability here is high to extreme with some areas with rock near surface. If phosphate is confirmed as an issue in this waterbody, groundwater flowpaths from these areas will need to be considered in addition to the surface and shallow sub surface pathways. Groundwater pathways are unlikely to be delivering significant quantities of sediment however.

3.2.2.2 DWWTS

Domestic wastewater treatment systems are unlikely to be a significant pressure here. Sanicose P risk maps indicate that there are no very high risk dwellings and approximately 30 high risk dwellings in the sub-basin, outside the lake contributing catchment. These are mainly in two clusters, one to the south and the second to the north east along the R512 and L8010, both clusters on shallow well drained soils.

3.2.2.3 Nutrient losses from Lough Gur

As outlined in section 2, results of limited nutrient monitoring in Ballycullane (Limerick)_010 suggest low river MRP, ammonium and nitrate levels in low river flow, with high levels of all three nutrients in one high flow sample. If nutrients are an issue in the river waterbody, the lake must be assessed as a potential source of phosphate and ammonium. It is not a source of nitrate as monitoring data show that lake nitrate levels are consistently low. Flow and nutrient monitoring are required to quantify the lake contribution to river ammonium and phosphate levels (see proposed approach to LCA in section 6).

3.2.2.4 Hydromorphology

The main channel and tributaries of Ballycullane (Limerick)_010 are maintained under the Maigue Arterial Drainage scheme (see map in appendix IX) therefore Hydromorphology is a likely significant pressure in this waterbody. MQI condition is moderate for most of the river channel, dropping to poor close to the outlet, along the two northern outlet channels (appendix X). The score is mainly driven by channel morphology due to the arterial drainage scheme.

3.3 Conclusions on Significant Pressures

3.3.1.1 Lough Gur

As outlined earlier in this report, desk-based assessments confirm the EPA initial characterisation (cycle 3) finding of agriculture as a significant pressure on Lough Gur.

The EPA SLAM output identifies atmospheric deposition as contributing the greatest TP load to the lake. This would also be linked to agricultural land use, both within and extending beyond the PAA boundary.

DWWTS was identified as a pressure in the EPA initial characterisation. The contribution from this pressure is estimated at 16kg P per annum (taken from the mid-range figure between the SLAM output of 5kg per annum and the desk-based calculation of 27kg per annum). This equates to 35% of the total required lake TP reduction, indicating that DWWTS is a significant pressure here. This conclusion is supported by the findings of the earlier Corós assessment of septic tank systems in the catchment.

The visitor centre toilets are not a pressure on lake water quality.

Referrals can be made on the agriculture and DWWTS pressures. Assuming that the combined P loss from diffuse agricultural pathways and DWWTS is 47kg per day, this equates to the total required reduction to meet the good status lake TP EQS. It would not be possible to eliminate all P losses from these two pressures. As mentioned earlier, it is also important to consider the impact of periodic/episodic losses (from inappropriate slurry application for example). These episodic events may play a larger part in terms of catchment P contribution.

In relation to the EPA recommendation to reduce water column TP levels to below the high status EQS as appropriate for a charophyte lake, this does not seem achievable at present. Even if all P losses were eliminated from agriculture and DWWTS (a scenario which is not possible), this would still fall well short of the 132kg per annum required to meet the high status EQS.

3.3.1.2 Ballycullane(Limerick)_010

Hydromorphology is a likely significant pressure on Ballycullane (Limerick)_010. If phosphate is confirmed as an issue in local catchment assessment, agriculture is the likely pressure, particularly on the poorly draining soils close to the waterbody outlet. Lake contribution to river P levels will also have to be assessed.

4 Pathways Information and Analysis

4.1 Lough Gur

As outlined elsewhere in this report, there are no inputting surface waters to Lough Gur. The lake is fed mainly from groundwater with rainfall and surface runoff also contributing flow in wet weather. This is shown in the conceptual model in figure 4-1 below, reproduced from the Lough Gur Catchment Study Final Report (Langford and Gill, 2016). The catchment study included a hydrological assessment of lake inflow and outflow (see report extract reproduced in figure 4-2).

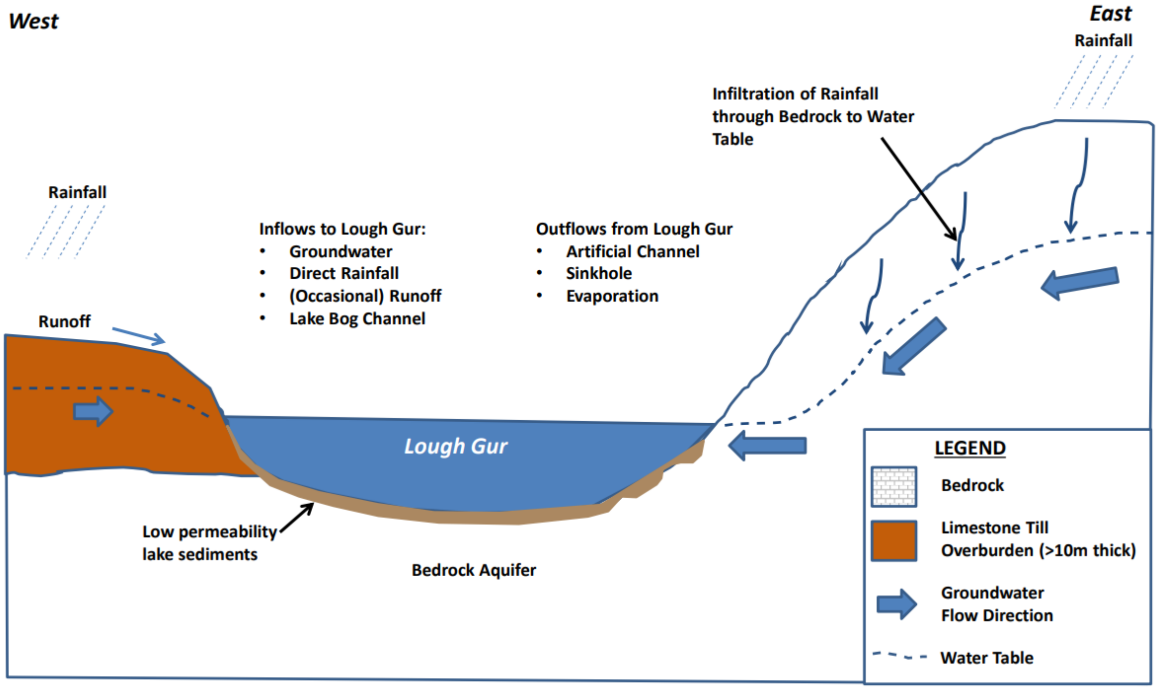


Figure 4-1. Conceptual model L Gur. From Langford and Gill, 2016.

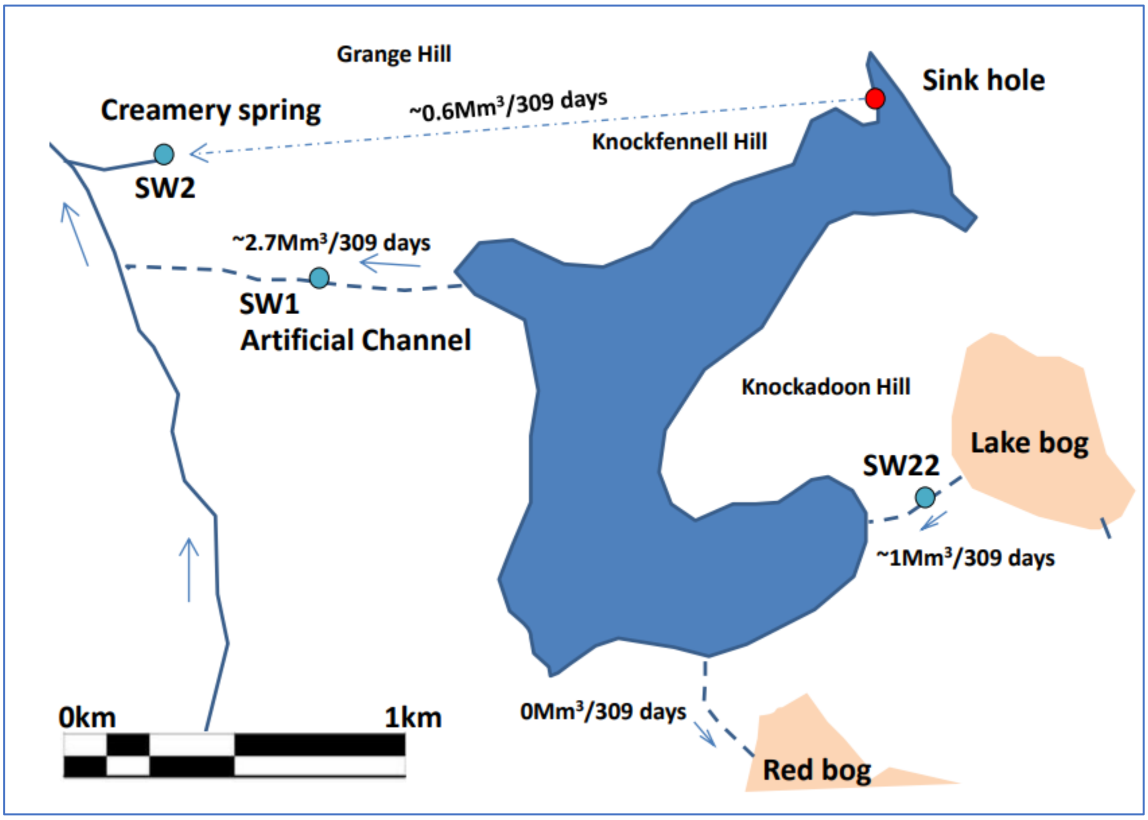


Figure 4-2: Measured lake inflow and outflow. From Langford and Gill, 2016.

For lake and coastal lagoon PAAs, the LAWPRO team normally undertakes local catchment assessment on the inputting rivers and streams, looking for the waterbodies with greatest contribution to the lake/lagoon significant issue so that referrals can be made to pressure owners. This approach can only be followed to a limited extent for Lough Gur because the only inputting stream is the man-made channel connecting Lake Bog to Lough Gur. As outlined elsewhere, this channel is only active after sustained heavy rainfall (Langford and Gill, 2016). Monitoring will be undertaken when the channel is flowing to determine the TP and ammonium contribution to the lake. Otherwise no fieldwork is planned for Lough Gur for the present although specialist assessment may be required in the future. Instead, it is proposed that referrals will be made on the basis of the desk study conclusions:

- For agriculture as significant pressure, draft referrals will issue to ASSAP with the nature of the referral being determined by the pollutant pathways to the lake.

- For DWWTS as significant pressure, letters will be issued to the higher risk residences in the lake contributing catchment, advising the occupants of their entitlement to apply for the DWWTS grant on condition that certain eligibility criteria are met.

The pathways conceptual model described in table 4-1 and shown in figure 4-2 has been prepared to assist in identifying agricultural referral areas with greatest risk of phosphate loss to the lake, via either surface or groundwater flow paths. Well drained soils are not considered for agricultural referrals, except in areas of extreme groundwater vulnerability with rock at or near surface.

The lake contributing catchment shown in appendix I and in figure 4-3 below, has been divided into two compartments in terms of agricultural referrals:

- Compartment 1a (poorly draining soils in higher risk areas for surface phosphate loss) is of greatest significance, particularly on lands adjacent to the lake. Pathway interception measures will be needed here, focusing on delivery pathways from the phosphate critical source areas (EPA PIPv3 maps, Rank 1 to 3, appendix II). As well as the risk of diffuse P losses, lands in these areas could potentially contribute a significant phosphate load to the lake via a small number of episodic events during the year, e.g. if slurry is applied in unsuitable weather conditions. The depositional nature of the lake environment means that any phosphate lost to the lake can be held in the sediment and potentially recycled into the water column. Mitigation measures should focus on informing and educating farmers on this risk.

- Compartment 1b (peat) is of less significance. The peaty areas here are mainly Lake Bog to the east. Red Bog to the south is outside the lake contributing catchment.

- Compartment 2 overlies areas of extreme groundwater vulnerability with rock at or near surface (X). This is the largest compartment in the contributing catchment, comprising more than 60% of the total area. There is significant risk of phosphate loss to the lake via groundwater flowpaths here depending on land use. Although the aquifer is mainly Rkd (appendix VIII), catchment mapping projects have confirmed that groundwater in this small lake contributing catchment all discharges to Lough Gur (Ball, 2004. Langford and Gill, 2016). Mitigation measures should be focused on assessing land use particularly where soils are thin and in the vicinity of rock outcrops and educating landowners on the risk of placing round feeders or spreading slurry or chemical fertiliser in these areas.

Table 4-1. Pathways conceptual model compartments, L. Gur

	Sub-Compartment 1A	Sub-Compartment 1B	Compartment 2
Soil type	Poorly draining	Peat	Mainly well drained. Pocket of poorly draining (overlap with compartment 1a) to the immediate southeast of the lake
Subsoil	Basic igneous till	Fen Peat	Rock (karstified limestone bedrock as surface)
Subsoil K	Low	Low	Mainly High
Aquifer category	Mix of Rkd, some Ll and Lm	Mainly Rkd and Ll	RKd, Ll and Lm
Groundwater Vulnerability	Mostly H, E. small area of X to the immediate SE of the lake overlaps with compartment 2	H, E	X
P04 Susceptibility	High - Rank 2	High - Rank 2	Mainly rank 4 and 5 but groundwater flow paths must be considered
P04 PIP	High. Rank 1 to 3	Low -mainly unranked. Small area Rank 4 to the south of the lake	Mainly Low, rank 4 to 7, but GW flowpaths are significant here
NO3 Susceptibility	Low. Mainly Rank 4, 5	Very low. All Rank 5	Very high. Mainly Rank 1 but small area of low risk to the SE
NO3 PIP	Very low. Rank 7.	Very low. Mainly Rank 6, 7	Very high. Mainly Rank 1 and 2. Small area low risk to the SE of the lake
Main Flow Paths	Overland and near surface	Overland and near surface	Groundwater

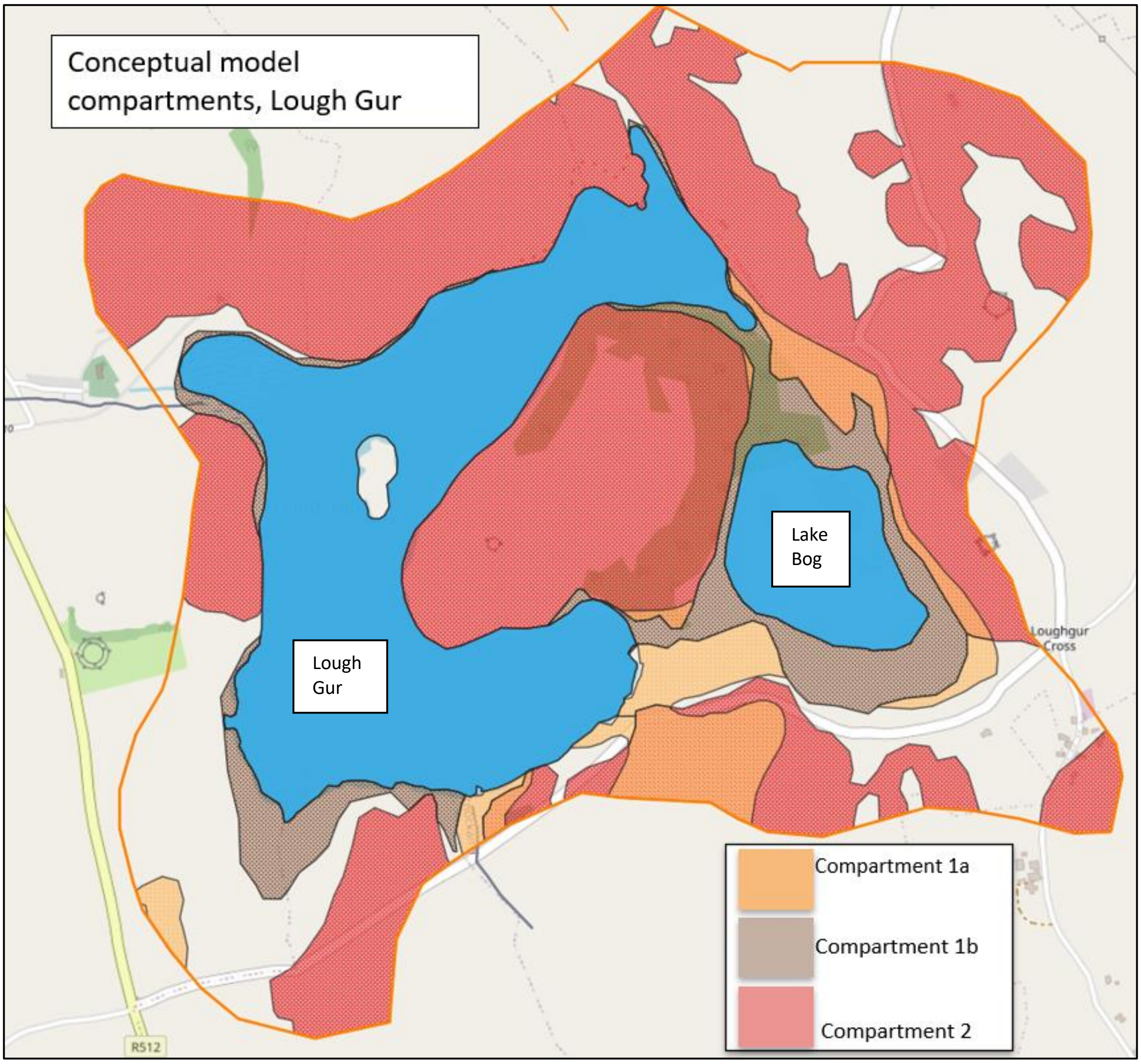


Figure 4-3. Conceptual model compartments, Lough Gur

4.2 Ballycullane (Limerick)_010

The pathways conceptual model for Ballycullane (Limerick)_010 was developed to help inform the approach to local catchment assessment in this waterbody.

The river sub basin has been divided into two main compartments based on soil type (see table 4-2 and figure 4-3):

- Compartments 1a and 1b (poorly draining and peat respectively) are the highest risk areas for both sediment and phosphate loss to waters. Pathways are via overland and near surface flow for phosphate and overland for sediment. Peaty soils also carry risk of ammonium loss.
- Compartment 2 (well drained) is less significant but subsurface pathways may exist for phosphate where soils are thin or absent. These pathways are unlikely to be significant for sediment.

Table 4-2. Pathways conceptual model compartments, Ballycullane (Limerick)_010

	Sub-Compartment 1A	**Sub-Compartment 1B**	**Compartment 2**
Soil type	Poorly draining	Peat	Well drained
Subsoil	Lacustrine sediments and limestone till (BminPD)	Cutover peat close to the waterbody outlet. Fen Peat at Lake Bog	Tills (Bmin DW) and areas with Rock (karstified limestone bedrock as surface)
Subsoil K	Low	Low	High
Aquifer category	Mainly Rkd. Lm close to the outlet	Mainly Lm, Ll. Peat pocket to the south overlies Rkd	RKd, Ll and Lm
Groundwater Vulnerability	Mainly M	Mainly M, small pocket of H to the south	H, E, X
P04 Susceptibility	High. Rank 2.	High. Rank 2	Very low. Rank 5
P04 PIP	Moderate to High	High. Rank 1 to 3. Small area to the west of Red Bog under agriculture shown as moderate (Rank 4)	Mainly Low. Small areas of Moderate
NO3 Susceptibility	Very Low. Mainly Rank 5	Very Low. Mainly Rank 5	High, Rank 1 to 3
NO3 PIP	Very Low. All Rank 7	Very Low. All Rank 7	Mixed
Main Flow Paths	Overland and near surface	Overland and near surface	Groundwater

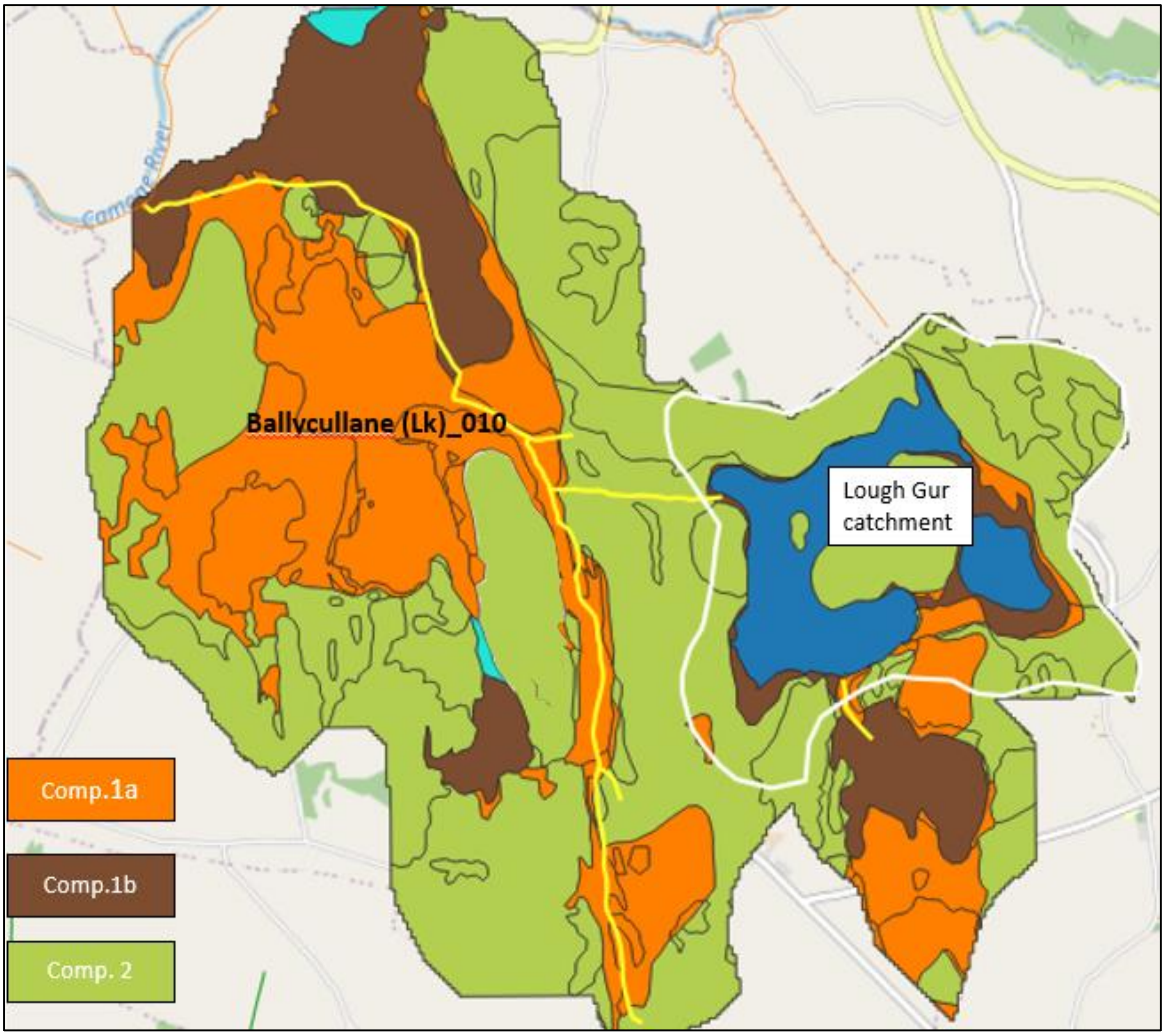


Figure 4-4. Conceptual model compartments, Ballycullane (Limerick)_010

5 Interim Story of the PAA

5.1 Lough Gur

- Lough Gur is at Moderate status (2013-2018) and *At Risk.*
- The lake is Type 10 (low altitude, high alkalinity, shallow and large).
- It is fed by groundwater springs and surface runoff from adjoining lands. Lake Bog to the east also discharges to Lough Gur via a man-made channel but this channel is only active after periods of sustained heavy rainfall.
- There are two outflows from the lake, Pollavaddra swallow hole at the northeast end which emerges at two springs to the north of Knockfennel and an artificial channel to the northwest which connects the lake to the Ballycullane_010 main river channel.
- Total phosphorus (TP) is the main significant issue impacting on lake water quality. Ammonium has been elevated on occasion as have chlorophyll α and pH (linked to TP and reduced alkalinity due to photosynthesis).

- Atmospheric deposition, Agriculture and DWWTS are the significant pressures delivering TP to the lake. Phosphorus is also likely to be recycled from lake sediment.
- Pathways for TP from agricultural and DWWTS pressures are via overland and shallow subsurface flow in the poorly draining soils and via groundwater flow in the well-drained areas where groundwater vulnerability is extreme with rock at or near surface.
- Specialist lake assessments may be undertaken in future if required but local catchment assessment is not planned here for the present, other than an assessment of ammonium and phosphate levels in Lake Bog. This is because there are extensive data already available on lake water quality and no surface streams flowing to the lake for assessment. Instead it is proposed to refer DWWTS and agricultural pressures directly from the desk study.

5.2 Ballycullane (Limerick)_010

- WFD Cycle 3 –*Review.* WFD status is now moderate (extrapolated, based on expert judgement).
- WFD Cycle 2 –*Review.* WFD Status was unassigned.
- The waterbody is not currently monitored under WFD but conclusions from the desk study indicate that sediment is likely to be a significant issue impacting on water quality here. Limited results from local catchment assessment undertaken for the Camoge PAA suggest that nutrients TN, MRP and NH4N may also be elevated in high river flows but significantly more data are needed to confirm this.
- The significant pressure from the EPA initial characterisation is Anthropogenic-unknown. Hydromorphology is a likely significant pressure. There are areas at high risk for surface phosphate loss (PIP Rank 1 to 3) towards the waterbody outlet. If phosphate is confirmed as an issue, agriculture is a potential pressure which will require investigation. Lake contribution to river nutrient levels will also need to be assessed.
- OSi 50k and Prime 2 maps indicate that the Ballycullane (Limerick)_010 discharges to the Camoge_020 via three tributary channels but aerial imagery shows a possible fourth channel to the north.
- Local catchment assessments will commence with a stream walk to confirm discharge locations to Camoge_020.
- Biological assessments will be undertaken at the outlet of each tributary where habitat is suitable for assessment.
- If results are not indicative of impact, further fieldwork will not be required here. If results indicate impact or assessments can't be undertaken due to unsuitable habitat, local catchment assessment will be undertaken as follows:
  - Where sediment is confirmed as an issue, sediment extent, depth and type will be assessed along the channel following LAWPRO's sediment assessment methodology and sources will be identified.
  - Nine locations will be monitored for field parameters and for MRP, ammonium and nitrate over a minimum of three surveys. If phosphorus and/or ammonium are confirmed as significant issues, flow monitoring will also be required to quantify nutrient load. This will enable load contribution from the lake to be determined and it will also enable load contribution to the downstream Camoge PAA to be quantified.

6 Workplan

6.1 EPA further characterisation actions

Table 6-1. EPA further characterisation actions

WB Name	ID	Action	Responsible Organisation	Further Characterisation Action details
Ballycullane_010	FC002223	IA3. Determination of water quality in unassigned waterbody	LAWPRO	The outflow from Lough Gur enters here and there is also high PIP around the lake. Likely to be *At Risk*, but need water quality samples to confirm. Take samples above and below input.
Lough Gur	FC002221	IA1 provision of information	IFI	Follow-up with IFI, MSc on Lough Gur found that a share of TP was coming from Red Bog.
	FC002222	IA1 provision of information	LAWPRO	Engage with local community
	FC002223	IA1 provision of information	LAWPRO	Is GW as a pressure? Lake is GW fed. Limerick CoCo has information that would support the theory that this is becoming a bog. Work has been completed to determine the water balance - the outcome of which is with GSI. Coring of lake sediment was also carried out recently and indicated that the serious nutrient issues began in the 1980s.

6.2 Local Catchment Assessments

Lough Gur

There are no significant surface water discharges to Lough Gur. The only surface stream flowing to the lake is the man-made channel which delivers flow from Lake Bog after periods of sustained heavy rainfall. While specialist assessment may be undertaken in the future, the only fieldwork proposed here for the present is to assess levels of ammonium and phosphate in this outflow channel. However Lough Gur has been extensively studied and monitored so there is a reasonable degree of certainty around the desk study conclusions on the significant issues and pressures impacting on lake water quality. Referrals will be made based on desk study conclusions that agriculture and domestic wastewater are the significant pressures here.

The main focus of fieldwork in the PAA will be on the Ballycullane (Limerick)_010.

Ballycullane (Limerick)_010

From the OSi Prime 2 and 50k maps, the Ballycullane (Limerick)_010 appears to discharge to the Camoge_020 river waterbody via three outlet channels (see Sites 6, 7 and 9 on figure 6.1). However, from aerial imagery there may be a fourth channel close to Site 9. Fieldwork should commence with stream walks as shown in figure 6.1 to confirm the outlet locations for further assessment.

SSIS or rapid assessment should be carried out at Sites 6, 7 and 9 if habitat is suitable. If SSIS/RA results are not indicative of impact, then no further work will be required here.

If biological assessment is indicative of impact or habitat is not suitable for assessment, undertake LCA as outlined in steps 1 to 6 below and as shown on figure 6.1:

1. Sediment is a likely significant issue in this waterbody. Sediment assessment (visual % cover, depth, type, shuffle index) should be undertaken at Sites 6 and 7 and 9. If sediment is confirmed as a significant issue, walk upstream to identify potential sources. Stream walks for sediment should be undertaken in wet weather when pathways are visible.
2. Nutrient sampling should be undertaken at all sites over a *minimum* of three surveys representing varying flow conditions to determine which (if any) nutrients are an issue in this waterbody. If results are inconclusive, additional surveys will be required.
3. Chemistry sampling should include all three nutrients (MRP, ammonium and nitrate) because results of preliminary nutrient monitoring undertaken as part of the Camoge LCA showed elevated levels of all parameters in one high flow sample.
4. Field parameters should be measured at each sampling location.
5. If nutrients are a significant issue, flow measurement will be required in order to convert concentrations to loads. Flow monitoring is proposed here rather than use of hydrotool flow estimates because there are no estimate points for either of the northern channels. The hydrotool estimate point for the waterbody outlet (segment code 24_1577) gives estimated percentile flows for the entire sub basin and does not take into account diverted flow via these two northern channels. Flow monitoring may not be required for all surveys. It may be possible to extrapolate from the appropriate hydrotool percentile estimate downstream of Site 8 (segment code 24_405), based on measured data from two surveys.

Site selection details

- Site 1 is located on the outflow channel from Lough Gur. Site 2 is upstream and Site 8 is downstream of the confluence with this channel. The main purpose of nutrient and flow monitoring at these three locations is to try to quantify the total phosphorus contribution from Lough Gur to Ballycullane (Limerick)_010.
- Sampling between Sites 8 and 3 should give an indication of any additional nutrient contribution delivered via the Grange Springs.
- Sites 3, 4, 5, 6, 7 and 9 are all located in higher risk areas for surface phosphate loss. If MRP is confirmed as a significant issue in this waterbody and the lake is not found to be a significant contributor to the MRP load, monitoring at each of these locations will provide information on nutrient issues in Ballycullane (Limerick)_010. Results from Sites 6, 7 and 9 will also provide useful information on nutrient contribution to the downstream Camoge PAA.

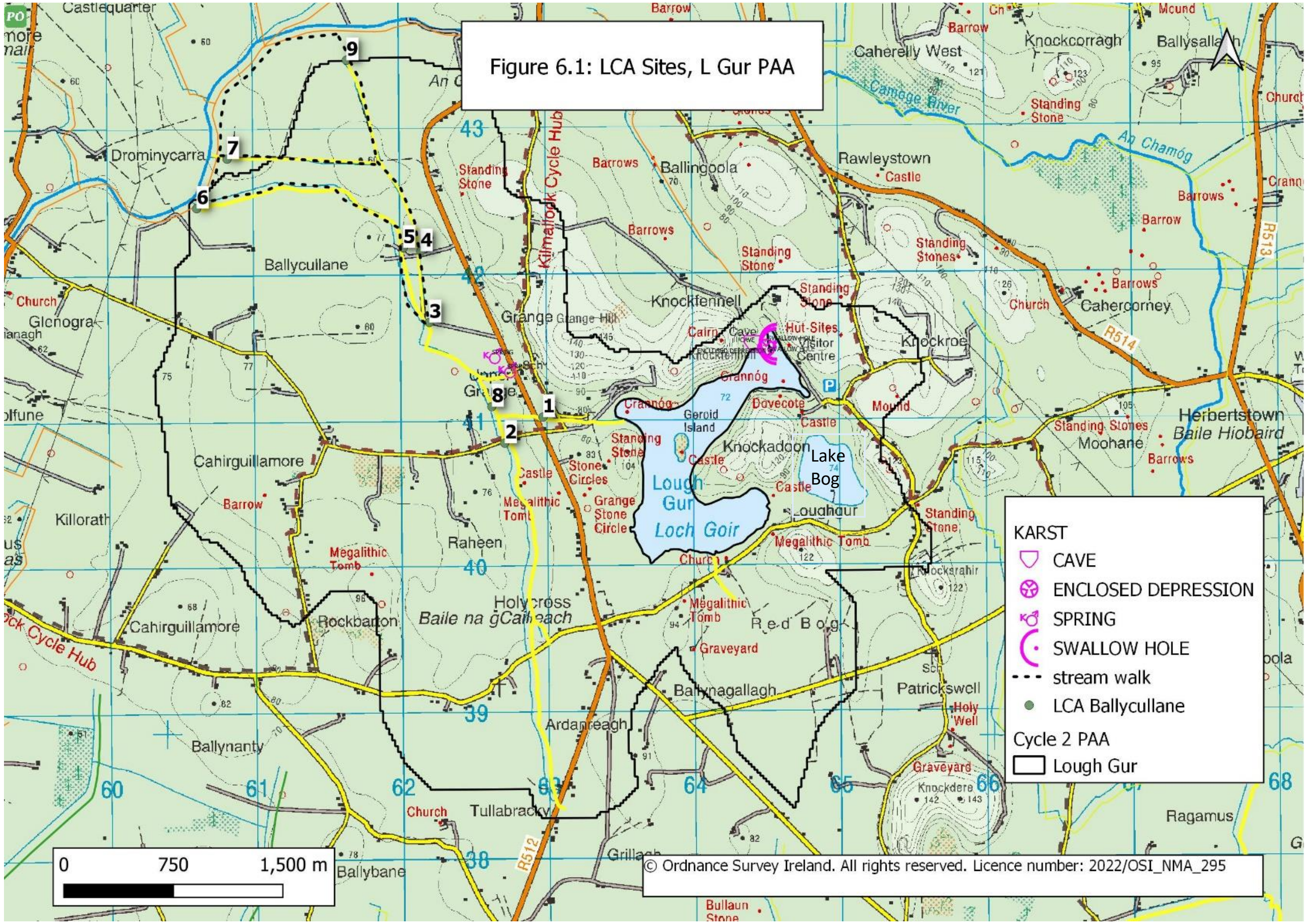


Figure 6-1, LCA sites Ballycullane (Limerick)_010

7 Communications

The public meeting for Lough Gur PAA took place via Zoom on the 8th September 2021.

Key messages

- Lough Gur is at moderate WFD status and *at risk*.
- Lake phosphorus levels are elevated. Ammonium is also periodically elevated here.
- We have concluded from our desk study that agriculture and septic tanks are likely significant pressures impacting on lake water quality, particularly on the poorly draining soils around the lake but also on the very thin soils here.
- Ballycullane (Limerick)_010 was unassigned at the time of the public meeting as it is not monitored under WFD. However the EPA have recently determined its status to be moderate, based on expert judgement.
- Limited monitoring data suggest that nutrients (nitrogen, ammonium and phosphate) may be an issue here in high flows but we need to carry out local catchment assessment to confirm this and also to determine where these nutrients may be coming from.

Summary of issues raised

- Comment was made that Lough Gur has been nominated as a UNESCO World Heritage site and concerns were expressed about buffer zones and animals accessing the lake.
- Questions on water quality, why has the lake improved from poor to moderate status?
- Query whether the ASSAP advisors are working with farmers in the catchment at the moment.
- Query on the larger Camoge PAA and how the work in Lough Gur will tie into this.
- Several questions around communications, whether further meetings are proposed and when attendees can expect to see the results of LAWPROs work. Also queried how LAWPRO proposes to keep attendees informed if domestic wastewater treatment systems are an issue here.
- Catchments.ie maps were praised but attendees would like more information on how to use them.

8 Appendices

Appendix I: Lake contributing catchment

Appendix II: Surface P PIP Map

Appendix III: Surface P Susceptibility Map

Appendix IV: Corine Landuse Map

Appendix V: Soils hydrology Map

Appendix VI: Groundwater Vulnerability Map

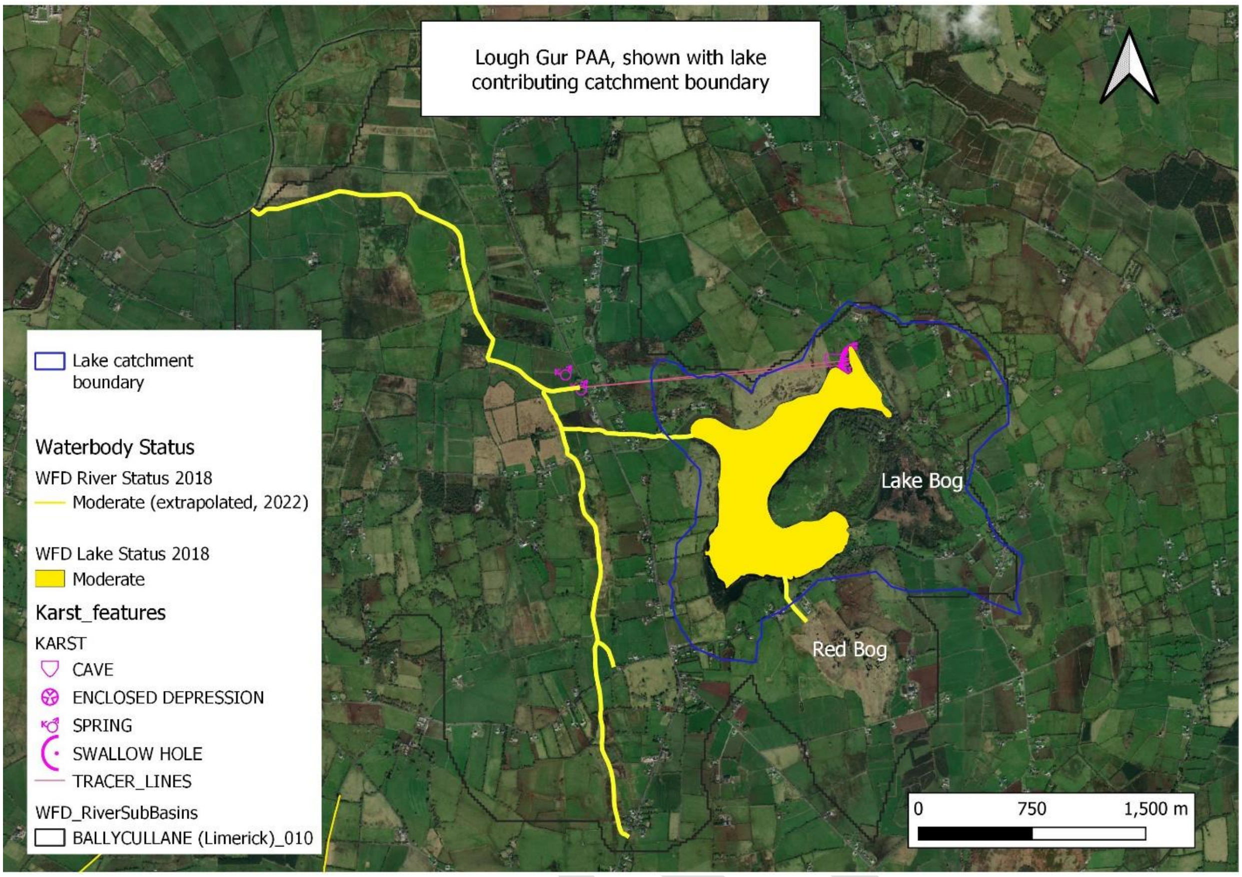
Appendix VII: Karst features map, L Gur

Appendix VIII: Aquifer Map

Appendix IX: OPW Drainage Channels

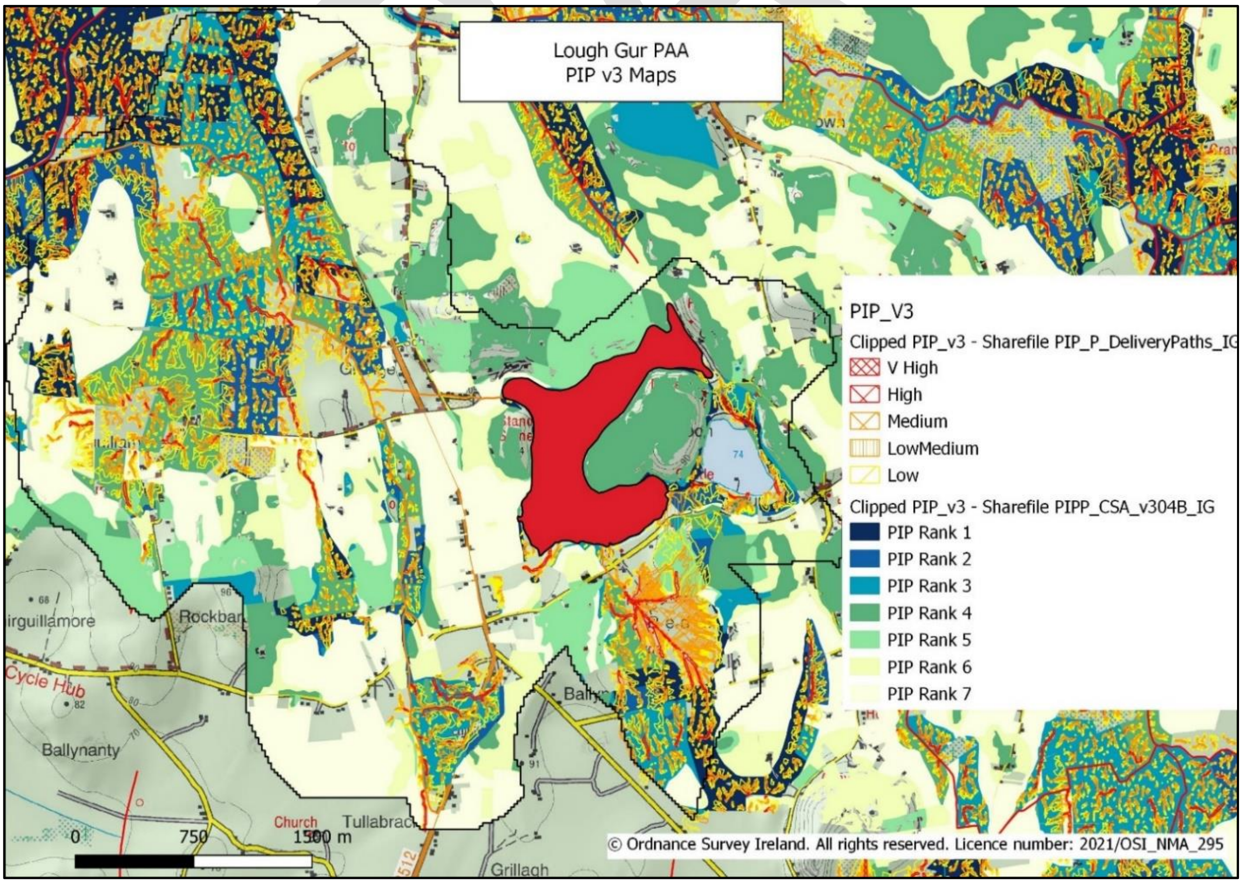
Appendix X: MQI Condition

Appendix I: Lake contributing catchment



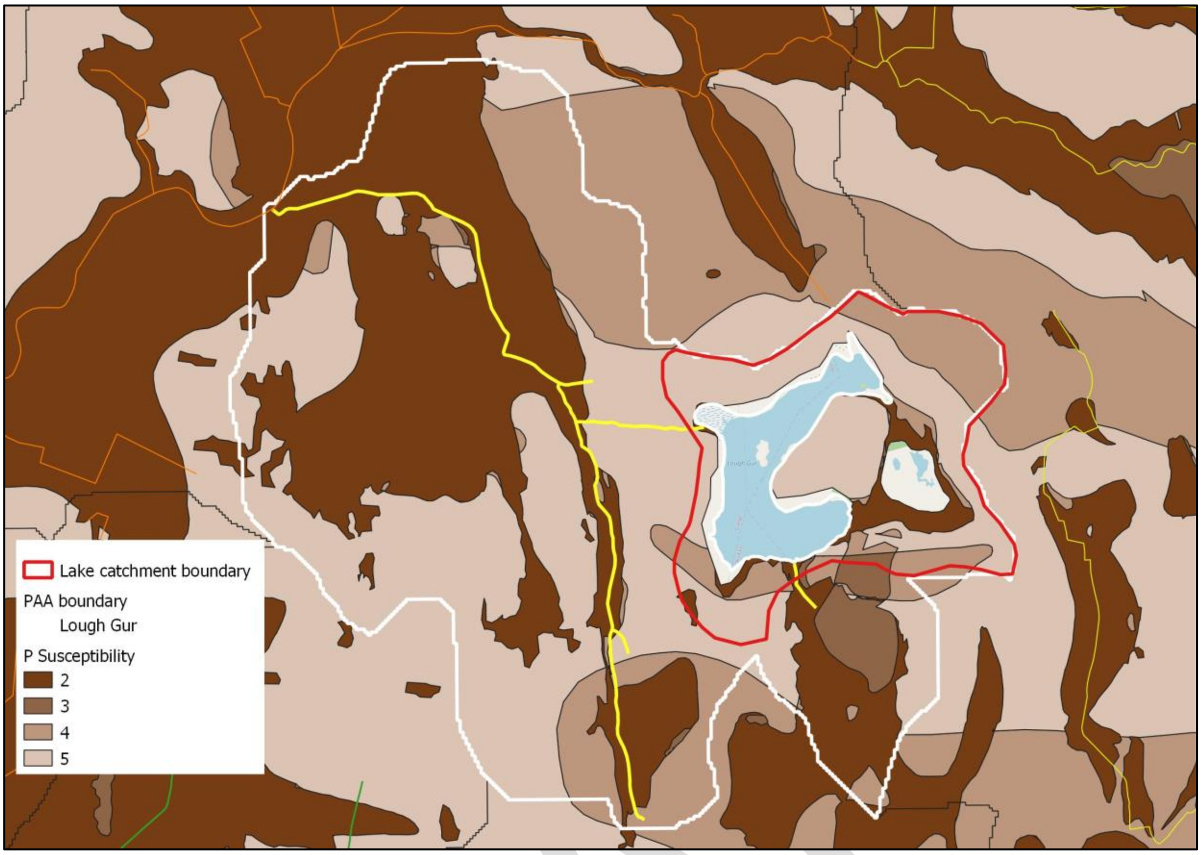
Source: Langford and Gill, 2016

Appendix II: Surface P PIP Map



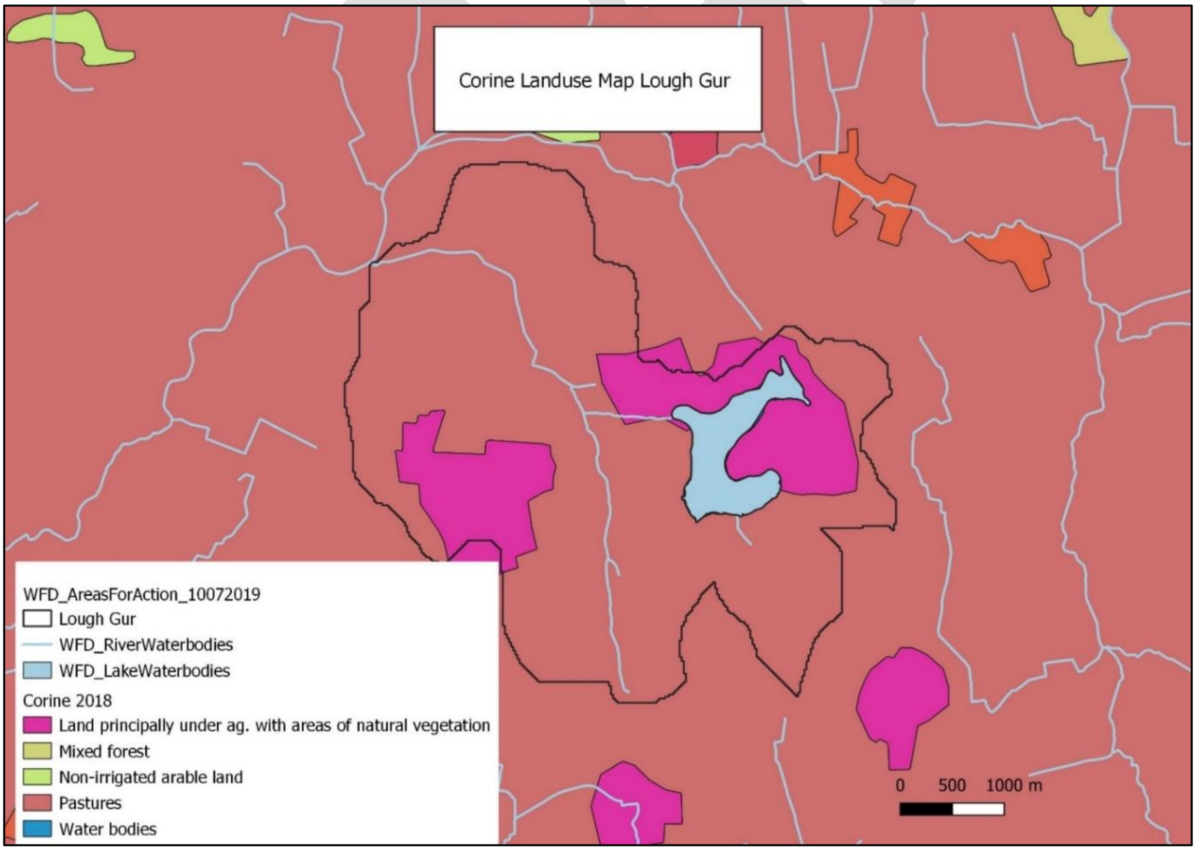
Source EPA

Appendix III: Surface P Susceptibility Map

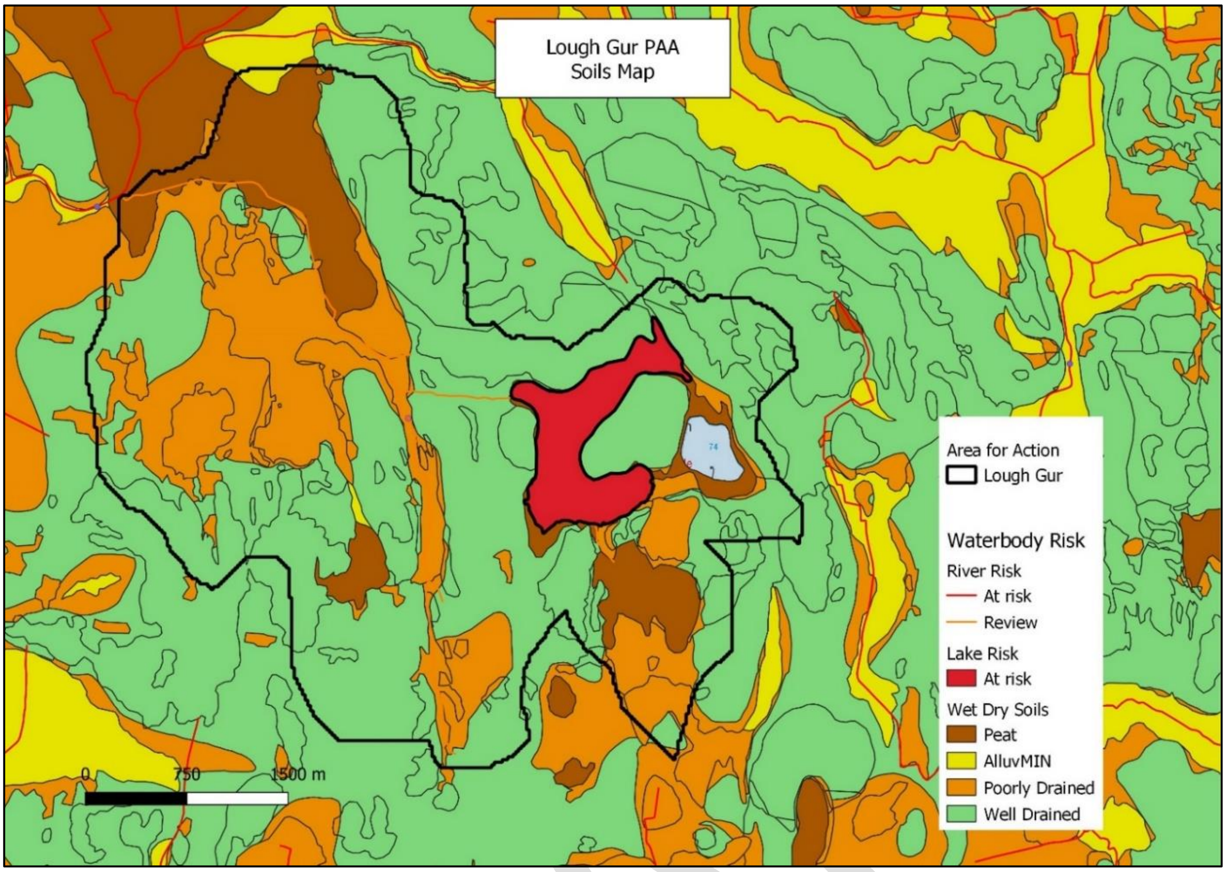


Source EPA

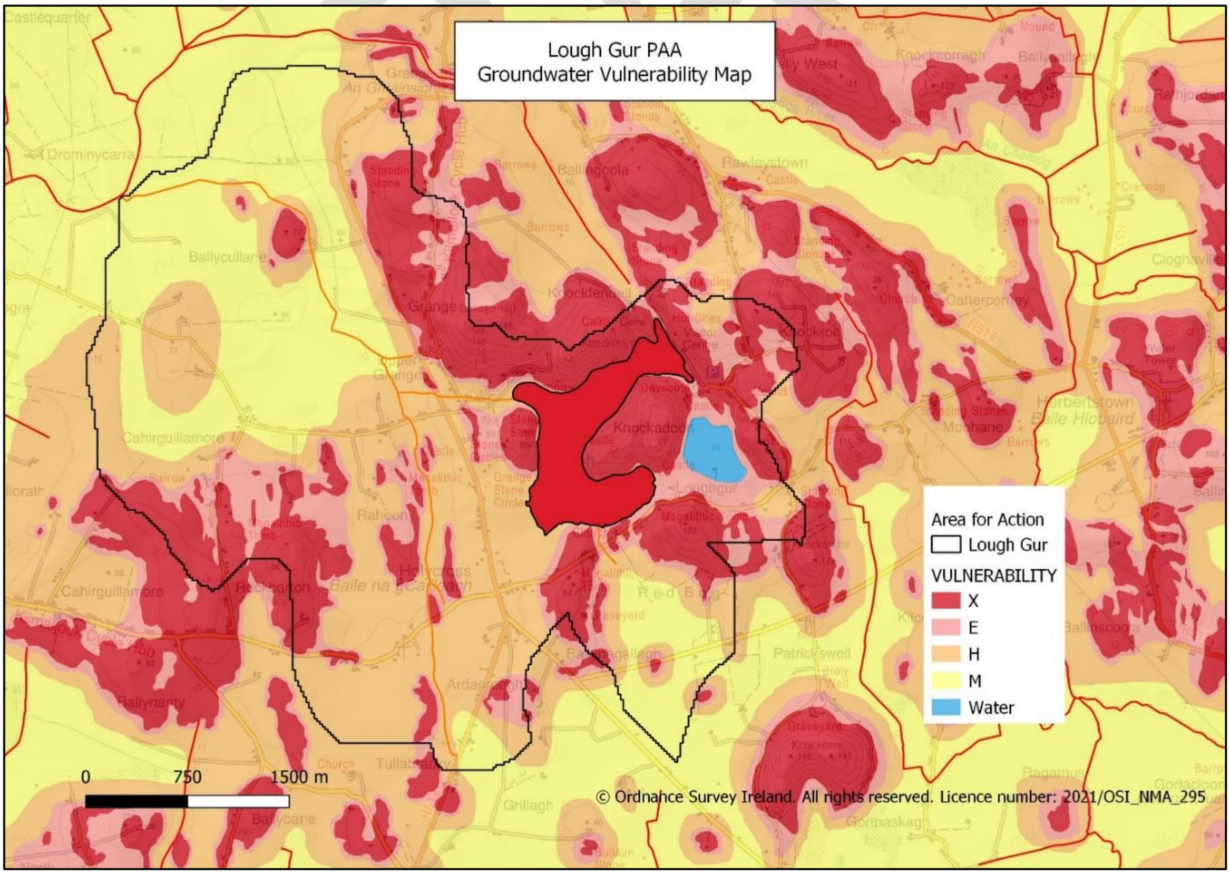
Appendix IV: Corine Landuse Map



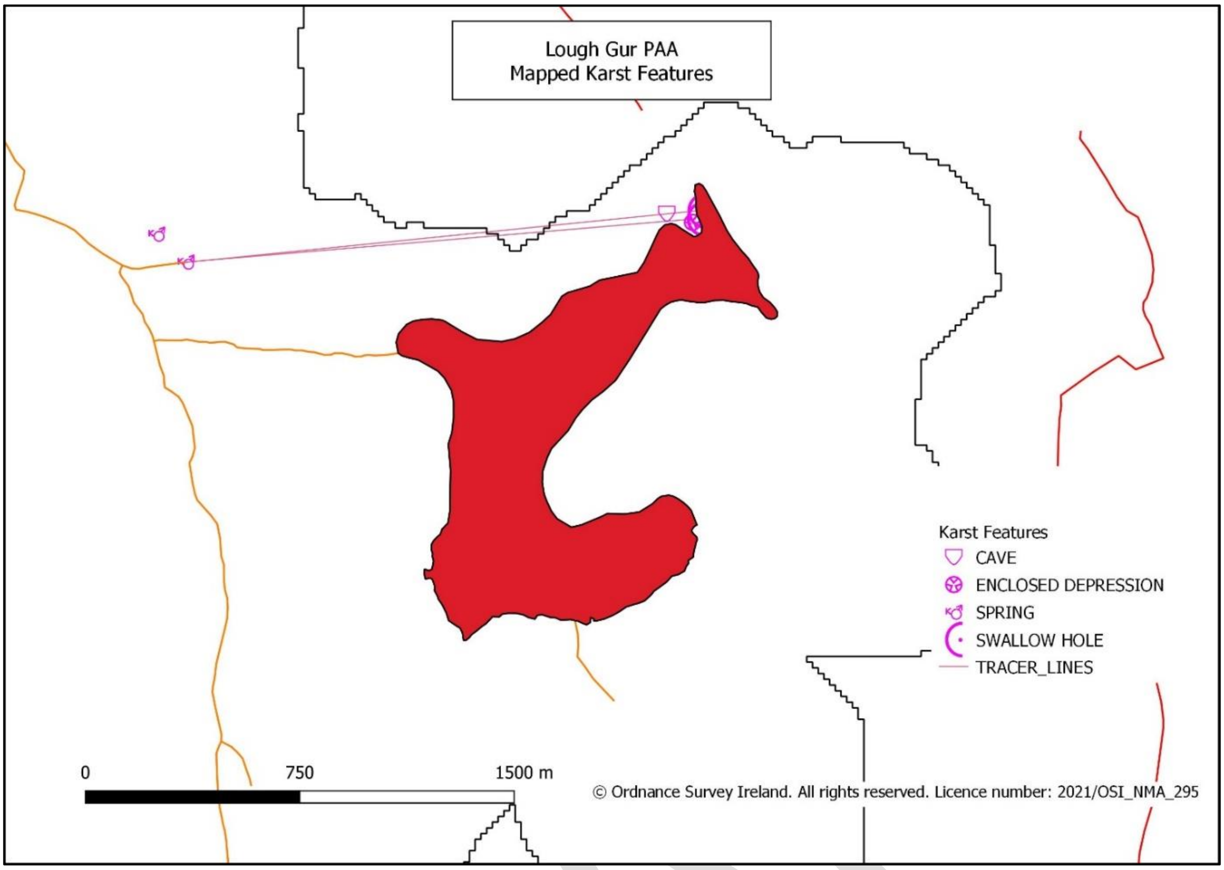
Appendix V: Soils hydrology Map



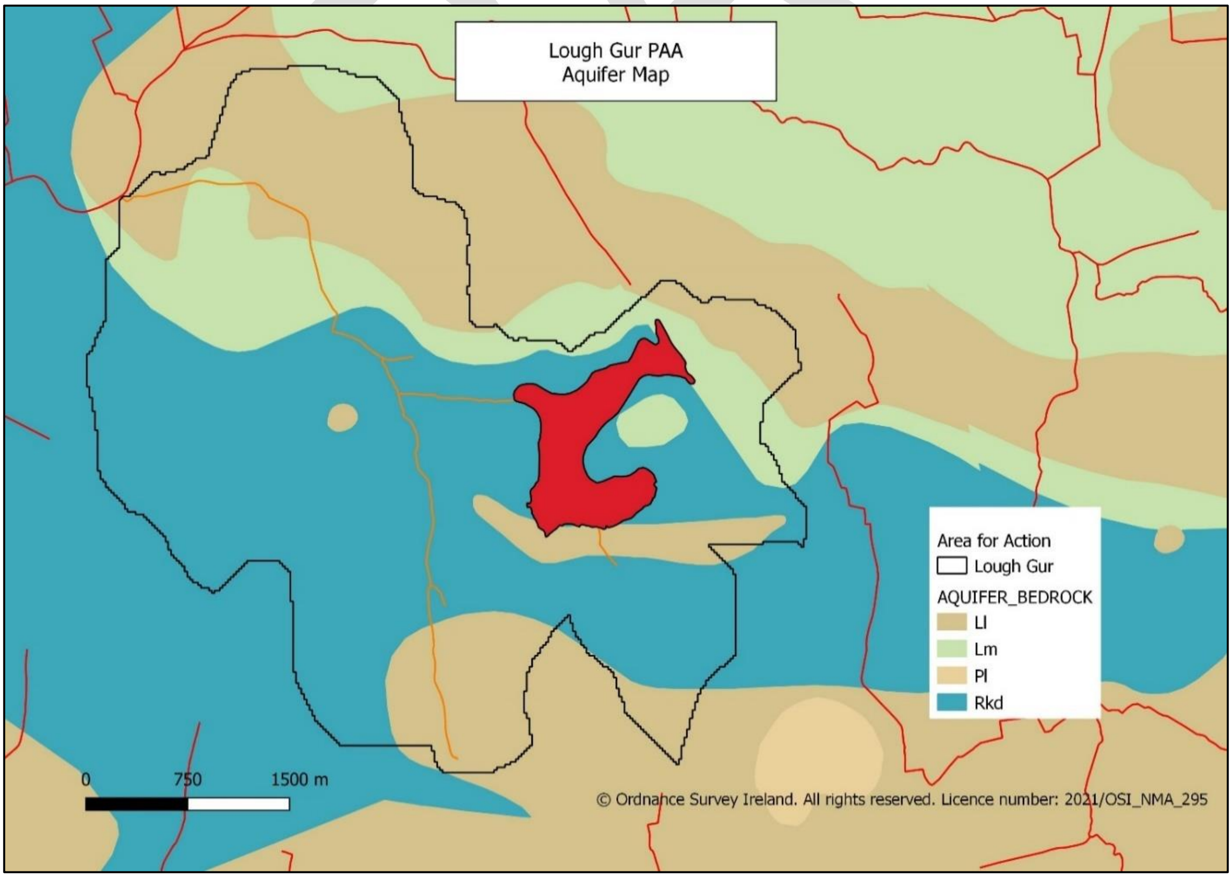
Appendix VI: Groundwater Vulnerability Map



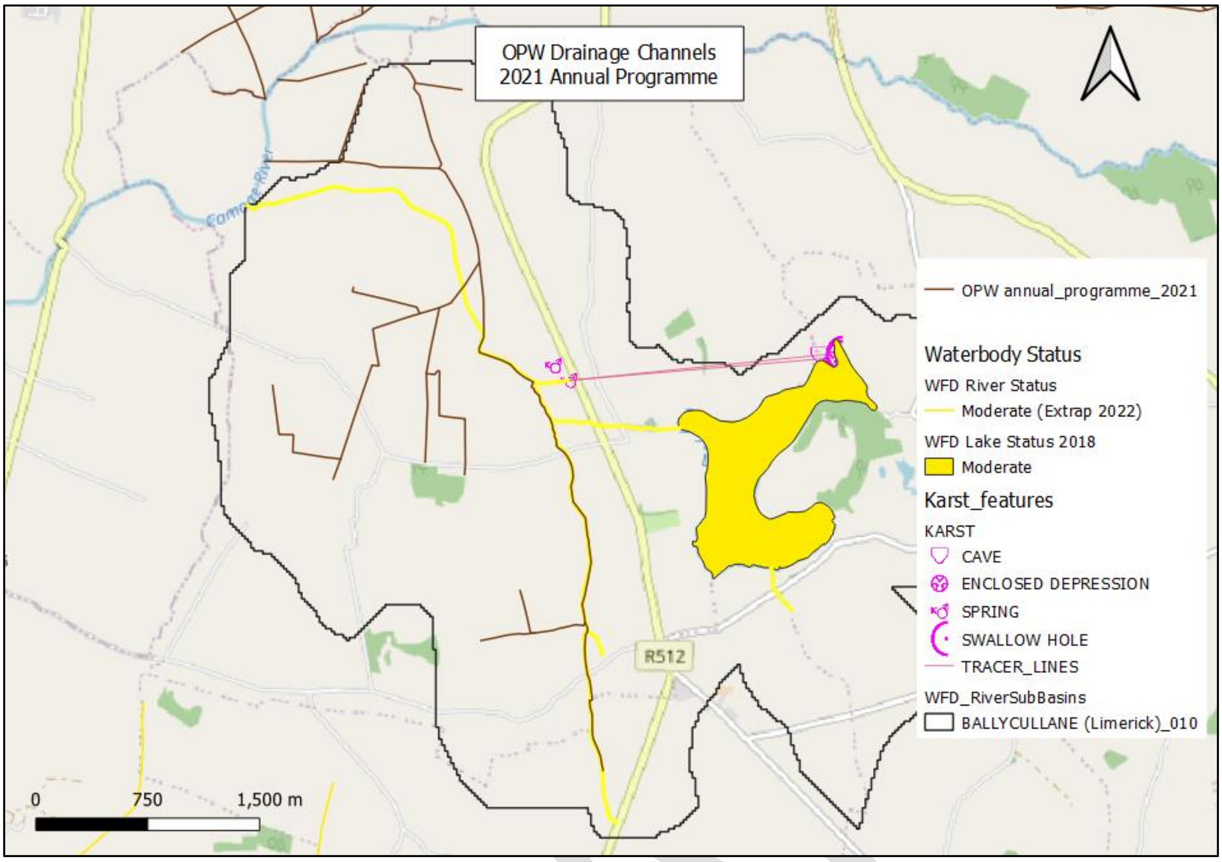
Appendix VII: Karst features map, L Gur



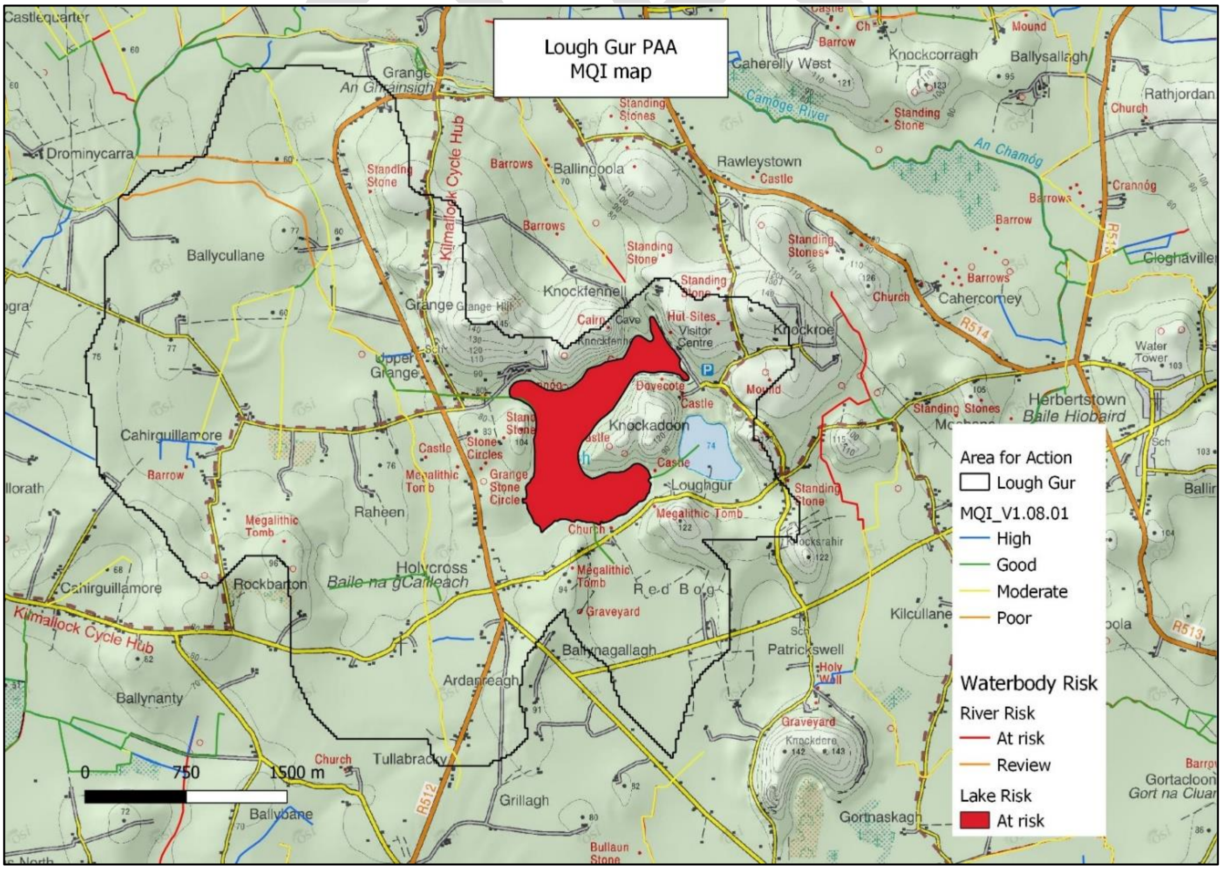
Appendix VIII: Aquifer Map



Appendix IX: OPW Drainage Channels



Appendix X: MQI condition



Source EPA