Ballinahown
Water Management Plan

Ecological Water Management Plan
for Ballinahown Village

Prepared for
Ballinahown Community Development Company Ltd.

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Summary

This Water Management Plan for Ballinahown village examines potential impacts on the river and proposes remedial actions to address these impacts. As such the plan examines ways to improve water quality, create healthy water flow patterns and enhance the biodiversity value of the River Worm, which flows through the village.

To this end, some specific elements were examined over the course of 2023, namely:

1. Examining EPA maps to assess existing water quality and catchment data;
2. Examining historic maps to see changes to the river and catchment over time;
3. Assessing river water quality using physical and chemical analysis;
4. Carrying out an ecological assessment of the river;
5. Conducting a River Safari to identify the inflows within the village;
6. Assessment of the habitats along the river;
7. Examining existing biodiversity data for the village.

The findings from these elements have identified the following:

1. The course of the river has been altered over time, with meanders removed and the channel deepened compared with the natural flow dynamics;
2. The underlying clay subsoils appear to provide some percolation for sewage, but not 100% of the existing discharge volume;
3. As such a certain amount of the overflow from percolation areas and/or septic tanks appears to be entering the river;
4. The most likely discharge route is via the stormwater drainage network;
5. Lab analysis appears to confirm that the inputs are sewage effluent in origin (rather than agricultural or solely agricultural);
6. That said, EPA maps for the River Worm show “good” status. Also, the river is classified as “not at risk” of missing 2027 water quality targets.

Based on the above findings, a series of recommendations have been outlined to bring about a steady improvement in water quality and biodiversity within the river:

1. Introduction of a large stormwater wetland for filtration of the main stormwater pipe within the village (gathering flows from the main village car park and entering the river just upstream of the village);
2. Connection of smaller piped inputs within the centre of the village; with a pumped feed to a stormwater wetland at the west of the village;
3. Smaller projects to filter stormwater flows at selected locations;
4. Works within the village and the river channel itself for habitat enhancement;
5. Engagement with the wider community for full catchment enhancement;
6. Continued advocacy for full sewage treatment by Irish Water;
7. A number of other water-related projects and initiatives within the village to assist with continual improvement to water quality over time.

1.0 Introduction

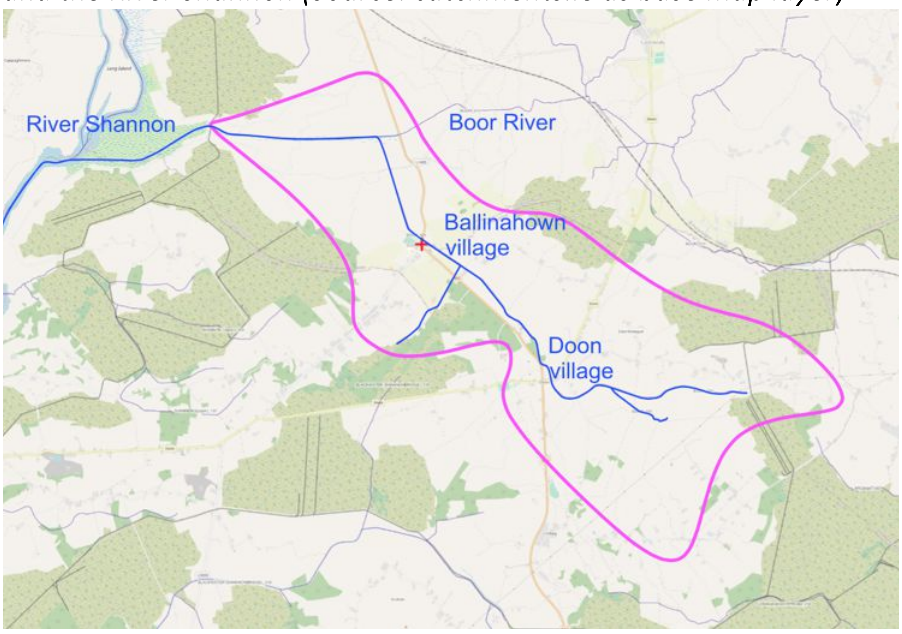
The Water Management Plan for Ballinahown has been commissioned by the Ballinahown Community Development Company to identify potential negative impacts that the village may have on the river and propose remedial actions to address these impacts. As such the plan examines ways to improve water quality, create healthy water flow patterns and enhance the biodiversity value of the River Worm, which flows through the village.

1.1 Ballinahown in the context of water flows

Ballinahown village is located in the centre of Ireland and also centrally within the Shannon Catchment. The River Worm (listed on EPA maps as the Boor_020; www.catchments.ie) rises in cutover peatland about 3km east of Doon in Co. Offaly. It flows a total length of *c*. 7.8km from the source, through Ballinahown, to the main channel of the Boor River. From there the Boor continues a further 4.5km to the River Shannon at Curraghbee, *c*. 8km south of Lough Ree. From there the Shannon flows a further 100km to Limerick and out into the Shannon Estuary and the sea.

Fig. 1.1 – Ballinahown in the context of the River Shannon Catchment

Fig. 1.2 – Catchment of the River Worm, showing connections to the main Boor River channel and the River Shannon (Source: catchments.ie as base map layer)



The mains water supplied to Ballinahown is piped in from Co. Offaly, from outside the Boor catchment area. Thus while the activities, land use and water use within the Boor catchment directly influence the water quality in the river; it is the activities, landuse and water use in the source catchment that influence the quality of the water flowing from the taps in Ballinahown. Given that our bodies are comprised of about 60% water, the health of that water is of greater importance than we often consider. This Water Management Plan examines the water quality within the river, and thus the wastewater and stormwater leaving the village, but does not look further at the Irish Water mains supply. Thus for a broader overview of drinking water quality then the source catchment, land use and the medication and sterilising chemicals added to the water should be examined as part of a separate process.

The mains water supply for Ballinahown is piped from the Clara/Ferbane Public Water Supply. For information on the standard water testing results visit https://www.water.ie/help/water-quality/results/ and enter "Ballinahown" in the address prompt. Results over the past number of years are basically good for the parameters tested. Note that the results include for a certain minimum threshold of chlorine to kill bacteria that may enter the system and additions of fluoride as a medical additive (which, by contrast, is a practice that has been stopped in many countries around the world on health grounds).

1.2 Trends in water quality in Ireland

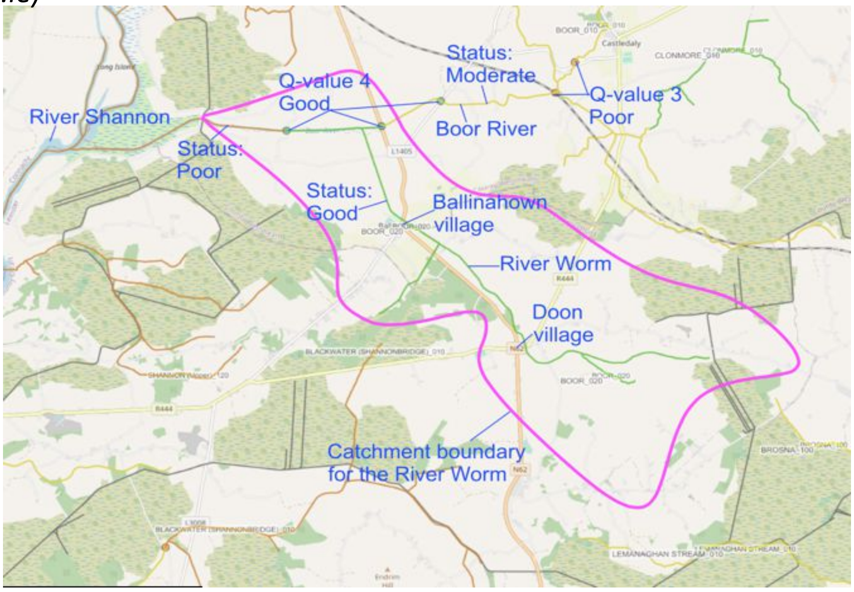
Throughout the country waterways are suffering from a variety of pressures. These include activities such as urban stormwater runoff and sewage inputs as well as landuse pressures such as agricultural runoff, forestry inputs and peat harvesting activities. On the positive side, the number of badly polluted watercourses has fallen considerably in the past 30 years. However the number of pristine watercourses has similarly declined. Furthermore, in the most recent assessment of water quality in Ireland by the EPA[1], it has been found that water quality in our rivers, lakes groundwater and estuaries has deteriorated; with no locations in Co. Westmeath showing High ecological status.

The EPA classifies river water quality on a scale of 1 (Bad) to 5 (High), based on the results of ecological monitoring. Essentially the greater the number of particular types of macroinvertebrates found in a given sampling location the greater the Q-value. These are shown as coloured dots in Fig. 3 below. There are no Q-value locations shown on the River Worm so instead we can compare the samples taken from the River Boor, upstream and downstream of the point where the Worm enters the Boor. We can see that they are both shown as green, Q-value 4.

Water quality status takes the ecological monitoring or Q-values into account, and also includes factors such as physical and chemical analysis and hydromorphology (health of the river flow and channel shape, obstacles etc.). The River Worm has a water quality status of 4 (Good) on the most recent EPA maps (2016-2021). This is an improvement on the two previous cycles of Water Framework Directive assessment (from 2010-2016) which showed "moderate" status.

1 Trodd, W., S O'Boyle and M Gurrie (2022) *Water Quality in Ireland – 2016-2021*. EPA, Wexford. https://www.epa.ie/publications/monitoring--assessment/freshwater--marine/water-quality-in-ireland-2016--2021-.php

Fig. 1.3 – Q-value and Status of the Rivers Worm and Boor (Basemap source: catchments.ie)



Despite the improvement of the water quality status from Moderate to Good in recent years, the EPA maps list the rivers Worm and Boor as being "at risk" of not meeting their Water Framework Directive objectives. As such this Plan offers a process of identifying inputs to the river to help improve the overall status of the River Worm and to ensure that the inputs from Ballinahown Village in particular are identified for action so that they can be minimised going forward.

It is worth noting that this project relates to the inputs from the village itself rather than the wider catchment. Agriculture and extractive industries are listed on the EPA maps as the main pressures on the River Worm. As such, while this report outlines measures to address stormwater, sewage, hydromorphology and habitat value within the village itself, a wider catchment approach at a future date may help to address the identified issues associated with wider landuse practices.

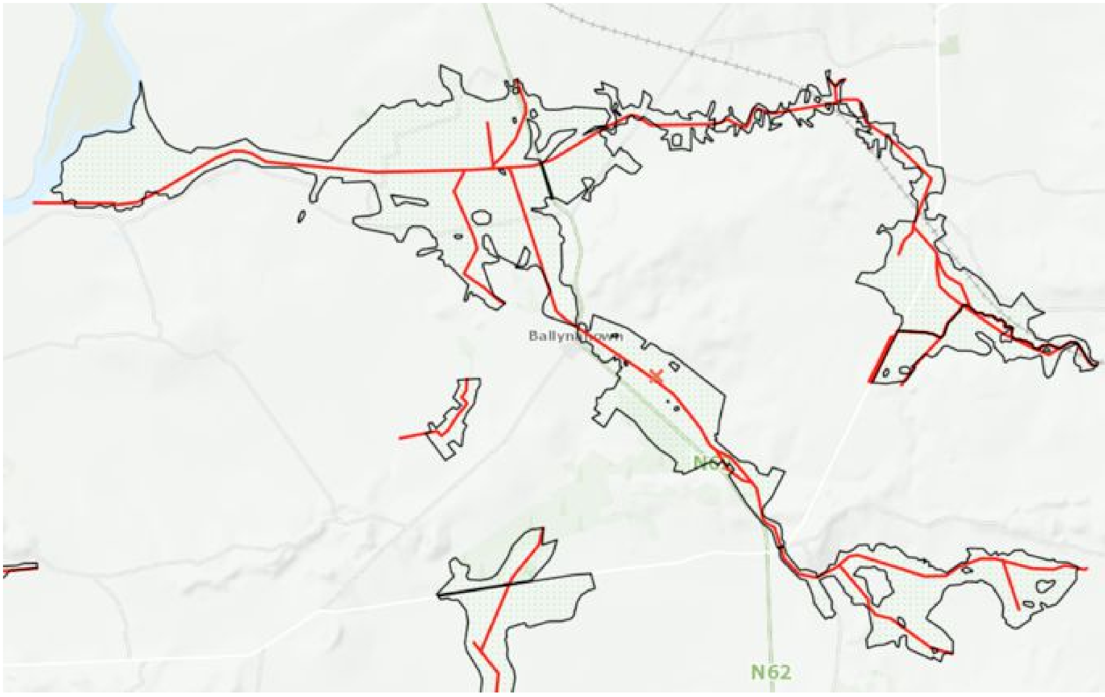
1.3 Hydromorphology of the River Worm

Hydromorphology is the term used to describe water flows and riverbed shape. The River Worm has been extensively altered through the centuries; to straighten the river and to drain lands for agriculture.

The GeoHive map hub provides an interesting overview of the historic changes to the river channel and to the village generally. To see these visit the website and turn on the different map layers at https://webapps.geohive.ie/mapviewer/index.html. The 6' maps date from 1829-41. The 25" maps date from 1897 to 1913. Aerial maps are dated on the website.

Under the Arterial Drainage Act, 1945, channels within "drainage districts" are maintained by the Office of Public Works (OPW) on behalf of the local authorities. While this work originally helped to open up lands for productivity at a time when food production was all important in a post-war Europe, it has distinct negative consequences on water quality, habitat, fish and other aquatic life within waterways throughout Ireland. At a time of unprecedented biodiversity crisis there is an urgent need to reform the Act and to explore our relationship with waterways and how we best select land management practices to reflect the changing values and priorities for society and the world today.

Fig. 1.4 – Drainage District Channels showing drained channels (including the River Worm) and areas impacted by dropped groundwater levels.
Source: www.floodinfo.ie/map/drainage_map/



1.4 Water Management Plan overview

This Water Management Plan document specifically addresses the water quality of the river itself; possible inputs and their impacts, and then remedial actions which may be used to address these. It does this under three main headings:

1. Baseline water quality assessment – physical and chemical analysis
2. Biodiversity and Q-value assessment of the River Worm
3. Stormwater and sewage inflow assessment and recommendations

As such the plan examines the feasibility of water based ideas and solutions for sustainable water management within Ballinahown, including sustained urban drainage systems (SUDS), possible sewage treatment opportunities, and identification of runoff issues that may be present within the village along with remedial solutions.

The document provides baseline information for a future Sustainable Water Plan for Ballinahown and will support the village and wider community in implementing practical solutions for water quality improvement in the River Worm.

2.0 Baseline Water Monitoring – Physical and Chemical Analysis

2.1 Identification of sampling locations

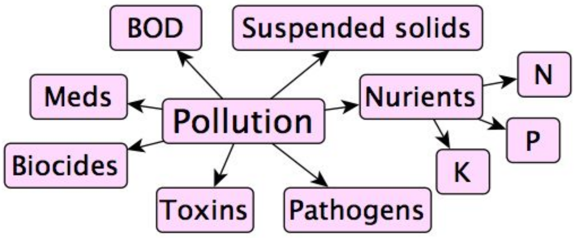
Baseline water quality analysis has been carried out to obtain a snapshot of the quality of the River Worm. Due to the limited timeframe for delivery of the project, this analysis was limited to the spring and early summer of 2023. As such it captures data from a relatively brief moment in time. However it helps to provide a general overview of the physical and chemical properties of the river. In this way it helps to steer the process of identifying potential solutions and possible measures for improving the river quality in Ballinahown.

Two sampling locations were initially selected, shown as SW1 and SW2 in fig. xxx. The intention was to provide data on the water quality in the River Worm at one location upstream of the village and another downstream to draw conclusions about the potential impact of activities in the village on the river. After completion of three sampling dates, a new pipe was discovered (SW3) which was later found to be the main inflow point for at least half of the village, if not more; carrying stormwater and also contamination of sewage at a minimum. Details of the sampling process are set out later in this section of the report.

Fig. 2.1 – Sampling locations on the River Worm for chemical and physical analysis.

2.2 Selection of parameters

In the Western context generally, wherever there are human habitation and livestock, there is a rise in water pollution. Nutrients which feed excessive plant growth, organic loading (measured as BOD) which leads to excess microbiological activity, and suspended solids are all generated from black water (from toilets), slurry and farmyard washings. Stormwater from roads, roofs and paved surfaces can contribute these to a reduced extent, to microplastics from tyre wear, and also impact on a waterway by altering river flows, leading to flood/drought exacerbation. Biocides, heavy metals and other toxins and medications can be added to the river via toilets, grey water, farms, industrial activities and even the water treatment process itself.



These inputs impact on the river in different ways. BOD is essentially a measure of the food value for microbes in the water. The higher the BOD levels, the more the microbes can multiply and strip oxygen from the water. Thus for very polluted waters fish can drown for want of oxygen in the water.

Total suspended solids is the total amount of fines within the water. At high concentrations it can settle out in rivers to clog spawning beds or freshwater pearl mussel beds, or can make it difficult for fish or insects to find and catch prey. It may also be indicative of other factors in the water such as algae or elevated nutrients from lake sediments, for example.

Ammonia, Nitrate and Nitrite are all commonly sampled nitrogen compounds in water pollution assessments. Nitrogen and Phosphorus compounds are important because above a relatively small baseline level they lead to proliferation of plant growth, and algal growth in particular. They are commonly applied as a fertiliser on farmland and have a great potential to flow off into watercourses where they can cause pollution. They are also the main nutrient pollutants in sewage, so municipal discharges or septic tank effluents can also lead to pollution by leading to nutrient enrichment of receiving watercourses. Ammonia and nitrite can also be toxic to aquatic organisms such as fish, and as such are important factors in assessing the health of a watercourse for wildlife.

Microbial analysis of Total and Faecal Coliforms, and the indicator species *Escherichia coli* (*E. coli*), are common indicators of faecal pollution – typically from sewage or livestock in a water pollution context. Many Coliforms are not generally pathogenic in themselves, but act as a relatively safe indicator of the possible presence of pathogens in a watercourse. The greater the number of coliforms, the greater the potential for, and likely concentration of, pathogens in the water.

The total viable count (also known as a total bacterial count or colony counts) is a similar test, carried out to assess the overall concentration of bacteria in a water sample.

Parameters selected for this project include biochemical oxygen demand, suspended solids, ammonia, nitrates, total phosphorus and microbiological analysis. Other potential parameters such as heavy metals or other toxins or pharmaceuticals may also impact on river water quality but are not within the scope of this process.

Water samples were taken over four sampling dates in the spring and early summer of 2023 and sent to IAS laboratories for physical and chemical analysis. Parameters selected included the following:

Oxygen Demand and Suspended Solids:

- Biochemical Oxygen Demand (as mg/l O2)
- Total Suspended Solids (mg/l)

Nutrients:

- Ammonia, (NH3, as N, mg/l)
- Nitrate (NO3, as N, mg/l)
- Total Kjeldahl Nitrogen (as N, mg/l)
- Total Oxidised Nitrogen (as N, mg/l)
- Total Phosphorus (as P, mg/l)

Microbiological:

- Total coliforms (MPN/100ml; most probable number/100ml)
- E. coli (MPN/100ml)
- Total viable count (cfu/ml @22°C)

2.3 Sampling of the River Worm for chemical analysis

Sampling was carried out on the River Worm over the months of February and May of 2023 on four separate sampling dates. Standard sampling procedure was observed, to ensure that samples were not contaminated with disturbed sediments. Samples were posted on the day of sampling to IAS Labs in Bagenalstown, Co. Carlow for chemical analysis.

Sampling locations were selected both upstream and downstream of the village with the aim of assessing the impact of stormwater and/or sewage inputs from the village. However following the third sampling date a discharge pipe was found entering the Worm at a location upstream of the upper sampling location. As such the upstream samples would not have given the clean “upstream” results that were planned.

As a results, an additional sample was taken in mid May. This sampling date coincided with a prolonged dry spell and the upper pipe was dry on the day of sampling, leading to limited comparative value with the previous upstream sample location, which was also sampled on that date.
Subsequent assessment of pipe connections, combined with data reported from previous dye testing in the village have determined that this pipe contains a mixture

of stormwater and septic tank effluent. Some percolation appears to be occurring en route to the discharge pipe, hence the lack of flow during our mid May sampling date. Thus the results expressed below do not show a true "upstream" result.

2.4 Laboratory results for physical, chemical and microbiological parameters
The following tables show the results obtained for downstream (SW1) and upstream (SW2) samples on the four sampling dates.

Table 2.1 – Results obtained for SW1, upstream sampling location

Downstream					
		14/02/23	09/03/23	22/03/23	18/05/23
BOD	mg/l	2	1	3	1
E coli	MPN/100ml	985	72	728	>100
Ammonia	mg/l NH3-N	0.06	0.01	0.05	0.09
Nitrite	mg/l NO2-N	0.02	0.01	0.05	0.06
Nitrate	mg/l NO3-N	2.75	2.51	3.05	2.39
Total Phosphorus	mg/l P	0.01	0.02	0.03	0.02
Suspended Solids	mg/l	8	10	16	9
Total Coliforms	MPN/100ml	5172	959	4106	>100
Total Oxidised Nitrogen	mg/l N	2.77			2.44
TVC @ 22	c.f.u./ml	>300	>300	>300	>300
KJN			56	84	21

Table 2.2 – Results obtained for SW2, upstream sampling location

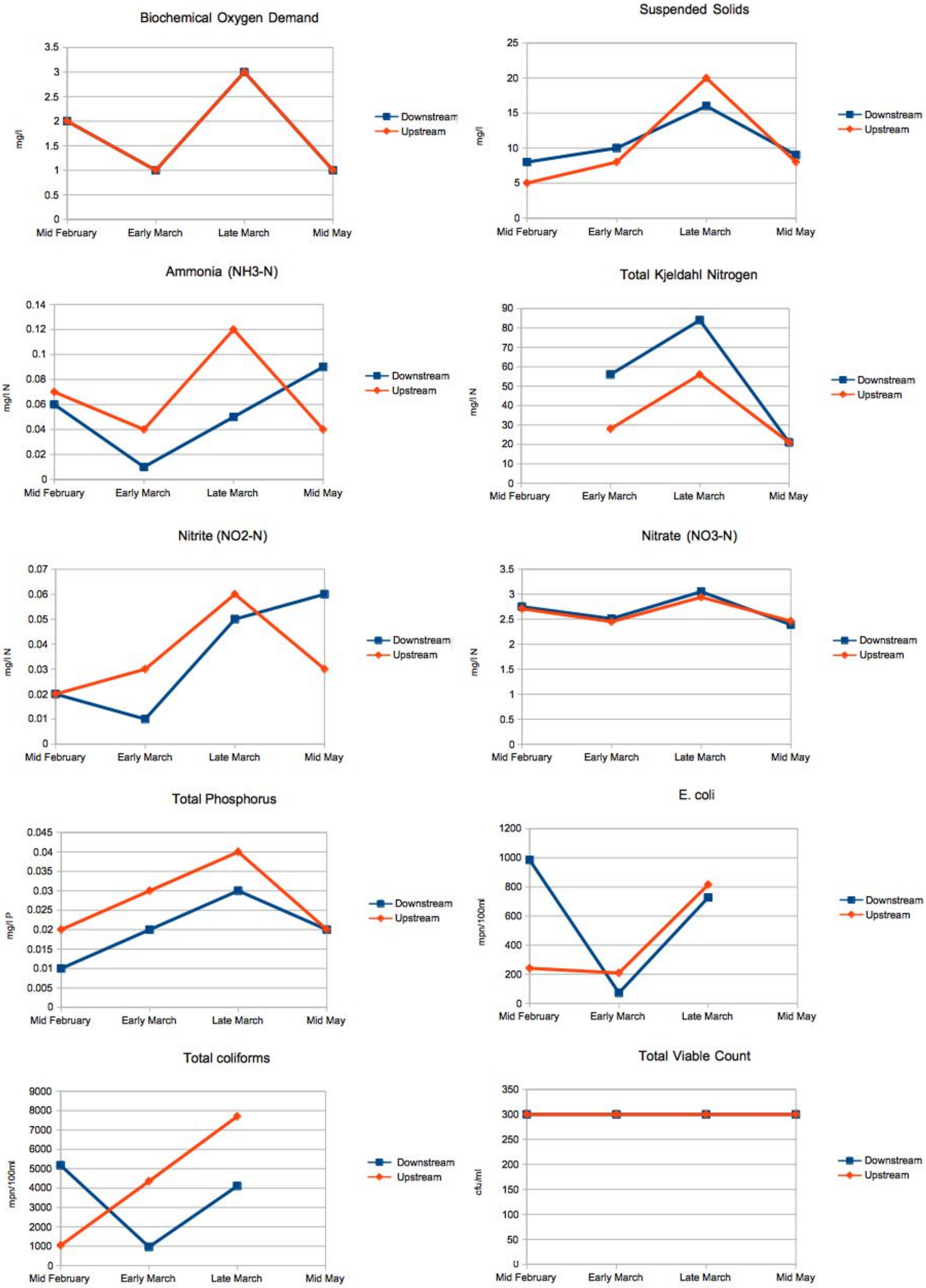
Upstream					
		14/02/23	09/03/23	22/03/23	18/05/23
BOD	mg/l	2	1	3	1
E coli	MPN/100ml	241	209	816	>100
Ammonia	mg/l NH3-N	0.07	0.04	0.12	0.04
Nitrite	mg/l NO2-N	0.02	<0.03	0.06	0.03
Nitrate	mg/l NO3-N	2.71	2.45	2.94	2.46
Total Phosphorus	mg/l P	0.02	0.03	0.04	0.02
Suspended Solids	mg/l	5	8	20	8
Total Coliforms	MPN/100ml	1043	4352	7701	>100
Total Oxidised Nitrogen	mg/l N	2.73			2.49
TVC @ 22	c.f.u./ml	>300	>300	>300	>300
KJN			28	56	21

Table 2.3 – Results obtained for SW3, sampling location above SW2

Further Upstream		
		14/02/23
BOD	mg/l	1
E coli	MPN/100ml	>100
Ammonia	mg/l NH3-N	0.07
Nitrite	mg/l NO2-N	0.04
Nitrate	mg/l NO3-N	2.46
Total Phosphorus	mg/l P	0.01
Suspended Solids	mg/l	7
Total Coliforms	MPN/100ml	>100
Total Oxidised Nitrogen	mg/l N	2.5
TVC @ 22	c.f.u./ml	>300
KJN		21

Results are presented in tabular form overleaf. Note that due to limited consistency in returned results for TON (Total Oxidised Nitrogen) these do not translate well to graph form and have thus been omitted. Similarly the TVC (Total Viable Count for microorganisms) shows a flat line graph due to reaching the upper limit of detection at the dilution levels selected in all samples.

Fig. 2.2 – Graph of results for selected parameters for SW1 and SW2



2.5 Discussion of results obtained

The first notable feature of the graphs in fig. 2.2 is the consistent pattern common to all parameters. In general overview the results read high in mid February, dropping for early March, rising in late March and dropping again in mid May. There are some exceptions, but this general trend is relatively consistent across all parameters. This pattern is common to both upstream and downstream sampling locations.

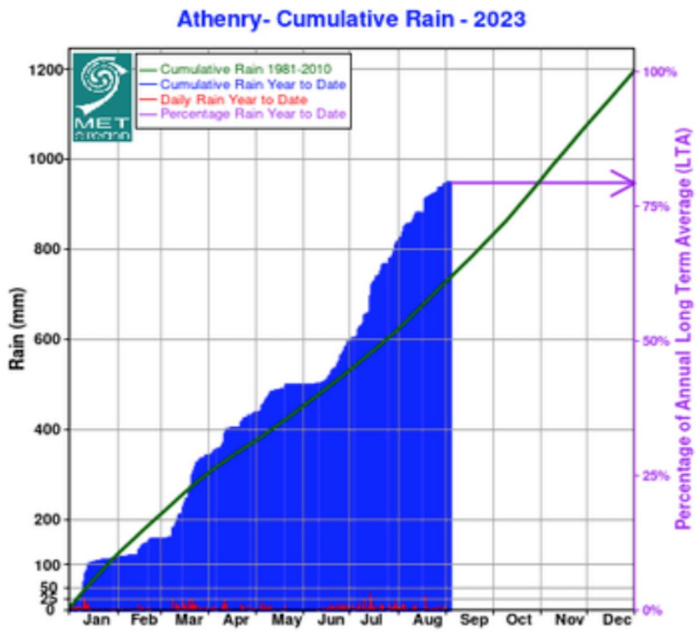
Although there is variation between parameters, in general terms there is no clear consensus that the upstream samples were cleaner or dirtier than the downstream samples. This is consistent with what was subsequently discovered during the river safari in early April; in that what appears to be one of the main discharge point for the village sewers (both storm and foul) is actually located further upstream than was originally projected, and essentially both of our locations are downstream of this primary input source.

Thus what the samples show is that the impacts on the watercourse do not vary significantly between the higher (SW2) and lower (SW1) locations down-gradient of the main discharge point. However what we do see is variation in pollution levels over time. When we compare this variation to rainfall we can see a clear pattern emerging.

Influence of rainfall

Cumulative Met Éireann rainfall data for early 2023 shows that there was a rainfall pattern that helps to explain the pattern of results obtained. There was low rainfall in late January and early February; and again in early March; and from mid May to mid June (as indicated by the flat lines in the cumulative graph below). Wetter weather was observed around mid February and again in mid March.

Fig. 2.3 – Met Éireann rainfall data for the early part of 2023 (source: www.met.ie)



This rainfall pattern appears to correlate with the results observed from the lab analysis data. Although there are exceptions, In general overview the data shows elevated readings for a number of parameters at the mid February and late March sampling times compared with the early March and mid May sampling times.

This suggests what the subsequent pipe connections confirm:

1. that sewage appears to be entering via the stormwater sewer network;
2. that some percolation appears to be available in the underlying soils, which provides some sewage treatment and/or dilution during dry weather flow conditions;
3. and that pollution of the river from sewage inputs is currently an issue that needs to be addressed to protect the river water quality and biodiversity.

SW3 sampling point

Note that there was an additional sample taken in the mid May sampling time to assess the difference between the selected "upstream" location and the area upstream of the stormwater/sewage discharge pipe. This sampling date was during a spell of drier weather and the upper pipe (between SW2 and SW3) was dry. The drain flow testing had not been carried out at this stage, and as such the full significance of this pipe had not been realised. The lack of flow on the sampling date means that the data for SW2 and SW3 was essentially the same.

Comparison with relevant water quality standards

In order to make sense of the data from a water quality standpoint, comparison with relevant regulations and standards is helpful. The following tables are taken from *Parameters of Water Quality - Interpretation and Standards,* EPA. 2001. They are shown here for comparison with the measured results.

Table 2.4 – Irish water quality standards

Irish Water Quality Standards								
Parameter	Units	Drinking Water	Surface Water Regs				Salmonid Water	Bathing Waters
		SI No. 81,1988	1989-1998		I/MAC	SI No. 77,2019	SI 293 of 1988	1989-1998
		I/MAC	A1	A2	A3	/	I/MAC	
BOD	O2, mg/l	/	5	5	7	High status ≤1.3(mean); ≤2.2(95%ile); Good status≤1.5(mean); ≤2.6(95%ile)	≤5	/
TSS	solids, mg/l	/	50	/	/	/	≤25	/
Nitrate	NO3, mg/l	50	50	50	50	/	/	*(1)
Nitrite	NO2, mg/l	0.1	/	/	/	/	95%≤0.05 *(2)	/
Ammonia, ionised	NH4, mg/l	0.3	0.2	1.5	4	/	<1 *(3)	/
Ammonia, unionised	NH3, mg/l	/	/	/	/	High status ≤ 0.04 (mean); ≤0.09 (95%ile); Good status≤0.065 (mean); ≤0.14 (95%ile);	≤0.02 *(4)	*(1)
Total P	P, mg/l	/	/	/	/	High status ≤ 0.01 (mean); Good status ≤0.025 (mean)	/	/
Total Coliforms	no/100ml	/	5000	25000	100000	/	/	≤5000 in 80% ≤10000 in 95% *(5)

*(1) Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters ... or, in the case of... ammonia, that there is a tendency towards eutrophication."

*(2) "≤0.05 in 95% of samples over a sampling period of 12 months, with sampling at least once per month"

*(3) "<1 subject to conforming with the standard for non-ionising ammonia"

*(4) "≤0.02 (Standard may be exceeded in the form of minor peaks in the daytime)"

*(5) "To be conformed with by (given)% or more of samples and not to be exceeded by any two consecutive samples in any case."

Table 2.5 – European water quality standards

European Water Quality Standards

Parameter	Units	Drinking Water	Surface Water			Freshwater Fish		Bathing Waters	Groundwater	Shellfish	Dangerous Substances
		80/778/EEC or 98/83/EC	75/440/EEC		I/MAC	78/659/EEC		76/160/EEC	60/66/EEC	79/923/EEC	76/464/EEC
		I/MAC	A1	A2	A3	(S)	(C)				
BOD	O2, mg/l	/	/	/	/	G value ≤3	G value ≤6	/	/	/	/
TSS	solids, mg/l	/	/	/	/	G value ≤25	G value ≤25	/	/	*(2)	/
Nitrate	NO3, mg/l	50	50	50	50	/	/	*(1)	/	/	/
Nitrite	NO2, mg/l	0.1	/	/	/	/	/	/	List 2	/	List 2
Ammonia, unionised	NH3, mg/l	/	/	/	/	G≤0.005, I/MAC <0.025	G≤0.005, I/MAC <0.025	*(1)	List 2	/	List 2
Nitrogen, Kjeldahl	N, mg/l	/	1	2	3	/	/	/	/	/	/
Orthophosphate	P2O5, mg/l	5	/	/	/	/	/	*(1)	List 2	/	List 2
E. coli	no/100ml	0	/	/	/	/	/	/	/	/	/
Total Coliforms	no/100ml	0	/	/	/	/	/	/	/	/	/

*(1) Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters ... or, in the case of... ammonia, that there is a tendency towards eutrophication."

*(2) "A discharge affecting shellfish waters must not cause the suspended solid content of the waters to exceed by more than 50% the content of waters not so affected."

Table 2.6 – Interim standards for phosphorus

Phosphorus

Phosphorus: Interim Statutory Standards for Rivers

	Existing biological Quality (Q) rating		EQS*	Corresponding min target Q rating
MRP (mg/l P)	5		0.015	5
	4 to 5	Unpolluted	0.02	4 to 5
	4		0.03	4
	3 to 4	Slightly polluted	0.08	4
	3 to 4		0.05	3 to 4*
	2 to 3	Moderately poll	0.07	3*
	<2	Seriously polluted	0.07	3*

EQS* as annual median value as MRP (mg/l P) for year 2007
* proposed interim EQS.

Figures from p87 of EPA Water Quality Parameters, 2001.

Comparing the above tables with the results obtained we can see that the suspended solids and nitrates loadings for both upstream and downstream locations for all dates are within the acceptable standards as listed above.

BOD is acceptable for most regulations, but at an average upstream loading of 1.6mg/l and downstream loading of 1.75mg/l it does not achieve either high or good quality threshold averages of ≤1.3mg/l or ≤1.5mg/l respectively; a requirement under the Water Framework Directive by 2027.

Nitrites are acceptable for drinking water legislation but exceed the Salmonid waters regulations for one sampling date for each of the upstream and downstream locations – for mid May and late March respectively. This means that salmonid species such as salmon and trout may not thrive in the river Worm under the current water quality conditions.

Average ammonia results are 0.0525mg/l (NH_3-N) for the downstream sampling dates and 0.068mg/l for the upstream results (including both SW2 and SW3 samples). This places measured ammonia concentrations as being in excess of the freshwater fish directive 78/659/EEC for both salmonid and cyprinid fish species (salmon/trout plus coarse fish). It also places river water quality as being outside the acceptable range for high status waters and the upstream results as being outside the range for good status waters (SI No. 77,2019).

In terms of phosphorus concentrations, for the “interim statutory standards for rivers” in the EPA Water Quality Parameters, 2001, the median concentration measured at Ballinahown of 0.02mg/l puts the water quality here as being in the Q4 to Q5 categories, which is higher than may be expected based on other parameters. However these standards have since been updated in SI No. 77 of 2019 to ≤0.01 mg/l mean value for high status waters and ≤0.025mg/l mean value for good status waters. The mean values for Ballinahown have been measured at 0.02mg/l for downstream and 0.024mg/l for upstream, the latter of which only just comes in under “good” status and are well short of “high” status figures.

Under the drinking water directive *E. coli* figures need to be zero in drinking water, but that otherwise it is not a parameter listed in the Irish or EU legislation or guidance. Measured *E. coli* figures are in the range 72 to 816 mpn/100ml. However given that the river is not drinking water, this value is not a fair comparison. Faecal coliforms are listed in the regulations for surface waters, but were not assessed for this project. In hindsight faecal coliforms would have been a more appropriate parameter than *E. coli*, and should be used going forward for any new analysis – at the appropriate dilution rates.

Total Viable Count figures obtained were unusable since the dilution rates used by the lab were set for drinking water expectations rather than for surface waters. As such the maximum threshold set was 300 cfu/ml (colony forming units), which was reached for all parameters on all sampling dates, removing any opportunity to compare results. Going forward, any new analysis should have dilution rates appropriate for A3 surface waters.

The total coliform count however gives us the opportunity to compare the River Worm with national and EU guidance for microbiological parameters. Total coliform numbers in the range 959 to 7701 mpn/100ml (most probable number/100ml) are within bathing water regulation limits and within A2 and A3 surface water limits. They exceed the zero limit for drinking water, understandably; and also exceed the A1 surface water limit of 5000 in mid February (upstream) and late March (downstream), meaning that a higher standard of treatment would need to be applied than for an A1 quality watercourse for abstraction purposes. Note that the mid May sample was not returned as low as is indicated in the graph, but as having reached the threshold of detection, which was set by the lab for that date as 100mpn/100ml.

In summary the water quality in the River Worm is relatively acceptable for a broad range of legal limits, but still does not meet sufficient quality requirements to support as wide a range of biodiversity as may be desired, nor necessarily to achieve good quality status by 2027 as is required under the Water Framework Directive.

3.0 Q-Value Assessment

Q-values are based on biological assessments of a watercourse, specifically the number and diversity of a suite of macroinvertebrates (insects and other similar aquatic fauna). They offer a picture of the habitat value of a river or stream and thus a good overview of general water quality over an extended time period. Blue dots denote high quality; green denotes good quality; yellow denotes moderate quality; orange denotes poor quality and red denotes bad quality. Thus the coloured dots on the map below show the Q-values for watercourses across the country. Note that in general terms the high status waters (Q5; blue dots) are located in upland areas with faster flowing water as well as the absence of housing or intensive agriculture.

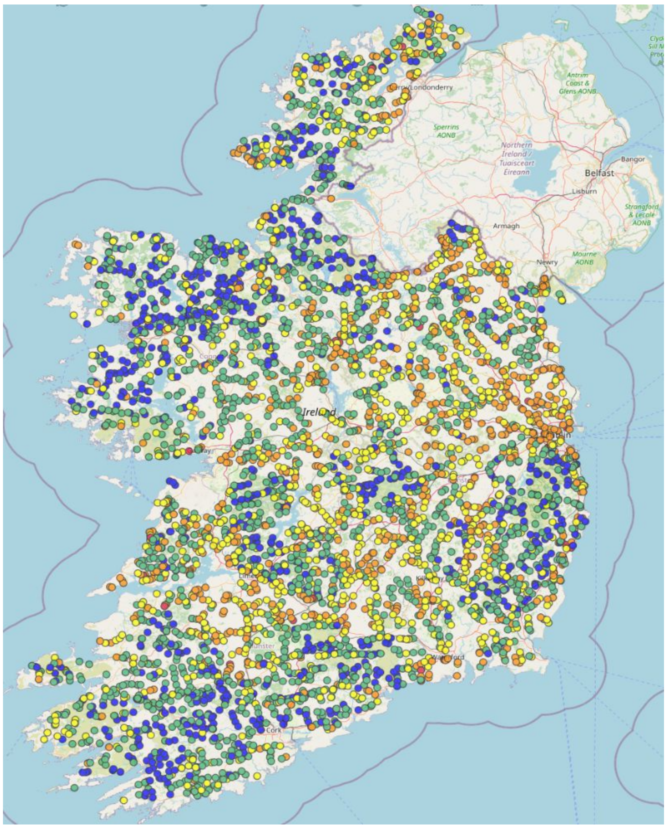


Fig. 3.1 – Water quality in Irish rivers and streams (2016-2018).

Source; Open Street Maps (from www.catchments.ie), under Open Database Licence

The graph overleaf shows the change in water quality in Irish rivers and streams since the late 1980s. While there has been a welcome reduction in serous pollution, there is also a worrying drop in the number of high status water bodies.

Note that a further subdivision of the high quality waters includes a category called "reference quality"; rivers and streams that have essentially not known pollution. This category has seen a precipitous decline from almost 15% in the late 1980s to *c*.1% in the past decade. Notice also from fig. 3.2 that the general quality of waters has been dropping steadily since the 2010-2012 time period. What these two factors mean in practice for biodiversity is that the habitat available for species who require clean water has been declining – rapidly for those reference quality species with the lowest tolerance for pollution; and steadily for those with tolerance for some oxygen depletion but who still require water to be of high quality to live there.

Fig. 3.2 – Water quality in Irish rivers and stream samples from late 1980s to most recent round of assessments shown (2016-2018).

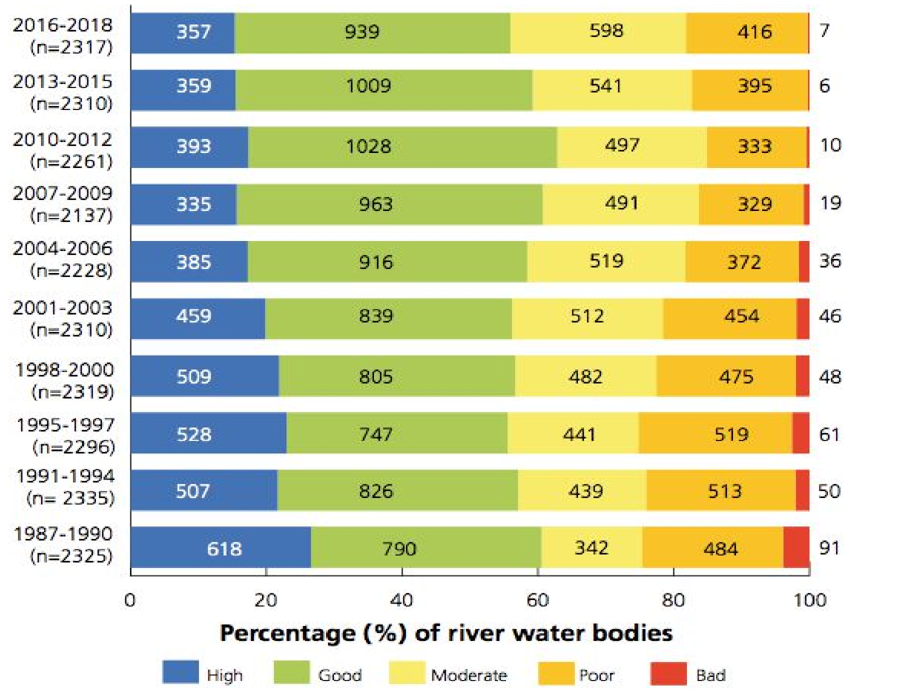


Figure 2.8: National trends in macroinvertebrate quality of water bodies using the Q-value rating system between 1987 and 2017. Number in parentheses on y-axis is total number of water bodies

Source: Water Quality in Ireland 2013-2018. EPA Wexford

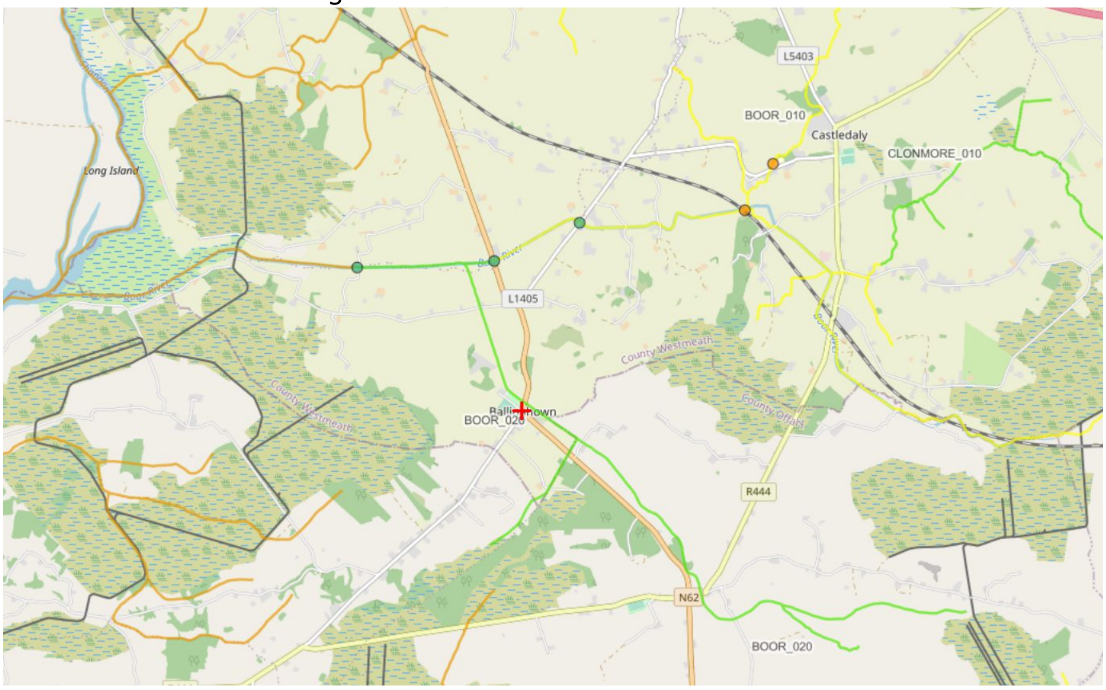
The latest Q-values for the River Worm (from the EPA website www.catchments.ie) show that the river water quality is classed as "good". Part of the context for this water management plan is to examine the water quality and to explore ways to improve the status of the river. By reducing pollution inputs to the River Worm and enhancing the habitat value of the stream bed, we can set our sights on achieving "high" status waters here. This will have direct benefits not only for water quality, but also for the species that will be able to live in the higher cleaner water.

Fig. xxx shows the River Boor catchment area including its tributary the River Worm at Ballinahown (marked with a red cross on the map). The orange and green dots show the Q-value assessment locations and results along the main Boor channel. There are currently no EPA macroinvertebrate sampling points along the River Worm, so the status is inferred by the good status of the River Boor at the point where the Worm enters it, combined with any physical and chemical analysis that may have been carried out by the EPA, along with hydromorphological information to hand (data on the river flow patterns and presence or absence of obstacles such as weirs or hard engineering bordering the river).

There is a requirement for all rivers and streams within the EU to achieve "good" status as a minimum standard by 2027 – the next round of assessments under the water Framework Directive. Due to the existing status of the Worm, it is deemed as "not at risk" of reaching this goal, however the wider Boor and then Shannon show "at risk" and "review" status (an intermediate category which denotes that they are less polluted but still not necessarily on course for achieving the desired targets).

Any improvements that can be implemented within the Worm catchment area will have a direct impact, however modest, for the wider Boor and Shannon catchments. Thus raising the Q-value in Ballinahown from Q4 to Q5 would help to be part of the wider measures to bring the lower Boor status from Q2 to Q4.

Fig. 3.3 – Boor River catchment area including its tributary the River Worm at Ballinahown (marked with a red cross on the map) showing Q-value assessment locations and results along the main Boor channel.



Source; Open Street Maps (from www.catchments.ie), under Open Database Licence

Part of the Water Management Plan process was due to include a biotic index assessment (the name given to Q-value assessments when carried out by ecologists other than the EPA) by an ecologist to assess the macroinvertebrate populations within the river Worm upstream and downstream of the village. Due to heavy rainfall for extended periods this year this ecological work has been postponed until the river is more accessible and the ecological results more reliable.

The ecological work will be carried out prior to implementation of the main measures outlined in this Plan so that a comparison of before and after data will be possible; thus assessing our effectiveness of efforts to raise the quality of the river for aquatic species.

4.0 River Safari – Assessing River Inflows

A river safari is a site walk-over to assess inputs to rivers or streams, highlighting possible or known pollution inputs. This river safari was carried out on 11 April 2023 as part of the water management plan to assess inputs with a view to seeking input from the local community and explore options for improvement of the water quality.

For this process the river was divided into three sections or reaches in order to show the photographs in sufficient detail. The different pipes seen to enter the river were photographed and then overlaid on a map of the relevant section of the river as set out below.

4.1 – Walking the river

Figure 4.1 – River Safari, reach 1

Inlet points identified in reach 1:

1. 9” concrete pipe up-gradient of village suspected to carry stormwater and/or sewage. Subsequently investigated further and found to the be the main inlet point for stormwater drains from the road near the community centre and church, with sewage inputs from Woodland Avenue and at least some other houses in the village.

2. Open channel from farmland. Not investigated further. Would be suitable for natural farm-scale filtration measures if desired.
3. Possible 4" field drain. Dry during wet weather on day of safari. Not investigated further.
4. 1' concrete pipe entering river between church field and private garden. Dry during wet weather on day of safari. Investigated by local interviews but origin not determined.

Figure 4.2 – River Safari, reach 2

Inlet points identified in reach 2:

5. 4" pipe with stormwater and/or sewage inputs. Source likely to be stormwater from Rohan's yard. Sewage contamination possible but not assessed further.
6. Cattle access to river. Not investigated further. Fencing would improve water quality.
7. Two pipes entering one above the other: 6" and 4". Upper pipe flowing grey on day of assessment and thus suspected to be Rohan's yard. Lower pipe flowing clean and suspected to be roof runoff. Sewage contamination possible but not assessed further.
8. 4" pipe with modest flow and visible greying below pipe. Suspected to be septic tank ingress. Not assessed further.

9. Seepage point. Possible pipe hidden behind undergrowth but not found on day of safari. Greying of sediments may point to septic tank ingress. Not assessed further
10. Clay piping; apparently disused. Not assessed further.
11. Stormwater inputs from road near bridge.
12. Stormwater inputs from road near bridge.

Figure 4.3 – River Safari, reach 3 [swap 2" and3/4" numbering]

Inlet points identified in reach 3:

13. 4" pipe with suspected stormwater and/or sewage inputs. Not unduly greying around base, so may be stormwater only.
14. 4" pipe with suspected stormwater and/or sewage inputs. Greying around base so suspected to include sewage, with or without stormwater.
15. 2" water pipe across or into river. Not assessed further.
16. 3/4" water pipe across or into river. Not assessed further.
17. Piping and wiring for pond water delivery from river.

4.2 – Follow-up assessments of drain flows

Subsequent to the River Safari, drain connection testing was carried out on 15/6/23 and 8/7/23 to assess potential connections between stormwater and foul sewers and the river. On both occasions dye testing was used, but not effective insofar as dye at the outlet end of the pipes tested was not clearly discernable. However an effective measure that was also used was flow testing by adding large volumes of water to the upstream location and observing a notable rise in input volumes at the river. It is suspected that there is considerable storage volume in the ground, which either contained or diluted the dye added in the upstream locations on each occasion. Nonetheless, the testing process was successful in confirming a direction connection between a number of locations and the river.

Testing of safari ingress point No. 13 was carried out in mid June, and it was determined that there was a direct connection between the sports centre car park and the river. Water was added to the toilets in the sport centre as well, with dye, but no conclusive result was determined. This may be due to a lack of any connection, or due to storage volume in the septic tank and/or percolation area which buffered either the flow volumes or the dye.

Testing was carried out in early July on the on-street gullies at the road in front of Fr. Brendan's house. These flow to a manhole in the field opposite. While there was a small base-flow of cleanish looking water in the manhole, there was initially zero flow entering the river from the 9" pipe on the day of the visit. Only after a considerable volume of water had been added to the gully did a flow appear at the river – in large quantities once it started. On previous occasions the same pipe was observed to carry water during a heavy rainfall event within the village; but was also observed to be dry during DWF conditions.

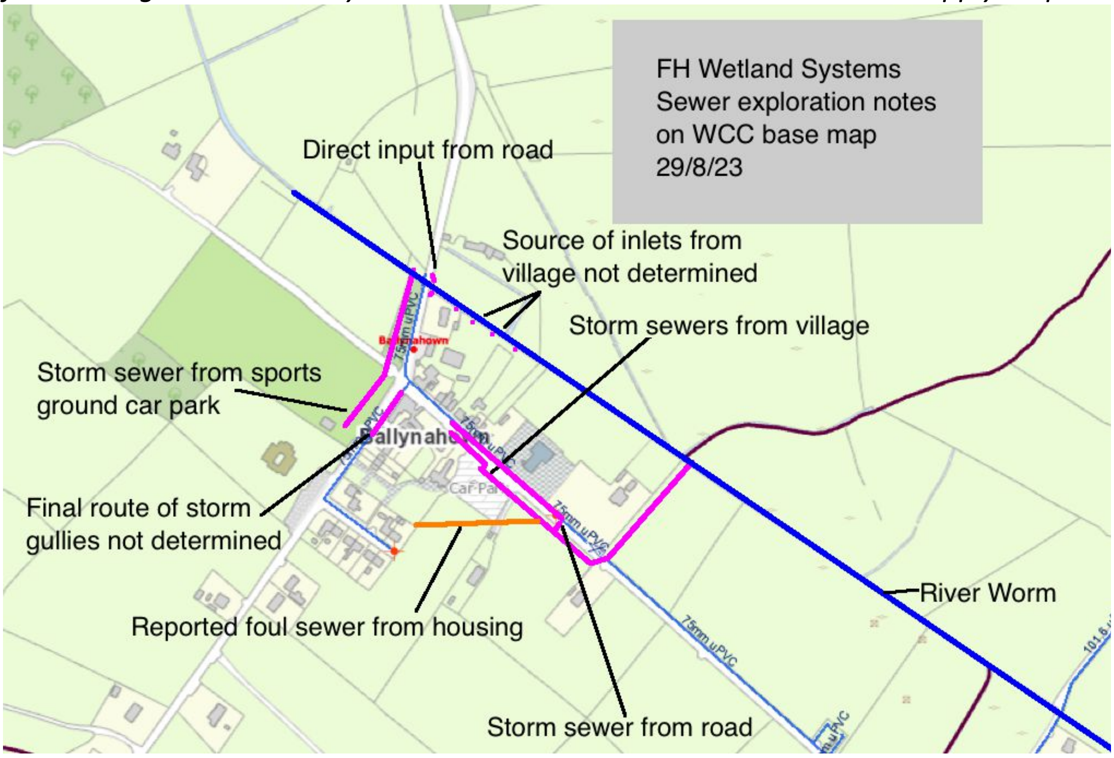
The houses at Woodlands Avenue have their own collective septic tank, serviced and maintained by Westmeath County Council on an annual basis. Local reports are that the septic tank is connected to the storm sewer, but as of the time of writing this has yet to be confirmed as part of this management plan. Given the heavy clay soils underlying Ballinahown it is likely that other houses within the village ultimately connect either into the storm sewers or to the river directly.

Thus it can be assumed that there is at least some foul sewer input into the stormwater drainage network; leading to a direct conduit for contamination of the river. Some percolation appears to be occurring between the manhole and the river along the pipe run, hence zero flows into the river during dry weather flow conditions. Note that if there was no percolation or other bypassing of the piped network, a flow would be expected in the pipe from septic tank overflow on a semi-continuous basis.

Figure 4.4 shows detail added to a Westmeath County Council water mains supply map, providing a schematic drawing of foul and/or storm sewer layout based on dye testing and flow volume testing by FH Wetland Systems over the summer of 2023. Details include dye testing feedback from previous work carried out by others also.

There may also be other sewer inputs into the storm drains to the centre of the village and from the western side of the village. The extent of the work require to confirm all pipe inputs is beyond the scope of this plan, but could be conducted as a community citizen science initiative by posting an observer in the river during dry weather flow conditions (hence no stormwater) and turning on taps in selected houses for a suitable period of time to generate a good flow, and connecting which taps connect to which ingress points.

Fig. 4.4 – Draft schematic of stormwater and foul sewers based on dye testing and flow testing. FH Wetland Systems detail overlain on WCC water mains supply map.



Further work:

- Follow up on pipe checks in centre of village and west of village.
- Assess options for stormwater/sewage treatment.
- Implement treatment for same to protect the water quality and biodiversity in the river.

5.0 Biodiversity along the Riparian Corridor

5.1 Ecological walkover of the selected project area

An ecological walkover of the river corridor was carried out on a number of occasions during the preparation of this plan. The river corridor through Ballinahown can be classified as FW2 – depositing/lowland rivers.

The corridor within the village is very narrow, having been straightened and deepened historically. Thus the riparian zone for wetland plant establishment is very limited in area. The river corridor is overshadowed by tall trees, which include sycamore, ash, non-native conifer species, and others. In addition to the tree over, the immediate riparian habitat is dominated by tall riparian vegetation (branched burr reed and yellow flag Iris), briars and grasses.

5.2 Existing flora and fauna records

An extensive ecological survey and biodiversity plan[2] has been prepared for Ballinahown Village by ecologist Catherine O'Connell. This plan describes the habitats present in Ballinahown and records species observed during two site walk-overs. The plan also includes extensive areas for action for enhancing and protecting biodiversity within the village.

The biodiversity plan area includes the main public areas of the village, but generally excludes the river corridor itself due primarily to lack of easy access from public lands. As such the biodiversity plan offers an excellent partner report to this water management plan, which examines the river habitat itself and sub-habitat types within the river channel.

To compliment the overview of habitats in the Biodiversity Plan, the aerial map view in Fig 5.1 is provided to show those habitats that specifically border the River Worm, or are in themselves wetland habitats; notably the artificial pond in the car park (FL8) and the wet grassland south of the village (GS4).

5.3 Assessment for non-native invasive species

During the biodiversity plan process in 2022, three plant species were found within Ballinahown that were categorised as invasive. These were Snowberry, Laurel and Variegated Poplar. These were all found in terrestrial habitats and as such are not a concern for this water management plan.

No non-native invasive plant species were recorded along the banks River Worm within the village during the process of preparing this plan. A search of the National Biodiversity Data Centre maps for the main listed invasive species of aquatic and riparian habitats also yielded no results for Ballinahown village; although Japanese Knotweed and Rhododendron were both recorded in a location in the upper Worm

2 O'Connell C. A. (2022) *Ballinahown, Co. Westmeath Community Biodiversity Plan 2022-2026.* Prepared for Ballinahown Community Development, Ballinahown, Co. Westmeath.

catchment; with American Mink recorded downstream of the village, near where the Worm enters the Boor. Bank voles have been recorded both upstream and downstream of the village, although not within the project area as such.

Given the general absence of non-native riparian invasives within the village and immediate hinterland, there is no undue concern about movement of machinery in and out of the village for works that may be required under the recommendations of this plan.

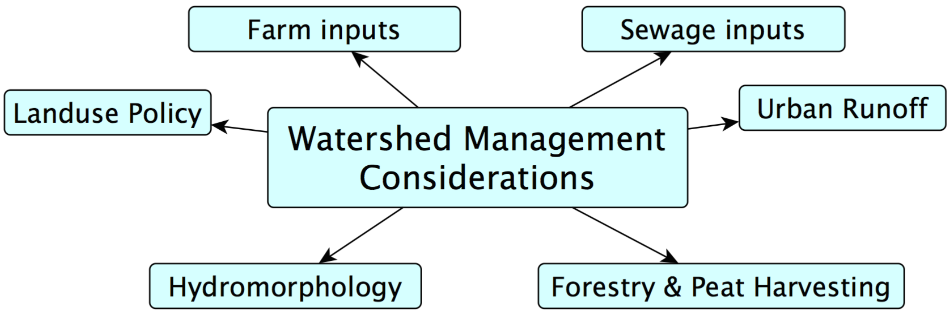
Fig. 5.1 – Primary habitat types bordering the River Worm and within Ballinahown village. (Source map: catchments.ie)

Legend to Habitat Codes used above[3]:
FL 8 – Artificial lakes and ponds
FW2 – Depositing/lowland rivers
FW4 – Drainage ditches
GA1 – Dry calcareous and neutral grassland (improved grassland)
GA2 – Dry meadows and grassy verges
GS4 – Wet grassland
WD5 – Scattered trees and parkland
WL1 – Hedgerows
WL2 – Treelines

3 Fossitt JA (2000) *A guide to the habitats in Ireland.* The Heritage Council, Dublin.

6.0 Overview of Water Quality Challenges

In common with many parts of the industrialised world, the primary challenges for water quality in Ballinahown include impacts from sewage, stormwater and agriculture. There are also other landuse factors in this case such as peat extraction, which is likely to have contributed a substantial historic suspended solids loading to the River Worm. The other major impact has been that of hydromorphological changes by river drainage under the arterial drainage act, which impacts this catchment.



Potential inputs to the River Worm:

1. Sewage from public and private buildings
2. Stormwater from public and private buildings, business premises, sports grounds, roads, car park and the wider village
3. Likelihood of combined sewer of both stormwater sewers and septic tank effluent
4. Agricultural runoff from yards and fields
5. Other issues such as peat harvesting, commercial forestry activities, land drainage and other land-use related impacts.

For each impact or pollution source there is an opportunity for improving water quality within the village. The following sections provide an overview of the main impacts and the opportunities that are present for improving water quality and enhancing the ecological status of the River Worm.

7.0 Sewage Inputs and Treatment Options

The primary impacts from sewage pollution in rivers and streams include high BOD (Biochemical Oxygen Demand), suspended solids and nutrients such as nitrates and phosphates which lead to eutrophication; an overabundance of algae and plant growth in the waterways. Other impacts include pathogenic bacteria, microplastics from washing machines (tiny clothing bits from artificial fibres), heavy metals and other toxins (typically from household cleaning chemicals) and medications (flushed down the toilet, either via the homeowners body or discarded directly).

Ballinahown has no central sewer network nor sewage treatment system. Most buildings are served by individual septic tanks, with some of the newer houses connected to a group septic tank. The heavy clay soils that underlie the village mean that the percolation areas that are meant to permit both infiltration and treatment of septic tank effluent are likely to be ineffective. Thus it is suspected that most septic tanks are essentially routed to the River Worm, either directly via stormwater drainage pipes.

7.1 Overview of options

Sewage treatment options can be categorised under the following general headings:

- Primary settlement and percolation
- Treatment wetlands
- Willow treatment systems
- Packaged filter media units
- Mechanical aeration systems
- Dry toilet systems (using one of the other system types here for the grey water element of the sewage)
- Source separation technologies
- Tertiary treatment systems for additional polishing of effluent quality (typically required for discharges to surface waters)

Septic tanks for primary settlement followed by percolation areas can offer good treatment where suitable free-draining soils are sufficiently high above bedrock or water table. In many areas however, poor soil characteristics mean that septic tank effluent can flow overground into rivers or streams, where it is a cause of pollution. This is likely to be the case at Ballinahown, where septic tanks are in standard use but where the heavy clay soils offers little opportunity for treatment.

Due to the heavy soils underlying the village, a far preferable option would be to have full secondary and tertiary treatment prior to discharge to the river Worm; or to have a willow-planted area for full or partial uptake of liquid generated from toilets, washing machines etc. throughout the village.

This section focuses on the more eco-friendly sewage options which may be used for sewage treatment for one-off houses, community buildings or potentially even the full village. These eco-friendly options are typically more cost effective to install than standard mechanical aeration systems and are have a lower overall running cost.

However the benefits of mechanical treatment units or packaged filter media units include familiarity of use and maintenance by standard operators and also greatly reduced land-take compared to treatment wetland or willow options. As such, if budget permits, then these conventional approaches should be considered alongside

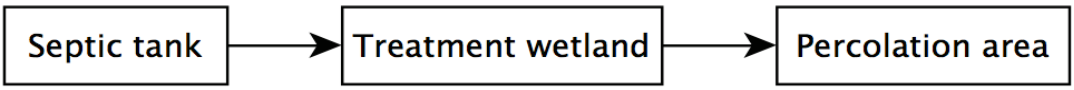
7.2 Treatment Wetlands

Treatment wetlands can be subdivided into the following primary categories; may include ponds as part of the overall layout, and can be hybrids or combinations of the list below:

- Soil-based constructed wetlands (Free Water Surface systems - FWS)
- Horizontal Sub Surface Flow gravel reed beds (HSSF)
- Vertical-flow reed beds (VF)

Other treatment wetland types include Integrated Constructed Wetlands (ICWs), sand-filled vertical flow reed beds and modular packaged reed beds. These are outlined in *Septic Tank Options and Alternatives*, (Harty F. (2014) Permanent Publications, Hampshire, UK) but are not detailed further below.

Standard treatment wetlands follow a settlement tank or treatment system; and the treated effluent is routed to an infiltration area for disposal to ground, as follows:



Pros and Cons compared to other treatment options

Pros

- Low construction and running costs.
- Zero electricity inputs where pumping of effluent is not needed.
- Robust systems, tolerant to variable or seasonal loading rates.
- Can achieve excellent reductions of biochemical oxygen demand (BOD) and suspended solids (SS).
- Can remove of a wide range of pollutants.
- Secondary benefits in terms of potential wildlife habitat enhancement and visual aesthetics.
- Versatile systems for use with old or overloaded systems.

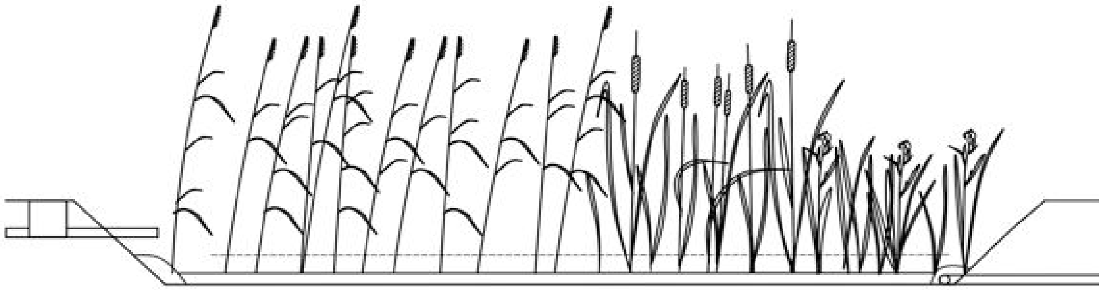
Cons:

- Need lots of space.
- Require fencing.
- Biodiversity benefits may include unwanted insects.
- Possible odour nuisance, depending on detergent use and proximity.
- Can become saturated with sediment or phosphorus over time.

Soil-based constructed wetlands

These are marsh type systems, typically lined with indigenous impermeable clay subsoil or a plastic membrane. Surface area requirements 20m^2/person for secondary treatment; plus 10m^2/person for tertiary treatment where needed.

Fig. 7.1 – Section view of standard constructed wetland system



Pros and Cons compared to other treatment wetlands

Pros

- Offer higher treatment than gravel options based on Irish EPA design sizing.
- Resilient to sludge overloading and hydraulic shock loading (i.e. sudden overloads of effluent).
- Can receive stormwater from roof surfaces as well as grey and black water and still provide reliable treatment standards.
- Potentially the lowest cost systems: where subsoil conditions negate plastic lining.
- Can be the lowest embedded energy treatment option (excluding dry toilets which don't even need the septic tank; and willow systems which actively sequester carbon).
- Best treatment wetlands for wildlife.

Cons

- Greater potential for odour generation.
- Possible safety hazard with (shallow) open water.
- Unsuitable for small sites.
- Larger than gravel systems.
- EPA Code requires 2m metal perimeter fence.

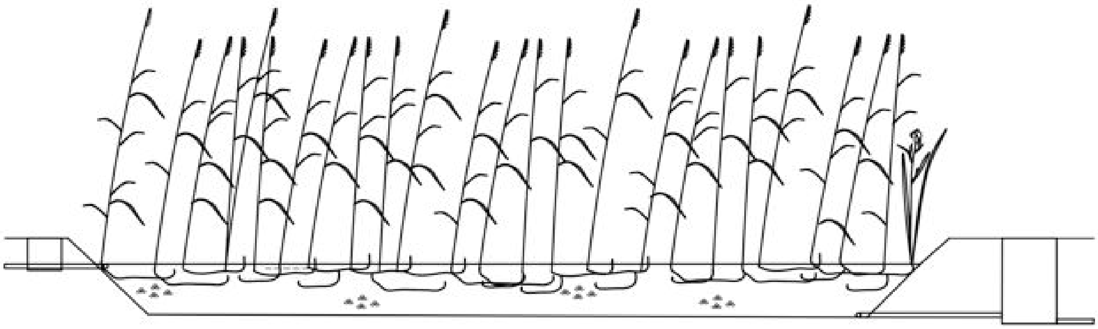
Fig. 7.2 – Ponds can be a beautiful addition to treatment wetlands

Fig. 7.3 – Newly planted wetland system for single dwelling, filled with clean water for planting and plant establishment.

Horizontal-flow gravel reed beds

These are gravel filled basins planted with a selection of wetland plants which provide aeration and filtration to the effluent passing beneath the surface of the gravel. EPA Code of Practice recommends a size of $5m^2$/pe for secondary treatment and $1m^2$/pe for tertiary treatment, but a slightly larger sizing (allow $8m^2$ and $2m^2$ respectively) will achieve greater treatment.

Fig. 7.4 – Section view of gravel reed bed system



Pros and Cons for HSSF reed beds compared to other treatment wetlands

Pros

- Generally smaller than soil based constructed wetland systems.
- No open water as safety hazard; and odour generation may be reduced.
- Lower head loss: more suitable for sites with minimal gradients.

Cons

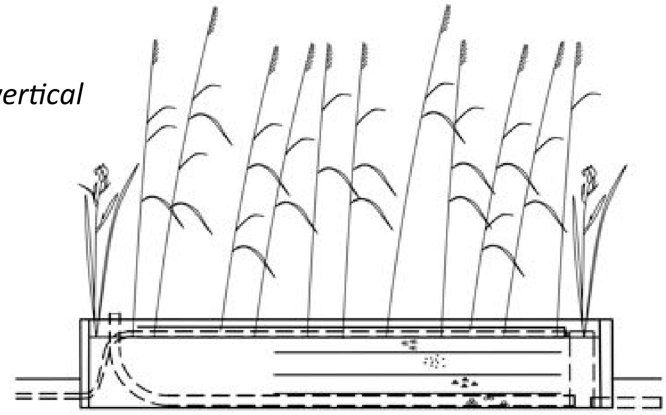
- More expensive than clay lined wetlands.
- Septic tank maintenance vital. Less resilient to sludge loadings.
- Requires occasional replacement of substrate and plants (may be 10-20 years).
- May have exposed effluent at inlet section, varies with design and maintenance.

Fig. 7.5 A and B – Newly planted reed bed and the same system two years later

Vertical-flow gravel reed beds

Pump fed (with exceptions) stone media filter planted with common reed and yellow flag Iris. EPA size requirements are for $4m^2$/pe for secondary treatment and $2m^2$/pe for tertiary treatment. Do not use sand on top layer due to potential for system clogging.

Fig. 7.6 – Section view of vertical flow reed bed



Pros and Cons compared to other treatment wetlands

Pros

- Can achieve greater oxygenation/treatment of effluent in a smaller surface area.
- Good ammonia reduction potential.
- Effective component in overall treatment wetland design.

Cons

- Typically pumped (but gravity dosing boxes may be used where gradient allows).
- Typically used with a horizontal flow reed bed, so additional cost and space rather than replacement of same.
- Good septic tank maintenance and/or pretreatment needed.

Treatment wetlands comparison summary

Treatment Wetlands Compared (also showing standard proprietary system for comparison)

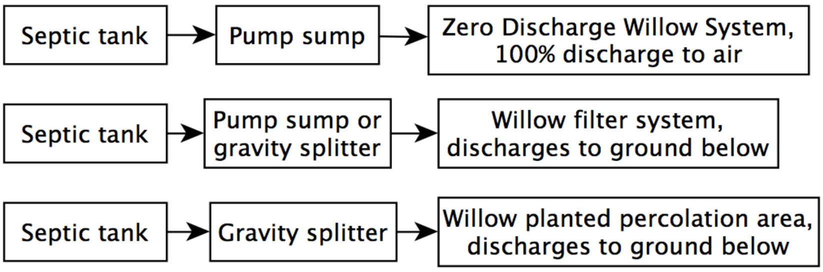
	CW	**HF-RBTS**	**VF-RBTS**	**STW**
Treatment effectiveness	High	Medium	Medium	Medium
Ecological footprint	Low	Med	Med	High
Wildlife value	High	Medium	Medium	Low
Capital cost on standard site	€€	€€	€€	€€
Capital cost on heavy soils	€	€€	€€	€€
Running costs	€	€	€€	€€€
Odour potential	High	Low	Medium	Low
Safety risk	High	Low	Medium	Low
Size	Large	Medium	Medium	Small
Fencing	2m metal	Child-proof	Child-proof	No
Electricity needed	No	No	Yes, for pump	Yes, 24/7
Resilience to sludge overloading	High	Low	Low	Medium
Can receive stormwater inputs	Yes	No	No	No

CW – soil based constructed wetland
HF-RBTS – Horizontal flow reed bed treatment system
VF-RBTS – Vertical flow reed bed treatment system
STW – standard packaged mechanical aerated sewage treatment system
Note that these are general details only. All of the above can have exceptions to every entry outlined, but in general terms the details are accurate.

7.3 Willow Treatment Systems

Willow treatment systems are willow planted treatment areas that may be fully contained with a plastic liner (zero discharge systems) or unlined. They can be divided into three main categories, as follows:

- Zero discharge willow systems
- Willow filters for nutrient removal
- Willow planted percolation areas



Pros and Cons compared to other treatment options

Pros

- Can have excellent removal of nitrates and phosphates.
- Can be designed with gravity splitters as zero energy input systems.
- Good for wildlife and can be attractive garden features.
- Willow biomass can be used for fuel or chipped for landscaping.
- Sequesters atmospheric carbon.
- Can be designed to protect watercourses during summer months, or be 100% zero discharge, depending on design.
- May be suitable for failed sites with no percolation.
- Can be used as effective upgrade system on existing sites.

Cons

- Willows may be too tall for garden (to 6-8m).
- Need large space.
- Require maintenance to cut willows on 3-yr rotation.
- Zero discharge option is expensive to install.

Fig. 7.7 – Willow system photographed in June; showing three tall rows at the rear, due for coppicing the following February, and three front rows with fresh growth.

Zero discharge willow facilities

Zero discharge willow facilities are plastic lined, soil filled basins that rely upon the willows for 100% evapotranspiration of septic tank effluent. Typically 6m wide and vary in length from 35-75m depending on the location in Ireland (rainfall and evapotranspiration rates dictate size, as well as water use of home owners).

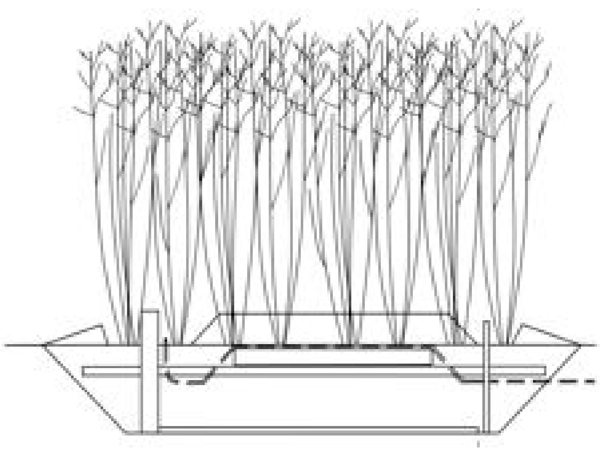


Fig. 7.8 – Typical section view of Danish zero discharge willow system

Pros and Cons compared to other willow treatment options

Pros

- Can be fully zero discharge if designed following new FHWS/TCD design protocol.
- Zero pollution to surrounding environment.

Cons

- Costly to install (€20-50,000 for a single dwelling system).
- Larger than some other willow options.
- Typically requires electricity for pumped inlet, although this may be avoided where suitable gradient exists.

Fig. 7.9 – Newly planted zero discharge willow system in Denmark, showing three rows of cuttings on either side of the central covered spreading pipe. Outer bund work due for completion the following February.

Willow filter systems

Unlined willow systems are typically sized to achieve high nutrient uptake. They have full summer uptake of liquid and usually allow some infiltration to ground during winter months. Size may be smaller or larger than the zero discharge system depending on the degree of nutrient uptake required.

Pros and Cons compared to other willow treatment options

Pros

- Much more cost effective to construct.
- Still have excellent environmental protection.
- May qualify as zero discharge option for planning in certain circumstances.

Cons

- Some seasonal infiltration to ground unless specifically excluded in designs.

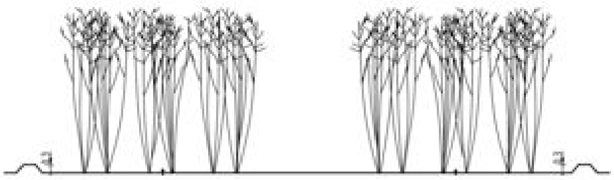


Fig. 7.10 – Section view of pump-fed willow filter area

Willow planted percolation areas

These are essentially EPA Code compliant percolation areas except that the piping layout has been updated to allow for planting with willows in such a way as to avoid clogging with willow roots. Size systems as per EPA Code of Practice for percolation areas (if following a septic tank) soil polishing filters (after secondary treatment) or distribution areas (after tertiary treatment).

Pros and Cons compared to other willow treatment options

Pros

- Low cost option for additional N and P uptake from infiltration area.
- Smaller than other willow options.

- Coppicing regime more flexible, and can allow for 5yr rotation rather than the standard 3yr cycle; and thus can be used as a firewood crop.

Cons

- Lower nutrient removal than full willow filter area.

Fig. 7.11 – After three years of growth the willow stems will be large enough for chipping for fuel or landscaping. Leave for longer if you want firewood (design permitting).

Willow system comparison summary

Willow Systems Compared (also showing treatment wetland for comparison)

	ZDWF	WiFi	WPPerc	CW/RBTS
Treatment effectiveness	High	High	Medium	Medium
Ecological footprint	Low	Low	Low	Med
Wildlife value	High	High	High	Medium
Capital cost	€€€	€€	€	€€
Running costs	€€	€€	€€	€
Odour potential	Low	Low	Low	Medium
Safety risk	Low	Low	Low	Medium
Size	Large	Large	Medium	Small
Fencing	No	No	No	Yes
Electricity needed	Yes	No	No	No
Resilience to sludge overloading	Low	Low	Low	Variable
Can receive stormwater inputs	No	No	No	Sometimes
100% evapotranspiration to air	Yes	Sometimes	No	No

ZDWF – Zero discharge willow facility
WiFi – Willow filter for nutrient uptake
WPPerc – Willow planted percolation area
CW/RBTS – constructed wetland or reed bed

7.4 Source separation and composting systems

There are a number of specific problems associated with conventional flush toilets. These include:

- Over-consumption of treated, potable water for use as flush water and the associated issues of over extraction from surface water reservoirs and groundwater aquifers. Water conservation using dry toilets has been cited by Dubber and Gill in the EPA STRIVE report, 2013.
- Pollution of surface water resources and groundwater aquifers by the contaminants of domestic sewage.
- Ongoing diversion of biomass and nutrients from agricultural land to water or landfill by way of waste food and human excreta and the associated erosion of both quantity and quality of agricultural soil nationally and globally.

- The fossil fuel consumption and pollution of the aquatic environment by artificial fertilisers that are used to address the chronic losses of recyclable biomass material back to agricultural land. Vinnerås (2001) notes that by returning human urine, faeces and biodegradable solids (uneaten food waste and the food waste present in grey water) back onto agricultural land, the need for “fossil nutrient supplementation” would drop significantly.

There are many different eco-toilet designs available to overcome these issues. Urine separator toilets, compost toilets and faecal separators, to cite three categories, all developed out of an awareness of the growing problems of wasting both water and nutrients by flush toilets and causing water pollution with sewage effluent. Many different sewage management technologies have been developed and researched to meet our need for greater sustainability. Scandinavia has been particularly advanced in this regard, and is a European leader in urine separation for both domestic and municipal scale applications; compost toilet development; and faecal separation for use with flush toilet infrastructure.

Pros and Cons of Source Separation Technologies and Compost Toilets
Pros

- Water saving for low flush and dry toilet models, and thus also energy/carbon savings on water delivery to dwelling.
- Recoups biomass and/or nutrients.
- Less polluting of groundwater and surface waters than conventional flush systems.
- Potential for off-grid applications in remote locations.
- Compost toilets can be the lowest cost and most effective sanitation option.
- In-sewer systems such as Aquatron and Solviva Brownfilter systems look identical at the bathroom end of the system.

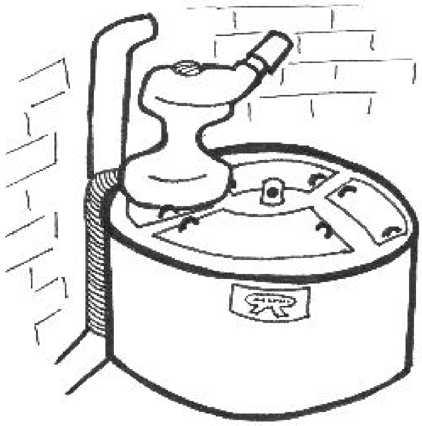
Cons

- Less familiarity at planning level and thus more costly for professional fees at planning stage.
- Less familiarity amongst tradesmen and less available in local hardware shops and thus may be more costly at installation.
- Less familiarity with users and reluctance on the part of some users (notably visitors, for example) to use compost toilets.
- Still requires treatment of grey water by another means.
- Although compost toilets are mentioned in EPA Code of Practice and other documentation, they are not clearly specified, thus hampering regulatory approval.
- Note; it is still necessary to design, construct and maintain with care to ensure full local waterway protections and sanitary management.

Urine Diversion Toilets
These include flush systems such as the Swedish Dubbletten toilet, as well as urine diversion inserts within toilet seats for compost toilets. Urinals are another form of urine diversion infrastructure, which are most common for men, but have also been developed for women. These range from elaborately designed ceramic plumbed

units to folded plastic fittings plugged into straw bales for outdoor festival settings, where the carbon nitrogen mix then composts down to form rich humus.

Fig. 7.12 – Urine diverting flush toilet. Image source: www.Dubbletten.nu



Faecal Separation with Flush Toilets

The main commercially available in-sewer faecal separator unit is the Swedish Aquatron unit. This uses gravity and centrifugal force to separate solids (faecal material and paper) from liquids (water and urine).

Fig. 7.13 – Aquatron faecal separator. Pipe from toilet at upper right; pipe from grey water fittings at upper left. Image: Susie Harty

Another separator system is the US Solviva Brownfilter system which uses a mix of woodchips (90%) soil (5%) and compost (5%) as a filter matrix, through which the flush water is routed for separation and filtration, leaving the top surface retained for vermicomposting.

Compost Toilet Systems

There is a vast array of compost toilets available, from low cost DIY models to commercial scale pre-moulded units. The following general classifications may be useful in selecting a model that works well for a given context:

- Indoor or outdoor.
- Self-contained composting types or remote composting types.
- Electrically powered aeration, manual rotary aeration or stationary.
- Electric drying or not.
- Urine separation or mixed.
- Compost chamber size.
- Maintenance input.
- Fully Dry Toilet or Hybrid System.
- Cost.

Fig. 7.14 – Community scale compost toilet; French designed Kazuba toilet model. Image source: www.waterlesstoilets.co.uk

Fig. 7.15 – Example of indoor bucket-type compost toilet system with outside compost set-up. (silver bucket for wood shavings). Image source: D. Taylor

8.0 Potential Sewage Treatment Options

Action for water quality protection and enhancement can be taken at all levels, from the local, to the national to the global. Given that there is no sewer network in Ballinahown and no sewage treatment other than septic tanks with, it appears, mostly failed percolation areas, any actions to address sewage pollution would be of direct benefit to the river quality.

The main areas for treatment can be grouped under the headings below, listed in order of their impact on the River Worm.

1. New full village sewer connection, with removal from storm sewers; and full secondary and tertiary treatment.
2. New system for the septic tank serving the houses at Woodland Avenue; this being the largest single population size in the village.
3. New system(s) serving public buildings: school, sports grounds building, community hall and church.
4. New systems serving individual houses and businesses in the village on a case by case basis.

Note that the preferred option is a full new system, but given that the timeframe for Irish Water projects is outside of local control, the other items on the list may be implemented on a case by case basis, depending on the budget available.

Given the poor percolation characteristics of the underlying soil in the village, it should be assumed that any sewage treatment system will ultimately discharge to the River Worm. As such, whether a treatment system is proposed for an individual building or the entire village, it is recommended that full secondary and tertiary treatment be used. Tor a typical treatment system the following elements are required:

1. Settlement stage (e.g. septic tank)
2. Secondary aeration (e.g. standard mechanical sewage treatment system, constructed wetland, gravel reed bed etc.)
3. Tertiary treatment (e.g. additional constructed wetland or gravel reed bed)
4. Disposal (e.g. direct discharge to the river, infiltration on suitable lands if percolation to ground is possible, willow-planted percolation system for enhanced uptake of effluent to air)

The previous section of the report outlines the main ecological methods of wastewater treatment in general terms. The following two options that stand out as being most viable for the village, given the heavy underlying clay subsoil in the area. These are a constructed wetland system or a willow filter system; each with further options set out within the list of components required.

Either would be effective in addressing sewage treatment concerns so they are not listed in order of preference. Note that these methods may be used for any or all of the areas listed above.

Option A – Treatment wetland system:
1. Septic tank for primary settlement
2. Constructed wetland secondary treatment (or reed bed, or mechanical treatment if space is limited)
3. Constructed wetland tertiary treatment (or reed bed option if space is limited)
4. Willow planted percolation area
5. Overflow discharge to River Worm.

Option B – Willow filter system:
1. Septic tank for primary settlement
2. Willow plantation for effluent filtration and uptake of nutrients; may or may not have zero discharge depending on design.
3. Overflow designed into the system to allow for discharge to River Worm during wet conditions. A follow-up wetland filter may be a useful addition en route to discharge

Sizes of each of these approaches will vary with the application, and thus population size, chosen. Wetland and reed bed areas per population size are given in chapter 7; willow system sizing is more case-specific.

8.1 Village scale opportunities

The ideal scenario is for a new sewer and treatment system to be installed by Irish Water within the next 12-24 months.

Treatment wetland or reed bed

An excellent example of thorough village scale treatment is at Kiltimagh in Co. Mayo. A mechanical aeration system provides secondary treatment of foul sewage from the village; and tertiary treatment is provided by a large constructed wetland following it. Stormwater from the village is also routed to the same constructed wetland for filtration there. Storm surge overflow from combined foul and storm sewers bypasses the mechanical aeration unit to protect it from inundation and instead reroutes this excess flow volume of mixed sewage and stormwater into the constructed wetland system. In this way the treatment wetland provides high quality treatment of sewage, management of stormwater and overall protection of the receiving river, into which the final effluent flows.

Such a system would provide excellent protection of the River Worm if implemented at Ballinahown. The system could be very modest in cost if the mechanical aeration system was replaced with a large initial secondary treatment sized constructed wetland. This can be particularly cost effective for sites such as Ballinahown where the underlying subsoil would make a perfect impermeable liner, thus avoiding the cost of a plastic membrane.

Based on CSO figures, a population size of 300pe has been selected. Thus a village system would require a constructed wetland size of 9000m^2 (*c*.2 acres) to provide full secondary and tertiary treatment. Alternatively a gravel reed bed system would require approximately half an acre of ground; either for a vertical flow or horizontal flow reed bed type. These would require lining with plastic, and as such may be more costly than the larger constructed wetland option. Estimated constructed wetland cost: €100k; or reed bed costs of a similar amount despite the smaller footprint area.

Mechanical aeration option
Mechanical aeration is the standard secondary treatment approach, and has the advantage of having a smaller land-take. If used, a follow-on tertiary treatment constructed wetland would need to be 3000m^2 in size. Alternatively a horizontal flow reed bed of 300m^2; or a vertical flow reed bed of 600m^2 could be used. The main drawback of mechanical aeration is the carbon footprint of ongoing pump operation and the requirement of a steady electricity supply for effective treatment. Estimated costs for a basic mechanical aeration system: €100-150k plus tertiary treatment wetland costs of €30-50k or reed bed costs of €15-25k. Note that this could rise to over €1M if a full Irish Water system specification is required (cost not including the sewer network work itself).

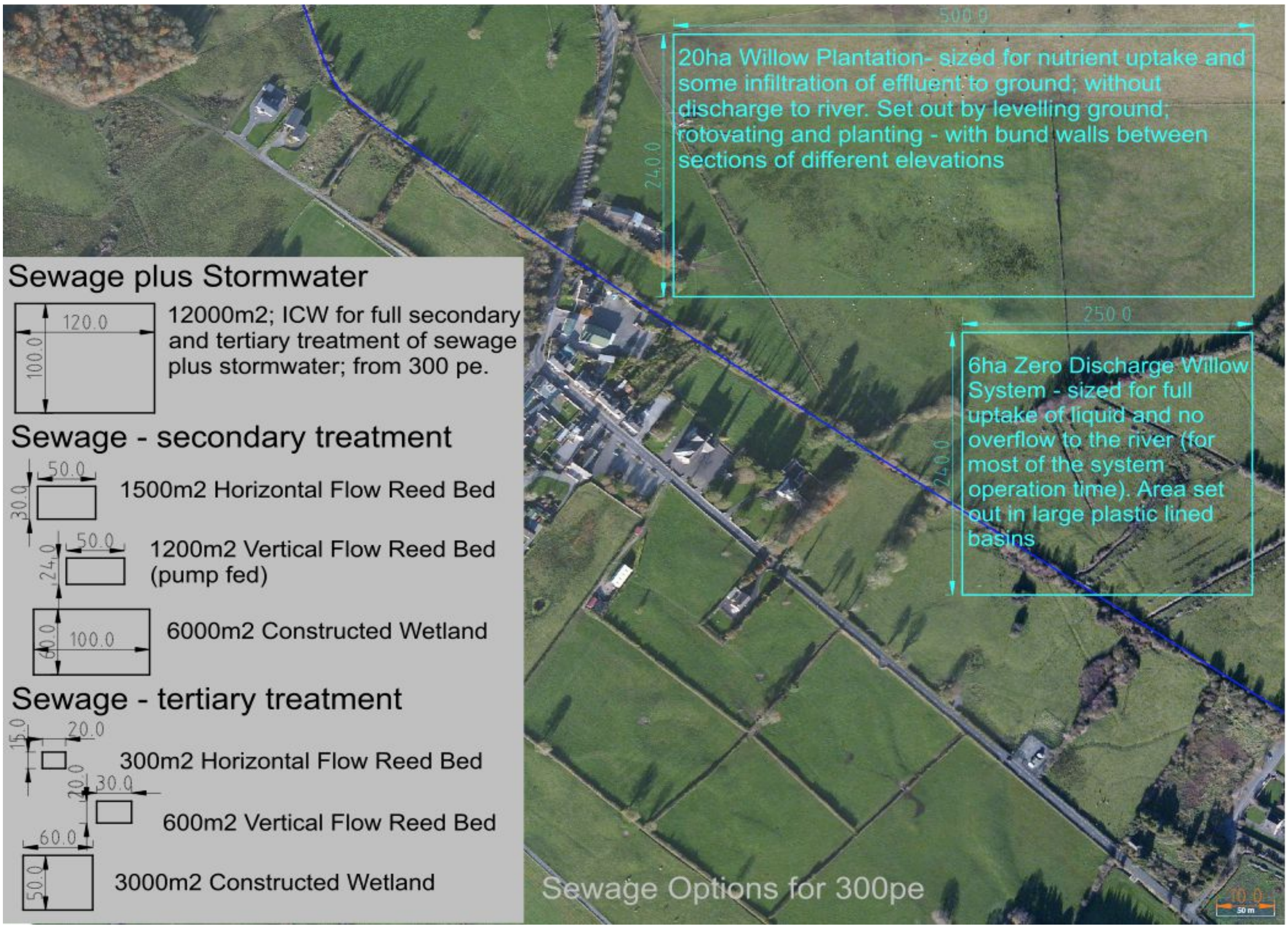
Whichever system is selected for secondary aeration and tertiary polishing, the primary cost of the overall system is likely to be the construction of a new sewer network to gather the effluent and pump it to the treatment area. Estimated costs for new sewer network: €5-900k.

ICW option
With any sewage system, removal of stormwater inputs is recommended for optimum treatment system effectiveness. If a constructed wetland is used then full removal may not be strictly necessary given that these systems can handle the variability in flow rates; but the treatment wetland size should be increased from 9000m2 (for full sewage treatment to both secondary plus tertiary standard) to 1.2ha (Integrated Constructed Wetland system sizing to include both sewage plus stormwater, as per Dept of Ag. ICW guidance document). This is the internal effective area, the wet area of the system; with embankments etc. being additional.

Zero discharge willow option
An alternative to standard secondary and tertiary treatment is to use a zero discharge willow filter or a willow planted percolation area. The area requirements for 300 persons would be *c*. 6ha of land; at 1.5m system depth set out in blocks of 6m width, with 5m buffer area between each block. A cover plastic sheet of 3m per block is used to divert rainfall. Estimated lined willow system cost: €500k-1M plus sewer network construction.

Willow filter
Another approach is to use a sewage irrigated willow plantation; with no liner and no cover plastic. The system size requirements for Ballinahown climatic conditions and allowing a 1mm/d infiltration rate are *c*. 20ha. This could be used as a commercial willow crop for supply to the ESB. Establishment costs are estimated to be €500k plus sewer network construction.

Fig. 8.1 – Sizing options for reed bed and constructed wetland systems; showing Integrated Constructed Wetland (ICW) for combined storm and sewage treatment; or standard EPA sizing for sewage only, with stormwater removed. Wetland and willow options shown on aerial map as an indication of scale. Areas shown are effective areas only and do not include embankments, ancillaries or minimum separation distances to housing, roads, waterways etc.



Focus on what can be done

All this said, given that a new system is not currently known to be in the Irish Water plans in the near future, there are many options for smaller initiatives that may be undertaken within Ballinahown to begin to address the impacts of sewage pollution on the River Worm in the immediate term.

8.2 System for selected public buildings

While a full village system remains the prerogative of Irish Water, it is still possible to implement specific actions at village level. One such action is to build a sewage treatment system for one or more of the public buildings in the village. Sewage from public buildings such as the church, community hall, school and/or sports grounds changing rooms could be pumped to a suitable location for full treatment, independently of any Irish Water measures that may be carried out.

The following population sizing has been used to calculate the loading rates from different public buildings within Ballinahown:

Table. 8.1 – Population sizing calculations for Ballinahown sewage designs.

Wastewater source and description	# units	Persons / unit	Total persons	PE category (EPA 2000 Table 7)	flow, l/p/d	BOD, g/p/d	ref. flow fig.	pe, for flow	ref BOD fig.	pe, for BOD	Total Flow l/day	BOD loading g/day
School: students	1	102	102	Non-residential no canteen	40	20	150	27.2	60	34.0	4080	2040
School: staff	1	9	9	Non-residential no canteen	40	20	150	2.4	60	3.0	360	180
Hall; max night	1	30	30	Amenity sites - function rooms	10	10						
Hall; avg daytime event	1	50.0	50	Amenity sites - function rooms	10	10						
Hall; max daytime event	1	300.0	300	Amenity sites - function rooms	10	10	150	20.0	60	50.0	3000	3000
Sportspark: 30 people for toilets (2d/wk)	1	30	30	Amenity sites - football club	30	20	150	6.0	60	10.0	900	600
Church: FH estimates	1	10	10	Amenity sites - toilet blocks (per use)	5	10	150	0.3	60	1.7	50	100
							150	0.0	60	0.0	0	0
Total pe figures			**491**					**55.9**		**98.7**	**8390.0**	**5920.0**

Note that the hall number selected is given for the larger projected community events. These are occasional events only, and are unlikely to double up with the standard hall usage, and as such they are accounted for separately from average daily usage figures used in the system design calculations. If daily usage figures were to be used for the hall instead of the larger gathering figures, the overall loading rates for the community buildings drops to *c*. 40pe for flow and *c*. 60pe for BOD loading, as compared with 55.9pe for flow and 98.7pe for BOD shown above. As such if a smaller design size is required to fit a given area, this may reasonably be adopted without compromising on effluent quality.

Other than for the hall, the population sizes above show average usage for each venue. The number of times that each venue is used varies, and is typically considerably lower than 365d/yr. Thus the calculation sizes for treatment system options shown below are likely to be somewhat overestimated. Thus the treatment effectiveness is likely to be of a higher quality than standard; or conversely the system size may possibly be adjusted down if required to fit a given area of land.

If we look at wetland and willow options as per the previous section and apply the wastewater loading calculated above (rounded up to 100pe for a combined community building system), the following system sizes are required:

Option A – Treatment wetland system:

1. Septic tank for primary settlement; size requirement of 16m^3 (this may already be accounted for within the existing tank capacities already present at each separate location)
2. Constructed wetland secondary treatment system size of 2300m^2 including embankments (or reed bed of 600m^2; or mechanical treatment if space is limited).
3. Constructed wetland tertiary treatment system size of 690m^2 (or HF reed bed option of 100m^2; or VF reed bed of 200m^2 if space is limited).
4. Willow planted percolation area of between 1400m^2 and 2.8ha depending on the design rationale selected. Sizes within the range 1400 – 4000m^2 are based on the standard EPA Table 10.1 infiltration area sizing for the slower draining soils within the acceptable range of values (Percolation Values between 75 and 120 minutes; which are quicker draining than will be achieved at Ballinahown due to heavy clay in the area). The larger size of 2.8ha is based

on achieving full nutrient uptake (assuming full daily usage, which is an overestimate of the size needed). For this project, sizing should take into account the availability of area as well as wastewater loading factors. A more reasonable preliminary estimate may allow for 50% usage across all venues; leading to a revised nutrient uptake area of 1.4ha of willow area as an upper maximum useful system size. Note that the smaller size of 1400m^2 will still offer greater nutrient removal than a direct discharge to the river and should not be dismissed if land availability is too limited for the larger option.

5. Overflow of excess liquid flow to River Worm under licence from Westmeath County Council at times of year when evapotranspiration is low and rainfall is high.

Fig. 8.1 – Sizing options for selected buildings only

Option B – Willow filter system:

1. Septic tank for primary settlement of 16m^3 as described above.
2. Willow plantation for effluent filtration and uptake of nutrients; sized at 3.1ha for full phosphorus uptake or 2ha for zero discharge to surface waters (allowing for 1mm/d infiltration to ground; 1m system depth and zero plastic cover sheeting around basin perimeters). Note that the sizes here vary from the willow percolation sizes outlined above due to differences in nutrient

loading for septic tank effluent vs tertiary treated effluent; and also on the differences between willow design sizing and EPA infiltration area sizing.

3. Overflow to be designed into the system to allow for discharge to River Worm during wet conditions as a failsafe measure, via a wetland filter.

8.3 Individual homes and/or businesses

On an individual home or business level, suitable sewage treatment systems may be installed to address each building for those who wish to stop contributing to the sewage pollution of the River Worm. All of the systems previously discussed would also be suitable on a much smaller scale.

Options include the following - within sites that are large enough to accommodate them. The systems below are sized for 3-bedroom dwellings (taken to have a population equivalent of 5 persons, based on the EPA Code of Practice for domestic scale wastewater treatment systems).

Secondary treatment system sizing and approximate costs for treatment element alone; excluding septic tank, pumping if needed, or percolation area/discharge to the river.

- Constructed wetland system – 100m^2. €2000 on clay subsoils
- Horizontal flow gravel reed bed – 25m^2. €3000
- Vertical flow gravel reed bed – 20m^2. €3000
- Mechanical aeration system or media filter unit – 4m^2 tank. €3-5000 + electrical connections

Tertiary treatment system sizing should be used with any of the above for enhanced treatment:

- Constructed wetland system – 50m^2. €1000 on clay subsoils
- Horizontal flow gravel reed bed – 5m^2. €2000
- Vertical flow gravel reed bed – 20m^2. €2000
- Sand filter or media filter unit – 5 to 16m^2 depending on brand and system type. May be covered with soil in a small garden. €1500-3000

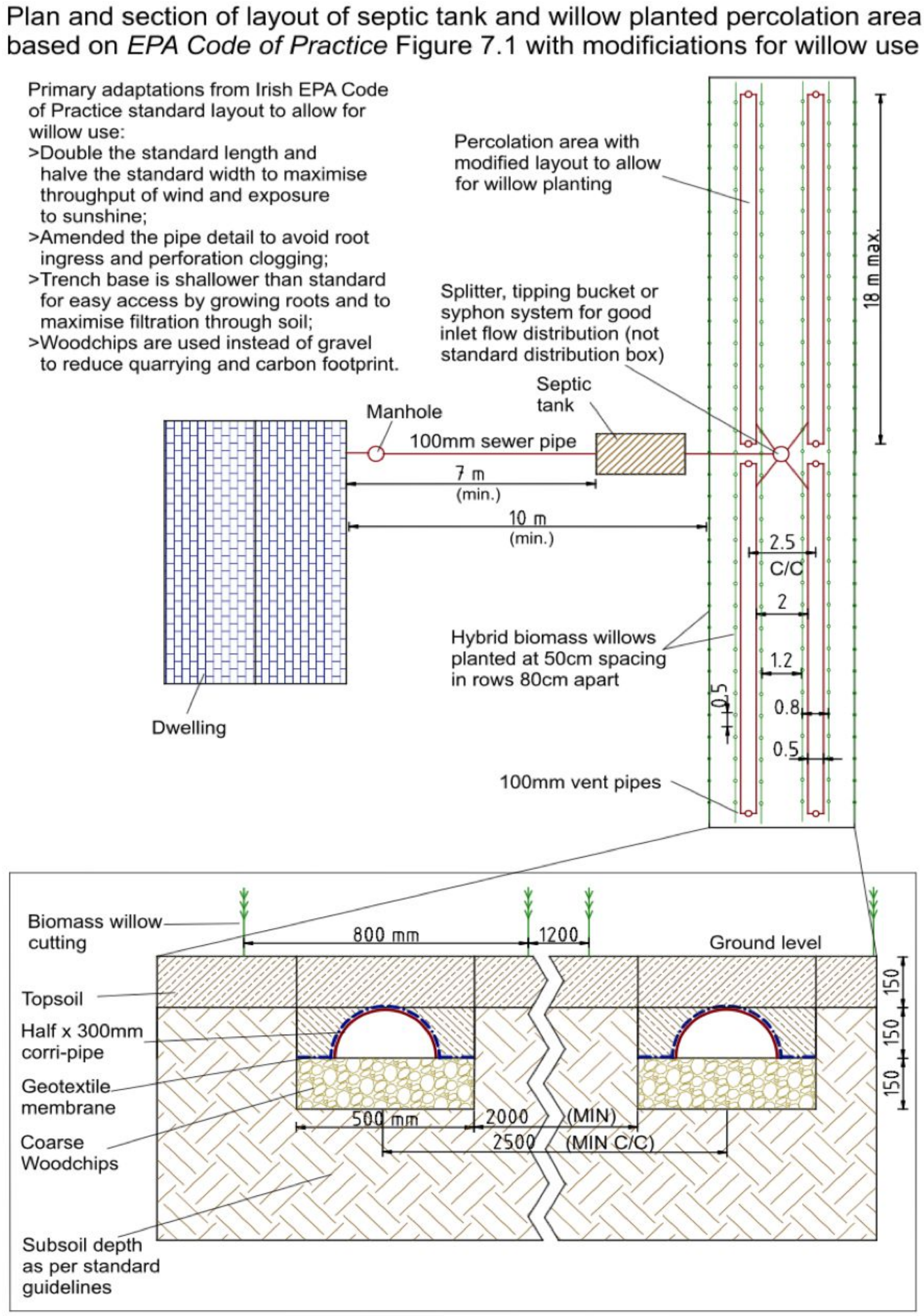
Discharge to river

Note that the high clay content in Ballinahown means that infiltration to ground is unlikely to be successful. Thus a discharge to surface waters is the only practical route (except for a zero discharge willow system, which would require a combined treatment and disposal area of 6m x 60m; at a cost of *c.*€30,000).

Willow planted percolation

Ecologically a willow planted percolation area would provide a lot of uptake of nitrates, phosphates and liquid volume during the growing season, and thus give greater protection to the river. The required system size is as per a standard percolation area (125m^2 for 5pe; see Fig 8.2 below). Design in an overflow pipe to the river for use during the dormant season when plants aren't growing and at times of high rainfall. Note that this is recommended as an add-on to the Code requirements for secondary plus tertiary treatment; but if sized appropriately may be used as a replacement to full secondary and tertiary treatment. A discharge licence is generally a legal requirement for any system discharging to a watercourse, but given that the existing set-up includes informal discharges it may be possible to negotiate an exemption with WCC for the village as a whole as part of the process of improving river water quality.

Fig. 8.2 – Willow planted percolation area layout is essentially as per standard EPA guidance but with a modified pipe set-up to prevent blocking by willow roots.



8.4 Water reduction and stormwater management

Not every garden will be large enough for any of the systems mentioned here. Neither will everybody have the budget to spend on a new on-off treatment system. There are other options however which would be beneficial for water quality if implemented by individual homes and businesses in the village.

- Water conservation to reduce the volumes of septic tank effluent being discharged; and thus helping to maximise the effectiveness of the existing percolation areas.
- Reducing pollution loading to the septic tank (and thus the river) by avoiding the use of garbage grinders; avoiding pouring liquids such as spoiled milk down the drain but instead adding it to home compost systems. (As standard always avoid pouring toxic or non-natural substances down the sink).
- Compost toilets are an excellent way to generate rich soil instead of pollution, particularly where inadequate treatment is in place for dealing with black water from flush toilets. These offer both water reduction and pollution reduction benefits.
- Avoid stormwater misconnections. Check that washing machines and dish washers in particular have not been plumbed to rainwater gutters, thus bypassing the septic tank and entering the storm drainage network directly. The urgency for this measure is somewhat tempered by the likelihood that much of the septic tank effluent in the village may already flow directly from failed percolation areas into the stormwater drains and on to the river.
- Plant all existing percolation areas, where garden layout permits, with biomass willows. This will help to mop up nitrates and phosphate from the effluent and thus keep the river cleaner. In the absence of replacement of piping as per fig 8.2, this process has a high likelihood of blocking sewer pipes so should be carried out only as an interim measure pending full sewage treatment infrastructure being introduced.
- Remove all storm sewer networks (street gullies, downpipes etc.) from percolation areas to ensure that the percolation areas are given the maximum opportunity to function correctly.

8.5 Sewage system implementation considerations

- Responsibility and authority: Irish Water have both the responsibility and authority to construct a village scale system. Two approaches may be taken in the village in this regard; either liaise closely with IW to promote and encourage them to build a village scale system in the next 12-24 months or explore avenues with IW and WCC to begin progressing system construction independently and seek alternative funding for this work yourselves.
- System size: for group or full village treatment, a minimum separation distance from the system to any dwelling will vary from 28m to 50m; and the area required for constructed wetlands and willow filters are large in comparison to mechanical aeration systems with direct discharge to surface waters. Thus a large land area will be needed for these options.
- Budget: The cost of these measures varies from a domestic scale willow filter buffer zone of €1000; up to a village scale system of up to €1M or more (may be lower if not to full IW spec.).

- Odours: Factor odour generation into the design phase allow for careful siting. Polluting the river doesn't smell, whereas returning septic tank effluent to a constructed wetland basin or willow plantation has the potential to have occasional odour generation. This can be ameliorated by careful use of grey water chemicals and minimising bleach use and by careful siting of the system.
- Phasing of the works: Ideally over time a full village scale system would be built, sooner rather than later. However waiting for the budget or IW green light should not be obstacles to progress on other areas. Ideally for any project larger than a single building (or two neighbouring ones, for example), select a site that would be large enough to expand to accommodate a larger village-scale system at a future date.
- Coordination with other projects: stormwater infrastructure is currently intertwined with the existing foul sewage set-up. As such any works on one will require coordination with the other.

8.6 System maintenance considerations

Regardless of the system selected it is important that the settlement systems (the septic tank or settlement stage of a mechanical aeration system) are kept desludged as needed such that solids are not carried on to the next phase of the system.

Other factors to consider during maintenance of any system include regular checks on pumping equipment, free flow into and out of system, integrity of fencing, and checks on the quality of effluent (often optional but recommended).

Constructed wetland systems are remarkably maintenance free once the above issues have been addressed. If sludge accumulates at the inlet this may need removal over time, but otherwise the system can function effectively without input for years at a time.

Willow filters require regular harvesting. Typically willows are harvested on a 3-yr rotation basis. Domestic scale systems are usually harvested a section at a time each year, with occasional rest-years, whereas larger willow plantations all harvesting is typically done in a single year. This allows for economies of scale, reducing the rent of harvesting machinery per unit area and offsetting these costs with greater volume of cut willow chips for sale. ESB's Edenderry power plant is currently co-fired with willow biomass and has the potential to provide a market for any large-scale willow biomass generation at Ballinahown.

9.0 Stormwater Impacts and Options

Stormwater is the term used to describe the water flowing from paved surfaces such as roads, roofs and yard areas. Stormwater flowing from roads and yard surfaces typically has high levels of hydrocarbons from petrol, diesel and oil drips on the roads; microplastics from tyre wear; silt and grit; and some levels of BOD, N and P at levels somewhat lower than for sewage.

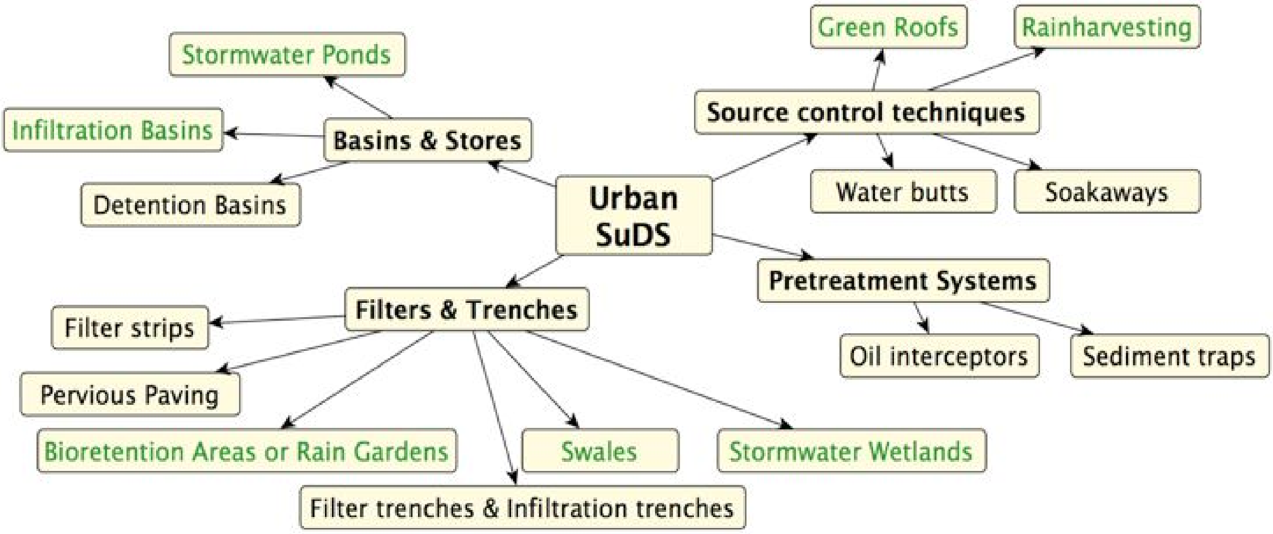
Another important factor in stormwater is the variability of the loading rate. When heavy rains fall on roads and paved surfaces the resulting runoff moves into adjacent watercourses much more quickly than if it lands on natural habitat such as woodland, intact peatland or undisturbed grassland. This results in a greater overall volume of rain appearing as surface runoff; a much faster catchment response time – the time taken for rainfall to show up in rivers and streams; and a greater flood peak – the maximum volume of water in the river at any one time. The result of these three factors is that where natural habitat or farmland are converted to urban areas or paved surfaces, the potential for both flooding and droughts in the receiving surface waters will increase.

There is a further issue with stormwater which is suspected to be present at Ballinahown. Namely that where foul sewers (from toilets and grey water) are combined with storm sewers (from roof surfaces, roads and yards) the sewage has a tendency to get flushed through any treatment system too quickly during times of heavy rainfall. This is noticeable when there is a spate of beach closures following heavy summer rainfall, for example. The sewage volumes haven't necessarily changed, but the rainfall mixing with the existing sewage loading flushes through the treatment systems and is piped directly into the beach or nearby river.

In the case of Ballinahown it isn't so much that there is a planned storm flow diverter (a pipe which routes sewage to the river during heavy rainfall in order to protect the main sewage treatment system or septic tank from being flushed out) but that the village does not have any collective sewage treatment at all. Flow and dye-test assessments show that overflow from septic tanks from at least some of the houses in Ballinahown enters percolation areas with inadequate soakage which then drain directly into the stormwater drainage pipes, leading to the River Worm. Thus to assist with the functioning of the existing percolation areas, such as they may function at all on the heavy clay subsoils, it may be greatly beneficial to catch and store stormwater from roof and yard surfaces and keep it above ground, separate from the sewage pipework beneath. This would help separate the two water sources, making the sewage easier to treat appropriately and reducing the impact of stormwater on the River Worm.

In terms of solutions, Sustained Urban Drainage Systems (SUDS) or Sustainable Drainage Systems (SuDS) are techniques or technologies that are used to protect waterways from silt, nutrients or other contaminants in stormwater. SUDS were developed as a design solution in an urban context to help prevent flooding downstream of new developments or existing urban areas. SUDS are designed specifically to offer hydraulic buffering for flood control, and can also offer water filtration as part of their overall design, depending on the system selected.

Fig. 9.1 – Overview of urban SUDS options. Green denotes more ecofriendly options



Following are some of the different categories of SuDS units that can be used for urban runoff from areas such as Ballinahown. Many can also be used on a smaller scale for individual houses where home owners want to minimise their impact on the River Worm by reducing flood peak runoff volumes and the potential for storm sewer overflows.

- Source control techniques include **green roofs**, **soakaways**, **water butts** and **rainwater harvesting systems**. These minimise the volume of water contributed to the wider catchment during a storm event, making storage and treatment more straightforward and effective.
- Pre-treatment systems such as **oil interceptors** and **sediment traps** are typically concrete or plastic tanks which are useful (and/or necessary) where hydrocarbons are stored or likely to be part of stormwater runoff.
- **Filter strips** are wide grassed or thickly planted buffer zones adjacent to impervious surfaces for treatment of runoff water. These are typically used alongside new motorways, but perimeter planting adjacent to car parks can be an effective urban application.
- **Filter trenches** and **infiltration trenches** are gravel filled trenches which treat runoff water from road edges or paved areas.
- **Swales** are wide grassed channels which (typically) permit infiltration as well as transporting runoff water and/or providing storage. These are useful on sites where the topography supports an easy introduction of open drainage rather than covering in pipework.
- **Bioretention areas** are shallow planted areas that temporarily store stormwater runoff and allow it to percolate into the ground. Sometimes called **Rain Gardens**, these are typically engineered areas that are filled with soil, gravel or other medium and planted with plant species that can tolerate cycles of flooding and drying. They are used most often in urban landscapes

for receiving road runoff as a landscaped feature within a street or car park. They are also useful for receiving roof runoff from individual buildings in the form of a raised planter.

- **Detention basins** are designed for water quality improvement as well as storage of runoff in storm events. They are typically dry basins, but built to facilitate flooding to a considerable depth as needed for storage purposes, then releasing water to the receiving environment or the next stage of the SUDS treatment train. They are often plastic lined and not necessarily as effective at pollution removal as stormwater wetlands for example, so while they provide flood water storage, they are not necessarily the best option where uptake of residual oil/petrol or silt inputs are likely.
- **Infiltration basins** function in a similar manner to detention basins, but are designed specifically to facilitate infiltration of all flows into the ground. These can be very cost effective to build, and can often simply rely on contouring of existing ground within green spaces down-gradient of runoff areas.
- **Pervious paving** allows water to flow into a gravel substrate beneath the paved surface where it is stored for percolation, reuse or for filtration through the substrate to the receiving water or next stage of the SUDS.
- **Geocellular systems** are preformed plastic media which can be used to store runoff water below ground beneath paved areas. They are expensive to install, particularly in existing sites and do not offer a filtration function.
- **Sand filters** are typically used from industrial yards or urban runoff areas where elevated pollution loads are anticipated, or where receiving water sensitivity is high. They require more regular maintenance than some other solutions such as ponds, stormwater wetlands or infiltration basins.
- **Ponds** are a popular SUDS component for both motorway runoff and urban runoff. They are designed to maintain a sufficient depth of water, as well as providing runoff water storage and filtration. They can double as a habitat for wetland wildlife.
- **Stormwater wetlands** are relatively shallow wetland areas that are designed to both store and filter the water volume generated during a storm event. They can be low cost to build and maintain, and provide valuable wildlife habitat.

Although SUDS units are typically designed for urban areas, they can also be used for single houses by home owners wishing to help contribute to a healthy catchment. The most common domestic stormwater SUDS type is a soakaway, in gardens that have sufficient infiltration to allow water to percolate into the ground. Other management methods that are common but not healthy for the wider catchment are direct discharge to streams or rivers (resulting in exacerbation of both flood and drought events) and discharge to foul sewer (what is then called a combined sewer, which results in overloading of the sewage system during rainfall events and consequent pollution of the watercourse that receives the final sewage effluent).

Options for single house stormwater management that offer greater protection to nearby waterways can include water butts for garden watering or rain harvesting for domestic reuse, green roofs, swales, stormwater ponds, bioretention areas or rain gardens (including raised planters) and swales. These all slow the flow of water from any single rainfall event, helping to minimise the potential for both flooding and droughts, and some also allow for greater filtration prior to water reaching the nearest waterway.

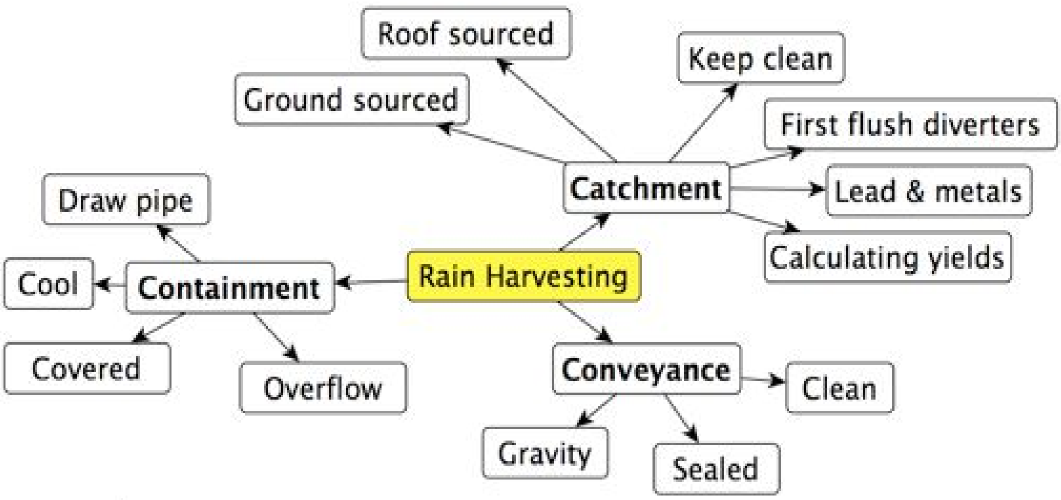
Regardless of the application any SUDS unit needs to be carefully designed and constructed or installed in order to fulfil the required objectives, in this case amelioration of an existing runoff issue in terms of both volumes and quality. The CIRIA SUDS Manual[4] is a useful reference for SUDS design. Note that many of the low-tech, low-cost solutions can often involve lower maintenance in the long term, as well as being more affordable at the start. Where green areas are present, contouring of the ground can provide an effective infiltration basin or filter wetland, depending on the infiltration rate in the indigenous soils on site.

The SUDS systems that are considered most suitable for application at Ballinahown are presented in more detail below.

9.1 Rainwater Harvesting

Catching rainwater and using it for garden watering, driveway washing or car washing is an excellent way to reduce the overall amount of rainwater flowing to the stormwater sewers.

Fig. 9.2 – Rain harvesting elements: catchment, conveyance, containment.



For domestic scale rain harvesting the most common water source will be the roof of the house; routed via gutters and down pipes to a water butt. If there is lead flashing you may wish to avoid using the water on your vegetable garden; or paint the flashing with suitable paint to seal it and keep the water cleaner. Excess water may be routed back to the storm sewer or preferably to a garden pond or rain garden.

4 Woods-Ballard B, Kellagher R, Martin P, Jeffries C, Bray R, Shaffer P (2007) The SUDS Manual. CIRIA, London

Fig. 9.3 – Downpipe with rainwater diverter fitted and routed to water butt. When fitted just below the top of the water butt, this device routes excess water back into the existing drainage gully. The downpipe enters into a separate container in this example but may just as easily be routed to the storm sewers, garden pond or rain-garden instead.

9.2 Swales

Grassed or wetland planted channel set on or close to the contour for filtration of water en route to the river. (See *In Praise of Swales* in Horticulture Connected, 2019, for more Info: https://horticultureconnected.ie/?s=feidhlim+harty&post_type=post)

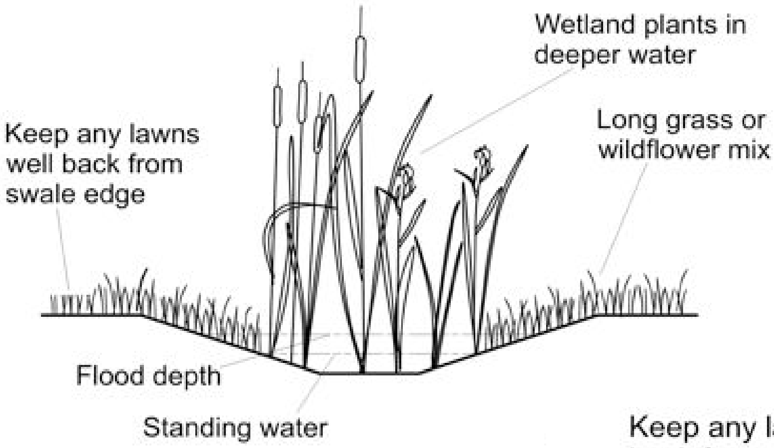


Fig. 9.4 – Section through planted wet swale (L). In essence, a wider version of this set-up serves as a stormwater wetland.

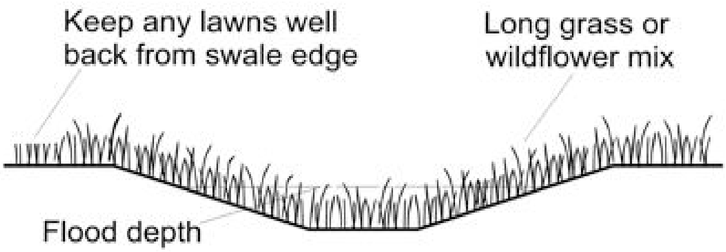


Fig. 9.5 – Section through a grassed dry swale (R). Careful contouring of suitable ground can create opportunities for filtration with very little cost.

Fig. 9.6 – Roadside swale in north Cork, with earthen check-dams and pocket pools planted by volunteers as part of local community scheme.


Fig. 9.7 A & B – Two swale examples from a stormwater drainage system in Denmark for village urban runoff. Dry grassed swale (L) and wetland planted swale (R) both filter water en route to a stormwater wetland lower in the catchment.

9.3 Bioretention areas / rain-gardens

Planted infiltration areas for receiving runoff from roads or car park areas to provide both filtration and attenuation of the runoff en route to ground. These may have an overflow facility to surface water for excess volumes during storm events, but during dry weather flows are typically able to store and percolate all inputs. (https://horticultureconnected.ie/horticulture-connected-print/2020/spring-2020/site-drainage-with-an-eco-twist-feidhlim-harty/)

Fig. 9.8 – Rain-garden during downpour (R) Reproduced with permission from State College PA, USA. www.statecollegepa.us/345/On-Street-Rain-Gardens

Fig. 9.9 – Sunken rain-garden strips between parking rows (below). Image source: www.ecolandscaping.org

Fig. 9.10 – Rain-garden for car parking or street-side areas

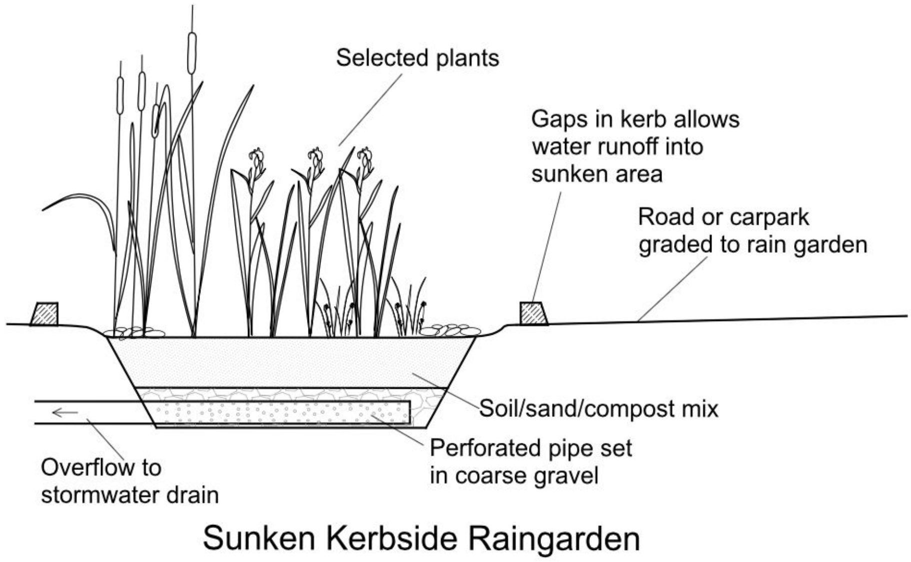


Fig. 9.11 – Rain-garden for domestic garden or community green area

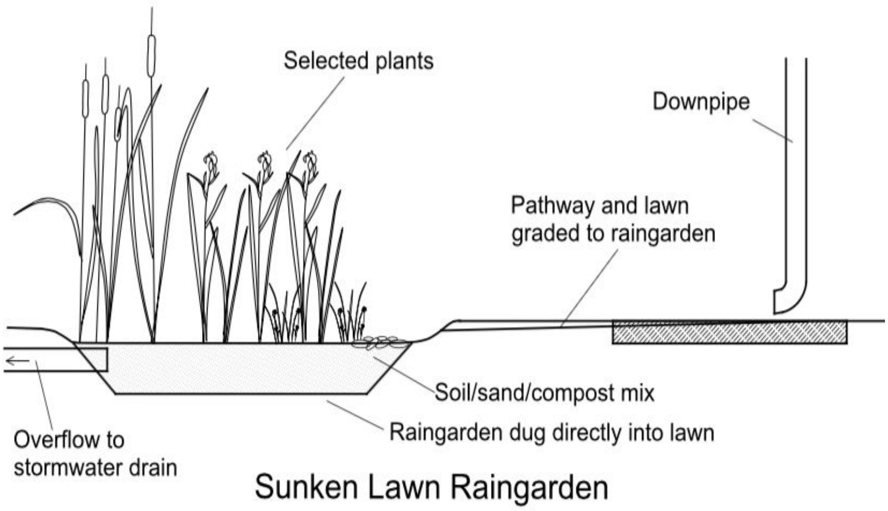
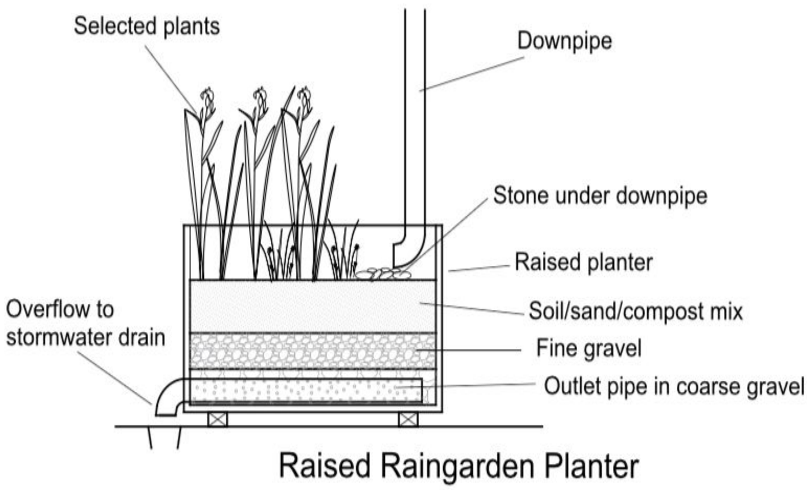


Fig. 9.11 – Raised rain-planter for beside homes or public buildings



9.4 Stormwater ponds and wetlands

Filter marsh or pond areas can receive rainfall runoff from streets for storage and filtration en route to the river. Some infiltration may occur, but the base is sufficiently impermeable to support a wetland habitat (in the case of stormwater wetlands) or is lined with indigenous clay, peat or synthetic liner membrane (in the case of ponds). (See: https://www.wetlandsystems.ie/Stormwater.html)

Fig. 9.11 – Stormwater wetland examples at University of Limerick (L); and Moycullen stormwater pond, Co. Galway (R and lower)

10.0 Potential Stormwater Treatment Options

In many ways it is easier to commence with stormwater management measures than sewage measures. Planning permission is generally not a requirement for the former, and stormwater is generally easier to incorporate into park and green-space layout than is sewage effluent treatment.

Despite the comparatively low pollution levels in stormwater in general terms, it must be remembered that here in Ballinahown the stormwater is likely to be combined with septic tank effluent. While this may raise challenges in terms of allowing for potential contamination, it means that any stormwater measures will benefit the river more than would otherwise be the case.

The main priorities for stormwater management are the areas where it is combined with septic tank effluent. With this in mind the following list is prioritised in order of value to the river water quality.

1. Full village stormwater filter system, potentially tapping into the existing stormwater sewer system and ensuring that all septic tank effluent ingress and grey water misconnections are excluded and rerouted.
2. Smaller systems for selected areas of the village, again excluding all septic tank effluent and grey water misconnections. The larger the catchment area collected the greater the positive impact on the river; prioritising those areas which are most likely to have septic tank effluent ingress or are easiest to verify as being contaminated. Specific areas for action could include some or all of the following:
    - Individual houses/buildings or groups of of houses
    - Selected sections of public roadways
    - Agri-supply yard and buildings
    - Community hall and car park
    - St. Colmcille's Church building and car park
    - School and sports buildings, yards and car parks

The previous section of the report outlines the main ecological methods for stormwater management; predominantly focusing on SUDS units for both filtration and attenuation, plus habitat value and/or reuse of harvested rainwater. The options that stand out as being most suitable for use in Ballinahown include the following:

- Stormwater wetlands
- Stormwater ponds
- Village scale bioretention areas (large planted infiltration basins)
- Hydrocarbon interceptors (where needed) for initial separation of petrol, diesel and oils from road/yard runoff
- Rainwater harvesting for domestic water needs; yard and garden use
- Raised planters
- Bioretention areas or rain-gardens for gardens or car park areas
- Swales – for above-ground routing runoff water from source to treatment.

Selection of each system type will depend on the given application and will vary with catchment type and hence surface pollution load, likely effluent contamination levels, reuse applications, area availability and budget.

Note that all grey water misconnections to stormwater sewers should be either returned to the septic tanks or filtered via a reed bed or other system prior to release to the stormwater drains.

Following are some possible approaches that may be taken at Ballinahown to address stormwater inputs to the River Worm; ranging from a full village scale system to domestic scale actions.

10.1 Village scale stormwater treatment

If full sewage treatment is to be built for Ballinahown by Irish Water, this would include a reconstruction of the existing stormwater drainage network. While that scenario would clearly be very beneficial for water quality in the River Worm, the likelihood is likely to be low, so in the meantime efforts can remain focused locally to reduce stormwater inputs to the existing storm sewer network, which is work which can more easily be done at a community level. Much of the work that can be done to address current stormwater runoff would be useful for any future sewage treatment works. Thus local action can commence immediately without compromising future works nor doubling up overly on works.

If a new sewage system is to be installed this should include for an appropriately sized stormwater wetland at the same time; with hydrocarbon interception at locations where oil inputs are likely to be elevated, such as at the front of the petrol pumps and any other areas where petrol and diesel are likely to be used; if these are not already in place.

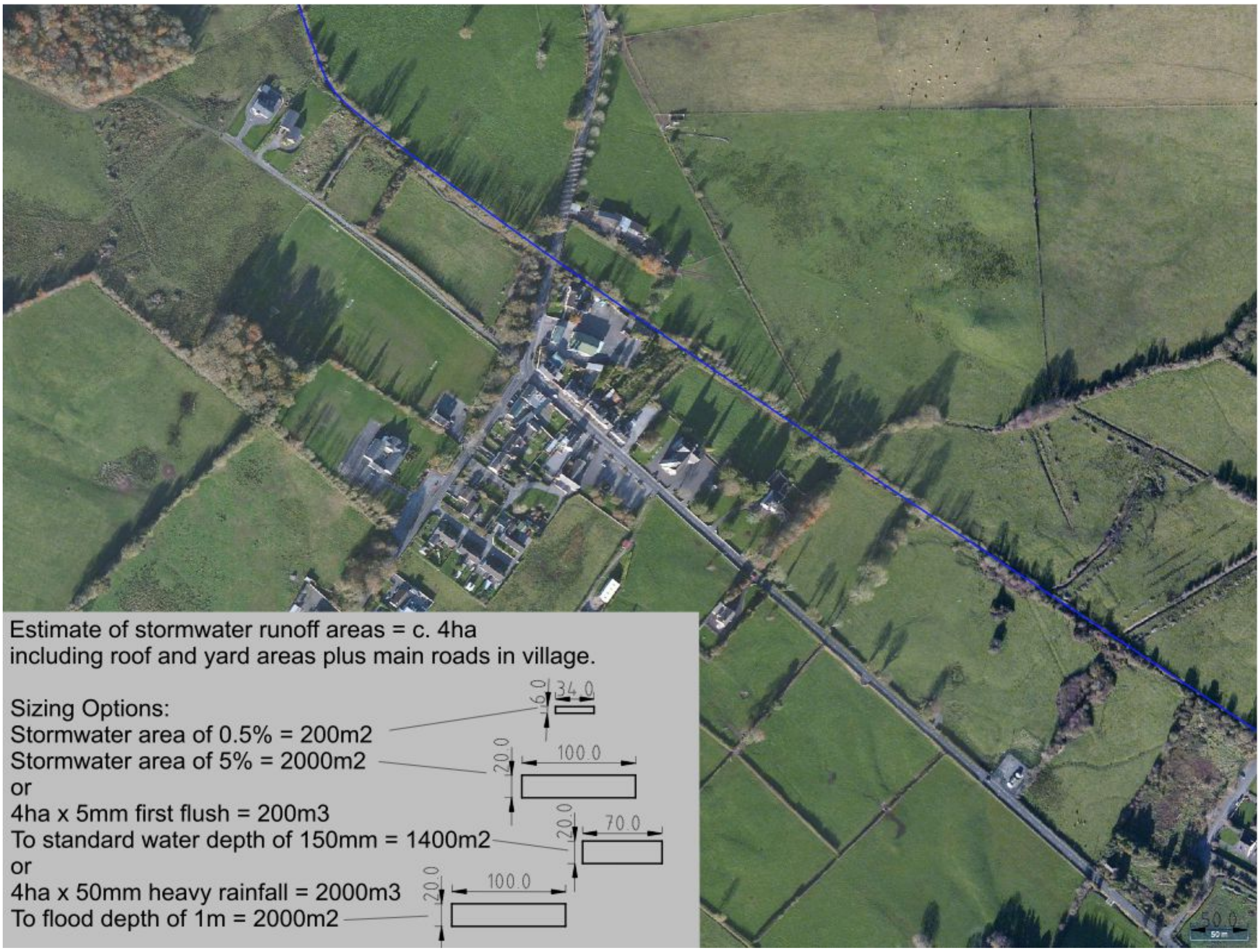
Even in the absence of a new sewage treatment system, a main village stormwater system is still an option and would be of great benefit to the river. Typical sizing of stormwater wetlands for motorway and urban runoff varies in size between 0.5 and 5% or more, depending on the source (Cooper et al., 1996[5] and Livingstone et al., 1989[6]). Cost estimated at €20-50k depending on size and degree of excavation required in a given project area; or *c*. €300 k to include laying a new storm sewer to collect pipes not currently connected to the main stormwater line.

Size options for a village scale stormwater wetlands are outlined in the map below. A more detailed worked example of a proposed stormwater wetland for the village is shown the main proposals map in chapter 14; Mapping a Course for Action.

5 Cooper PF, GD Job, MB Green and RBE Shutes (1996) *Reed beds and constructed wetlands for wastewater treatment*. WRc Swindon, Wiltshire, UK.

6 Livingston EH (1989) *Use of Wetlands for Urban Stormwater Management*. In: Hammer DA, (ed.) *Constructed wetlands for wastewater treatment – municipal, industrial, agricultural*. Lewis Publishers, Chelsea, MI, USA.

Fig. 10.1 – Examples of sizing options for a stormwater wetland for the full village



10.2 Stormwater system for selected community areas

If the budget is not available for a full scale village stormwater system; the following areas have been identified as suitable for stormwater treatment; with SUDS component options outlined for each.

- School and sports centre, yards, car parks and pitches
  - Sunken rain gardens alongside car parks and playground
  - Raised planters under downpipes from roof surfaces
  - Ponds for excess flow from roof surfaces or rain garden areas
  - Rerouting misconnected grey water pipe back to the septic tank or install a small reed bed (raised or sunken) to filter water en route to storm drains at rear of school building
  - Stormwater wetland or pond from astroturf pitch drainage at the point of entry to the stream
  - Stormwater wetland for stormwater pipe through GAA pitch
- Selected sections of public roadways
  - Hydrocarbon interception at runoff from petrol pump area; if not present
  - Open swale drainage to replace existing piped drainage where possible to incorporate into current/future road design

- Stormwater wetland for filtration of all pipes entering the river

- Community hall and car park
  - Sunken rain gardens alongside car park area and at building for roof runoff
  - Raised planters or wall mounted planters under downpipes from roof

- Church building and car park
  - Sunken rain gardens and/or pond alongside car park
  - Raised planters under downpipes from roof surfaces
  - Ponds for excess flow from roof surfaces or rain garden areas
  - Alternatively route all water from roof and car park to a stormwater wetland at rear of church, fed via planted swales where possible; replacing the above three measures.

As an example on the ground, the works required for implementation of rain-gardens for the runoff water from the community hall car park are described here:

1. Remove the existing top-soil level at the three planted triangles at the entrances to the car park. Set to one side for reuse.
2. Dig out subsoil to a depth of 30cm and set aside for reuse.
3. Dig out deeper subsoil (poorer quality and more compacted) to a further depth of 30cm and remove from the site.
4. Replace upper subsoil layer - without compacting.
5. Replace topsoil layer such that the top ground surface slopes gently to the centre and is all below tarmac level - the aim is to allow rainfall to flow unhindered from the car park into the new bioretention area / rain-garden surface and then soak in over time.
6. Remove kerb stones at the lowest point of the tarmac around each triangle. Cut in half and replace half in the gap where one was removed. Only 5-6 kerb stones may need to be removed in total.
7. Tidy up around site works.
8. Planting with selected species that tolerate both flooding and periods of dry conditions to be carried out after works are complete.

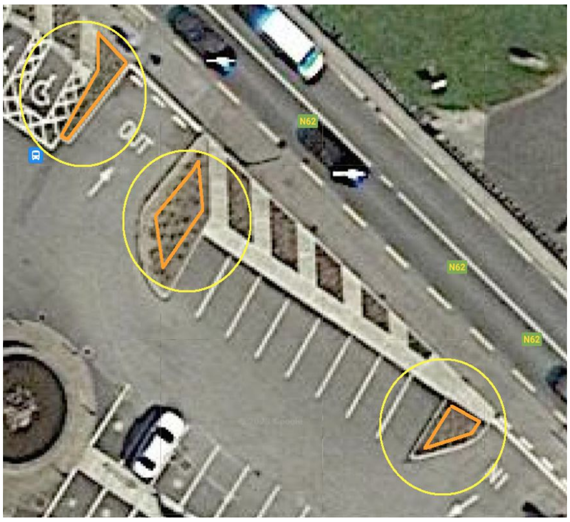


Fig. 10.2 – Plan view of discussion sketches for rain-gardens in community hall car park.

Further examples of community scale stormwater opportunities have been listed for the sports grounds car park, the main community hall car park and church roof in chapter 14.

10.3 Stormwater systems for individual homes/businesses

On an individual scale, there is much that can be done by home owners and businesses in the village. Examples include the following:

- Agri-supply yard and buildings
  - Hydrocarbon interception, (if not already present and if hydrocarbons are present on site in sufficient quantities to merit it)
  - Swales or stormwater wetland to take runoff from the main yard area en route to the river
  - Separate stormwater wetland or pond to take roof runoff, which will be cleaner than from yards
  - Rainwater harvesting; if useful to the running of the business – e.g. for yard cleaning

- Individual houses or groups of houses
  - Rainwater harvesting for any gardens where outside watering is needed
  - Sunken rain gardens or ponds for stormwater collection and infiltration or for attenuation/filtration prior to existing storm drains
  - Raised planters under downpipes from roof surfaces, routed to ground or to stormwater drains
  - Repair any misconnections by rerouting misconnected grey water back to the septic tank or providing a small reed bed (raised or sunken) to filter water en route to storm drains

10.4 Stormwater implementation considerations

Consider the following elements in the context of any stormwater plans and implementation:

- The primary issue with the existing stormwater network in Ballinahown is the suspected widespread contamination with septic tank effluent. This means that the stormwater itself will contain pathogens and other pollutants, making the resulting water much more challenging to treat and posting a potential health hazard, depending on the treatment system/location selected. This has been accounted for in the proposed actions in chapter 14 by allowing standard sewage-spec minimum distances from the initial section of the proposed stormwater wetland to any buildings.

- System size / availability of space: a stormwater wetland for the full village would be *c*. 2000m^2 in surface area for treatment (assuming no sewage ingress); or larger if additional habitat area is desired after the main stormwater wetland; or if, as in this case, some sewage inputs are present which call for additional treatment area. On a much smaller scale, water butts or raised planters at individual homes can be used effectively to store heavy rainfall prior to slower overflow into the existing storm drainage network. This would be a low-footprint option with benefit ro the wider stormwater system.

- Budget: The cost of these measures will vary depending on the system design, size and location. The cost of a full new village system, independent of the main foul sewage system may be *c*. €300,000 for the drainage network, pumping and stormwater wetland creation (excluding land rental/purchase). If work is done as part of the main sewage system then the costs may be as low as €20k for additional machine works and pumping alongside existing trenching and coordination. Similarly the cost of introducing a stormwater wetland within existing drainage infrastructure may also be modest, at about €20-50k. On the other end of the scale, domestic measures can use recycled materials for free, or at a very modest cost.

- Phasing of the works and coordination with sewage works: While the most effective way to achieve full stormwater treatment is for the system to be combined with as sewage project by Irish Water. In the absence of any immediate plans, a village scale stormwater system could be built along the route of the existing stormwater pipe network. Phasing of these works is shown in Chapter 14 to allow work to progress on a step by step basis as budgets become available. Note that many gains can be made by reducing the stormwater inputs to the existing storm drainage network and keeping water flows above ground insofar as possible. Such measures could be carried out relatively cost effectively and without compromising the viability of any future storm sewer network overhaul. Examples of such overground measures include rain gardens, rainwater harvesting, planters and swales in an independent overground stormwater network.
- For areas where contamination of stormwater with sewage is a possibility, then there is a potential health risk to maintenance operations. This won't be an issue for systems with direct rainfall feed such as rainwater harvesting or rainwater planters; nor for shallow surface systems such as swales or rain gardens for car park runoff.
- Deep water is also a potential drowning hazard, so appropriate fencing should be considered at the design stage of any stormwater ponds.

10.5 Stormwater maintenance

Different measures will require differing degrees of maintenance. In general terms large stormwater wetlands and ponds will require minimal input after the main construction and planting elements are completed.

The primary maintenance input is to check for sediment accumulation and to desilt the system as needed. Indicative inspection and maintenance frequencies are set out in table 10.1 for different system types.

Table 10.1 inspection and maintenance frequencies for SUDS system

Stormwater system type	**Inspection frequency**	**Desilting frequency**
Stormwater wetlands	annual	10yr interval
Stormwater ponds	annual	20yr interval
Village scale bioretention areas	annual	10yr interval
Garden scale bioretention areas or rain gardens	annual	2-5yr
Car park rain gardens	annual	2-5yr
Swales	annual	2-5yr
Hydrocarbon interceptors	quarterly	annual
Rainwater harvesting for domestic water needs	quarterly	annual
Rainwater harvesting for yard and garden use	quarterly	annual
Raised planters	quarterly	annual

An important factor to consider with maintenance works is the availability of personnel or budget to do the work needed into the future. Also, where littering takes place, plastic can accumulate in car park rain gardens or stormwater systems. As a community, reflect on who has responsibility for clean-up and maintenance on each system being explored for use.

11.0 Farms and Farming

Agriculture is recognised as having one of the largest impacts on water quality in Ireland. BOD, suspended solids, nitrates and phosphates, pathogens and residual biocidal chemicals all pose difficulties for water quality, wetland habitats and the species that live in them. The challenges for farmers include, *inter alia*, the sheer volume of Irish rainfall; liquid infrastructure in the form of slurry rather than solid manures; CAP payment reward structures; historic guidance and practice on removal of habitat space.

The challenge for water quality of using liquid slurry rather than compost is that while raw sewage has a BOD of 300mg/l, slurry can have a BOD of 10,000mg/l. Silage effluent, although low in volume, can have a BOD concentration of ten times this amount. As such, even small amounts of runoff from yards or fields can lead to serious issues for local waterways. By contrast, if we were to develop composting machinery to make solid nutrient and biomass cycling easier on farms, it would create an abundance of soil-building, nutrient rich humus. This would improve drainage and moisture holding capacity of our soils as well as improving soil biodiversity and thus crop health.

Current agricultural payment scheme generally reward the removal of natural habitat from our farmland, in favour of satellite images of grass or ploughed fields. This inevitably puts pressure on farmers to remove buffer zones and the natural water filtration benefits of boggy field corners, wooded areas and hedgerows from low pockets of the land. These are invaluable for water filtration and habitat, but less useful for farming, so while habitat may be the perfect use for these areas from a whole-farm plan, the push to create open space edges out the many uses these areas can provide.

Agricultural guidance and the practice of farming over the past few generations have both had the old post-war-Europe focus on food at all costs. Before that time there was an acknowledgement of the value of wild spaces, as witnessed in phrases such as “the hare's corner”, a space left to on side for wild things in the land.

The hydrological impacts that we have explored for urban stormwater are also present for land that has been drained or converted from habitat to farmland. Impacts include peak flow (larger volume during a storm event), accelerated catchment response (quicker movement off the land and into rivers and streams) and overall increases in rainfall presenting as runoff; as well as reductions in water quality. While the results per acre are not as acute as from paved surfaces, the area of farmland cover across Ireland is much greater than that of urban areas, so the impacts on river flow patterns are substantial.

This water management plan focuses specifically on Ballinahown Village rather than the wider catchment, but every river is a reflection of the land in which it sits. Thus the water quality and health of the river in Ballinahown village are the direct result of all of the landuse decisions upstream, including those concerning the dominant landuse of farming.

During the stakeholder engagement process it became clear that local farmers had an interest in learning about water quality improvement measures that would be effective on their farms. As such this chapter has been included as a resource to help guide farm-scale improvement measures.

Pollution inputs from farms can be divided into two main categories:

- Point source pollution is the runoff from identified sources such as from farm yards. This can come in the form of slurry, silage effluent, yard runoff and/or parlour washings. Runoff from roof surfaces, farm roads and less used yard areas may not require containment but can still contribute to the general degradation of nearby watercourses by changing flow balances or reducing quality.
- Diffuse pollution is less immediately identifiable on the ground, but not necessarily less problematic. It includes field runoff of slurry, biocides etc. to waterways; or infiltration into the soil, which can lead to groundwater contamination, which then in turn migrates to rivers and streams.

11.1 Point source pollution

Point source pollution from stored slurry, silage effluent and yard/parlour washings can be addressed by adequate containment and land-spreading or by reducing storage requirements by diverting yard and parlour washings to a filter system such as an Integrated Constructed Wetland (ICW) or willow filter. (Note that landspreading of slurry and wash waters can be a major source of diffuse pollution in its own right).

ICW systems are an established method for dealing with washwater and farmyard runoff, used mostly for dairy farms. Note that slurry and silage effluent still need to be stored and spread following standard guidance. There is established guidance on ICW systems from the Dept of Agriculture[7]. Systems require planning permission and a discharge licence for final outflow. Land area requirements are 200% of the total yard area including roof surfaces, making them relatively large filter systems – reflective of the very high pollution potential from yard and parlour wash water.

Zero discharge willow systems are used in Denmark for yard and parlour washings and can be equally effective here. Guidance has yet to be prepared here, but it may be possible to get planning permission as part of a trial process where a farmer wishes to use this method of 100% washwater disposal to air via the willows.

A lower-tech, but higher land-area option is to irrigate a willow plantation with wash water; or to irrigate commercial forestry lands with wash water where conditions are suitable. Note that by saturating the soil under commercial forestry there is an

7 Department of the Environment, Heritage and Local Government (2010) *Integrated Constructed Wetland Guidance Document for Farmyard Soiled Water and Domestic Wastewater Applications*. DEHLG, Dublin.

increased risk of wind-throw, so care needs to be taken in designing the overall system and selecting loading rates.

Fig. 11.1 – Farm scale constructed wetland system

Fig. 11.2 – Spreading pipes in an irrigated willow plantation

Inputs from clean yards, sheds and roads has until recently been regarded as unimportant from a water quality perspective. Standard practice was to discharge directly to drains or streams. Although the pollution load from these sources is much lower than from soiled yard areas, it still has the potential to have a negative impact on waterways unless adequately filtered and attenuated. Suitable measures include silt traps, in-channel filter marshes and in-channel ponds directly within the drains exiting the runoff areas.

- **In-channel wetland buffer zones**: essentially overgrown open drains. The presence of tall wetland vegetation in a slow moving channel offers all of the treatment mechanisms that are present in a standard constructed wetland system. The pollution loading rates are lower than for an ICW, but the processes are identical. The plants slow the flow of water and take up nutrients; sediments settle out; bacteria reduce the overall organic loading in the water, leading to healthier conditions for fish and insect life in the drain and streams further down the catchment.

Fig. 11.3 – In-channel linear buffer (essentially a planted farm drain modifications to better filter water)

Fig. 11.4 – In-channel pond for habitat; and removal of nitrates

- **Silt traps and in-channel ponds**: The difference between these is a matter of scale. Silt traps can be as small as a slight widening and deepening of a farm drain, so that silt and soil can settle out in the slower moving water. In-channel filter ponds are larger, and offer greater opportunities for removal of fines, nutrients and other contaminants.

Sizing of in-channel wetland buffer zones, silt traps and ponds is more a function of availability of space and budget than of pollution loading per se. That said, the larger the filter area, the greater the potential for treatment; or conversely, the greater the likelihood of contamination, the larger the system should be. By way of general guidance, allow a wetland or pond surface of 5% of roof surfaces and 10% of yard surfaces or road inputs, where either are relatively lightly used.

11.2 Diffuse pollution

Diffuse pollution is by its nature more difficult to identify than point source pollution; and can thus be more difficult to address. With a diverse spread of causes it is important to apply a diverse spread of solutions. Such solutions can include the following flow pathway categories:

- Slow and filter the flow of surface runoff exiting fields via buffer zones
- Use in-channel buffer zones in farm drains as outline in section 11.1
- Reduce the inputs of polluting substances onto the fields
- Reduce movement of contaminants down through the soil into the groundwater

Buffer Zones for field runoff

By looking at water and how it flows, filters and carries, we can see patterns to guide our actions for protecting waterways from field runoff. Exposed soil releases more silt, nutrients and water than land with leaf cover and a good root network. Uninterrupted rivulets in fields will carry silt and nutrients from land into watercourses. Removal of habitats will remove their natural capacity to slow the flow and filter water as it moves. By contrast, if we keep soils covered with vegetation, reinstate and protect woodlands and wetlands, provide pools and pockets for rainwater to settle and be still, we can slow down the exodus of water, soil and nutrients and protect water quality.

In addition we can introduce filter buffer zones. These are planted filter strips which slow the flow of water and maximise the uptake of silt and nutrients by plants and soil. Wetland or woodland planting along stream and river edges provide the same basic filtration as in a constructed wetland or willow system, cleaning the water en route to the watercourse beyond. Even a level or gently sloping grassed strip of fenced ground between field and stream can provide some filtration. On more steeply sloping ground a shallow wetland channel may be dug parallel to the watercourse to catch and filter water.

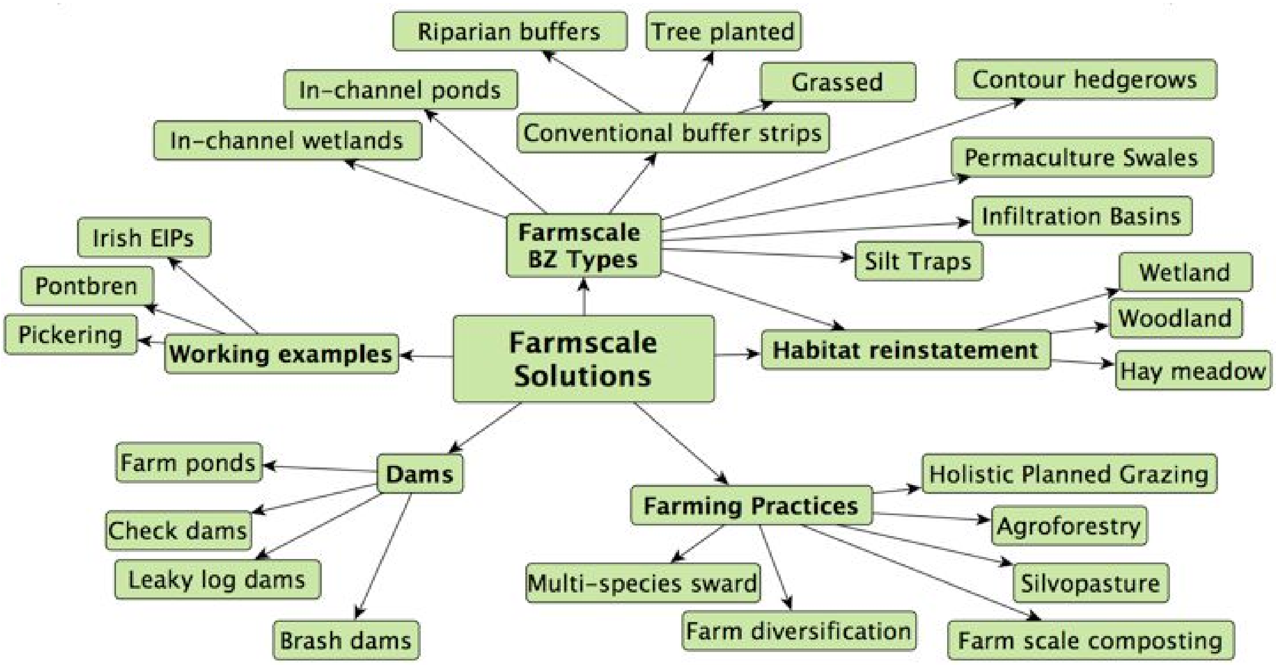
There may already be informal buffer zones on your land, filtering water without complaint. These may include grassed field headlands, stream-bank vegetation or densely planted open drains and hedges planted along the contour of sloping fields.

These will all trap debris in surface runoff water, filter sediments and take up nutrients that may otherwise end up in streams and rivers.

Planted buffer zones can generally be categorised by their position in the landscape, as follows:

- **Conventional buffer strips**: grassed or wooded strips of land, typically planted along the lower contour of a field to trap soil runoff, nutrients and chemicals. Hedges, ditches and wooded strips of ground can all act as effective buffer strips on sloping land. Even gently sloping land benefits from a small buffer strip along its lower boundary.
- **Riparian buffers**: stream-bank areas that are fenced off from livestock and allowed to form a natural barrier between the field and an adjacent watercourse. The Teagasc and Inland Fisheries Ireland guide *Minding our Watercourses*[8] gives guidance on these basic yet effective measures for stream protection. Planting of wetland plants or native trees along these areas can enhance nutrient uptake.
- **Contour planting** of hedgerows, or wooded strips on higher ground, can catch runoff from fields, providing infiltration into the soil beneath. Infiltration rates within wooded areas fenced off from livestock can be 67 times greater than on adjacent grazing land[9]. That's a 67-fold increase in the capacity for soil to mop up heavy rainfall and recharge groundwater, protecting the down-gradient fields from excess runoff, keeping nutrients and soil on the land rather than washing into watercourses.

Fig. 11.5 – Overview of main farm-scale solutions for water quality enhancement



8 *Countryside Management Series 8 - Minding our Watercourses*. Teagasc and Inland Fisheries Ireland.

9 Keenleyside, C (2013) *The Pontbren Project - a farmer-led approach to sustainable land management in the uplands*. COED CADW Woodland Trust, Wales.

Filter measures for open farm drains

A further way to address catchment scale water quality issues from either point source or diffuse pollution is to use in-channel measures within farm drains, regardless of input source. A straightforward approach is to use settlement ponds and filter marsh areas, which are described in the section 11.1, but which can apply equally well to general water quality improvement in farm drains.

Water-friendly farm drain maintenance is another approach to take within stream or drain channels. Since planted buffers and filters can provide excellent protection of nearby watercourses, it becomes clear that care of existing planting within farm drains is an equally effective and lower-cost way to retain existing natural filter systems on the farm. Following are some basic measures that can be adopted to maximise the natural treatment qualities of wetland plants within the farm. For water quality enhancement follow these general guidelines:

- Minimise the frequency of plant removal from open drains by reducing the maintenance frequency. Only dredge a farm drain if the water level in the drain is building up above the level of the in-field drainage piping. Deep drains below such piping do not generally need any desilting.
- When you are dredging, widen the drains to increase the surface area available for filtration purposes.
- Maximise width, while minimising depth. If the water level is too deep it will limit plant growth and the treatment properties that plants offer.
- For additional habitat enhancement single-side desilting can be carried out so that silt from only one side of the channel is removed. This preserves the habitat and vegetation which can then quickly recolonise the drain while still achieving a lowering of the drain depth.
- To minimise sediment losses into receiving watercourses carry out dredging in intermittent runs so that there is plenty filter planting remaining downstream of the work area. Thus when dredging, work on only limited sections of the total channel length (20-50m sections), staggering the work so that plants have time to recover before the next maintenance year. The objective is to maintain an abundance of tall wetland plants throughout much of the channel at any given time. This measure is also wonderful for biodiversity, which has time to recover between maintenance events.
- Introduce steps or low earthen weirs within the drainage channel to allow water to settle along the full drain length, thus enhancing growth of wetland plants and wetland filtration.

Stream-side dredging or clearing requires permission from Inland Fisheries Ireland, as does any work that is likely to reduce water quality. As such the above measures refer to farm drains only and not to streams, which have a different habitat dynamic and should be left alone. Also, it is very important to carry out any drain works in a way that minimises silt generation to the wider catchment.

Reduce the application of contaminating inputs to the field

There are also many ways to reduce or cut out standard waterway contaminants, before ever driving through the gate into the field. Following are some examples:

- Composting instead of slurry: Slurry has the advantage of being easy to catch and store, but there the advantages seem to end. Dry composting of farmyard manures offers many benefits. Nutrients are held in a stable humus matrix and thus do not wash away into groundwater or streams as quickly. Thus they are available for crops, while waterways are protected. Compost also improves soil drainage as well as moisture retention. With regular compost applications you can build healthy soils that are resilient to extremes of wet and dry weather. Compost also builds soil depth, and thus the filtering capacity of the soil for protection of groundwater and surface waters, as well as growing healthier crops.
- Using hay rather than silage: hay does not have any effluent generation, whereas silage effluent can have a BOD loading of 100,000mg/l (compared with raw sewage BOD loading of 300mg/l). Thus even small volumes of silage effluent can be very polluting and often poses a challenge for containment and storage on even the best managed farms. Hay making is a viable alternative to silage[10], and offers a much safer option from a water quality perspective had has biodiversity and soil health benefits.
- Avoiding artificial nitrogen additions. Artificial nitrogen has multiple issues regarding soil health, soil carbon removal and thus erosion, water pollution and greenhouse gas emissions. It is also increasingly expensive to buy. Alternative methods include using clover interplanted with the sward, fixing nitrogen for free, in a natural way that has benefits for pollinators as well as water quality. Compost is another way to introduce nitrogen, as well as phosphorus and a host of micronutrients, to the soil in a way that has multiple benefits rather than drawbacks. Effective Microorganisms (EM) are increasingly being used to boost soil health and nutrient availability for plants. These are reported to have most impact where used on soils that are most heavily degraded of biological activity, so fields with historic inputs of nitrogen fertiliser are an ideal place to apply them.
- Avoiding biocidal chemicals. In general terms the greater the diversity of life that is present in an ecosystem, the more resilient it will be; the lower the incidence of infestations by pests or disease; the greater the capacity for water filtration; and the more effective it will be for carbon sequestration and storage. Biocides seek to kill off pest species and in doing so cause considerable damage to other plant and animal life, both on the farm and in the wider catchment. Water quality in the wider catchment can be improved by seeking other ways to work with nature on the farm rather than using chemical means.
- Regenerative practices such as continuous cover cropping, mixed species swards, and specific grazing management techniques. For example Holistic Planned Grazing[11] is a livestock rotation methodology that preserves soil

10 https://www.farmersjournal.ie/tips-on-making-top-quality-hay-162055

11 https://savory.global/holistic-planned-grazing/

cover, limits parasite transfer and builds soil humus – which has knock-on benefits for drainage, moisture retention, nutrient availability and water quality. HPG is more intensive of labour than standard rotational grazing, keeping livestock on the move each day, so it is not necessarily suitable for every farming context.

Reduce movement of contaminants into groundwater

Any measure that builds healthy soil or limits applications of potential pollutants will reduce contamination of the groundwater beneath. Thus all of the measures discussed above will be part of this suite of measures. In addition, water may be filtered through the soil more effectively by using continuous cover cropping, multispecies swards and trees on the land.

- Continuous cover cropping (no-till and/or permanent pasture) is gaining increasing interest in Ireland as part of a wider suite of measures under the banner of conservation farming[12]. By minimising soil disturbance and avoiding exposure of bare soil, rainfall can't wash away soil nutrients into the groundwater beneath, causing both pollution and nutrient loss from the farm.
- Multispecies swards have the direct advantage for water quality in that they have a deeper rooting depth, and thus provide a greater depth of filter for soluble nutrients en route to the groundwater beneath. The diversity of plants also provides a diversity of uptake rates at different times of year, thus providing a more robust filter.
- Incorporate trees within agroforestry or silvopasture designs for the farm. Contour hedgerows or contour tree planting in particular can be very effective subterranean filters, mopping up nitrates and phosphates that have washed down below the reach of the sward or arable crops.

EPA mapping tool for identifying possible pollution inputs

Diffuse pollution by its nature can sometimes be difficult to identify and thus address with the measures described above. Each farmer knows his or her own land and waterways best and thus the most effective way to address diffuse pollution is one farm at a time by working with the farmers on the ground. That said, some areas are more prone to pollution inputs than others. The EPA PIP (Pollution Input Pathways) maps can offer insight into where pollution is likely to be present.

Fig. 11.6 – PIP-P Flow Delivery Paths and Flow Delivery Points – the orange coloured ribbons on the map show the potential input pathways based on topographic maps. Source: www.Catchments.ie (Created out of the EPA DiffuseTools Research Project)

12 https://www.baseireland.ie/

12.0 Addressing Other Impacts

Although farming is the dominant landuse pattern in Ireland as a whole, peat extraction and forestry are also significant in terms of the land area that they occupy. By extension these also have a significant bearing on water quality.

12.1 Peat extraction

Peat extraction has a number of distinct impacts on water quality in the wider catchment. First and foremost removal of peatland habitat seriously interrupts the hydrodynamics of the catchment, removing a valuable sponge in the upper catchment area which stored heavy rainfall, releasing it during drier weather. This can lead to flooding events downstream and river or stream channels going drying summer months. Drained peatlands also release nutrients, dissolved organic carbon and silt into waterways, leading to enrichment and degradation of water quality. The River Worm is quite silted in a number of places in Ballinahown. While this may be from sewage or agricultural inputs, it is suspected to be mostly due to historic peat extraction in the upper catchment.

The saving of peatlands from a water quality and biodiversity perspective may be the limitations on harvesting imposed by Irish atmospheric carbon reductions. All Bord na Mona extraction has ceased since 2019; with only harvested material being removed since then. This year (2023) is estimated to be the last year when harvested BnM peat will be removed from cutover bogs. There are still some private turbary turf cutting around the margins of BnM bogs, which can limit the capacity for restoring the hydrological integrity of a bog. Some private sites have ceased operations, while some others have increased extraction due a gap in supply more generally. The fate of the peatlands in the upper Worm catchment was not assessed as part of this project, but the general trajectory for peatlands is towards rewetting and restoration of wetland habitat. Projects such as Farm Carbon EIP in Co. Offaly specifically focus on drain damming to restore peatland hydrology, and groundwater raising to prevent deep carbon stores under peaty pasture lands from degrading (where the soil essentially evaporates as carbon into the air) and dropping in level.

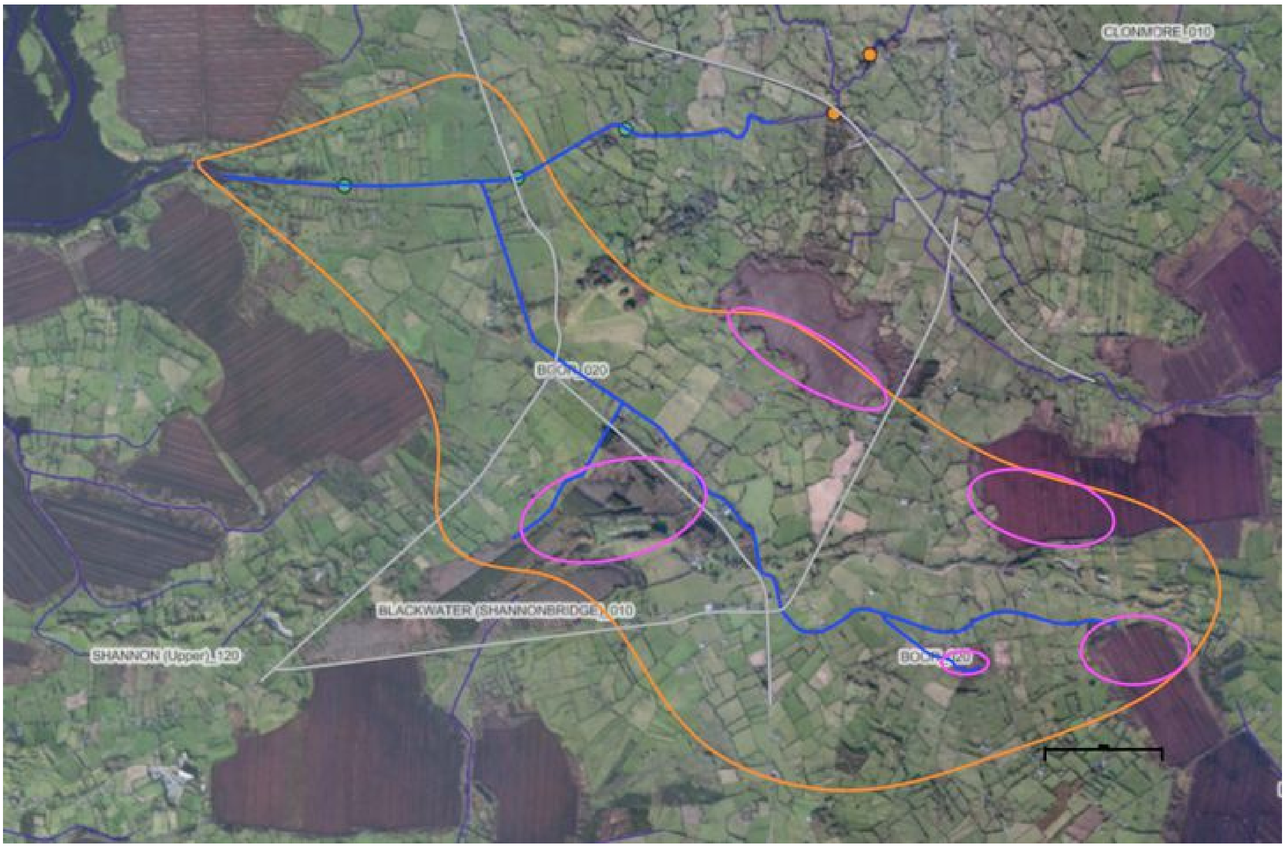
For peatlands still being harvested, silt ponds and in-channel wetland can provide filtration to deal with silt and nutrient generation.

12.2 Forestry

Forestry impacts on water will vary hugely depending on the type of forestry and the management style adopted. Native or broadleaved woodland cover on undisturbed or lightly impacted ground has considerable benefits for water in that the trees and root mass beneath hold water, slow the movement through the landscape and filter water flowing towards watercourses from neighbouring lands. Standard commercial coniferous monoculture crops by contrast can contribute to hydrological damage of the catchment by introducing extensive drainage channels in the landscape, by applications of fertilisers or biocides, and by wide-scale ground disturbance during harvesting.

By way of solutions, all of the measures described for farms can be equally applicable to commercial forestry crops. An additional measure is to gradually move from standard clear-fell practices to continuous-cover forestry, removing only the most suitable timber and leaving the bulk of the plantation intact to protect soil from erosion with additional benefits for soil ecology, wildlife, water quality and hydrodynamics.

Fig. 12.1 – Aerial photograph of the catchment of the River Worm and lower River Boor showing peatland and some limited areas of forestry cover.



Basemap image source: www.Catchments.ie

12.3 Hydromorphology

Hydromorphology describes the shape and flow patterns of a watercourse. Changes such as land drainage, straightening and deepening can have a great impact on the ecology of a river or stream. As it currently stands in Ireland the Arterial Drainage Act imposes a legal framework whereby drainage works and waterway clearing on selected river and streams continues apace. This means that in an age when both climate and biodiversity emergencies call for new ways of working with nature, our legal structures still steer maintenance and management towards ecologically destructive processes rather than regeneration and repair.

It is clear from looking at the River Worm, both the steep river banks and the straight canalised channel, that it has been drained and altered significantly over the years. There is great potential for recovery however, with growing awareness of the need to redirect the Arterial Drainage Act away from current practices and towards implementing ecological recovery in our watercourses[13].

The historic straightening of the River Worm and ongoing drainage under the Arterial Drainage Act both impact on the shape and river flow dynamics. These may be addressed on a number of levels; from introduction of in-stream measures to improve hydromorphology in selected areas to a wider catchment scale waterway rewilding initiative to begin to reinstate historic flood plain levels and water flow dynamics.

Physical barriers such as weirs or bridges can greatly impede fish passage. Thus fish that migrate from rivers to seas and back, such as salmon, lamprey and eels, for example, find that their route is blocked and their life-cycle thus interrupted. What this means in practice is that the capacity of the watercourse to support these species, and all of the other species that depend on them for their own ecological processes, may cease stop or be greatly compromised.

The removal of weirs and dams from rivers and streams is gaining momentum across Europe and North America. Where old redundant obstacles exist, their removal can restore fish migration routes that may have been completely blocked for over a century, helping to rewild our watercourses and restore valuable habitat.

Any instream measures will need to be designed and implemented in consultation with public bodies such as Inland Fisheries Ireland, the OPW, NPWS and/or the local authority; depending on the type of measures proposed.

In-channel measures that can have benefits for waterway hydrodynamics, channel shape, water quality and habitat include leaky log dams, brash dams, in-channel ponds and in-channel wetland creation, to take just some examples. Bankside or riparian measures that could have benefit in selected areas include riparian buffer zones (typically grassed, wooded or wetland planted), willow spiling where erosion is an issue, and/or bank reprofiling where overly steep banks are present and where land is available for allowing a wider overall channel.

See the chapter below on Habitat Reinstatement for additional details on hydromorphological repair.

12.4 Climate change

On the one hand, climate change has been shown to have significant impacts on flood/drought cycles, reservoir and groundwater recharge rates, wildfires, sea level changes and desertification. On the other it is worth noting that all of these symptoms of climate change can also be directly related back to water management within the landscape.

13 Anthea Lacchia, 20/2/2022. Breaking the Banks. *The Journal* https://www.thejournal.ie/breaking-the-banks-5678579-Feb2022/

Landuse changes can take a significant toll on water flows and quality. Draining, clearing and paving all reduce the resilience of a river or stream; leading to floods, droughts, pollution and poorer habitat for aquatic life. While carbon based warming may account for some flood/drought events in recent decades, removal of natural habitat and shifts in landuse plays a major role. Increasing research suggests that our global impact on water within the landscape may even be a greater driver in climate change than atmospheric carbon per se[14],[15].

While addressing carbon based climate change can seem overwhelming, addressing landuse based climate change can be a very straightforward and rewarding process. Changes introduced in one garden or farm can make a recognisable difference for the soil and water flows within that space. With the right measures, everything can fall into place. Soil organisms thrive. Nutrient cycles recover their equilibrium. Humus builds and accumulates, holding carbon, water and life. Everything that is done to help soil, helps water. Slowing the flow; building resilience to both droughts and floods; filtering and cleaning.

Cumulatively it is these small acts of repair that help restore our rivers and seas to health. On a global level, water management can be seen at the root of water table depletion, forest fires[16], sea level rises[17], Amazon basin drying[18], and of course flood/drought cycles that we see in Ireland and across the world. The beauty of this is that straightforward landuse repair measures can be used to restore water tables, reduce wildfires, stabilise sea levels, build on-farm drought resilience and reduce flooding. These can all happen under our care on our own land or our community spaces, using the techniques described throughout this report and particularly the chapter on farm-scale measures. The benefits for the wider world may be small, but they are tangible; recognisable from the day a new farm pond is built or in-channel wetlands planted within farm drains or stormwater channels.

12.5 Water conservation

While this report has focused mostly on the river end of our water management decisions in Ballinahown, water conservation is at the tap end of the process. At its most basic, conservation is important to preserve supplies. We all need clean, fresh water for drinking and cooking, washing, flushing toilets and garden watering. The standard EPA water usage estimate of 150 litres per person per day is quite a large volume of water to be flushing down the drain every day.

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14 Charles Eisenstein (2018) *Climate - A New Story*. North Atlantic Books, Ca., USA.

15 Judith D. Schwartz (2016) *Water in Plain Sight – Hope for a Thirsty World.* St Martin's Press, NY, USA.

16 Taufik, M., *et al*. (2017) Amplification of wildfire area burnt by hydrological drought in the humid tropics. *Nature Climate Change* 7, 428-431 (2017)

17 Robert McSweeney (11 Feb 2016) Water stored on land stopped recent sea level rise being up to 22% higher. *Carbon Brief*. https://www.carbonbrief.org/water-stored-on-land-stopped-recent-sea-level-rise-being-up-to-22-higher/

18 Fred Pearce (30 Oct 2019) Earth's most important rivers are in the sky – and they're drying up. *New Scientist. https://www.newscientist.com/article/mg24432540-600-earths-most-important-rivers-are-in-the-sky-and-theyre-drying-up/*

Taking water conservation to an arguably more important step, we eat food grown both locally and around the world that collectively has a vast "water footprint". This is the water used for irrigation, washing and processing of our food and other products. Much of the imported food we buy comes from areas with more sunshine, but less rainfall. Our water footprint extends far beyond Ballinahown, and into parts of Asia, Africa and the Americas where falling groundwater resources are a very real problem. In a sense we are importing water from areas that are already short.

But it's not just a problem for places far away. Despite our plentiful rainfall, we are not without water shortages in Ireland. Water demand in Dublin is such the abstraction from the River Shannon is at an advanced stage of planning. A lower-cost and lower-impact solution could be as simple as catching rain, not only on the roofs within Dublin, but within the wider landscape that feeds into the reservoirs that feed the supply.

So at a local level there are many ways to conserve water, including care when using water in the house and also storing rain water for outdoor use and irrigation. As part of our steps towards global water conservation we can take care with our shopping basket, selecting items that avoid drought-prone regions or water intensive crops.

12.6 Policy changes to support water quality

Perhaps the largest driver of water quality in Ireland is policy. Landuse policy in particularly has a direct bearing on the health of rivers and streams. Historic CAP payments, for example, have prioritised food production capacity rather than other important landuse factors such as flood control, habitat protections, biodiversity enhancement, drought resilience, carbon sequestration, inland fisheries management, amenity considerations and the like. As such, water quality and aquatic habitat health has suffered at the expense of keeping farmland open and “productive” - even in areas where there is considerable expense and energy used to keep poor quality farmland in food production.

Beyond landuse policy *per se*, our wider policy structures reflect social values of the past rather than the present. Thus even in our current era when biodiversity and climate are both known to be at crisis point and the natural world that we know and love is suffering under the strain of misuse, our current economic system is driving us inexorably away from sane and practical solutions. Not just ecologically, but also the destruction of indigenous cultures around the world, the steady decline in human health, and a deterioration in the indicators of wellbeing in our wider society in terms of housing, income, stress levels and mental health. While these factors may not seem to relate directly to water quality, they lead to decisions on a day to day basis that deprioritise those things that were once considered sacred, and still are in many cultures; namely earth, air, fire and water. If water was once again considered more important than money, what could our rivers and streams look like?

In terms of effecting change on policy, there are a number of specific levels that we can take action.

1. Firstly, we can look at our own decisions in terms of landuse in Ballinahown and the Worm catchment, and ask what would serve the river rather than what would be the most financially rewarding (the main way in which policy is implemented is to steer financial reward systems).
2. Secondly we can compensate for inadequacies in policy at an individual level by avoiding household cleaning products, for example, that externalise costs by passing the pollution implications onto the tax payer rather than covering them in the product costs. Thus household cleaning chemicals with antimicrobial ingredients, microplastics or toxins can be avoided in favour of products that support microbial processes in septic tanks and are less toxic to the river and its wildlife.
3. We can also look at the policies impacting negatively on the River Worm, directly and indirectly, and bring these to the attention of relevant politicians and businesses to encourage change in these areas. It is very encouraging to see so many examples in recent years of constructive policy changes that have a direct positive bearing on the wider environment. Examples include the plastic bag tax in Ireland, Rights of Nature legislation in Bolivia, legal personhood rights for rivers in New Zealand, bans on the sale of selected plastics in the EU and others. In other words, advocacy can lead to positive changes. Advocate.

13.0 Habitat Reinstatement and Protection

Habitat protection and restoration are invaluable measures for supporting water quality and water flow dynamics in the wider landscape. Boggy corners of fields, wetland edges to rivers or stands of native trees all provide valuable natural filtration and water storage. Ponds offer benefits for plants, insects, birds and the wider catchment. If ponds are part of the network of water flow on the land (as oppose to lined rain-fed ponds), they will slow the flow and modulate catchment extremes between wet and dry weather, as well as settling silt and nutrients.

Essentially wherever there is habitat, there is an increased capacity for water holding and filtration; whether that is a thick cushion of moss on a stone, a wet bulrushy corner of a field, or a diverse ancient wildflower meadow. These will all benefit both wildlife and water.

These are small steps towards rewilding the land. On a grand scale, this has been seen with the reintroduction of wolves to Yellowstone National Park in the US[19]. The wolves' presence has protected the river edge by keeping deer and bison away from easy grazing ground near the water. Where before there was steady erosion and deterioration of the banks through high hoof-fall, now aspen and willow and other trees are regenerating and binding the soil, offering natural buffer zone protection of the rivers and streams within the park. On a farm scale, keeping animals fenced from waterways offers a similar service to the stream. The more livestock are kept on the move, the closer we get to this natural predator-prey relationship, with benefits for soil health, carbon sequestration and water quality.

13.1 In-stream measures

Working within stream channels is another way to help restore water quality and healthy flow dynamics. In Sweden a state funded programme has encouraged the introduction of in-stream ponds to reduce nitrogen levels[20], using ponds of between 0.02 and 0.3% of the contributory catchment area. In-stream ponds also provide valuable habitat diversity, reduce silt levels and regulate flow patterns.

In the Irish context, In-stream works require permission from Inland Fisheries Ireland and potentially from National Parks and Wildlife Service. Like with any impact on waterways, there is a risk of causing more harm than good, but if the community are interested in pursuing this idea further there may be grants available from IFI for in-stream restoration measures for enhancing fish habitat.

19 Monbiot G. (2013) *For more wonder, rewild the world*. TED. https://www.youtube.com/watch?v=8rZzHkpyPkc

20 LB-M Vought and JO Lacourisère, *Wetlands for treatment of polluted waters: Swedish experiences*. In: U Mander and P Jenssen (2002) *Natural Wetlands for Wastewater Treatment in Cold Climates*. WIT Press, MA, USA.

IFI have an integrated watercourse protection strategy which provides guidance for working with waterways in urban environments[21]. Their four major steps are as follows, with recommendations within each zone:

1. **Protect the streamside riparian zone**.
   - Ensure sufficient space is set-aside (i.e. >10m).
   - Leave intact if in an undisturbed natural state.
   - If disturbed, landscape appropriately.
   - Plant with native marginal and emergent vegetation.

While there is access to the river from public lands behind the church and within the park, historic drainage has created a large difference in soil levels between the river bed and the surrounding land. This will add to the cost of any potential riparian project that seeks to drop the ground level and permit meandering and flood plain reintroduction. Historic disturbance and drainage could be remedied by landscaping and re-meandering in selected locations. Planting may usefully be employed on bare bank-side areas behind the Rohan Agri yard and alongside the park.

2. **Create a middle riparian zone** – can include amenity infrastructure, e.g. footpaths (15-30m).
   - Ensure sufficient space set-aside, i.e. >15m.
   - Leave intact if in an undisturbed natural state.
   - If disturbed, landscape appropriately.
   - Create amenity walks etc.
   - Plant with native trees and vegetation.

The middle riparian zone already contains the park as an expanded buffer zone to protect the waterway, with existing amenity features and landscaping. However it is not the natural undisturbed state for the river and has little interconnectivity with the river itself. There are also pipe routed through the park which would benefit from filtration. Other areas of the river do not have as much protection.

3. **Create an outer zone** to incorporate sustainable urban drainage systems (>80m).
   - Ensure sufficient space set-aside, i.e. >80m.
   - Leave intact if in an undisturbed natural state.
   - If disturbed, landscape appropriately.
   - Incorporate SUDS (e.g. swales, retention ponds etc.).
   - Ensure SUDS link appropriately to development in a treatment train.
   - Consider winder amenity uses if appropriate.

The park also falls within the area of the outer zone. Although not within the zone of the river, this general category may extend to the the slightly farther flung SUDS elements such as the rain gardens and stormwater wetland proposals within the village.

21 Igoe F (2020) *Planning for Watercourses in the Urban Environment*. Inland Fisheries Ireland, Dublin.

4. **Rehabilitate the river itself** to recreate diversity of instream features found in natural channels.
    - If watercourse was previously damaged by drainage, rehabilitate with appropriate habitat restoration techniques.
    - Contact Inland Fisheries Ireland for advice.
    - Recreate habitat variability.
    - Consider creation of angling pools if appropriate.
    - Consider safety requirements (e.g. avoid steep banks).
    - Ensure work is carried out to high ecological standard (consult with IFI for further advice).

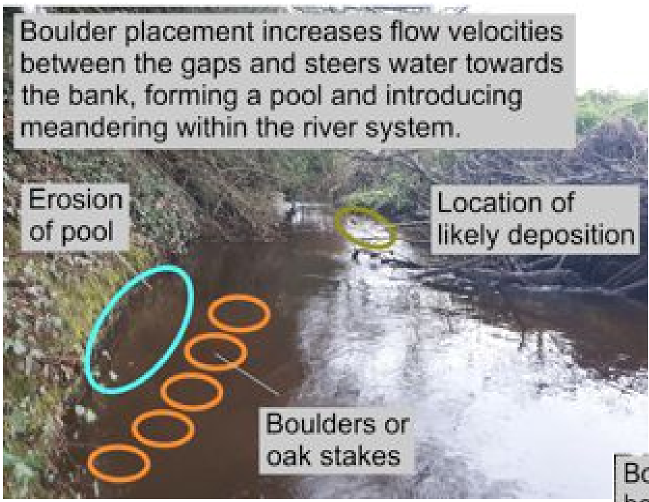
Given the closer proximity of high ground close to the river edge, what may provide most scope for actions on the ground are step 4 rehabilitation measures within the stream channel. The river has been deepened and straightened historically and this has had a negative impact on the habitat diversity within the stream channel. Measures which may be carried out include creation of pool, glide and riffle features within the muddy base of the river channel; introduction of meanders or ox-bow lakes; placement of boulders or logs; bank slope reductions or other suitable measures. Removal of weirs or obstacles is a common recommendation, but within Ballinahown village no such barriers to fish passage are present.

The IFI document lists the benefits of appropriate instream rehabilitation as improving channel stability, increasing fish numbers, enhanced aesthetics and amenity value, improved biodiversity for a range of aquatic wildlife and creation of angling pools for children to fish. In addition to these, the wider benefits from ecological management of waterways include flood control, drought resilience, water filtration, carbon sequestration and mental health and wellbeing.

As part of this management plan waterway advisor Dr. Rod Everett was consulted on low-input in-stream measures for habitat diversity and water flow management. By careful placement of rocks within a stream bed, water flow can be directed to encourage formation of pools and meanders. This has the benefit of enhancing the riverbed hydromorphology without excessive intervention, resource inputs or costs.

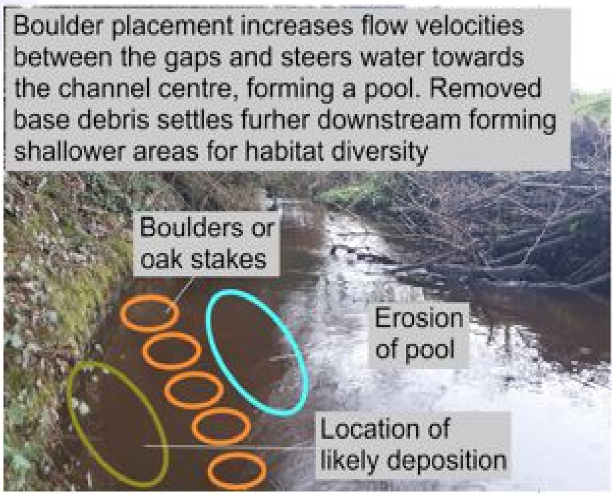
Recommendations during the consultation included placement of driven oak piles or boulders in formation at intervals along the stream bed. Differences in boulder placement lead to different outcomes during high flow events, causing scour of the river bed down-gradient of the stone and deposition further downstream. This leads to variations in bed shape and depth, which enhances the diversity of habitats present along the stream bed. Examples for a small section of the river are shown in the images below.

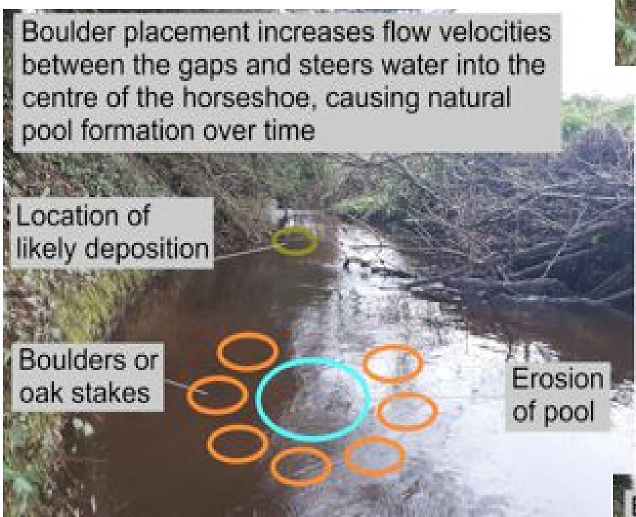
Fig. 13.1 (A-D) – Boulder placement for introduction of in-stream habitat variability



A - Example of boulder placement to encourage scour at river edge for naturally encouraging the river to re-meander.

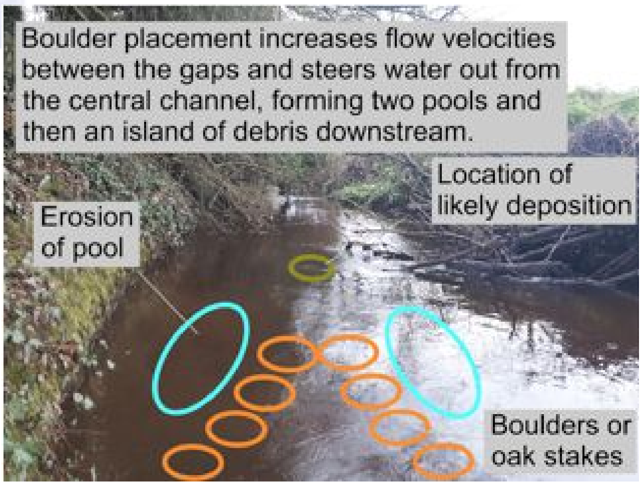
B - Example of boulder placement to encourage deepening of channel centre and deposition at channel edge





C - Example of boulder placement to encourage scour at river centre with deposition further downstream for creation of a braided channel.

D - Example of boulder placement to encourage pool creation within the stream channel with deposition and braiding downstream in the channel centre.



13.2 River Restoration and Waterway Rewilding

Over the past century or more, the River Worm and its tributaries has been straightened and deepened to improve adjacent lands for farming and peat extraction. This has led to a canalisation of the ricer channel, which reduces biodiversity potential and minimises the potential for habitat value along the river. This practice has been relatively common and widespread throughout Ireland and much of Europe. There is a growing trend towards restoring rivers to enhance their value to wildlife, with ancillary benefits for flood/drought prevention and natural water filtration processes. Such measures may be adopted here at Ballinahown to improve the habitat value of the River Worm.

River Restoration and Biodiversity - Nature-Based Solutions for Restoring the Rivers of the UK and Republic of Ireland outlines a suite of measures and a step by step process for implementation of river restoration, with wildlife value as a core focus. The report summarises the benefits of restoration of rivers and floodplains as follows:

- Valuable wildlife habitat for a suite of plants, for bats, fish, amphibians insects and other aquatic and terrestrial animals
- Drinking water supplies
- Food and materials (e.g. fish, reeds)
- Flood regulation
- Carbon storage and climate regulation
- Water purification
- Nutrient cycling
- Cultural inspiration and wellbeing
- Tourism and recreation

River Restoration and Biodiversity outlines a trend towards restoring natural processes, taking a catchment-wide approach if possible; rather than artificial alteration of the river form itself. This has the twin advantages of being lower cost and potentially more effective into the long term. While it will require working with IFI, it has advantage of potentially removing the need for planning permissions, flood studies assessments, OPW weir permissions and similar administrative checks, which in turn speeds up the process and focuses costs on practical works rather than office time.

Restoration of natural river processes can be categorised under the following headings:

- Lateral river movement – to allow for the return of natural erosion dynamics (or as a second preference approach, to allow for meander patterns to occur within the existing river channel)
- Lateral river connectivity – to allow for reconnection between the river and surrounding lands and flood plains (or restoration of bed levels or other measures to achieve a more natural river flow within the existing channel)

- Longitudinal connectivity – removal of obstacles to allow for unimpeded movement of fish and other wildlife (or modification of obstacles as a poor second)
- Riparian vegetation and in-channel wood – to allow characteristic bankside vegetation to establish (adding wood as an interim measures and then allowing fallen wood to remain in-situ over time)

Rewilding receives very mixed responses in Ireland; from celebration of the opportunities for wildlife, to suspicion of the implications for farming. In its essence, large scale rewilding involves two element:

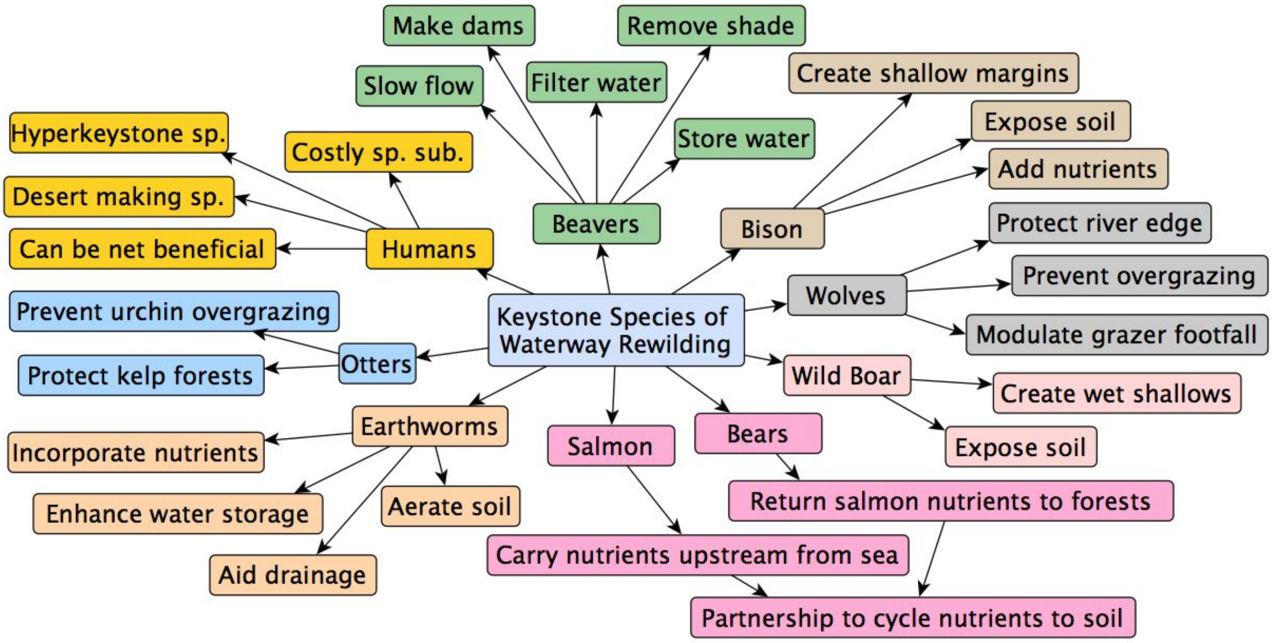
1. giving land back to nature to create sizeable safe core habitat areas
2. bringing nature back into the land to ensure that all of the members of the party are present to play their unique role.

There is also a requirement to link core habitat spaces with safe corridors so that genetic mixing can occur. Otherwise isolated habitat areas will see extinctions occurring due to lack of genetic vigour.

Perhaps the most significant policy change that government could make in the arena of habitat repair and facilitate biodiversity recovery is to actively reward those farmers who have the best habitat on their land. This is often land on which it is also most difficult to make a living from farming, so a preferential reward system makes sense on multiple levels.

There is also a great potential for employing the tools of rewilding within existing farming systems by asking what would the animals do in a given scenario. For example the beaver, common throughout continental Europe, makes dams, slows the flow, recharges groundwater, filters water quality and improves fish stocks. The European bison, recently introduced to Germany from a remnant population in Poland, opens up pasture, limits encroachment of scrub, removes trees, fertilises the soil, improves grassland soil carbon levels and soil depths and creates space for wildflowers to get established. The wolf, safely and quietly spreading westwards since the fall of the Iron Curtain in the late 1989s, protects river edges, limits overgrazing in any one area and helps regenerate forest cover by keeping animals on the move. We can look at these roles and employ the same measures in farming. This has helped to steer management decisions in regenerative agriculture which support nature, keeps farming families on the land and provides food and an income in the agricultural community.

Fig. 13.2 – Overview of keystone species for waterway rewilding (for reintroduction or replacement of missing role in the landscape)



While the dynamics of the bison and wolf (whether with the animals themselves or using people to act as proxy keystone species) will build soil and help with water dynamics in the wider landscape, it is the beaver who is most adept at facilitating changes to our waterways. In order to create the foundations for the return of beavers to Ireland a straightforward policy change would be to pay farmers a premium to create 20-50m buffer zones of land alongside rivers and streams and in lowlying arterial drainage areas. While these areas would regenerate naturally with wetland plants and trees to filter water and modulate flow dynamics, they would also provide potential habitat space for beavers, should they be reintroduced in the future.

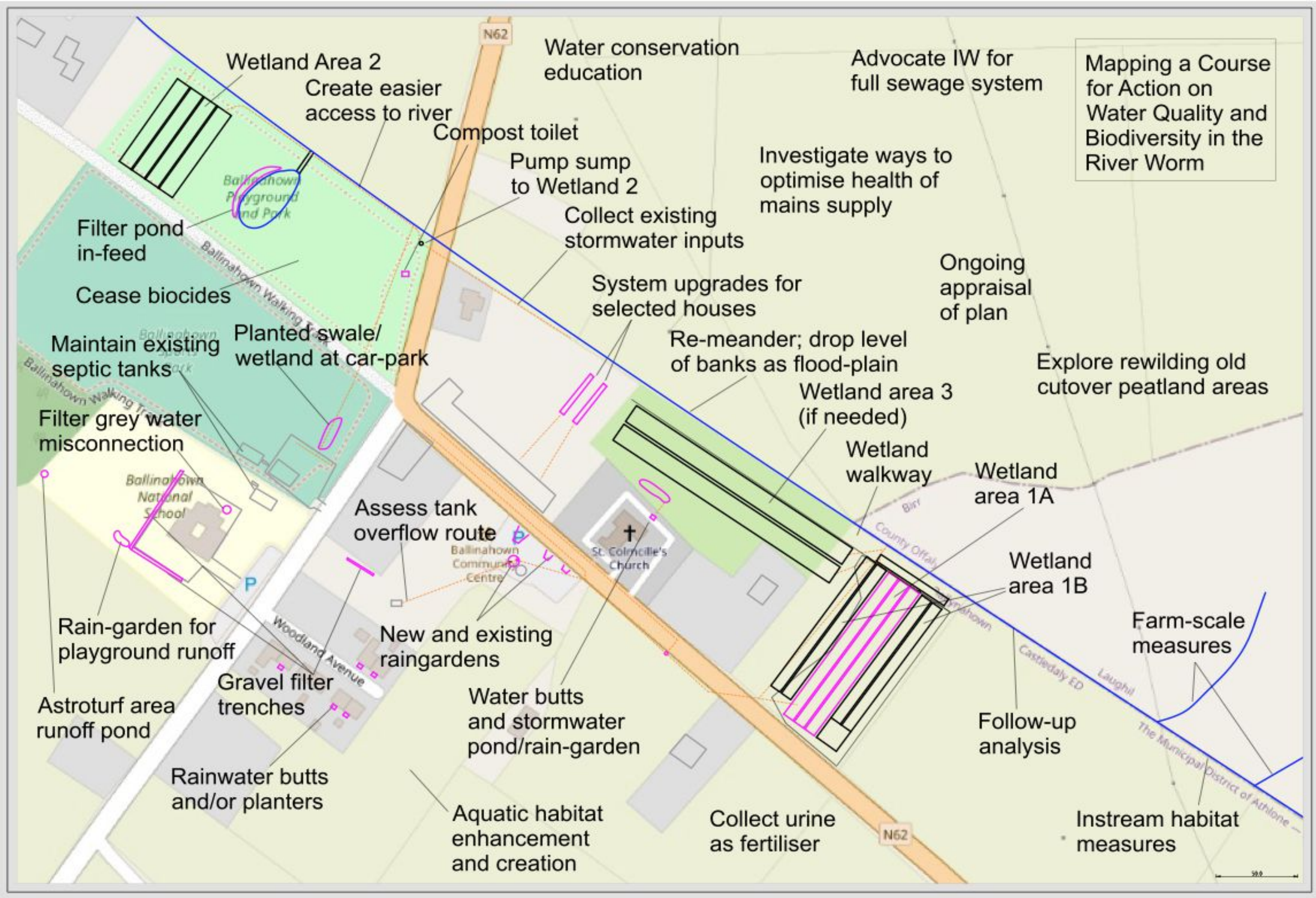
The elements of waterway rewilding specifically include getting rivers clean to allow the natural macroinvertebrate community to thrive; repairing damaged hydromorphology such as weir removal; and reconnecting the waterway with historic floodplains to allow for a more natural flood/drought dynamic. While the more ambitious of these may require large community buy-in, they are worth starting at any and every level. The measures outlined in this document provide a starting point for such a move.

14.0 Mapping a Course for Action

The options and proposals outlined in the preceding chapters provide a useful overview of the possibilities, but a more definite plan is required to map out practical measures that can be implemented on the ground on a phased basis.

To this end, the following list of measures is proposed as a pathway towards better water quality and biodiversity within Ballinahown. The list below shows the stormwater wetland measures first and then follows with other measures, both on-the-ground and educational. Either may be commenced first, and adopt flexibility in light of budget and resource limitations in any given funding year.

Fig. 14.1 – Action Summary Map of Ballinahown



While the main document has helped to identify the actions listed below, it takes a broader look at options and possibilities than the list here. As such, take each item on the list as a project in its own right and assess the design and implementation on a case by case basis. While the document gives context and background it does not have the scope to offer full designs and specifications in each case.

Note that the locations are indicative only. The location of wetland area 1 has been selected as a starting point because it is the route of the existing stormwater pipe, and as such is the easiest construction location; but this location is a preferred option without reference to landowner agreement and is thus flexible.

14.1 Actions for water quality enhancement

Actions listed below have been allocated approximate implementation costs. Note that these are estimates only and are subject to certain assumptions which may or may not hold for a given project; and as such should be reassessed on a case by case basis as they are put into practice.

	Measure	Cost
1	**Construct stormwater wetland Area 1A.** This primary stormwater filter area should be designed to take runoff from roads and the main community car park via the existing stormwater sewer pipe. Septic tank effluent is also known to flow into this storm sewer so the initial filter area shown designed with standard EPA minimum separation distances in mind. Lower the ground level for the central wetland basins shown to allow for full gravity filtration of all stormwater runoff. Area: 2310m^2.	20-50k
2	**Collect existing stormwater inputs** from the village centre by gravity; install a **settling tank and pump sump**; construct **stormwater wetland area 2** (2268m^2). Note; there may be some sewage inputs here due to historic misconnections, so standard EPA separation distances should be observed.	20-50k
3	**Construct stormwater wetland Area 1B.** Pump the water from the end of Area 1A into a series of raised stormwater wetland basins for additional polishing (Area: 2940m2).	20-50k
4	**Construct stormwater wetland Area 3.** This area may be used as additional filter beds for stormwater polishing prior to discharge areas 1A and 1B require further filtration. It should be designed to be gravity fed from area 1B. Note that further filtration would only be needed if sewage is present, and yet this area is closer than 50m to buildings, which is within the EPA minimum distance requirements – thus while this measure can be a helpful way to achieve greater protection of the river, a full Irish Water treatment system would fit more comfortably within national guidance. Area: 3840m^2. Gravity fed from the higher portions of Wetland Area 1.	20-50k
5	Install a **compost toilet** in the biodiversity park as an example project and to serve a practical eco-friendly function for this location.	8k
6	Install **willow-planted percolation areas or full secondary and tertiary treatment** for existing houses, community buildings and/or businesses where space is available. This is proposed as an example of septic tank effluent filtration, particularly for use as a repair process for existing failed percolation areas.	5k/hse
7	When putting in any stormwater wetlands, build a **wetland walkway** around the perimeter of the project areas for members of the public to enjoy the wildlife. The more this walkway can interlink with existing pathways the better, preferably remaining off-road where possible.	5k
8	Explore measures to **bring people into closer contact with the river**; potentially by dropping a section of the park down closer to water level.	5k
9	**Explore waterway rewilding options** such as allowing the river to re-meander and to re-flood during heavy rainfall, even if only in selected areas.	15k

10	Any input drains or tributaries to the River Worm would benefit from **farm-scale measures** to slow the flow and catch nutrients and to filter water. Also, **liaise with local land owners** in the wider Worm catchment to introduce farming practices that support water quality generally.	500/farm
11	**In-stream measures** to be designed into the main channel of the Worm for habitat enhancement. This is to be done in consultation with Inland Fisheries Ireland.	10k
12	Collect water from the **church roof** in a water butt and route overflow to **rain garden or pond** in the adjacent field.	2k
13	**Rain-gardens in community hall car park** area for attenuation and filtration of stormwater; some in place and new one proposed.	500
14	Explore opportunities for **aquatic habitat enhancement and creation** on private and public lands throughout the village and surrounding area. Even small garden ponds and bog gardens can make valuable habitats for wetland wildlife.	2.5k
15	**Celebrate and protect existing wetland habitat** areas. For example, there is a wet area behind the community hall car park with a broad suite of wetland plant species.	500
16	**Study the existing wetland habitat** areas via **citizen science** projects, BioBlitz events, or other similar initiatives.	500
17	**Assess the exit route from main septic tank** and any other sewage system tanks or manholes to assess whether or not they are routed to the storm sewers or the river.	500
18	**Rainwater butts** and/or **planters** to be used **for local houses** that wish to use them, as a measure to catch rainfall and minimise the loading to the storm sewers.	100/hse
19	Explore options for **filtering road runoff** in-situ for existing road layout or for any future road works.	500
20	**Gravel trenches and/or open swales** to collect runoff from newly tarred road near recycling centre to filter runoff water and maximise natural infiltration to ground.	2k
21	**Gravel trenches and/or open swales** to divert runoff from the school playground area to reduce flooding at yard surface. These should flow to **shallow bioretention basin** dropped below trench invert level and planted with willow, alder and birch.	3k
22	**Astroturf runoff** to be routed through a small **stormwater pond** to attenuate flow volumes during heavy rain.	3k
23	**Grey water pipe misconnection at rear of school building** to be routed to new grey water reed bed.	1k

24	**Existing septic tanks** and percolation areas for school and sports grounds; **continue with standard maintenance.** Check the quality of stormwater exiting the sports ground car park rain-garden to assess the potential for sewage contamination of the storm drains in this location.	500
25	Construct a **rain garden or planted swale for sports centre** stormwater runoff; gravity fed.	5k
26	**Cease the use of glyphosate and biocides** generally in all public spaces due to growing health and wildlife problems associated with them.	no cost
27	**Filter inputs from the river to the new park pond** via a new wetland filter area. This would also add habitat value, as well as keep the pond water cleaner for biodiversity.	3k
28	**Outline educational measures** for home owners and local businesses to explain and encourage **water conservation** and best practice in terms of **minimising chemical inputs** to the drains from each building. Include measures to reduce our **water footprint**, globally as well as locally, by looking at our shopping baskets and the impact of our purchases on water elsewhere.	1k
29	**Adopt a role in the future of the upper catchment** area; specifically in the old peat harvesting areas; with a view to exploring opportunities for rewilding this area for maximum wildlife and water quality benefits.	no cost
30	**Collection of urine** from urinals and/or urine separating toilets to minimise nutrients to sewer and offset fertiliser imports on local farmland.	1.5k/ location
31	**Follow up with water quality assessments**; testing regularly for N and P using low-cost test kits as well as lab analysis on an occasional basis for calibration; and annually for a repeated biotic index assessment (to check the Q-value of the river).	500/ sampling date
32	**Explore the quality of drinking water** delivered to Ballinahown village from the council mains supply. Chlorine and fluoride are specifically added to the water and yet there are questions over the health of each, in different ways. Support the community in researching the most up to date scientific findings and solutions in this regard.	free or 1.5k consultancy input
33	**Continue to advocate for full secondary and tertiary treatment** by Irish Water using the most ecologically sound methods available. A willow plantation designed for full nitrogen and phosphorus uptake would probably be the system that would offer the most effective and yet practical protection measure for the river.	no cost
34	**Liaise with a third level institution** to explore options for student research projects on the ecological, hydrological and water quality aspects of the project.	no cost
35	**Reassess this action list** on a yearly basis. Continue to reassess the possibilities for water quality improvement in Ballinahown until the river is at Q5 status of "high" water quality with a vibrant aquatic flora and fauna and is the valued jewel flowing through the centre of the village.	no cost