Kealkill Wastewater Treatment Plant – A0398-01

Freshwater Pearl Mussel Assessment; Water Quality Monitoring 2017

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On behalf of:
Irish Water

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TABLE OF CONTENTS

1. INTRODUCTION

Ecofact Environmental Consultants Ltd. were commissioned by Irish Water to undertake a water quality assessment of the Owvane River upstream and downstream of Kealkill Wastewater Treatment Plant (WwTP) in 2017. This follows on from a recommendation to conduct regular monitoring of the river (Ecofact, 2016) and a prior recommendation in the report *'Ecological Impact Assessment on the potential impacts of discharges from the waste water works in Kealkill, Co. Cork on the freshwater pearl mussel (Margaritifera margaritifera) population in the Owvane River'* (Evelyn Moorkens & Associates, 2011).

The Kealkill WwTP is located in Kealkill, a small village about 10km northeast of Bantry, Co. Cork. Kealkill village lies at the junction of two regional roads, the R584 and R585. Kealkill WwTP is situated approximately 500m southwest of this junction, off the R584.

1.1 Kealkill WwTP Details

According to the Wastewater Discharge Certificate of Authorisation, dated 2009, wastewater treatment at Kealkill is serviced by two WwTP units which receive wastewater under gravity. An oxidation ditch located some 500m southwest of Kealkill village, near the Owvane River serves 82 houses with a population equivalent (p.e.) of 246 and has a treatment capacity of 273 p.e. A septic tank 200m to the northwest of the village adjacent to the R584 serves a small number of properties equating to a p.e. of 25. The septic tank to the northwest of the village is designed to cater for a maximum p.e. of 39. The septic tank provides primary settlement only.

The WwTP to the southwest of Kealkill village is comprised of a rectangular oxidation ditch bisected by a separator wall. On one side of the separator wall is a settlement compartment facilitating decanting of clarified liquid. One brush type aerator is in operation at the site. The total active volume of the oxidation ditch is approximately 109m^3. The existing outfall discharges effluent to the River Owvane adjacent to Kealkill WwTP at Grid Reference E103923, N055885. In the discharge licence application submitted to the EPA, the normal and maximum daily emission volumes from the Kealkill WwTP are given as 92.7m^3 and 278.1m^3 respectively, while the maximum discharge rate/hr is given as 11.6m^3. Details of the discharge from the Kealkill WwTP are provided in Table 1 below.

Table 1 Details of the quality of the discharge from the Kealkill WwTP (values taken from/ derived from the application for waste water discharge certificate dated 22nd December 2009), and also data from the Ecofact (2016) and current survey.

Source	BOD (mg/l)	Total Ammonia (mg/l)	Ortho-phosphate (mg/l)
Authorisation file (2009)	34 (mean)	8.8 (mean)	0.88 (median)
Ecofact (2016-2017)	49.13	14.14	2.68

1.2 Catchment overview

The Kealkill WwTP discharges into the Owvane River (EPA Code: 21O07). The Owvane River rises at the confluence of two first order streams approximately 300m above sea level in the Shehy Mountains. It flows ca. 10km southwest before receiving effluent from the Kealkill WwTP. Approximately 7km to the southwest of the Kealkill WwTP, the 5th order Owvane River flows into Bantry Bay.

The Owvane catchment is located in the 'Dunmanus-Bantry-Kenmare' Hydrometric Area (21) in the South-Western River Basin District (SWRBD). The main tributaries of the Owvane River are the Inchiroe River, the Owngar [Cork] River, the Breeny Beg River, the Owenbeg [Owvane, Cork] River, the Dromduff East River, the Gortroe 21 River and the Ballylickey River. The Kealkill WwTP

Discharge is located just downstream of where the Breeny Beg River flows into the Owvane. The majority of the Owvane catchment has been assigned 'Good' Water Framework Directive status in the period 2010-2015. The upper reaches of the Owvane, the upper reaches of the Owenbeg [Owvane, Cork] and the Owngar [Cork] River have all been defined as having 'High' WFD Status in the same time period. The WFD Risk status of all of the Owvane catchment has been designated as 'Not at Risk'.

The EPA carries out biological monitoring at six different stations within the Owvane catchment (Figure 1). The closest station to the source of the Owvane River (Station Code: 21O07 0200) was rated as Q4-5 in 2015, corresponding to WFD status 'High'. Two stations, one located on the Owenbeg [Owvane, Cork] River (Station Code: 21O03 0200) and one on the Owngar [Cork] River (Station Code: 21O04 0400) were rated as Q4-5 in 2015. There is one monitoring station located in Kealkill town (Station Code: 21O07 0300), upstream of the WwTP discharge on the Owvane River, which was rated as Q4 in 2006, corresponding to WFD status 'Good'. Following this, there is two monitoring stations on the Owvane River approximately 3km upstream of Ballylickey. The furthest upstream station (Station Code: 21O07 0400) was rated as Q4-5 in 2015, and the other (Station Code: 21O07 0410) was rated as Q4 in 2009.

Table 2 Historical EPA Biological Water Quality Ratings (Q-Values) for monitoring stations in the Owvane River Catchment.

Station Location	Station No.	Water Feature	EPA Code	2000	2003	2006	2009	2012	2015
Br SW of Cappaboy	RS21O070200	Owvane (Cork)	21O07	4-5	4-5	4-5	4-5	4-5	4-5
Br E of Maugha	RS21O030200	Owenbeg (Owvane)	21O03	4	4-5	4-5	4-5	4-5	4-5
Cahermoanteen Br	RS21O040400	Owngar (Cork)	21O04	4-5	4-5	4-5	4-5	4-5	4-5
Br NE of Kealkill	RS21O070300	Owvane (Cork)	21O07	4-5	4	4	-	-	-
Pierson's Br (LHS)	RS21O070400	Owvane (Cork)	21O07	4-5	4	4	4	4-5	4-5
Owvane (Cork) - Lisheen / Pierson's Br (RHS)	RS21O070410	Owvane (Cork)	21O07	3	4	-	4	-	-

The EPA biological monitoring station north-east of Kealkill, upstream of the Kealkill WwTP Discharge to the Owvane River has catchment characteristics that were noted in the 2012 EPA Interim Report on the Biological Survey of River Quality. According to the Report, the upstream catchment characteristics of this station show that 46% of the catchment area if comprised of Bogs, 47% is comprised of Pasture land, and the remaining 7% consist of Forestry. A record of zero was recorded for Urban Areas and miscellaneous agriculture. The Altitude was recorded as 21 metres above sea level. The catchment area is reported as 44km^2, and the bedrock consists of 100% siliceous bedrock. These figures have been based on the Corine land use information (EPA, 2012). The subsoils in this area of the catchment are Alluvium undifferentiated, Sandstone and shale till (Devonian / Carboniferous) and Bedrock at Surface (EPA Envision Maps).

The Wastewater Discharge Application for Keakill states that there are no water abstraction points downstream of the Kealkill WwTP discharge point. The EPA Maps do not show any licensed IPPC Facilities in the Owvane catchment.

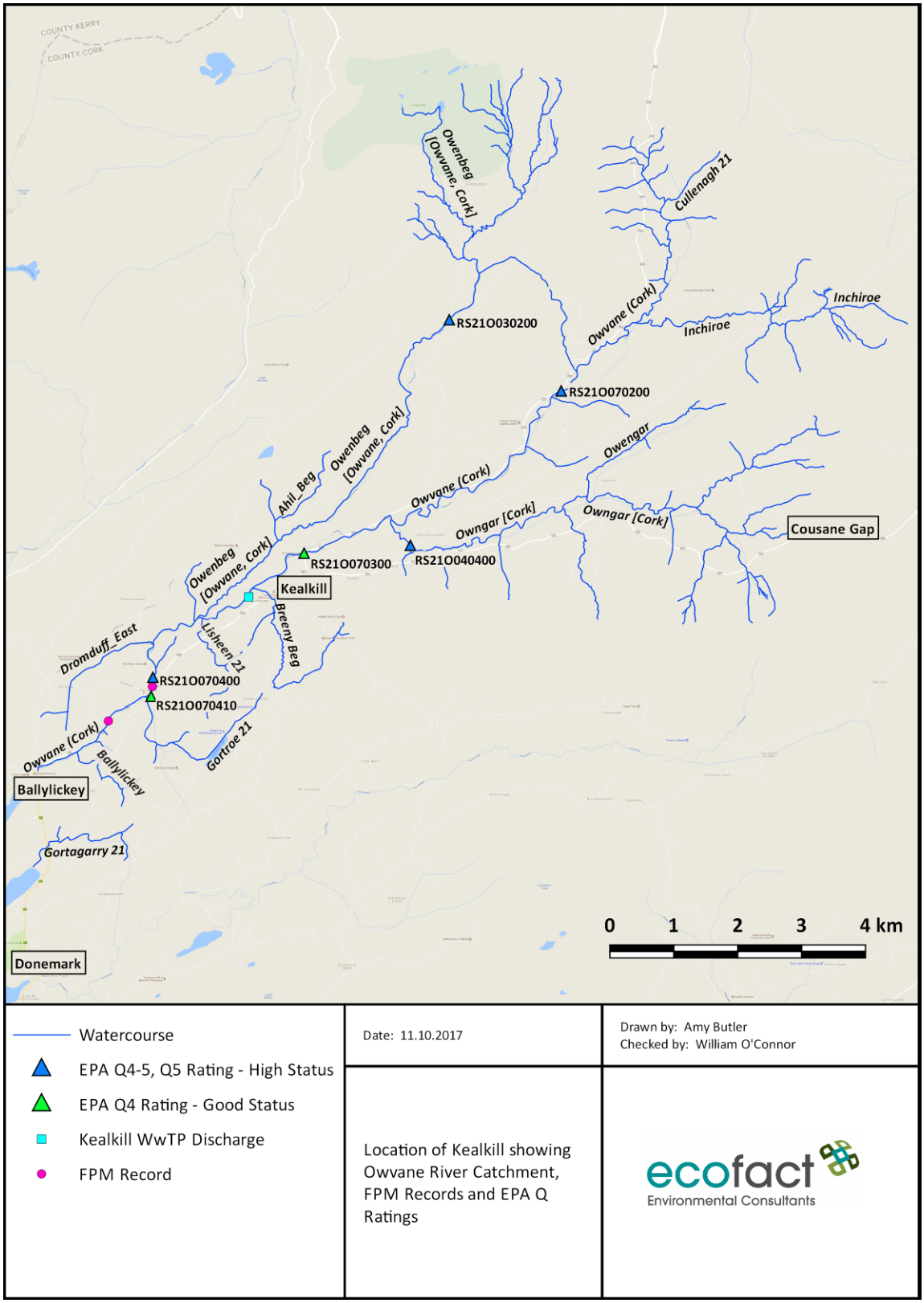

Figure 1 Location of the Kealkill showing Owvane River Catchment, FPM Records and EPA Q ratings.

1.3 Risks and pressures in the catchment

The Inner Bantry Bay Water Management Unit Action Plan lists Kealkill Sewerage Scheme as a point pressure. The pressures / risks include nutrient sources, point pressures, WwTPs and Industrial Discharges, Quarries, Mines & Landfills, On-site systems, Forestry and Abstractions. The main nutrient sources with particular reference to Total Phosphorus (TP) Sources are Agriculture (85%), Aquaculture (4%), Forestry (4%) and Septic Tanks (5%). It is noted in the WMU Action Plan that there are 1338 septic tanks in the WMU, 325 of which are located in areas of very high or extreme risk. O'Reilly (2002) mentions that the drainage scheme below Kealkill did great damage to the pools downstream of the village and notes that the river is quite featureless up to the weir at Kealkill village.

1.4 Summary of Previous Assessments

1.4.1 Water Quality Monitoring 2015

Ecofact Environmental Consultant Ltd. were commissioned by Irish Water to complete chemical water monitoring. Three rounds of water quality sampling were undertaken during the months of August and September of 2015. This sampling was conducted at two sites, upstream and downstream of the Kealkill WwTP at the locations examined in the 2011 report prepared by Evelyn Moorkens & Associates (2011).

The results of the 2015 chemical water quality monitoring programme indicated that Kealkill WwTP could be having some negative effects on the receiving water with regard to Freshwater Pearl Mussel requirements, with particular reference to the nutrients Ammonia and Nitrate and the metal Zinc. The reference site upstream of the WwTP showed elevated background levels of nitrate which exceeded the prescribed limits for Freshwater Pearl Mussel throughout the monitoring programme (Bauer, 1988). Moorkens (2006) found that the highest median nitrate levels associated with effectively recruiting populations of FPM are 0.125mg/l. The results of the 2015 surveys show that the concentrations of nitrate in the Owvane River were found to be well in excess of those required for FPM recruitment.

It was recommended in this report that additional sites should be added to the monitoring programme for the following year. The purpose of this was to gain a better understanding of the impact of the Kealkill WwTP Discharge to the Owvane River.

1.4.2 Water Quality Monitoring 2016

Three rounds (June to August) of water quality sampling were undertaken at the same sites identified in the preceding water quality monitoring reports, with additional ones added: Site 1 - 2.8km downstream of the Keakill WwTP discharge; Site 2 - 1.15km upstream of the Kealkill WwTP discharge; Site 3 - 0.6km downstream of the Kealkill WwTP outfall; Site 4 - 0.5km upstream of the Kealkill WwTP outfall and the discharge point itself. The sampling methodology is the same as the one employed in the current assessment.

The chemical water quality monitoring programme showed that there is some adverse variation in water quality between water samples collected downstream of Kealkill discharge point (Sites 1 and 3) and reference water samples taken upstream (Site 4 and Site 2) in the monitoring period. Suspended Solids (SS) at the outfall were double the target water quality standard for FPM. Nitrate results overall exceeded the target water quality. Concentrations of heavy metals were noted to be greater at Sites 3 and 4 in comparison to Sites 1 and 2. However, heavy metal concentrations were generally within the accepted parameters per the Surface Water Regulations (2009-2015).

It was also clear that there is localised pollution in the immediate vicinity of the outfall. Nevertheless, most parameters analysed showed relatively small changes between reference (upstream) and receptor (downstream) sites. The comparison of data from the two sites close to the outfall location, Site 4 (upstream) and Site 3 (downstream) reveal the following exceptions instantiated in increases in concentrations downstream of outfall:

- Ammoniacal Nitrogen as N (low level)
- Ammoniacal Nitrogen Low as NH3
- Nitrate as NO_3

The 2016 chemical water quality monitoring programme, and with special reference to Sites 3 and 4, revealed that Kealkill WwTP was having some effects on the receiving water. Discharges from the WwTP appear to be contributing to the already elevated background concentrations of Nitrogen in the River Owvane with regard to the requirements of FPM. The average downstream concentration of Ammoniacal Nitrogen as N (0.075mg/l) exceeded the limit for both High and Good Status (mean flows) given in the Surface Water Regulations (2009-2015). Due to the wet summer of 2016 95%ile flows were not realised and one of the three samples were taken under flood conditions. Therefore, the mean flow value is relevant here. It is noted that the upstream value (0.049mg/l) also exceeded the Total Ammonia Good Status at mean flows (≤0.040mg/l). Ammoniacal Nitrogen as NH_3 was also found to increase downstream of the outfall (86%). However, the waste assimilation capacity and dilution calculations made during this investigation suggested that the receiving water of the Owvane River theoretically has an adequate waste assimilation capacity for BOD, Total Ammonia and Ortho-phosphate under various conditions of flow and in relation to normal rates of discharges from Kealkill WwTP.

Biological monitoring was also completed in August 2016. A macroinvertebrate family richness of 23 was recorded at both sites. Group C (pollution tolerant) species were the most frequently occurring at both sites. Pollution sensitive *Ecdyonurus sp., Perla bipunctata,* and *Amphinemoura sulcicollis* all from Group A were recorded in each of the samples. Trichoptera species were well represented in each of the samples with both cased and uncased families recorded. One Group E (most tolerant) species: Bloodworm *Chironomous sp* were confirmed as Site 3. The two sites were assigned an 'Unpolluted (Q4)' rating which corresponds to Water Framework Directive (WFD) 'Good' status.

During this survey, many other pressures on the Owvane River were observed. The legacy of drainage works on the river has resulted in unstable river banks which are eroding and are a source of silt. This has been exacerbated by the spread of non-native invasive species (Japanese knotweed and Himalayan balsam) along the river banks. These plants out-compete other riparian plants and further destabilise river banks. The gravel trap at Site 4 is likely to cause fish passage problems affecting salmonid host fish. There is also a proliferation of one-off houses along the river bank downstream of Pearson's bridge and some of these houses are dumping grass cuttings and even domestic waste into the river in the main area where FPMs occur.

2. METHODOLOGY

2.1 Introduction

The WwTP at Kealkill is located to the west of Kealkill and the existing outfall discharges effluent to the River Owvane adjacent to the WwTP at Grid Reference E103923, N55885. There is an outfall at this location and this is the outfall that was sampled during the 2016 and 2017 surveys. According to Irish Water there may be an additional discharge into the stream which enters the Owvane River upstream from here. This stream joins the River Owvane downstream of Site 4 so the status of this site as a reference site remains unchanged.

A total of four survey sites were located on the Owvane River: two downstream of the Kealkill WwTP outfall (Site 1 and Site 3) and 2 upstream of the Kealkill WwTP outfall (Site 2 and Site 4). These sites are illustrated in Figure 2 below. Chemical water quality surveys were carried out at all locations while biological sampling was carried out at Site 3 and Site 4. The site locations for this survey were replicates on the previous chemical water quality survey carried out by Ecofact in 2016 (Ecofact, 2016). These sites were selected based on access, repeatability and safety.

Site 3 was located ca. 0.6km downstream of the WwTP outfall, approximately 200m downstream of the Owvane confluence with the Breeny Stream. This part of the Owvane River was easily accessible via an existing track from the R584 to the Owvane River. It is noted that the stretch of the Owvane River between the Breeny Stream confluence and the Kealkill WwTP outfall could not be accessed due to the character of the terrain. Along this reach of the river, the banks are high, steep and are vegetated by dense bramble scrub and Japanese knotweed (*Fallopia japonica*). This part of the river was deep and a survey site on this stretch would not have been suitable at flows higher than normal. The Breeny Stream is a minor 2nd order watercourse with a diminutive flow. Selection of receptor Site 3 downstream of the Breeny Stream confluence is not considered a significant factor in determining the impact of the Kealkill WwTP outfall on surface water quality taking into account the small size of the Breeny Stream relative to the Owvane River.

Table 3 Location of the survey sites on the Owvane River downstream and upstream of the Kealkill WwTP.

	Site 1	Site 2	Site 3	Site 4	Outfall
Location	ca. 2.8km downstream of the WwTP outfall	ca. 1.15km upstream of the WwTP outfall	ca. 0.6km downstream of the WwTP outfall	ca. 0.5km upstream of the WwTP outfall	
Grid Reference (X, Y)	102400, 54472	104701, 56540	104256, 56178	103453, 55641	103923, 55885
Chemical water quality	✓	✓	✓	✓	✓
Biological water quality			✓	✓	

2.2 Chemical Water Quality

A water quality monitoring programme was conducted from August to September 2017. Chemical water quality samples were taken from the Owvane River on three rounds on the following dates 1st of August (round 1), 16th of August (round 2) and on 26th of September (round 3). These three samples represented hydrological events that were deemed characteristic of conditions on the Owvane River. These were during 'normal' water levels, on a rainy day after a period of unusually dry weather and just following heavy rainfall when the river was in flood, during round 1, round 2 and round 3 respectively. On each sampling date, water samples were collected from four water quality sampling sites on the Owvane River.

Samples at sites located on the Owvane River were collected by wading into the river and immersing bottles supplied by ALS Life Sciences in flowing water of sufficient depth. Care was taken not to contaminate water samples by entering the river downstream of the sampling points and working in the upstream direction. The outfall was also sampled at each of the three rounds. Samples were collected by courier and promptly delivered to ALS. The sampling locations are given in Table 3.

The following physico-chemical parameters were tested: Toxic Metals, Alkalinity (Total as CaCO3), BOD, Ammoniacal Nitrogen as N, Nitrate as NO3, Phosphate (ortho) as PO4, Sulphate, Nitrite as NO2, Phosphorus, Iron, Aluminium, Metals Prep, pH, Total Suspended Solids. Onsite measurements of water temperature and Dissolved Oxygen (DO) were also taken by Ecofact staff using portable meters. Full results can be found in Appendix 1.

2.3 Biological Water Quality

Biological water quality sampling was undertaken at Site 1 and Site 2 (Figure 2) using standard EPA kick sampling (Toner *et al.,* 2005) during August 2017. The samples of invertebrates were preserved in isopropanol and examined in the laboratory. The Quality Rating (Q) System devised by Toner *et al.* (2005) was used to obtain a water quality rating (Q-Value).

2.4 Waste Assimilation Capacity

A Waste Assimilation Capacity (WAC) assessment was carried out to attempt to quantify the impact of the Kealkill WwTP on chemical water quality in the Owvane River. The results and calculations of this assessment will be included in the current report to aid in the current assessment of Kealkill WwTP.

WAC is a measure of the ability of water to assimilate or absorb pollutants whilst still maintaining acceptable water quality in relation to applicable water quality standards. The capacity of a waterbody to assimilate waste (i.e. WAC) provides a link between water quality standards and effluent emission standards. The 'Notional Clean River Values' were used. The notional values used follow criteria as set out by the EPA. The EPA uses this approach for a hypothetically clean stretch of river in the absence of sufficient chemical data. The EPA allow an arbitrary figure of 20% of the upper limit nutrient values for High Status River Water Bodies (as defined in S.I. No. 272 of 2009 (DoEHLG, 2009)) to be used as a mean value for the purposes of calculating the background nutrient value of a river upstream of a zone of impact. The rationale behind this approach is that regardless of how well treated the effluent being discharged is, the target EQS cannot be met if background water quality is not adequate. Table 4, gives environmental quality standards (EQS) set out in DoEHLG (2009a) and subsequent amendments in 2012 and 2015. The Notional clean values are provided in Table 5.

Table 4 Requirements of the European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I. 272 of 2009) for assigning rivers 'High' or 'Good' status with respect to Total Ammonia, Biochemical Oxygen Demand (BOD) and Ortho-phosphate (MRP).

Parameter	Mean flow		95%ile flow	
	High status	Good status	High status	Good status
Total Ammonia (mg N/l)	≤0.040	≤0.065	≤0.090	≤0.140
BOD (mg O_2/l)	≤1.3	≤1.5	≤2.2	≤2.6
Ortho-phosphate (mg P/l)	≤0.025	≤0.035	≤0.045	≤0.075

Table 5 Notional clean values used for Total Ammonia, Biochemical Oxygen Demand (BOD) and Ortho-phosphate in the WAC assessment for the Owvane River upstream of the Kealkill WwTP discharge point.

Parameter	Notional clean river value (20% of "High Status" standard)
Total Ammonia (mg N/l)	0.008 (mean) or 0.018 (95%ile)
BOD (mg O_2/l)	0.26 (mean) or 0.44 (95%ile)
Ortho-phosphate (mg P/l)	0.005 (mean) or 0.009 (95%ile)

The waste assimilation capacity of the Owvane River at the discharge point was calculated for 95%ile flows assuming notional clean background values for WFD 'high' and WFD 'good' status. The following formula was used to calculate waste assimilation capacity:

Waste Assimilation Capacity (WAC) = $(C_{max} – C_{back}) \times F \times 86.4$ kg/day.

where: C_{max} = maximum permissible concentration (mg/l);
C_{back} = background concentration (mg/l);
F = flow (m^3/s); and
86.4 = conversion factor.

The impact of the proposed discharge was assessed separately from impacts in the upstream catchment i.e. the theoretical impact of the discharge was determined in order to help quantify the magnitude of impact of the loading of the Kealkill WwTP. The theoretical impact of the discharge was assessed by conducting a mass balance calculation using adjusted background concentrations and comparing this against the EQS values:

$$\text{Resultant Concentration (T)} = \frac{FC + fc}{F+f}$$

where T = Resultant Concentration due to the discharge;
F = Flow in Receiving Water (95%ile flows 0.2057 m^3/s, 0.261 m^3/s);
C = Mean Background Concentration in Receiving Water (adjusted background concentrations);
c = Concentration in the discharge; and
f = Discharge Flow

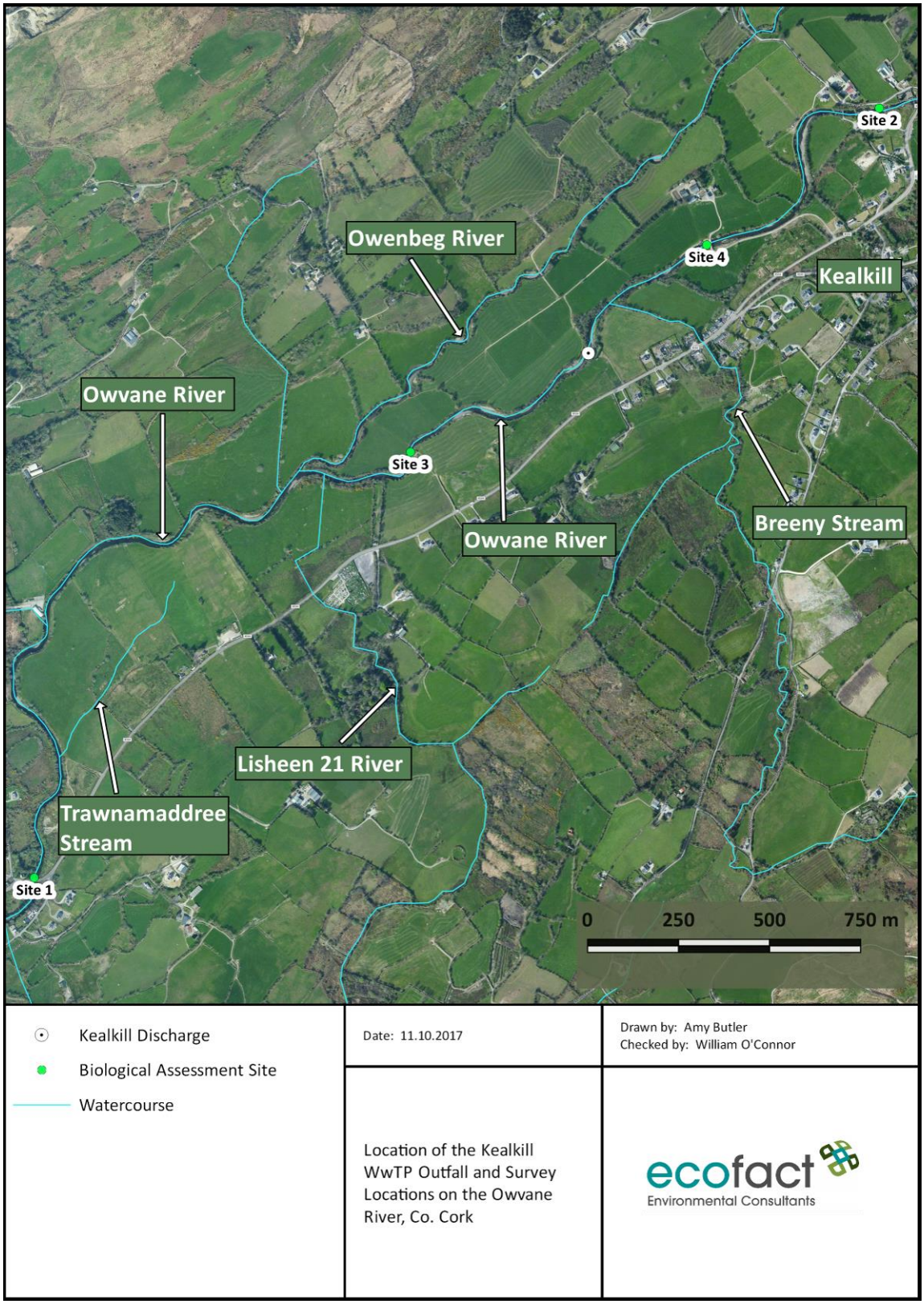

Figure 2 Location of the Kealkill WwTP discharge point and survey locations on the Owvane River, Co. Cork

3. RESULTS

3.1 Chemical water quality

The chemical water quality results for four sites sampled on the Owvane River and the Kealkill WwTP outfall are summarised in Tables 6 to 10 under the relevant headings. The full suite of chemical water quality results is included in Appendix 1. The results are interpreted in relation to standards given in the Surface Water Quality (Objectives) Regulations (2009-2015) and also general precautionary standards for Freshwater Pearl Mussel.

3.1.1 Site 1

Water samples taken from the Owvane River approximately 2.8km downstream of the WwTP discharge point during the monitoring programme from August to September were analysed for a suite of chemical water quality parameters (see Table 6). The pH readings ranged from 6.92 to 7.45. Suspended Solids and Phosphate (ortho as PO4) complied with the target water quality standards. Concentrations of Phosphorous were in excess of target water quality requirements in round two. Round three showed elevated concentrations of Nitrate (as NO3), Copper and Zinc. Heavy metal concentrations were within the lower limits as per Surface Water Regulations (2009-2015).

Table 6 A summary of water quality results taken from Site 1 (2.8km d/s outfall) on the Owvane River from August to September 2017. Suggested water quality objectives for FPM are included, as are surface water quality requirements defined by S.I. No. 272 of 2009: European Communities Environmental Objectives (Surface Waters) Regulations 2009-2015.

Parameter	LOD/Units	Round 1 (01/08/17)	Round 2 (16/08/17)	Round 3 (26/09/17)	Target water quality	Surface Water Regulations (2009-2015)
Temperature	^{o}C	15.1	14.5	19		
D.O.	%	108.3	105.0	105.8		
D.O.	ppm	10.73	10.32	9.18		
Conductivity (uS)				89		
Conductivity (20 deg. C)	<0.005 mS/cm	0.0733	0.0472	0.0873		
pH	<1 pH Units	7.04	6.92	7.45	6.5 – 7.2[b]	4.5 - 9.0
BOD	<1 mg/l	<1	-	<1		1.3 (mean 2.2) (95%ile)**
Suspended Solids (total)	<2 mg/l	<2	12.7	<2	<25*[c]	
Ammoniacal Nitrogen as N	<0.01 mg/l	0.0525	0.0278	0.027		0.040 (mean) 0.090 (95%ile)**
Nitrate (as NO3)	<0.3 mg/l	0.626	0.352	1.95	<0.5*[a]	
Phosphate (ortho; as PO4)	<0.02 mg/l	<0.02	<0.02	<0.02	<0.03[ab]	0.025 – 0.045
Phosphorous (tot.unfilt)	<20 µg/l	<20	64.9	31.1	<62[d]	
Arsenic (diss.filt)	<0.5 µg/l	0.674	0.625	0.596		25[†]
Copper (diss.filt)	<0.3 µg/l	0.606	0.731	0.779		5[†]
Lead (diss.filt)	<0.2 µg/l	<0.2	<0.2	<0.2		1.2[#]
Nickel (diss.filt)	<0.4 µg/l	<0.4	<0.4	<0.4		4[#]
Zinc (diss.filt)	<1 µg/l	2.11	<1	14.9		50[†]
Mercury (diss.filt)	<0.01 µg/l	<0.01	<0.01	<0.01		0.05[†]

*values are precautionary i.e., lowest target values from published sources are included; [a.]Bauer 1998; [b.]Oliver, 2000; [c.]Cooksley and Blake, 2014; [d.]EPA (2001); [†]annual average; [††]Not greater than a 1.5°C rise in ambient temperature outside the mixing zone; [#]these values are proposed as amendments to the Surface Water Regulations (2009-2015); ** High Status.

3.1.2 Site 2

Water samples taken from the Owvane River approximately 1.15km upstream of the WwTP discharge point during the monitoring programme were analysed for a suite of chemical water quality parameters (see Table 7). Elevated levels of Biological oxygen demand (BOD), Nitrate (as NO3), Arsenic, Copper and Zinc were reported in round three. Ammoniacal Nitrogen NH3, Phosphate (ortho as PO4), Lead, Nickel and Mercury were below detectable limits. Heavy metals were within accepted parameters per the Surface Water Regulations (2009-2015). All concentrations were generally within the suggested target water quality objectives for FPM with the exception of pH readings at round one and round three.

Table 7 A summary of water quality results taken from Site 2 (1.15km upstream of outfall) on the Owvane River from August to September 2017. Suggested water quality objectives for FPM are included, as are surface water quality requirements defined by S.I. No. 272 of 2009: European Communities Environmental Objectives (Surface Waters) Regulations 2009.

Parameter	LOD/Units	Round 1 (01/08/17)	Round 2 (16/08/17)	Round 3 (26/09/17)	Target water quality	Surface Water Regulations (2009-2015)
Temperature	^{o}C	14.6	14.4	16.4		
D.O.	%	105	104.5	99.3		
D.O.	ppm	10.25	10.24	10.40		
Conductivity (uS)				84.6		
Conductivity (20 deg. C)	<0.005 mS/cm	0.0687	0.0621	0.0725		
pH	<1 pH Units	7.34	7.06	7.36	6.5 – 7.2[b]	4.5 - 9.0
BOD	<1 mg/l	<1	-	3.06		1.3 (mean) 2.2 (95%ile)**
Suspended Solids (total)	<2 mg/l	<2	4.5	<2	<25*[c]	
Ammoniacal Nitrogen as N	<0.01 mg/l	0.0183	0.0371	0.0346		0.040 (mean) 0.090 (95%ile)**
Nitrate (as NO3)	<0.3 mg/l	0.492	0.439	1.14	<0.5*[a]	
Phosphate (ortho; as PO4)	<0.02 mg/l	<0.02	<0.02	<0.02	<0.03[ab]	0.025 – 0.045
Phosphorous (tot.unfilt)	<20 µg/l	<20	29.2	24.4	<62[d]	
Arsenic (diss.filt)	<0.5 µg/l	0.725	0.802	0.814		25[†]
Copper (diss.filt)	<0.3 µg/l	0.501	0.56	0.703		5[†]
Lead (diss.filt)	<0.2 µg/l	<0.2	<0.2	<0.2		1.2[#]
Nickel (diss.filt)	<0.4 µg/l	<0.4	<0.4	<0.4		4[#]
Zinc (diss.filt)	<1 µg/l	1.46	<1	2.06		50[†]
Mercury (diss.filt)	<0.01 µg/l	<0.01	<0.01	<0.01		0.05[†]

*values are precautionary i.e., lowest target values from published sources are included; [a.]Bauer 1998; [b.]Oliver, 2000; [c.]Cooksley and Blake, 2014; [d.]EPA (2001); [†]annual average; [††]Not greater than a 1.5°C rise in ambient temperature outside the mixing zone; [#]these values are proposed as amendments to the Surface Water Regulations (2009-2015); ** High Status.

3.1.3 Site 3

Water samples taken from the Owvane River approximately 0.6km downstream of the WwTP discharge point in the monitoring period from August to September were analysed for a suite of chemical water quality parameters (see Table 8). The pH readings were within the target water quality standards for FPM, in the range of 6.5-7.2. Suspended Solids, Lead, Nickel and Mercury were below LOD in all three rounds. Nitrate results were elevated in all three rounds, exceeding target water quality requirements for FPM. Phosphorous recorded in round three exceeded the target water quality standards for FPM. Such background high levels of nutrients make conditions in the river

unfavourable for FPM populations. Heavy metals were not an issue at this site and were within accepted parameters as per the Surface Water Regulations (2009-2015).

Table 8 A summary of water quality results taken from Site 3 (600m downstream of outfall) on the Owvane River from August to September 2017. Suggested water quality objectives for FPM are included, as are surface water quality requirements defined by S.I. No. 272 of 2009: European Communities Environmental Objectives (Surface Waters) Regulations 2009.

Parameter	LOD/Units	Round 1 (01/08/17)	Round 2 (16/08/17)	Round 3 (26/09/17)	Target water quality	Surface Water Regulations (2009-2015)
Temperature	^{o}C	16.3	14.7	18.2		
D.O.	%	107	105.0	96.6		
D.O.	ppm	10.25	10.20	9.09		
Conductivity (uS)				92.1		
Conductivity (20 deg. C)	<0.005 mS/cm	0.0785	0.0622	0.0787		
pH	<1 pH Units	7.15	7.01	7.25	6.5 – 7.2[b]	4.5 - 9.0
BOD	<1 mg/l	<1	-	<1		1.3 (mean 2.2 (95%ile)***
Suspended Solids (total)	<2 mg/l	<2	<2	<2	<25*[c]	
Ammoniacal Nitrogen as N	<0.01 mg/l	0.0381	0.034	0.12		0.040 (mean) – 0.090 (95%ile)**
Nitrate (as NO3)	<0.3 mg/l	0.633	0.543	1.83	<0.5*[a]	
Phosphate (ortho; as PO4)	<0.02 mg/l	<0.02	<0.02	0.0326	<0.03[ab]	0.025 – 0.045
Phosphorous (tot.unfilt)	<20 µg/l	<20	30.6	82.9	<62[d]	
Arsenic (diss.filt)	<0.5 µg/l	0.525	0.834	0.76		25[†]
Copper (diss.filt)	<0.3 µg/l	0.677	0.714	0.619		5[†]
Lead (diss.filt)	<0.2 µg/l	<0.2	<0.2	<0.2		1.2[#]
Nickel (diss.filt)	<0.4 µg/l	<0.4	<0.4	<0.4		4[#]
Zinc (diss.filt)	<1 µg/l	3.83	<1	3.03		50[†]
Mercury (diss.filt)	<0.01 µg/l	<0.01	<0.01	<0.01		0.05[†]

*values are precautionary i.e., lowest target values from published sources are included; [a.]Bauer 1998; [b.]Oliver, 2000; [c.]Cooksley and Blake, 2014; [d.]EPA (2001); [†]annual average; [††]Not greater than a 1.5°C rise in ambient temperature outside the mixing zone; [#]these values are proposed as amendments to the Surface Water Regulation (2009-2015); ** High Status.

3.1.4 Site 4

Water samples taken from the Owvane River approximately ca. 0.5km upstream of the WwTP discharge point during the monitoring programme were analysed for a suite of chemical water quality parameters (see Table 9). The pH readings for all three rounds were within the Surface Water Regulations (2009-2015) of 4.5-9.0. The nitrate results for round three exceeded the target water quality standards for FPM. Phosphorous was also found to be lower at this upstream site when compared to the downstream sites. Phosphorous levels were elevated during round two and three when water levels were higher than that of round one. Higher levels of Zinc were also recorded in this third round compared to the other two rounds. Heavy metals were all within accepted parameters per the Regulations (2009-2015).

3.1.5 Site KO (Outfall)

Water samples taken directly from the WwTP discharge point in the monitoring period from August to September were analysed for a suite of chemical water quality parameters (see Table 10). Suspended solids were 33.9mg/l during round three. BOD was 37.2 mg/l in round two, which is

considered slightly elevated. Phosphorus levels were considered elevated in rounds one (1030) and two (1060) mg/l). It is noted that this plant is below the threshold of the Urban Wastewater Treatment Regulations (UWWRs) (2001-2010) and there are no ELV limits in the COA. In addition, there are no Ammonia ELV limits in the UWWRs. The WwTP is designed for 25/35/125 BOD/SS/COD. The WWTP is not designed for nutrient removal.

Table 9 A summary of water quality results taken from Site 4 (500m upstream of outfall) on the Owvane River from August to September 2017. Suggested water quality objectives for FPM are included, as are surface water quality requirements defined by S.I. No. 272 of 2009: European Communities Environmental Objectives (Surface Waters) Regulations 2009-2015.

Parameter	LOD/Units	Round 1 (01/08/17)	Round 2 (16/08/17)	Round 3 (26/09/17)	Target water quality	Surface Water Regulations (2009-2015)
Temperature	^{o}C	15.1	14.6	17.8		
D.O.	%	95.2	100.2	108.1		
D.O.	ppm	9.79	10.20	9.74		
Conductivity (uS)				69.2		
Conductivity (20 deg. C)	<0.005 mS/cm	0.0675	0.0675	0.0726		
pH	<1 pH Units	7.26	7.25	7.33	6.5 – 7.2[b]	4.5 - 9.0
BOD	<1 mg/l	<1	-	<1		1.3 (mean 2.2) (95%ile)**
Suspended Solids (total)	<2 mg/l	<2	3.4	<2	<25*[c]	
Ammoniacal Nitrogen as N	<0.01 mg/l	<0.01	0.0382	0.0398		0.040 (mean) – 0.090 (95%ile)**
Nitrate (as NO3)	<0.3 mg/l	0.444	0.44	1.11	<0.5*[a]	
Phosphate (ortho; as PO4)	<0.02 mg/l	<0.02	<0.02	<0.02	<0.03[ab]	0.025 – 0.045
Phosphorous (tot.unfilt)	<20 µg/l	<20	28.5	32.5	<62[d]	
Arsenic (diss.filt)	<0.5 µg/l	0.754	0.823	0.865		25[†]
Copper (diss.filt)	<0.3 µg/l	0.425	0.575	<0.3		5[†]
Lead (diss.filt)	<0.2 µg/l	<0.2	<0.2	<0.2		1.2[#]
Nickel (diss.filt)	<0.4 µg/l	<0.4	<0.4	<0.4		4[#]
Zinc (diss.filt)	<1 µg/l	1.79	<1	3.79		50[†]
Mercury (diss.filt)	<0.01 µg/l	<0.01	<0.01	<0.01		0.05[†]

*values are precautionary i.e., lowest target values from published sources are included; [a.]Bauer 1998; [b.]Oliver, 2000; [c.]Cooksley and Blake, 2014; [d.]EPA (2001); [†]annual average; [††]Not greater than a 1.5°C rise in ambient temperature outside the mixing zone; [#]these values are proposed as amendments to the Surface Water Regulations (2009-2015); ** High Status.

3.2 Biological water quality

3.2.1 Site 3 (Downstream)

This sampling location was located approximately 600m downstream of the Kealkill WwTP outfall. A total of 18 macroinverebrate families were recorded. The macroinvertebrate community comprised pollution sensitive stonefly (*Perla bipunctata and Amphinemoura sulcicollis*) and mayfly larvae (*Ecdynurus* sp.) Group B (less sensitive) indicators included *Leuctra hippopus* stonefly larvae, and the caddisfly larvae *Agapetus fuscipes, Sericostoma personatum* and *Odontocerum albicorne*. Pollution tolerant (Group C) taxa included the caseless caddis fly larvae *Rhyacophila dorsalis and Plectronemia conspersa* and Dipteran larvae. Overall biological water quality at Site 3 was rated 'Unpolluted, Q4', corresponding to WFD 'good' status.

3.2.4 Site 4 (Upstream)

A total of 16 families were recorded at this site. The Class A indicators were Heptagenid mayfly larvae (Scarce/Few), Perlid stonefly larvae (small numbers), and Nemourid stonefly larvae (Present). Small numvers of the cased caddisfly larvae *Agapetus fuscipes* were recorded. Pollution tolerant (Group C) taxa included the caseless caddis fly larvae *Rhyacophila dorsalis and Plectronemia conspersa* and Dipteran larvae. Based on the macroinvertebrate composition and other determinants used in the Q-rating system (e.g. siltation, algal growth), biological water quality at Site 3 was rated 'Unpolluted, Q4', corresponding to WFD 'good' status.

Table 10 A summary of water quality results taken from Site KO (Outfall) in the Owvane River from August to September 2017. The levels required under the Urban Wastewater Treatment Regulations (2001-2010) are provided for comparison only. It is noted that the COA does not have ELV limits and it is below threshold for UWW Regulations requirements in relation to population size.

Parameter	LOD/Units	Round 1 (01/08/17)	Round 2 (16/08/17)	Round 3 (26/09/17)	Urban Wastewater Treatment Regulations (2001-2010)*
pH	<1 pH Units	6.9	7.02	6.96	
BOD, unfiltered	<1 mg/l	<25	-	37.2	<35
Suspended Solids (total)	<2 mg/l	41.8	15.2	33.9	<25
Ammoniacal Nitrogen as N	<0.01 mg/l	13.7	4.69	9.93	<15
Nitrate (as NO3)	<0.3 mg/l	<0.3	<0.3	<0.3	
Phosphate (ortho; as PO4)	<0.02 mg/l	0.678	0.858	1.02	
Phosphorous (tot.unfilt)	<20 µg/l	2440	1010	2130	
Arsenic (diss.filt)	<0.5 µg/l	2.35	2.26	3.18	
Copper (diss.filt)	<0.3 µg/l	5.14	4.28	10.3	
Lead (diss.filt)	<0.2 µg/l	<0.2	0.329	<0.2	
Nickel (diss.filt)	<0.4 µg/l	0.492	0.629	0.765	
Zinc (diss.filt)	<1 µg/l	4.22	6.33	12.5	
Mercury (diss.filt)	<0.01 µg/l	<0.01	<0.01	<0.01	

**Levels provided for comparison only.*

3.3 Waste Assimilation Capacity and Dilution

Using notional clean values for key water quality parameters, the maximum rate of discharge from the Kealkill WwTP of 287.4m^3/day and various flows in the Owvane River, the receiving water theoretically has adequate waste assimilation capacity for BOD, Total Ammonia and Ortho-phosphate (Good Status). Table 11 gives the WAC of the Owvane River and projected increases in concentrations of these parameters in the Owvane River under different scenarios at normal rates of discharge.

Using river flow data as per the values given in the application for the Kealkill waste water discharge, the Owvane River provides dilution of the effluent at a rate of 454:1 at median river flow and dilution at a rate of 64:1 at 95%ile river flow. Based on river flows returned by the EPA Hydrotool, the effluent discharged to the Owvane River is diluted by the receiving waterbody by a factor of 790 at mean flow and 68.5 at 95%ile flow. The above dilutions are for times of maximum daily discharges from the Kealkill (287.4m^3/day). At times of normal discharge from the plant, the Owvane River provides dilution of the effluent at a rate of 2,449:1 at mean river flow and dilution at a rate of 212:1 at 95%ile river flow.

Table 10 Macroinvertebrates recorded during biological sampling carried out on the Owvane River at Kealkill, Co. Cork during August 2016.

	Pollution sensitivity group	Relative abundance Site 3	Site 4
MAYFLIES (Uniramia, Ephemeroptera)			
Heptagenidae			
Ecdyonurus sp.	A	Present	Scarce/Few
Ephemerellidae			
Blue-winged olive *Seratella ignita*	C	Scarce/Few	Present
Baetidae			
Large dark olive *Baetis rhodani*	C	Common	Fair Numbers
STONEFLIES (Plecoptera)			
Perlidae			
Perla bipunctata	A	Small Numbers	Small Numbers
Nemouridae			
Amphinemoura sulcicollis	A	Present	Present
Leuctridae			
Leuctra hippopus	B	Common	Common
CASED CADDIS FLIES (Tricoptera)			
Glossosomatidae			
Agapetus fuscipes	B	Small Numbers	Small Numbers
Sericostomatidae			
Sericostoma personatum	B	Scarce/Few	
Odontoceridae			
Odontocerum albicorne	B	Present	Present
CASELESS CADDIS FLIES (Trichoptera)			
Hydropsychidae			
Hydropsyche sp.	C	Present	Scarce/Few
Rhyacophilidae			
Rhyacophila dorsalis	C	Small Numbers	Present
Polycentopodidae			
Plectronemia conspersa	C	Present	Present
TRUE FLIES (Diptera)			
Simulidae	C		
Similium sp.	C	Fair Numbers	Present
Chironomidae			
Green chironomid	C	Scarce/Few	Scarce/Few
BEETLES (Coleoptera)			
Elmidae			
Limnius sp.	C	Present	Scarce/Few
CRUSTACEANS (Crustacea)			
Amphipods (Amphipoda, Gammaridae)	C	Present	Scarce/Few
Gammarus duebeni			
BUGS (Hemiptera)			
Water striders (Gerridae)	D	Common	Common
Gerris sp.			
SPIDERS (Crustacea, Arachnida)	C		
Water mite (Order Hydracarina)	C	Present	
Diversity		**18**	**16**
Q rating		**Q4**	**Q4**

Table 11 WAC of the Owvane River for BOD, Total Ammonia and Ortho-phosphate and projected increases in concentrations of these parameters in the Owvane River under different scenarios at a maximum rate of discharge from the Kealkill WwTP of 278.4/day.

Waste Water Treatment Plant: Kealkill, Co Cork **Receiving Water:** River Owvane			
WwTP Characterisitics			
Discharge volume (m^3/day)	287.4	Discharge volume DWF (l/s)	
	BOD	**Total Ammonia**	**Ortho-phosphate**
Effluent quality 2016-2017 (mg/l)	**49.13**	**14.14**	**2.68**
Receiving Water Characteristics			
River mean flow (m3/s)	2.628	Mean flow dilution factor	790.0
River 95%ile flow[3] (m^3/sec)	0.228	95%ile flow dilution factor	68.5
	BOD (mg/l)	**Total Ammonia**	**Ortho-phosphate**
Background concentration (notional) (mg/l) 95%ile	**0.44**	**0.018**	**0.009**
Environmental Quality Standards			
	BOD	**Total Ammonia**	**Ortho-phosphate**
High Status mean flow (≤mg/l)	1.3	0.04	0.025
Good Status mean flow (≤mg/l)	1.5	0.065	0.035
High Status 95%ile flow (≤mg/l)	2.2	0.09	0.045
Good Status 95%ile flow (≤mg/l)	2.6	0.14	0.075
Predicted Loadings, Concentration Increases and Waste Assimilation Capacity (WAC)			
	BOD	**Total Ammonia**	**Ortho-phosphate**
Plant loading (Kg/day)	**14.12**	**4.06**	**0.770**
MEAN FLOW			
Concentration increase (mg/l)	**0.06**	**0.018**	**0.003**
- Resultant D/S concentration (mg/l)	**0.50**	**0.036**	**0.012**
- WAC (High Status)			
WAC (kg/day)	195.27	5.00	3.63
- Consumed by discharge (%)	7	81	21
Theoretical maximum WAC[9] (kg/day)	295.18	9.08	5.68
- Consumed by discharge (%)	5	45	14
- WAC (Good Status)			
WAC (kg/day)	240.68	10.67	5.90
- Consumed by discharge (%)	6	38	13
Theoretical maximum WAC (kg/day)	340.59	14.76	7.95
- Consumed by discharge (%)	4	28	10
95%ile FLOW			
Concentration increase (mg/l)	0.70014	0.20307	0.03841
- Resultant D/S concentration (mg/l)	**1.14014**	**0.221**	**0.047408**
- WAC (High Status)			
WAC (kg/day)	34.67	1.42	0.71
- Consumed by discharge (%)	41	287	109
Theoretical maximum WAC (kg/day)	43.34	1.77	0.89
- Consumed by discharge (%)	32.581	229	86.888
- WAC (Good Status)			
WAC (kg/day)	42.55	2.40	1.30
- Consumed by discharge (%)	33.184	169.094	59.242
Theoretical maximum WAC (kg/day)	51.22	2.76	1.48
- Consumed by discharge (%)	27.568	147.353	52.133

4. CONCLUSION

The chemical water quality analysis has shown that there is an unfavourable variation in water quality between water samples collected downstream of the Kealkill WwTP discharge point (Sites 1 and 3) and reference water samples taken upstream (Sites 2 and 4) in the monitoring period. Localised pollution was visible in the immediate vicinity of the outfall. It is acknowledged that this was within the mixing zone. However, a comparison of data from the two sites close to the outfall location, Site 4 (upstream) and Site 3 (downstream), reveal the following increases in concentrations downstream of outfall. This is based on mean data from the 2017 sampling.

- Ammoniacal Nitrogen as N (+118.30%)
- Phosphorous (tot.unfilt) (+64.81)
- Copper (diss.filt) (+54.62%)
- Nitrate as NO_3 (+50.75%)
- Phosphate (ortho; as PO4) (+21.00%)
- Zinc (diss.filt) (+19.45%)

Therefore the 2017 chemical water quality monitoring programme, and with special reference to Sites 3 and 4, does show that Kealkill WwTP discharge is having some effects on the receiving water. Discharges from the WwTP appear to be contributing to the already elevated background concentrations of Nitrogen in the River Owvane.

However, the average downstream concentration of Ammoniacal Nitrogen as N (0.05mg/l) complies with the limit for Good Status (mean flows) given in the Surface Water Regulations (2009-2015). It is also noted that the waste assimilation capacity and dilution calculations made during both the 2016 and 2017 investigations suggest that the receiving water theoretically has adequate waste assimilation capacity for BOD, Total Ammonia and Ortho-phosphate. The key problem in this catchment is unsatisfactory background water quality. The plant is affecting water quality, but limits are within ‘Good Status’ requirements.

The Freshwater Pearl Mussel population is located in the Pearson's bridge area of the Owvane River, which is located 2.7rkm downstream of the Kealkill WwTP outfall. The habitat in this part of the river is considered to be unsatisfactory for FPM populations. The Owvane catchment has background water quality problems, with agricultural activities being a significant pressure. During the current survey, many other pressures on the Owvane River were observed. The presence of non-native invasive species (Japanese knotweed and Himalayan balsam) was observed along the river banks. These plants out-compete other riparian plants and further destabilise river banks. The gravel trap at Site 4 is likely to cause fish passage problems affecting salmonid host fish, as also noted in the previous surveys. There is a history of drainage works in this part of the catchment and the fluvial geomorphology of the river has not fully stabilised as a result of this.

Overall, the monitoring programme completed during the 2015-17 period has identified upstream / background pressures on the FPM population in the River. The chemical monitoring has also identified that the WwTP discharge is resulting in increased levels of certain parameters downstream, but limits are within ‘Good Status’ requirements. This is the target for FPM catchments outside of SACs and is compliant with the EPA CoA. It is recognised that the FPM population is under pressure, and that the WwTP is a compounding pressure; however, there is no evidence that the WWTP is affecting the potential of the river to achieve Good Status or resulting in adverse effects on FPM, beyond the requirements of the EPA CoA. In the most recently available Urban Waste Water Treatment report in 2016 by the EPA (2017), Kealkill Co. Cork is mentioned as an urban area where improvements are required to resolve environmental issues. Improvements to the Kealkil WwTP to improve inlet screening are ongoing and these will result in a higher standard effluent in the future.

5. RECOMMENDATIONS

Ongoing monitoring of water quality in the receiving water upstream and downstream of the discharge point should be completed, along with assessment of the performance of the plant itself. Irish Water propose to undertake annual ambient monitoring of BOD, COD, SS ortho-P, ammonia and nitrate as part of their ambient monitoring programme, and this is considered sufficient. WwTP effluent monitoring is a requirement of the authorisation certificate and is undertaken bi-annually. This monitoring approach is considered sufficient for this WwTP discharge.

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PLATES

Plate 1 View downstream at site 1 during round 1, August 2017.

Plate 2 Water sample collection pointing in an upstream direction at Site 1 during round 1, August 2017.

Plate 3 Freshwater Pearl Mussel in the River Owvane at Site 1.

Plate 4 Freshwater Pearl Mussel in the River Owvane at Site 1.

Plate 5 River Owvane at Site 1, round 3 of sampling, September 2017.

Plate 6 Chemical water sampling during low flow at site K2 round 3, September 2017.

Plate 7 Class A *Perla bipunctata* from Site 3 (also recorded at Site 4).

Plate 8 Juvenile Brown trout *Salmo trutta* at Site 3.

Plate 9 Site 4 (approx. 500m upstream of outfall) during round 1, August 2017.

Plate 10 Kealkilll WwTP outfall to the River Owvane during round 1, August 2017.

Plate 11 Kealkilll WwTP Outfall to the River Owvane round 3, September 2017.

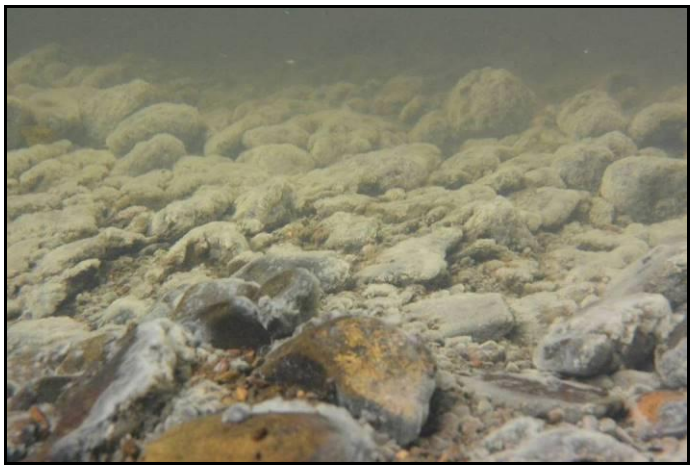

Plate 12 Riverbed downstream of WwTP discharge with localised severe pollution apparent.

APPENDIX 1 CHEMICAL WATER QUALITY RESULTS

Table A1.1 The full suite of chemical water quality parameters taken from Owvane River (Site 1 - Site 4) and the Kealkill WwTP outfall (KO). Results are from chemical water quality analyses completed by Alcontrol Laboratories (UK) and in-situ probe readings taken by Ecofact staff.

Parameter	LOD/Units	Round 1: 1st August '17					Round 2: 16th August '17					Round 3: 26th September '17				
		Site KO	Site 1	Site 2	Site 3	Site 4	Site KO	Site 1	Site 2	Site 3	Site 4	Site KO	Site 1	Site 2	Site 3	Site 4
Temperature	°C	-	15.1	14.6	16.3	15.1	-	14.5	14.4	14.7	14.6	-	19	16.4	18.2	17.8
D.O.	%	-	108.3	105	107	95.2	-	105.0	104.5	105.0	100.2	-	105.8	99.3	96.6	108.1
D.O.	ppm	-	10.73	10.25	10.25	9.79	-	10.32	10.24	10.20	10.20	-	9.18	10.40	9.09	9.74
Conductivity (20 deg. C)	<0.005 mS/cm	0.255	0.0733	0.0687	0.0785	0.0675	0.227	0.0472	0.0621	0.0622	0.0622	0.298	0.0873	0.0725	0.0787	0.0726
Suspended solids, Total	<2 mg/l	41.8	<2	<2	<2	<2	15.2	12.7	4.5	<2	3.4	33.9	<2	<2	<2	<2
Alkalinity, Total as CaCO3	<2 mg/l	90	17	15.5	17	16	85	9.5	12	13	12.5	120	24	17	20	20
BOD, unfiltered	<1 mg/l	<25	<1	<1	<1	<1	9	<1	<1	<1	<1	37.2	<1	3.06	<1	<1
Ammoniacal Nitrogen as N	<0.01 mg/l	13.7	0.0525	0.0183	0.0381	0.0263	4.69	0.0278	0.0371	0.034	0.0382	9.93	0.027	0.0346	0.12	0.0398
Ammoniacal Nitrogen as NH3	<0.2 mg/l	16.9	<0.2	<0.2	<0.2	<0.2	5.61	<0.2	<0.2	<0.2	<0.2	11.9	<0.2	<0.2	<0.2	<0.2
Arsenic (diss.filt)	<0.5 µg/l	2.35	0.674	0.725	0.525	0.754	2.26	0.625	0.802	0.834	0.823	3.18	0.596	0.814	0.76	0.865
Cadmium (diss.filt)	<0.08 µg/l	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Chromium (diss.filt)	<1 µg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Copper (diss.filt)	<0.3 µg/l	5.14	0.606	0.501	0.677	0.425	4.28	0.731	0.56	0.714	0.575	10.3	0.779	0.703	0.619	<0.3
Lead (diss.filt)	<0.2 µg/l	<0.2	<0.2	<0.2	<0.2	<0.2	0.329	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel (diss.filt)	<0.4 µg/l	0.492	<0.4	<0.4	<0.4	<0.4	0.629	<0.4	<0.4	<0.4	<0.4	0.765	<0.4	<0.4	<0.4	<0.4
Phosphorus (diss.filt)	<10 µg/l	699	<10	<10	<10	<10	1030	11.4	14.5	18.5	10.8	1060	<10	<10	52.8	<10
Selenium (diss.filt)	<0.5 µg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc (diss.filt)	<1 µg/l	1.79	4.22	2.11	1.46	3.83	6.33	<1	<1	<1	<1	12.5	14.9	2.06	3.03	3.79
Mercury (diss.filt)	<0.01 µg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite as NO2	<0.05 mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.075	<0.05	<0.05	<0.05	<0.05	0.159	<0.05	<0.05	<0.05	<0.05
Sulphate	<2 mg/l	13.7	<2	<2	<2	<2	9.9	<2	<2	<2	<2	15	<2	<2	<2	<2
Phosphate (ortho) as PO4	<0.02 mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	0.858	<0.02	<0.02	<0.02	<0.02	1.02	<0.02	<0.02	0.0326	<0.02
Nitrate as NO3	<0.3 mg/l	<0.3	0.626	0.492	0.633	0.444	<0.3	0.352	0.439	0.543	0.44	<0.3	1.95	1.14	1.83	1.11
Aluminium (tot. unfilt)	<50 µg/l	155	<50	<50	<50	<50	92.4	260	120	101	97	147	166	<50	<50	58.9
Phosphorus (tot.unfilt)	<20 µg/l	2440	<20	<20	<20	<20	1010	64.9	29.2	30.6	28.5	2130	31.1	24.4	82.9	32.5
Iron (tot.unfilt)	<0.024 mg/l	0.942	<0.024	<0.024	0.176	0.186	0.51	1.17	0.663	0.446	0.512	0.88	0.165	0.174	0.172	0.175
pH	<1 pH Units	6.9	7.04	7.34	7.15	7.26	7.02	6.92	7.06	7.01	7.25	6.98	7.45	7.36	7.25	7.33