OXFORD RIVERS PROJECT

Citizen Science Water Quality Sampling Final Report

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The Oxford Rivers Project has been a collaboration between the #EndSewagePollution Mid-Thames group, Thames21 and The Rivers Trust. Funding was provided by Oxford City Council, Thames Water, Patagonia Europe and the Coca Cola Foundation.

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Executive Summary

What is the Oxford Rivers Project?

The rivers in Oxford have long been integral to the history and culture of the city, and today are frequently used for a wide range of recreational activities, including rowing and wild swimming.

In the summer of 2020, many local Oxford residents were shocked after seeing the Rivers Trusts 'Is Your River Fit to Play In' map, and discovering the level of untreated sewage discharged to rivers nationally and locally. A local campaign was formed, the "End Sewage Pollution mid Thames group" whose aim is to campaign for cleaner rivers, for both people and wildlife.

After successfully petitioning Oxford City Council and Thames Water, the group approached the Rivers Trust and Thames21 who supported and developed a proposal to monitor the health of the rivers surrounding Oxford and apply for bathing water status. This proposal was partly funded by Thames Water, including the processing of the water quality samples and officer time, and by Oxford City Council and the Rivers Trust.

This report has been produced independently of Thames Water and has been impartially reviewed by a water quality and health expert. It highlights the findings of the monitoring, analyses the causes of pollution, and makes recommendations for further research and monitoring needed.

Where and how we sampled

18 river locations in Oxfordshire, in and surrounding Oxford City were sampled over the period January – December 2021. Figure 1 shows the locations of these sites. Eight of the sample sites were situated at popular recreational locations (e.g. for wild swimming, rowing, punting, kayaking and angling), primarily within Oxford's city boundaries.
10 of sample sites were situated on upstream locations, including on Thames tributaries Windrush (2 sites), Evenlode (2 sites) and Cherwell (4 sites), as well as 2 further sites on the main River Thames.

Samples were taken approximately once a month April – December from 14 sample sites. 4 central recreational locations (labelled J, M, P and Q on maps) were sampled weekly January-April 2021, and then monthly until December 2021, resulting in ~23 samples at each. This arrangement was due to restrictions from the Covid-19 pandemic.

Samples were tested in an independently accredited microbiology lab using a standard culturing method for bacteria species E Coli and intestinal enterococci ('feacal indicator organisms' or FIOs). The results obtained were compared to the standards for bathing waters set out in the Bathing Waters Directive (2013) as shown in Table 1.

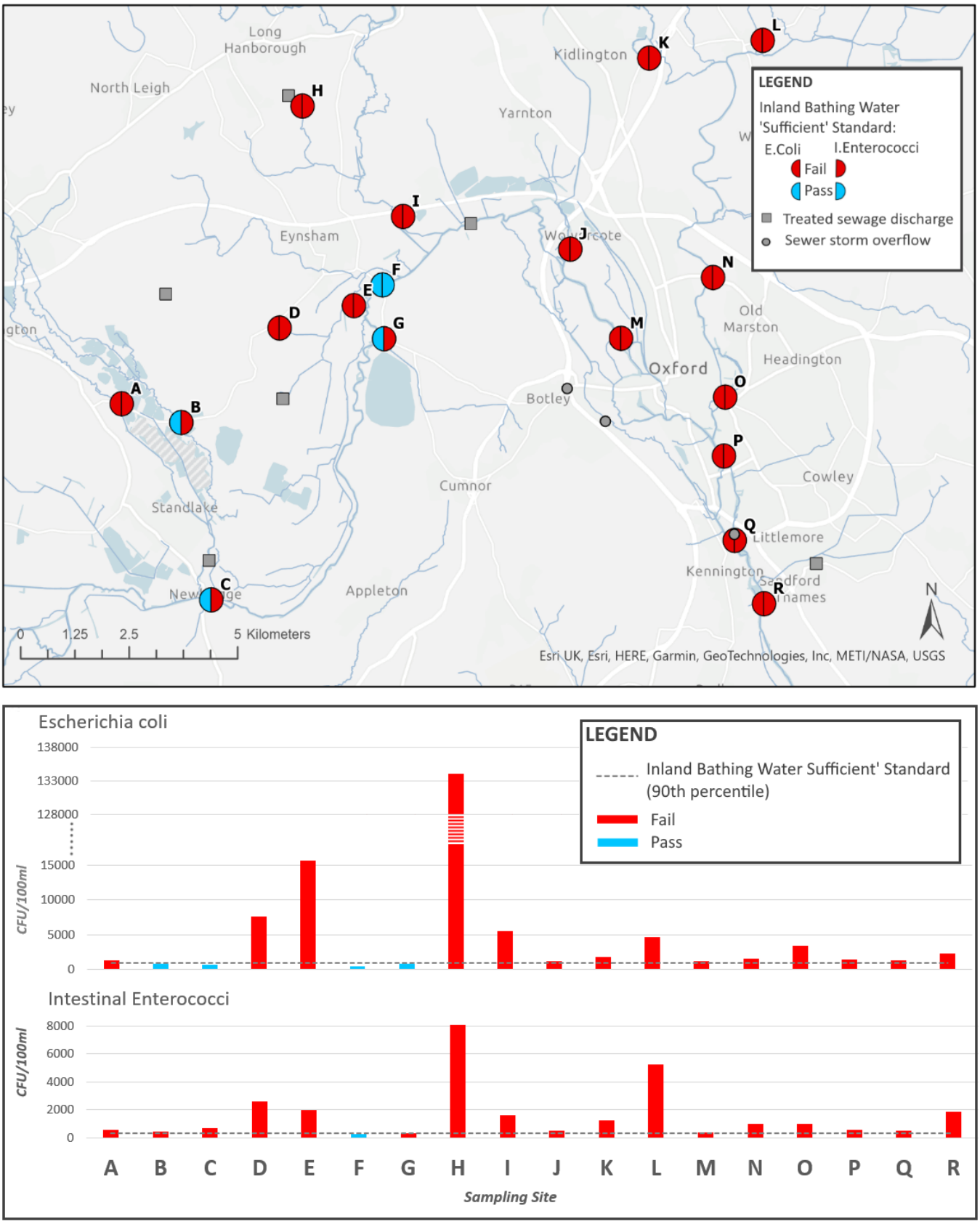


Figure 1. Sample sites map and bathing water quality assessment results.

Table 1. Standards for inland bathing waters

Parameter	"Excellent"	"Good"	"Sufficient"
Intestinal enterococci(1)	200(2)	400(2)	330(3)
Escherichia coli(1)	500(2)	1,000(2)	900(3)

(1) Colony forming units per 100 millilitres ("cfu/100 ml").
(2) Based upon a 95-percentile evaluation
(3) Based upon a 90-percentile evaluation

It is worth noting that although the method was standardised as much as possible, the results may not be directly comparable to official bathing water figures due to differences in sample number (the Bathing Water Regulations (2013) require at least 16 samples over two years) and season (bathing water designations are based on the 'bathing season' which runs from May 15th – September 30th).

The relationship of bacteria levels to rainfall and the ratios of the two species of bacteria were examined to determine the predicted sources of the FIOs. Due to the different survival rates of Intestinal enterococci (IE) and E Coli (EC)[1], in this study we assume an EC:IE ratio of 2:1 to 4:1 is indicative of point source inputs (e.g. untreated sewage, either from storm overflows or partially treated final effluent) whereas a EC:IE ratio closer to 1:1 is associated with diffuse inputs (e.g. livestock excreta, septic tanks, misconnections). The use of these ratios can provide an indication of the source of the faecal indicator organisms, although further monitoring and research is needed to evidence those sources[2].

Key findings

1. Only one of the eight recreational sites had bacteria levels low enough to class it as 'sufficient' for bathing.
2. Levels of FIOs were approximately 1.5 - 3 times the safe level at the other seven recreational sites
3. The source of pathogens at recreational sites was primarily point source sewage inputs (both treated effluent and raw sewage discharges), although some sites were also impacted by diffuse inputs from livestock.
4. Levels of FIOs were mainly correlated with rainfall, with concentrations falling to "Good" to "Excellent" levels in drier periods. This may help inform recreational users' safety at these sites.

[1] Sagarduy M, Courtois S, Del Campo A, Garmendia JM, Petrau A. *Differential decay and prediction of persistence of Enterococcus spp. and Escherichia coli culturable cells and molecular markers in freshwater and seawater environments*. Int J Hyg Environ Health. 2019 May;222(4):695-704.

[2] **For a review of the field**, see de Brauwere A., Ouattara N. K. & Servais P. (2014*) Modeling Fecal Indicator Bacteria Concentrations in Natural Surface Waters: A Review*, Critical Reviews in Environmental Science and Technology, 44:21, 2380-2453. **For a study which follows an approach similar to ours**, see Ouattara, N. K., Passerat, J., & Servais, P. (2011). *Faecal contamination of water and sediment in the rivers of the Scheldt drainage network*. Environ Monit Assess, 183, 243–257.

5. Upstream sites had very variable levels of FIO, from 1 – 100 times the sufficient level of FIOs. None of the 10 sites reached the 'sufficient' for bathing level (although they are unlikely to be designated).
6. The Windrush, Cherwell and Upper Thames sites appeared to be impacted mainly by agricultural and other diffuse inputs, whereas the Evenlode sites were heavily impacted by sewage (5 and 100x the safe level). The Limb Brook sites were impacted by both kinds of input.
7. Some of these sites were on narrow tributaries, 2-3m wide. The exceedingly high levels of FIOs e.g. in Site H raise significant concerns for the health of these smaller waterways, as well as the impact of smaller rural sewage treatment works.

Table 2. Recreational sites – results and conclusions

NB – Variable counts throughout the year are not reflected in the overall 90th percentile value. At some sites, the ratio, and hence source, of FIOs was different at different times.

Site name (Site letter)	Used for	E Coli at 90th percentile / Enterococci at 90th percentile (cfu/100ml)	Number of samples taken	Bathing water status	Main predicted sources of FIOs
Swinford Toll Bridge (F)	Wild swimming, kayaking, SUP-ing, boating	375/261	12	Good	n/a
Port Meadow North / Wolvercote (J)	Wild swimming, kayaking, SUP-ing, angling	1118/534	22	Poor	Sewage
Port Meadow South (M)	Wild swimming, kayaking, SUP-ing, boating, sailing, rowing	1221/417	22	Poor	Sewage
Victoria Arms (N)	Punting, wild swimming, kayaking	1524/983	10	Poor	Agriculture, septic tanks and mis connections and sewage
Magdelen Bridge (O)	Punting	3352/1025	10	Poor	Sewage
Longbridges Boathouses (P)	Rowing, kayaking, wild swimming	1370/556	22	Poor	Sewage
Kennington Meadows (Q)	Wild swimming, boating, kayaking	1268/535	22	Poor	Sewage
Sandford Lock (R)	Angling, boating, kayaking	2279/1870	10	Poor	Agriculture septic tanks and mis connections and sewage

Table 3. Upstream sites – results and conclusions

Watercourse (Sample letters)	E Coli at 90th percentile / Enterococci at 90th percentile (cfu/100ml)	Number of samples taken	Main predicted sources of FIOs
Windrush (A & B)	A 1279 / 577 B 775/480	9	Diffuse inputs (Agriculture, septic tanks and misconnections)
Evenlode (H & I)	H 134,148 / 8098 I 5548 / 1366	12	Sewage, both final effluent and storm overflows
Cherwell (K & L)	K 1777 / 1225 L 4567 / 5256	9	Diffuse inputs
Upper Thames (C & G)	C 703 / 717 G 756 / 374	9 - 12	Diffuse inputs
Limb Brook (D & E)	D 7550 / 2575 E 15,657 / 1965	9 - 12	Diffuse inputs and sewage, storm overflows.

Further research and recommendations

- Targeted monitoring immediately up and downstream of high risk sources of sewage discharge points, which are likely to be affecting recreational sites identified in this study, such as Combined Sewer Overflows and Sewage Treatment Works. This should include both spot sampling and real time probes.
- Church Hanborough sewage treatment works, where we have identified a particularly heavy load of FIOs in the treated effluent (100 times the level sufficient for bathing), should be investigated and improvements made.
- Following the designation of Wolvercote Mill Stream as a designated bathing site, we recommend higher resolution traditional sampling to determine sources of FIOs affecting this site e.g. simultaneous sampling at several sites between Cassington STW and Wolvercote Mill Stream, including tributaries and distributaries.
- Further research is needed to verify the "source apportionment" of bacterial pollution at river sites i.e. the proportion originating from treated sewage, raw sewage, livestock excreta, septic tanks and misconnections. Microbial source tracking using molecular sequencing methods could be used to accomplish this aim.
- We also recommend further research into the travel time, distance and viability of pathogenic bacteria released from treated effluent and raw sewage spills, in different river flow and weather conditions.

What does this mean for river users?

- Our results indicate unsafe levels of bacterial pollution in wet periods. We therefore recommend, in the current situation, to avoid activities which bring contact with river water 24-48 hours after heavy rainfall. The Thames Water sewage spill alert system, which will be extended from 6 to all 468 monitored spill locations by the end of 2022, can also help inform river users.
- River users, be they swimmers, anglers, canoeists, rowers, punters etc. should cover all open wounds before coming into contact with river water and wash their hands as soon as possible after touching river water and before consuming food.

Introduction

Due to restrictions on travel and indoor activities during the pandemic, more people than ever are connecting with their local waterways, and countrywide there has been a rise in the number of people taking to their local river for recreation and exercise.

With a rapid growth in recreational activities such as wild swimming, kayaking, paddleboarding and angling, this has led to community interest in natural history and environmental issues.
Rivers have been transformed from being viewed as dirty or dangerous to a treasured place in many peoples' minds.

This has been evident in Oxford, especially since 2020. It is not an exaggeration to say rivers are the lifeblood of the city: from students rowing and punting on them, to the popular riverside nature reserves where locals have swum for decades, to tourist boat tours and the resident canal boat community. People in Oxford care deeply about having clean, healthy rivers for people and wildlife, and have been disturbed by the Environment Agency (EA) reports stating not a single river passes chemical pollution standards set out in the Water Framework Directive (WFD) and by media reports about sewer storm overflows discharging untreated sewage into UK rivers.

In light of this, the #endsewagepollution mid-Thames campaign was established summer 2020 and following initiation of a formal partnership with Thames Water, Thames21 and The Rivers Trust, a sustainable and professionally managed citizen science and community engagement program was established, alongside the application for designated bathing water status being progressed by Oxford City Council. This application was successful and Wolvercote Mill Stream is now the second designated river bathing water in the UK, and will now be regularly monitored by the Environment Agency.

In Section 1 of this report we will cover results of bacterial water quality monitoring at four main recreational sites that began in January 2021. These were sampled initially as they were potential sites for official bathing water designation. Due to restrictions from the Covid-19 pandemic, Thames Water contractors originally sampled these four recreational sites. Trained volunteers took over sampling of the four core sites and a further fourteen sites (covered in Section 2) were added around the city and wider catchment in April 2021. Sampling continued until December 2021.

The main parameters tested for in the water quality assessment were the level of "Faecal Indicator Organisms" (FIOs) which are bacteria that are only present in the faeces and urine of warm-blooded animals that potentially pose a risk to public health.

The two FIO bacteria tested for are *Escherichia coli* (EC) and *Intestinal Enterococci* (IE) although commonly found in the gut and intestinal tracts of humans, when contaminated water is ingested or allowed to enter the bloodstream through open uncovered wounds, it can lead to gastrointestinal illnesses, infections, headaches, fever and in severe cases kidney and organ failure.

Alongside FIO analysis, samples were tested for chemical parameters COD, BOD (Chemical and Biological Oxygen Demand), pH, suspended solids, Ammonia, Sulphate and Soluble Reactive Phosphate (SRP).

The principal goal of the project was to assess the eighteen sites against the Bathing Water Regulations (2013) standard for FIO levels in inland waters, which the Environment Agency uses to assess and classify designated bathing water quality.

The four core recreational sites J, M P and Q are used frequently for swimming, rowing, angling and other watersports, even in the winter months. Sites N, O, R and F are also used for recreation, such as punting (sites N and O) and narrowboats (R and F), but primarily in the summer.

The key questions of the study were:

1. What are the levels of the two FIOs at each site, and how does this compare to the levels set out in the Bathing Water Regulations (2013)?
2. What are the primary sources of the FIOs (e.g. diffuse agricultural inputs, treated sewage effluent, untreated sewage discharges)?
3. Do levels of FIO vary year round and can this be related to any factors e.g. rainfall and/or raw sewage discharges?

Project Methodology

1. Sampling Frequency

From January to April 2021 the four main recreational sites (J, M P and Q) were sampled on a weekly basis by Thames Water contactors OHES Environmental Ltd. Sampling was then passed to trained Citizen Science volunteers to continue weekly at the four main recreational sites and a further 14 wider catchment sample points. All samplers and trained volunteers followed an aseptic sampling protocol developed by TH-Environmental Ltd for The Rivers Trust.

When the volunteer sampling commenced in April 2021 the 18 combined sample points were split into 4 zones (Table 1). One zone is sampled per week and all four zones in one month, meaning all 18 sample points are sampled and tested a minimum of once a month.

Sample Zone	Sample Point	Location	Grid Reference
1	Point A	River windrush	SP 38301 05888
	Point B	River Windrush	SP 39674 05459
	Point C	River Thames	SP 40365 01400
	Point D	Limb Brook	SP 41938 07621
2	Point E	Limb Brook	SP 43650 08134
	Point F	River Thames	SP 44310 08608
	Point G	Filchampstead Brook	SP 44345 07376
	Point H	Evenlode	SP 42465 12702
	Point I	Evenlode	SP 44784 10175
3	Point J	River Thames Recreational site	SP 48637 09427
	Point K	River Cherwell	SP 50455 13799
	Point L	Bletchington Brook	SP 53069 14205
	Point M	River Thames Recreational site	SP 49805 07386
4	Point N	River Cherwell	SP 51924 08778
	Point O	River Cherwell	SP 52204 06040
	Point P	River Thames Recreational site	SP 52176 04692
	Point Q	River Thames Recreational site	SP 52424 02761
	Point R	River Thames	SP 53098 01312

Table 1: Sample point and Zone detail

2. Sample Analysis

All samples are analysed for presence of *Total Coliforms* (TC), the bacteria *Escherichia coli* (EC) and *Intestinal Enterococci* (IE) at Thames Water's accredited laboratory using methods laid out in the Microbiology of Drinking Waters (2018).

The method used to analyse samples for EC and TC is the multiple tube method 'Colilert' producing a confirmed result within 18-24hrs.

The method used to analyse samples for IE is a 0.45-micron membrane filtration onto selective media (Slanetz & Bartley), producing a confirmed result within 40-48hrs.

All samples are carefully handled, and analysed on the same day as they are sampled as per requirements laid out in the Bathing Water Regulations (2013).

3. Statistical analysis

All results obtained are required to be statistically analysed and converted to a "percentile value" based on a percentile evaluation of the $\log_{10}$ normal probability density function of microbiological data used for the assessment as detailed in the Bathing Water Regulations (2013).

To be able to derive a percentile value the following method was followed:

a) take the $\log_{10}$ value of all bacterial concentrations in the data sequence to be evaluated or, if a zero value is obtained, take the $\log_{10}$ value of the minimum detection limit of the analytical method used.

b) calculate the arithmetic mean ("μ") of the $\log_{10}$ values taken under paragraph (a);

c) calculate the standard deviation ("σ") of the $\log_{10}$ values taken under paragraph (a);

d) derive the upper 90-percentile point of the data probability density function from the following equation: upper 90-percentile = antilog (μ + 1.282 σ); and

e) derive the upper 95-percentile point of the data probability density function from the following equation: upper 95-percentile = antilog (μ + 1.65 σ).

The conversion to a "percentile value" is done on all collated EC and IE results obtained from each sampling site over a defined period, the obtained result is then compared against the outlined water quality standards (Figure 1). In Section 1 only the main recreational River Thames sites J, M, P and Q have been statistically analysed over the defined periods detailed below, in Section 2 the remaining 14 sites have only been statistically analysed for period 1:

1. The full sampling period
2. Monthly breakdown
3. The designated bathing water season which is defined as May 15th to the end of September.

Note that the Bathing Water Regulations (2013) stipulate that at least 16 samples are required over a two year period to assess compliance with the bathing water standard. The data gathered by this

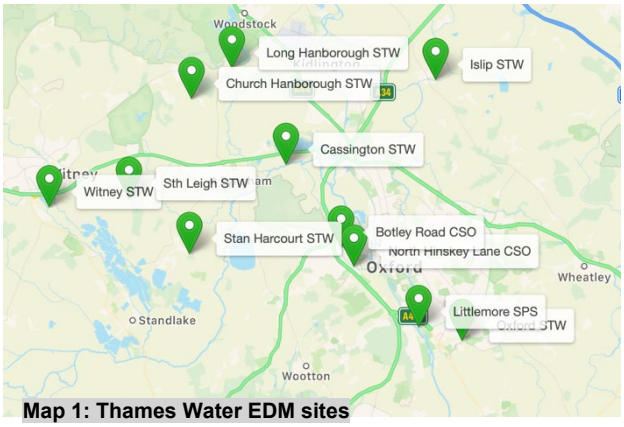
project could be used by the Environment Agency to develop a more rapid assessment of Wolvercote Mill Stream's compliance now that it has been designated.

	E.coli		
	BW status	**Levels**	**Percentile**
	Excellent	500	95
	Good	1000	95
	Sufficient	900	90
	Poor	>900	90
	Enterococci		
	BW status	**Levels**	**Percentile**
	Excellent	200	95
	Good	400	95
	Sufficient	330	90
	Poor	>330	90

Figure 1: Bathing Water quality designations

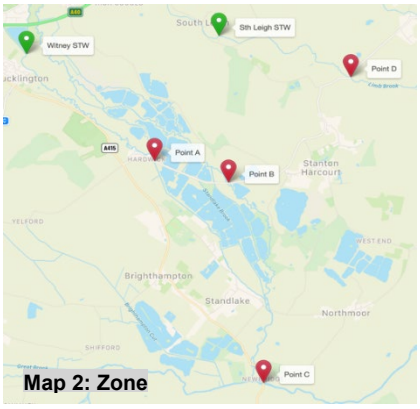
4. Thames Water spill data

Under excessive rainfall events, Thames Water are permitted to relieve pressure on their sewer network through release of partially diluted untreated sewage by 'spilling' at Combined Sewer Overflows (CSOs) and at Wastewater Treatment Works (WwTW) via Storm Tank outfalls.
These releases are known to have an effect on FIO levels within the river system, so for the duration of the project, Thames Water have agreed to provide all records of spills at 11 Locations (Map 1).

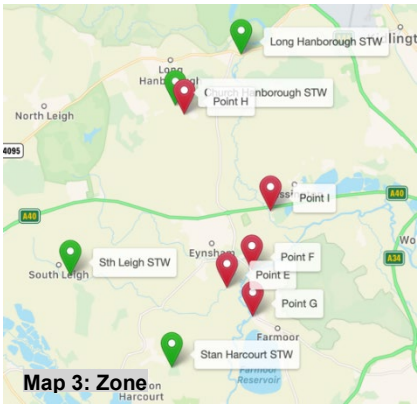


Map 1: Thames Water EDM sites

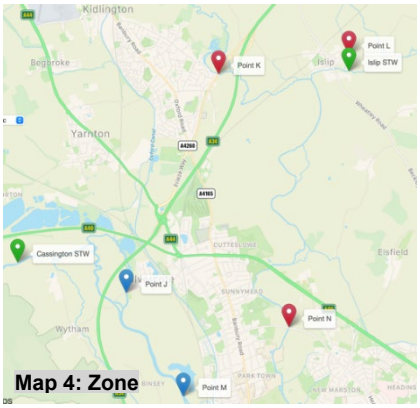
The Zonal Maps below (Maps 2, 3, 4 and 5) show sampling points (red) and the locations identified by Thames Water as affecting river stretches that have had Event Duration Monitors (EDM) installed.



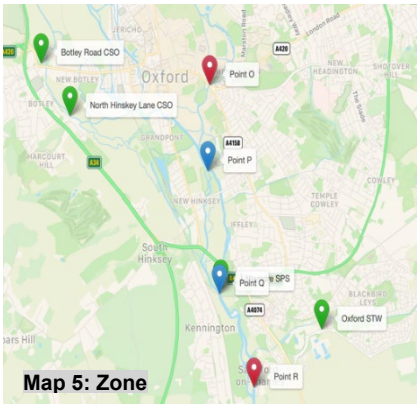
Map 2: Zone



Map 3: Zone



Map 4: Zone



Map 5: Zone

Information for the start and end time of spills is recorded through EDM's. The sites are suspected of having an impact on 15 out of 18 sample sites (Tables 2, 3, 4 and 5) only sample points G, K and L are not directly impacted by EDM sites.

Table 2: River Windrush			
EDM monitor	Sample point immediatley d/s	next d/s	final possible impacted sample point
Witney STW	A	B	C

Table 3: Limb Brook			
EDM monitor	Sample point immediatley d/s	next d/s	final possible impacted sample point
Sth Leigh STW	D	E	
Stanton Harcourt STW	E		

Table 4: Evenlode and tribs			
EDM monitor	Sample point immediatley d/s	next d/s	final possible impacted sample point
Church Hanborough STW	H	I	
Long Hanborough STW not an EDM site	I		

Table 5: Cherwell and tribs			
EDM monitor	Sample point immediatley d/s	next d/s	final possible impacted sample point
Islip STW	N	O	

Four of the sites have been identified as potentially impacting the recreational sample points J, M, P and Q (Table 6). Section 1 of this report will concentrate on the effect spills from those sites have on FIO levels at these sample points.

Table 6: Thames recreational sites			
EDM monitor	Sample point immediatley d/s	next d/s	final possible impacted sample point
Cassington STW	J	M	
Botley Road and Nth Hinskey Lane CSO's	P	Q	
Littlemore SPS	Q	R	
Oxford STW	R		

SECTION 1
Recreational Sites FIOs

Results

1. Full Sampling Period

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml
F9329758	15/01/2021	J	162	0
F9329762	18/01/2021	J	411	0
F9329766	26/01/2021	J	1120	200
F9329770	03/02/2021	J	1553	200
F9364077	11/02/2021	J	328	86
F9364081	19/02/2021	J	3000	200
F9364073	22/02/2021	J	461	78
F9395891	02/03/2021	J	308	0
F9395895	10/03/2021	J	365	52
F9395899	18/03/2021	J	125	25
F9395903	26/03/2021	J	152	13
F9395907	29/03/2021	J	210	30
F9395911	06/04/2021	J	219	34
F9458087	20/04/2021	J	29	0
f9458102	18/05/2021	J	757	110
F9458107	24/05/2021	J	649	520
F9563126	23/07/2021	J	276	130
F9562977	19/08/2021	J	172	110
F9653668	22/09/2021	J	448	350
F9653688	19/10/2021	J	326	230
F9563001	15/11/2021	J	153	102
F9796567	17/12/2021	J	161	58

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml
F9329759	15/01/2021	M	1986	0
F9329763	18/01/2021	M	4352	0
F9329767	26/01/2021	M	15634	200
F9329771	03/02/2021	M	10462	200
F9364078	11/02/2021	M	488	79
F9364082	19/02/2021	M	10000	200
F9364074	22/02/2021	M	435	85
F9395892	02/03/2021	M	435	0
F9395896	10/03/2021	M	146	35
F9395900	18/03/2021	M	1258	29
F9395904	26/03/2021	M	580	29
F9395908	29/03/2021	M	2606	46
F9395912	06/04/2021	M	189	23
F9458088	20/04/2021	M	161	320
F9458103	18/05/2021	M	7706	2146
F9458128	24/05/2021	M	1300	670
F9563130	23/07/2021	M	6488	39
F9562979	19/08/2021	M	3450	890
F9653669	22/09/2021	M	3655	5290
F9653989	19/10/2021	M	2748	280
F9563125	15/11/2021	M	2098	89
F9796568	17/12/2021	M	3654	82

Tables 7, 8, 9 and 10 show results obtained from sampling for the recreational sample points J, M, P and Q.

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml
F9329760	15/01/2021	P	365	0
F9329764	18/01/2021	P	308	0
F9329768	26/01/2021	P	1553	200
F9329772	03/02/2021	P	1203	200
F9364079	11/02/2021	P	308	58
F9364071	19/02/2021	P	2000	200
F9364075	22/02/2021	P	461	72
F9395893	02/03/2021	P	435	0
F9395897	10/03/2021	P	194	59
F9395901	18/03/2021	P	201	22
F9395905	26/03/2021	P	148	24
F9395909	29/03/2021	P	167	64
F9395913	06/04/2021	P	84	18
F9458091	29/04/2021	P	101	38
F9458115	26/05/2021	P	980	131
F9458128	22/06/2021	P	579	115
F9563133	26/07/2021	P	248	58
F9563136	23/08/2021	P	1046	710
F9653676	30/09/2021	P	2420	1060
F9563027	27/10/2021	P	491	108
F9796540	23/11/2021	P	308	79
F9796574	20/12/2021	P	308	111

The calculated "percentile value" for all four recreational sites for the full sampling period is shown in Table 11 for both EC and IE. Under present river conditions all four sites would be classified as Poor.

Tables 9 and 10: Results for sample point P (left) and point Q (right). Results in red indicate zero result and > LOD surrogates

Sample Point	E.coli		Enterococci	
	90 percentile	95 percentile	90 percentile	95 percentile
J	1118.37	1602.38	533.99	1113.11
M	1221.14	1782.61	417.4	863.03
P	1369.84	1932.85	556.45	1108.74
Q	1267.88	1755.38	534.59	1128.06

Table 11: Calculated "Percentile values" for the full year to date

2. Bathing Water Season

Under Bathing Water regulations (2013) there is a clearly defined BW season that runs from 15th May until end of September. Table 25 shows calculated "percentile value" of the four recreational sites from samples taken within the BW season period, under present river conditions, the overall BW status would be classified as Poor.

Sample Point J bathing water season

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
f9458102	18/05/2021	J	757	110	1350.90	1795.29	775.41	1073.57
F9458107	24/05/2021	J	649	520				
Blitz Average	18/06/2021	J	1524	845				
F9563126	23/07/2021	J	276	130				
F9562977	19/08/2021	J	172	110				
F9653668	22/09/2021	J	448	350				

Sample Point M bathing water season

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458103	18/05/2021	M	770	210	2566.42	3558.22	929.33	1657.42
F9458108	24/05/2021	M	1300	670				
Blitz Average	18/06/2021	M	3771	757				
F9563130	23/07/2021	M	613	33				
F9562979	19/08/2021	M	345	19				
F9653669	22/09/2021	M	387	54				

Sample Point P bathing water season

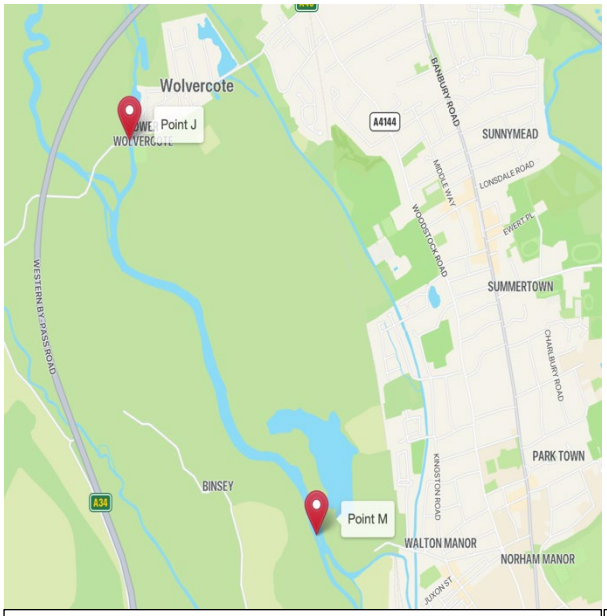
Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458115	26/05/2021	P	980	131	2885.82	3954.68	1533.92	2457.30
Blitz Average	18/06/2021	P	2237	1045				
F9458128	22/06/2021	P	579	115				
F9563133	26/07/2021	P	248	58				
F9563136	23/08/2021	P	1046	710				
F9653676	30/09/2021	P	2420	1060				

Sample Point Q bathing water season

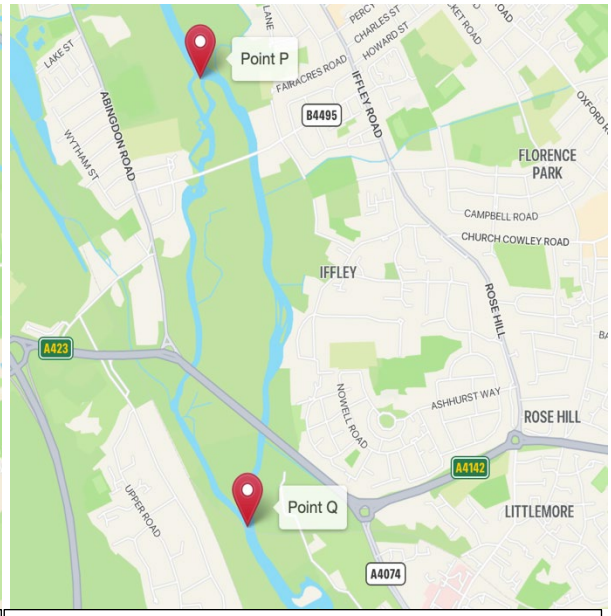
Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458116	26/05/2021	Q	1046	143	2054.43	2662.78	1517.69	2720.23
Blitz Average	18/06/2021	Q	2310	888				
f9458129	22/06/2021	Q	326	21				
F9563135	26/07/2021	Q	435	49				
F9563137	23/08/2021	Q	1120	890				
F9653677	30/09/2021	Q	866	530				

Table 25: Bathing Water seasons calculated "percentile value"

As already stated, sample points J, M, P and Q are the main recreational locations within the Oxford City boundaries and are used year-round for many varied recreational pastimes for example swimming, bathing, Fishing, canoeing and Rowing. Maps 6 and 7 show the locations within Oxford of J, M, P and Q



Maps 7 (Right): Showing the geographical location of Recreational sample points P and Q



Maps 6 (Left): Showing the geographical location of Recreational sample points J and M

3. Monthly breakdown

Table 12 and 13 show calculated "percentile value" for January and February and show significant degradation in water quality at all sites with a BW status of Sufficient to Poor for both EC and IE.

January

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.Coli 90 %ile	E.Coli 95 %ile	Enterococci 90 %ile	Enterococci 95 %ile
J	15/01/2021	162	0	1454.00	2075.41	295.22	909.99
	18/01/2021	411	0				
	26/01/2021	1120	200				
M	15/01/2021	186	0	1969.73	2918.17	295.22	909.99
	18/01/2021	435	0				
	26/01/2021	1553	200				
P	15/01/2021	365	0	1747.28	2423.60	295.22	909.99
	18/01/2021	308	0				
	26/01/2021	1553	200				
Q	15/01/2021	238	0	1754.98	2438.15	295.22	909.99
	18/01/2021	517	0				
	26/01/2021	1414	200				

Table 12: Januarys calculated "percentile value"

February

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli 90 %ile	E.coli 95 %ile	Enterococci 90 %ile	Enterococci 95 %ile
J	03/02/2021	1553	200	3452.21	5052.15	248.32	300.35
	11/02/2021	328	86				
	19/02/2021	3000	200				
	22/02/2021	461	78				
M	03/02/2021	1046	200	1256.39	1506.82	252.58	309.35
	11/02/2021	435	71				
	19/02/2021	1000	200				
	22/02/2021	435	85				
P	03/02/2021	1203	200	2299.05	3153.59	264.35	336.80
	11/02/2021	308	58				
	19/02/2021	2000	200				
	22/02/2021	461	72				
Q	03/02/2021	1733	200	3224.04	4781.09	273.74	356.93
	11/02/2021	308	49				
	19/02/2021	2420	200				
	22/02/2021	345	71				

Table 13: Februarys calculated "percentile value"

Tables 14 and 15 show calculated "percentile value" for March and April showing a significant improvement in water quality during this period with a site variation in BW status of Sufficient, Good and Excellent. There was a high IE result for Q in April which meant status became Poor.

March

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	02/03/2021	308	0	382.90	452.51	100.90	178.49
	10/03/2021	365	52				
	18/03/2021	125	25				
	26/03/2021	152	13				
	29/03/2021	210	30				
M	02/03/2021	435	0	431.02	556.42	87.97	154.94
	10/03/2021	146	27				
	18/03/2021	155	29				
	26/03/2021	68	8				
	29/03/2021	260	44				
P	02/03/2021	435	0	362.75	423.74	159.87	298.34
	10/03/2021	194	59				
	18/03/2021	201	22				
	26/03/2021	148	24				
	29/03/2021	167	64				
Q	02/03/2021	248	0	585.07	723.39	117.62	208.41
	10/03/2021	770	35				
	18/03/2021	228	29				
	26/03/2021	210	29				
	29/03/2021	186	36				

Table 14: Marchs calculated "percentile value"

April

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	06/04/2021	219	34	498.17	843.06	142.57	356.91
	20/04/2021	29	0				
M	06/04/2021	179	23	477.72	895.51	82.28	186.05
	20/04/2021	16	0				
P	06/04/2021	84	18	108.86	114.21	51.49	62.54
	29/04/2021	101	38				
Q	06/04/2021	82	35	211.81	252.46	786.76	1399.36
	29/04/2021	161	320				

Table 15: Aprils calculated "percentile value"

Tables 16 and 17 show calculated "percentile value" for May and June showing a significant deterioration in water quality during this period with a site variation in BW status of Sufficient to Poor. There was an improvement in the IE result for P and Q in May which meant status became Excellent.

May

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	18/05/2021	757	110	805.88	838.82	977.78	1464.82
	24/05/2021	649	520				
M	18/05/2021	770	210	1608.44	1843.28	1073.74	1452.14
	24/05/2021	1300	670				
P	26/05/2021	980	131	980	980	131	131
Q	26/05/2021	1046	143	1046	1046	143	143

Table 16: Mays calculated "percentile value"

June

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
P	22/06/2021	579	115	3874.29	5507.04	2562.85	4551.13
	18/06/2021	2237	1045				
Q	22/06/2021	326	21	5121.47	8525.04	4071.06	10787.24
	18/06/2021	2310	888				

Table 17: Junes calculated "percentile value"

Table 18 shows results obtained throughout the day of 18th June 'Blitz event,' samples were taken every 2 hours starting at 07:30 am through to 17:30, water quality throughout the day was significantly poor and showed a rise in IE levels from 11:30 to the end of the day, meaning BW status would be Poor.

June Blitz

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	18/06/2021	1986	1190	2588.64	3096.57	1260.44	1433.67
	18/06/2021	727	720				
	18/06/2021	1986	980				
	18/06/2021	2420	630				
	18/06/2021	980	1070				
	18/06/2021	1046	480				
M	18/06/2021	1203	182	7581.23	9826.65	1747.82	2378.29
	18/06/2021	2420	240				
	18/06/2021	3000	910				
	18/06/2021	2000	780				
	18/06/2021	8000	1290				
	18/06/2021	6000	1140				
P	18/06/2021	1000	730	3653.60	4304.07	1423.46	1568.27
	18/06/2021	2000	770				
	18/06/2021	2420	1060				
	18/06/2021	4000	1030				
	18/06/2021	2000	1260				
	18/06/2021	2000	1420				
Q	18/06/2021	770	530	4844.47	6403.47	1348.87	1545.40
	18/06/2021	1046	580				
	18/06/2021	1046	870				
	18/06/2021	5000	1370				
	18/06/2021	3000	840				
	18/06/2021	3000	1140				

Table 18: Junes Blitz events calculated "percentile value"

Tables 19 and 20 show calculated "percentile value" for July and August. July showed an improvement in water quality during this period with a site variation in BW status of Good to Excellent. Only site M showed poor water quality for EC with a BW status of Sufficient. August showed variance between sites J and M with a BW status of Excellent and P and Q with a BW status of Poor.

JULY

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	23/07/2021	276	130	276	276	130	130
M	23/07/2021	613	33	613	613	33	33
P	26/07/2021	248	58	248	248	58	58
Q	26/07/2021	435	49	435	435	49	49

Table 19: Julys calculated "percentile value"

AUGUST

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	19/08/2021	172	110	172	172	110	110
M	19/08/2021	345	19	345	345	19	19
P	23/08/2021	1046	710	1046	1046	710	710
Q	23/08/2021	1120	890	1120	1120	890	890

Table 20: Augusts calculated "percentile value"

Tables 21 and 22 show calculated "percentile value" for September and October. September showed mixed improvement and deterioration in water quality during this period with a site variation in BW status. Site P showed the poorest water quality for both EC and IE with a BW status of Poor. October showed an improvement at all sites with a BW status of Excellent for both EC and IE at sites P and Q and Excellent to Good for sites J and M.

SEPTEMBER

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	22/09/2021	448	350	448	448	350	350
M	22/09/2021	387	54	387	387	54	54
P	30/09/2021	2420	1060	2420	2420	1060	1060
Q	30/09/2021	866	530	866	866	530	530

Table 21: Septembers calculated "percentile value"

OCTOBER

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	19/10/2021	326	230	326	326	230	230
M	19/10/2021	272	280	272	272	280	280
P	27/10/2021	491	108	491	491	108	108
Q	27/10/2021	248	0	248	248	1	1

Table 22: Octobers calculated "percentile value"

Tables 23 and 24 show calculated "percentile value" for November and December showing a significant improvement in water quality during this period with a BW status of Excellent at all sites for both EC and IE.

NOVEMBER

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	15/11/2021	153	102	153	153	102	102
M	15/11/2021	206	89	206	206	89	89
P	23/11/2021	308	79	308	308	79	79
Q	23/11/2021	194	77	194	194	77	77

Table 23: Novembers calculated "percentile value"

DECEMBER

	Date	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
				90 %ile	95 %ile	90 %ile	95 %ile
J	17/12/2021	161	58	161	161	58	58
M	17/12/2021	365	82	365	365	82	82
P	20/12/2021	308	111	308	308	111	111
Q	20/12/2021	228	82	228	228	82	82

Table 24: Decembers calculated "percentile value"

Evaluation

1. Rainfall impact

Over the sampling period there have been significant high rainfall events followed by sustained dry periods. The data clearly shows a correlation between rainfall periods and a deterioration in water quality (Figure 2 and 3).
Under stress of excessive rainfall events, Thames Water are permitted to relieve pressure on their sewer network, through release of partially diluted untreated sewage 'spills' at Combined Sewer Overflows (CSOs) and at Wastewater Treatment Works (WwTW) via Storm Tank outfalls. Data shows there is a significant impact on water quality at locations associated with these intermittent outfalls.

This is most clearly shown by results obtained during the 16th June 'Blitz event' (Table 18) which showed recorded levels throughout the day, when converted to calculated "percentile values" were between 3x and 7x the accepted sufficient BW status levels at the 90 percentile value.

Significant rainfall events also have an impact on the overland mobilisation of agricultural based FIO sources, providing the conduit to transport them from land surface into river system. Along with septic tank inputs and misconnections, overall significant rainfall events cause a detriment to river water quality but by looking at the ratios of and increases in individual FIOs, a conclusion can be drawn as to the most significant contributor to FIO levels in the river system.

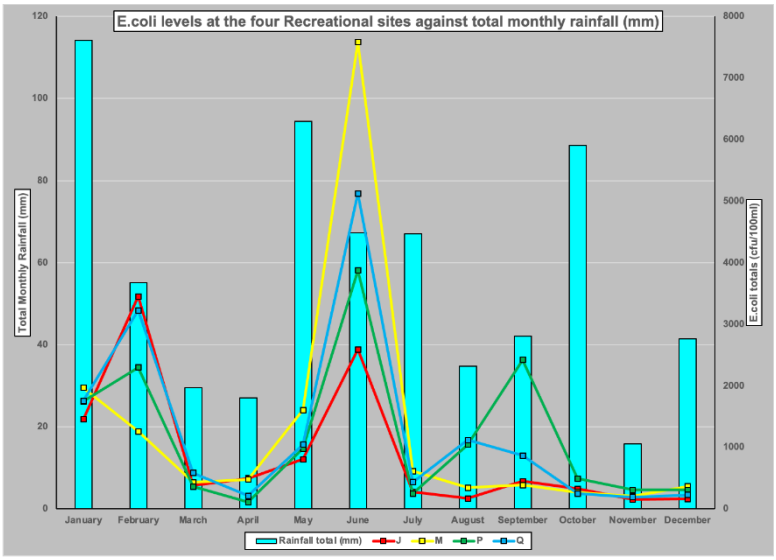


Figure 2: Shows the impact of rainfall on E.coli levels in the River

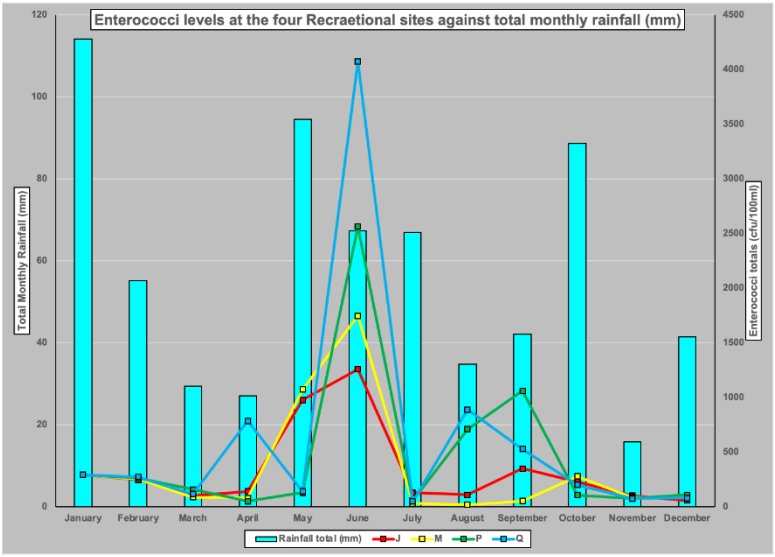


Figure 3: Shows the impact of rainfall on Enterococci levels in the River

EC and IE have variable survival periods when outside of the host body, with EC surviving between 36-48 hrs and IE between 72-96 hrs in both a terrestrial and aquatic environment when variables such as solar degradation and temperatures are accounted for.

Looking at ratios between EC and IE you can conclude whether levels of FIOs are caused by intermittent/diffuse inputs (spills, overland flow) or consistent point source inputs (WwTW outfalls). Typically, EC would be at levels 2-4x higher than IE.

If recorded counts are at a ratio that favours IE, it is due to a longer residence time within the watercourse without being added to by another sewage input occurrence. Therefore, under dry conditions you can conclude that the input was a result of a spill, due to a longer residence time resulting in lower EC counts as they begin to die off.

When the ratio is closer to the typical then FIO input is consistent with EC levels being replenished regularly.

Therefore under rainfall conditions, if the increase during or post rainfall event significantly favours EC and closely correlates to the typical ratio, you can conclude that it is point source, not diffuse overland/agricultural inputs.

2. Spill Correlation

The evaluation criteria for assessing whether spills correlated with and impacted sample results are as follows:

- Was the spill no more than 72 hrs before the sample date
- Did the correlating sample show an increase in EC and IE levels when compared with the previous sample
- Was the rise significant, resulting in BW status becoming Poor

The four recreational sample points were impacted by four of the EDM sites reported by Thames Water (Table 6). Overall P and Q were significantly impacted by the correlated spills, with J and M only showing one significant rise correlated to a reported spill (Table 26 and 27)

Sample ID	Date	Sample time	Sample Point	Total Coliforms MPN/100ml	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	Spill impact on Water Quality	Spill details (duration and dates of spills)
F9329766	26/01/2021	09:00-15:00	J	4000	1120	200	Detrimental	Spill at Cassington STW on 26/01 started 02:58 ended 06:10 for a total of 3.19 hrs also spills on 23/01 for a total of 9.71 hrs
F9329767	26/01/2021	09:00-15:00	M	4000	1553	200		
F9364077	11/02/2021	09:00-15:00	J	1414	328	86	No impact	Spill at Cassington STW on 08/02 intermitent for a total of 22.28 hrs, spill on 09/02 intermitent for a total of 10.49 hrs and on 11/02 intermitent for 5.50 hrs started 01:28 ended 09:10
F9364078	11/02/2021	09:00-15:00	M	1203	435	71		
F9395891	02/03/2021	09:00-15:00	J	1203	308	0	No impact	Spill at Cassington STW on 02/03 intermitent for a total of 5.39 hrs never for longer than 1.82 hrs over two distinct periods 03:29-10:45 (am) and 18:55-23:18 (pm)
F9395892	02/03/2021	09:00-15:00	M	1753	435	0		
F9395895	10/03/2021	09:00-15:00	J	2000	365	52	No impact	Spill at Cassington STW on 07/03 for a total of 12.05 hrs started at 12:13 ended 00:16 on the 08/03
F9395896	10/03/2021	09:00-15:00	M	687	146	27		

Table 26: Showing the correlated spills at Cassington STW and sample dates

Sample ID	Date	Sample time	Sample Point	Total Coliforms MPN/100ml	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	Spill impact on Water Quality	Spill details (duration and dates of spills)
F9329772	03/02/2021	09:00-15:00	P	5000	1203	200	Detrimental	Spill at BR on 02/02 started at 08:26 ended 09:11 for a total of 0.75 hrs.
								Intermitent spills at NHL throughout 02/03 for a total of 22.21 hrs and 03/03 started at 09:13 ended 15:00 for 5.79 hrs.
F9329773	03/02/2021	09:00-15:00	Q	4000	1733	200		Intermitent spills at Little SPS on 01/02 for a total of 8.74 hrs, on 02/03 for a total of 15.20 hrs and on 03/03 intermitent spills starting at 09:02 for a total of 7.05 hrs ending at 23:59 longest spill 1.74 hrs
F9364079	11/02/2021	09:00-15:00	P	1203	308	58	No impact	No spill at BR in the time period (72hrs before the sample was taken)
								No spill at NHL in the time period (72hrs before the sample was taken)
F9364080	11/02/2021	09:00-15:00	Q	921	308	49		2 small spills on 07/02 for a total of 0.75 hrs
F9364071	19/02/2021	09:00-15:00	P	3000	2000	200	Detrimental	Spills at BR on 17/02 from 06:58 to 09:00 for a total of 2.05 hrs and 18/02 from 09:07 to 10:10 for a total of 1.05 hrs
								No spill at NHL in the time period (72hrs before the sample was taken)
F9364072	19/02/2021	09:00-15:00	Q	3000	2420	200		No spill at Little in the time period (72hrs before the sample was taken)
F9563136	23/08/2021	09:00-15:00	P	12000	1046	710	Detrimental	Spills at BR on 21/08 from 13:24 to 14:09 for a total of 0.75 hrs
								No spill at NHL in the time period (72hrs before the sample was taken)
F9563137	23/08/2021	09:00-15:00	Q	11000	1120	890		No spill at Little in the time period (72hrs before the sample was taken)
F9653676	30/09/2021	09:00-15:00	P	16000	2420	1060	Detrimental	Spills at BR on 28/09 from 20:30 to 21:21 for a total of 0.8 hrs
								No spill at NHL in the time period (72hrs before the sample was taken)
F9653677	30/09/2021	09:00-15:00	Q	5000	866	530	No impact	No spill at Little in the time period (72hrs before the sample was taken)

Table 27: Showing the correlated spills at the CSO's Botley Rd (BR), Nth Hinskey Lane (NHL) and Littlemore SPS (Little) and sample dates

This impact from an associated spill from one of the EDM sites is seen in Figures 4, 5, 6 and 7 (the red circled point is the average result from the 'Blitz' diurnal samples).

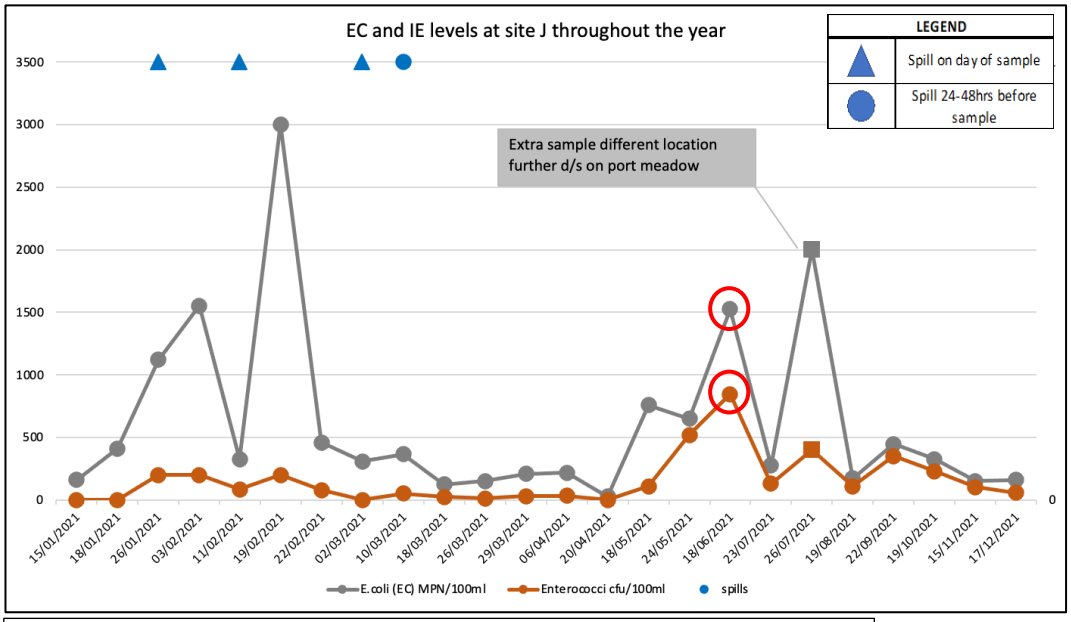


Figure 4: Shows the correlation of EDM spills and Water quality results at site "J"

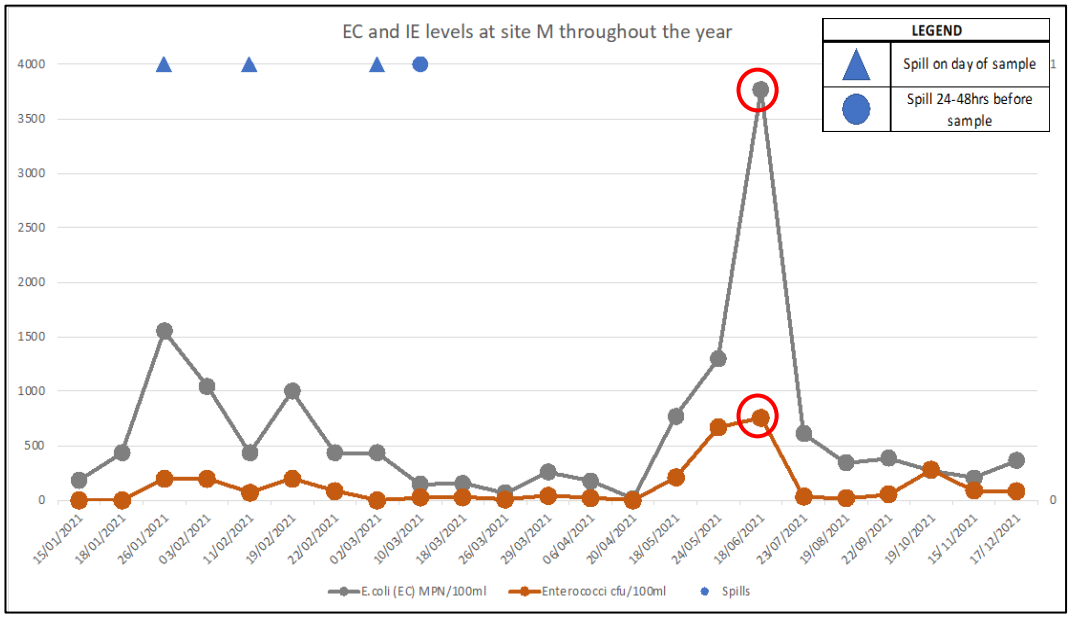


Figure 5: Shows the correlation of EDM spills and Water quality results at site "M"

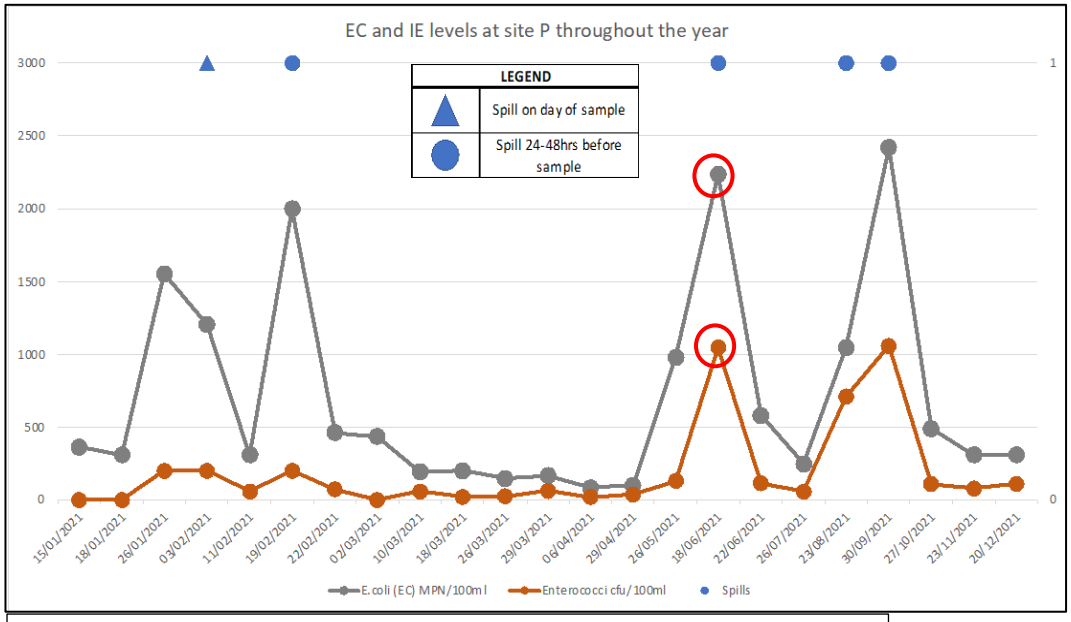


Figure 6: Shows the correlation of EDM spills and Water quality results at site "P"

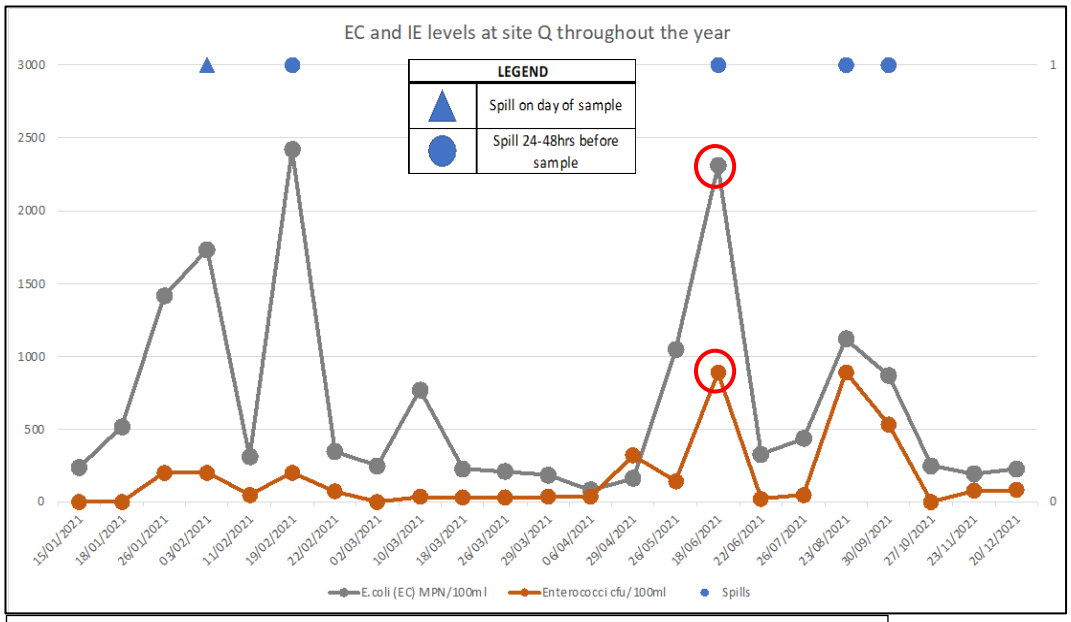


Figure 7: Shows the correlation of EDM spills and Water quality results at site "Q"

EDM monitors at the four associated sites (with the exception of Botley Rd CSO) recorded no spills after the following dates:

- Cassington STW – 07th March 2021
- North Hinskey Lane CSO – 05th February 2021
- Littlemore SPS – 07th February 2021

The following sample dates matched the evaluation criteria but had no associated spills or were after the dates when the associated EDM site recorded no more spills. This is despite significant recorded rainfall during May, June and July that were greater than rainfall recorded in February and March (Table 28).

- Recreational sites J and M – 03/02, 19/02, 18/05, 24/05 and 23/07 (M only)
- Recreational sites P and Q – 26/01, 26/05, 22/06 and 10/03 (Q only)

Month	Rainfall total (mm)
January	114.1
February	55.2
March	29.5
April	27.1
May	94.5
June	67.3
July	67
August	34.8
September	42.1
October	88.6
November	15.9
December	41.4

Table 28: Total rainfall recorded for 2021 at the Oxford Met Office Rain gauge.

Diffuse inputs would also need to be considered as the causation of these significant rises, but overall the data correlates with a direct point source input as described in Evaluation Section 1: Rainfall impact.

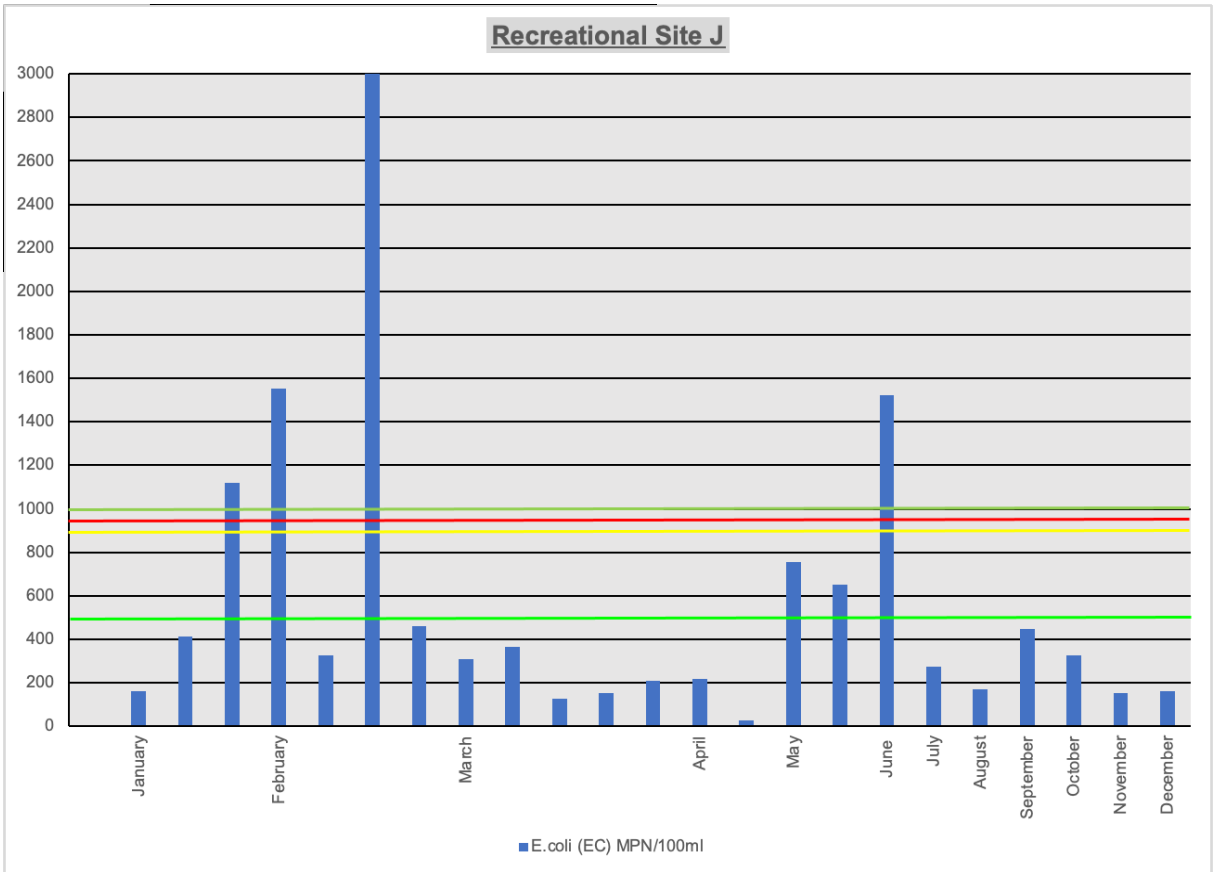
Results obtained on the 16th June 'Blitz event' showed significant impact due to extreme rainfall experienced on the day, but despite data being indicative of significant point source inputs, only Botley Road CSO recorded a spill. The spill started at 10:28 am and ended at 15:58pm (spilling for a total of 5.49 hours). Data clearly shows a detrimental impact to water quality from this spill, with higher levels post 11:30 on the day at sites P and Q (see Table 18).

Conclusion

As highlighted throughout 12 months of sampling at Sites J and M, only 8 out of 12 months (March, April, July, August, September, October, November and December) met bathing water standards between Good and Excellent. For sites P and Q only 6 out of 12 months (March, April, July, October, November and December) met bathing water standards between Good and Excellent, the failing months recorded between 1x and 2 acceptable sufficient status at the 90 percentile.

Throughout the defined BW season, data gathered would result in the four sites being awarded a BW status of Poor overall for both EC and IE with results being between 1.5x and 3x the levels required to meet sufficient status at the 90 percentile.

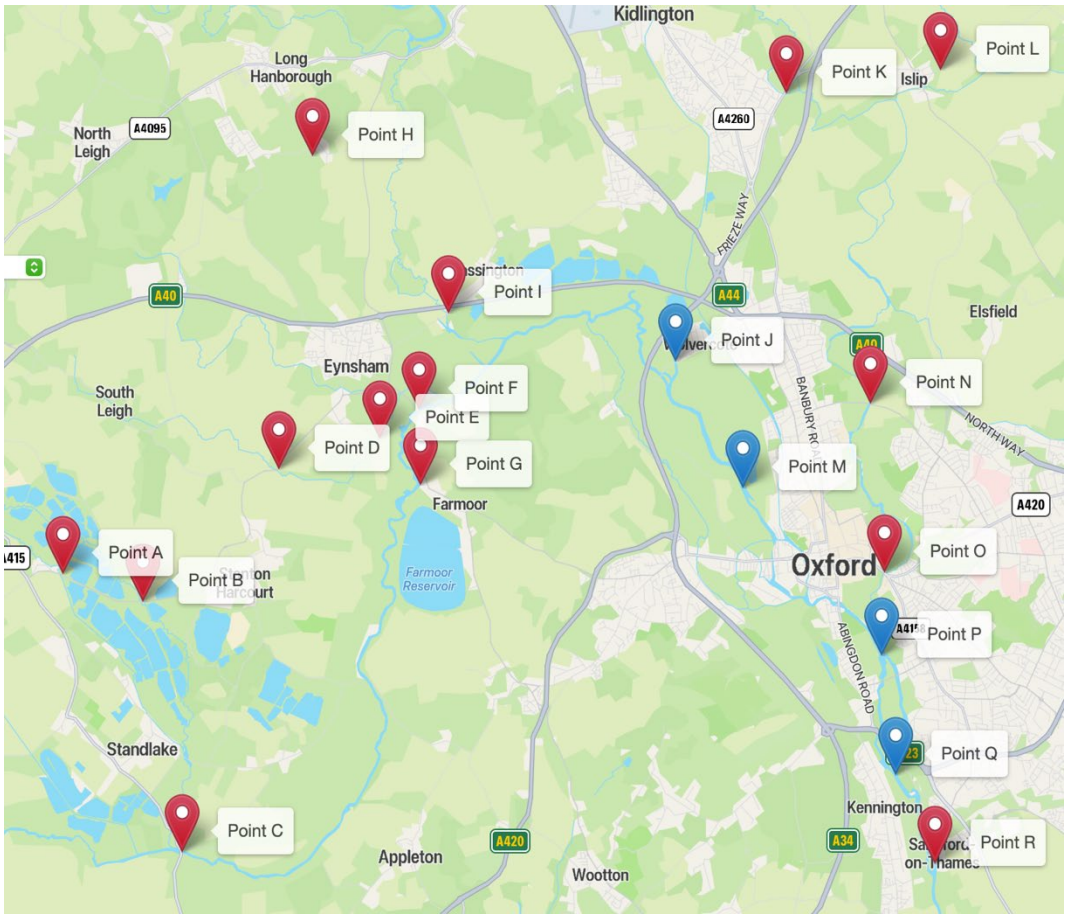
Recreational sites P and Q are more significantly impacted by all factors affecting water quality than sites J and M. Overall, data clearly indicates that the causation of detrimental water quality can be linked to continuous and intermittent point source inputs, and the impact rainfall events have on the quality of outfalls into the River Thames. Diffuse inputs are not to be discounted as adding to water quality problems but it is my conclusion that data indicates the most significant impact is caused by fully and partially treated sewage inputs.



SECTION 2
Wider catchment FIOs

Introduction

As part of the Oxford Rivers Project, the wider catchment was sampled concurrently on a monthly basis from April 2021 to ascertain water quality in the river catchments that feed into the mid Thames River.
In total a further 14 sample points were sampled and tested for the same parameters as the recreational locations (see Map 1). This section of the final report will cover FIO results of these sample points within each of these catchments including BW status throughout the whole year (due to the smaller data set). The results and conclusions will be grouped into separate catchments as detailed below.



Map 1: Wider catchment sample locations (Red) and Recreational sites (Blue)

Catchment Details

In total samples covered 4 major river catchments, including associated tributaries as shown in Table 1. The catchment sampling starts at the furthest most point away from Oxford within a maximum radius of 10 miles working their way North to South and West to East towards the central location of Oxford. All of the catchments have an impact on the main River Thames water quality, whereas some impact specifically (the recreational locations J and M (Evenlode and Limb Brook) P and Q (Cherwell)).

River Catchment	Sample points	Description
Windrush	A	Main River
	B	Main River
Evenlode	H	Tributary - Hanborough Stream
	I	Main River
Cherwell	K	Main River
	L	Tributary - River Ray
	N	Main River
	O	Main River
Thames	C	Main River
	G	Tributary - Flitchampstead Brook
	F	Main River
	D	Tributary - Limb Brook
	E	Tributary - Limb Brook
	J	Main River
	M	Main River
	P	Main River
	Q	Main River
	R	Main River

Table 1: River Catchments sampled and their associated sample points

Windrush Catchment

1. Results

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458095	07/05/2021	A	153	355	1279.46	1613.37	577.27	676.08
F9458120	03/06/2021	A	517	112				
F9563055	18/06/2021	A	866	430				
F9563048	07/07/2021	A	461	480				
F9563140	03/08/2021	A	349	340				
F9562995	06/09/2021	A	1120	350				
F9653681	08/10/2021	A	700	440				
F9653692	04/11/2021	A	661	355				
F9796545	08/12/2021	A	1120	330				

Table 2: Windrush sample point A results and BW status percentiles

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
f9458094	07/05/2021	B	53	248	774.64	1021.52	480.09	608.47
F9458119	03/06/2021	B	488	320				
F9563058	18/06/2021	B	548	520				
F9563045	07/07/2021	B	276	270				
F9563139	03/08/2021	B	345	125				
F9562993	06/09/2021	B	308	72				
F9653680	08/10/2021	B	649	330				
F9563030	04/11/2021	B	356	248				
F9796544	08/12/2021	B	179	98				

Table 3: Windrush sample point B results and BW status percentiles

"Please note that the results in red indicate a "Cancelled in the Lab/No sample taken sample" this was not set as 0, as done in the recreational locations because it was too small a dataset and would skew the statistical analysis, so it was set as the average of gathered data"

2. Evaluation

Spill correlation

The Windrush catchments sample locations (A and B) are affected by Witney STW spills, but there were no associated spills that met the criteria as detailed in Section 1: Evaluation.

3. Conclusion

There were no occurrences where results indicated point source impact as seen in Figure 1 and 2, both sample points A and B's data indicates an EC to IE ratio (as detailed in Section 1: Evaluation) more commonly linked to diffuse FIO inputs such as agriculture, septic tanks and misconnections. This causes annual BW status Poor overall for both IE and EC except B is moderate for EC at the 90 percentile.

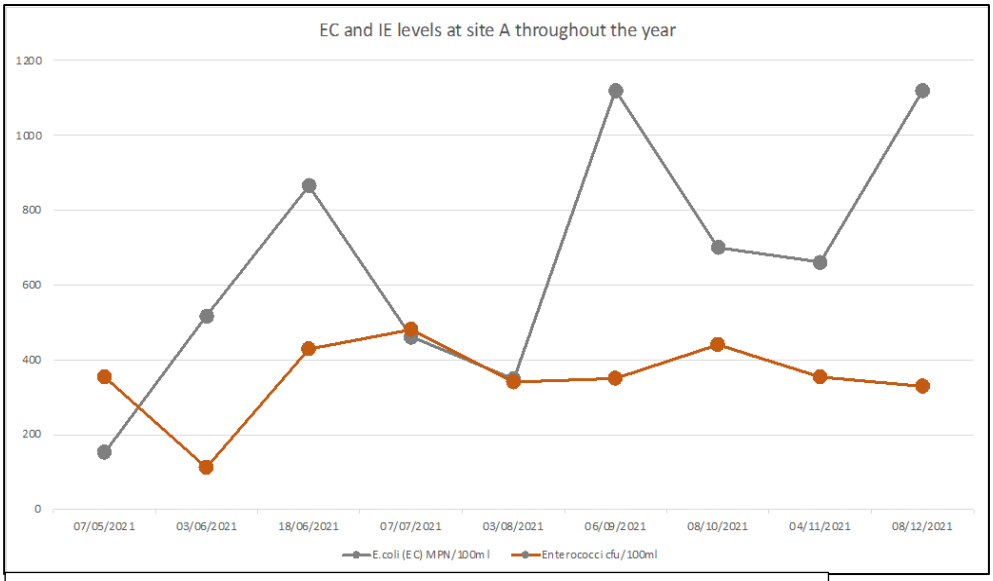


Figure 1: Shows the EC and IE results at sample point A throughout the year

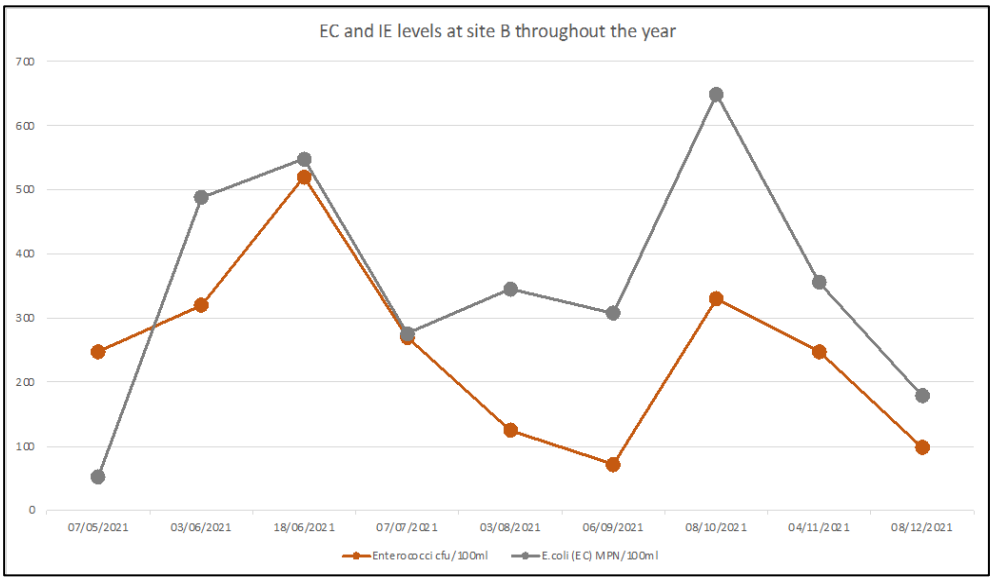


Figure 2: Shows the EC and IE results at sample point B throughout the year

Evenlode Catchment

1. Results

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458082	13/04/2021	H	15[illegible]00	1[illegible]00	134147.74	191690.59	8098.37	10212.27
F9458099	10/05/2021	H	2[illegible]000	4[illegible]00				
F9458123	11/06/2021	H	1[illegible]000	5[illegible]00				
F9563076	18/06/2021	H	1[illegible]5000	[illegible]800				
F9563128	15/07/2021	H	[illegible]0000	[illegible]600				
F9645899	11/08/2021	H	49[illegible]00	5[illegible]00				
F9653656	14/09/2021	H	1[illegible]0000	2[illegible]000				
F9653657	14/09/2021	H	1[illegible]0000	2[illegible]000				
F9563004	11/10/2021	H	24[illegible]00	12[illegible]400				
F9653665	12/11/2021	H	62[illegible]000	5[illegible]80				
F9796552	09/12/2021	H	2[illegible]0000	5[illegible]80				
F9796550	09/12/2021	H	4[illegible]0000	5[illegible]80				

Table 4: Evenlode sample point H the tributary Hanborough Stream results and BW status percentiles

"Please note when there was a > result on the neat sample and a 0 on dilution, the number input was the LOD for the test, or if there was a > result on all neat and dilutions then the LOD on the lowest dilution was input. This is denoted by blue numbers"

2. Evaluation

Spill Correlation

The Evenlode's catchment sample locations (H and I) are affected by two Thames Water sites Church Hanborough STW and Long Hanborough STW. Spill data for Church Hanborough is the only location monitored by EDM. In total there were 3 associated spills that met the criteria as detailed in Section 1: Evaluation.

Table 5: Evenlode sample point I results and BW status percentiles

At sample point H, there were 3 occurrences 11/08, 12/11 and 09/12 where data indicated a point source input (sewage release) but there was no associated spill notification. These are circled in blue on Figure 3. At sample point I there was 1 occurrence 09/12 where data indicated a point source input (sewage release) but there was no associated spill notification these are circled in blue on Figure 4.

3. Conclusion

It is clear from the data that flow in sample point H is primarily from the final effluent input of Church Hanborough STW; it is heavily polluted and contains on average 59,750 cfu/100ml of EC and 4,300 cfu/100ml of IE. What the data also clearly demonstrates is the impact of "storm" spills from the STW, on 3 occasions where a sample was taken that correlated with a spill (Figure 3) the increases seen are

significant enough to indicate a release of raw sewage not a partially diluted release as expected from a WwTW storm tank. This has severely impacted BW status throughout the year with it being classed as Poor, being excessively above the permitted level for both EC and IE.
Sample point I is in better overall health in regard to FIOs with an average throughout the year of 1,341 cfu/100ml of EC and 434 cfu/100ml of IE. On 3 occurrences (10/05, 18/06 and 14/09) where there was correlation between a sample taken and a spill, an impact was observed (Figure 4) that is indicative of a point source input of raw or partially diluted sewage from the "storm" spill. This has resulted in BW status being Poor for both EC and IE (significantly above the permitted levels).

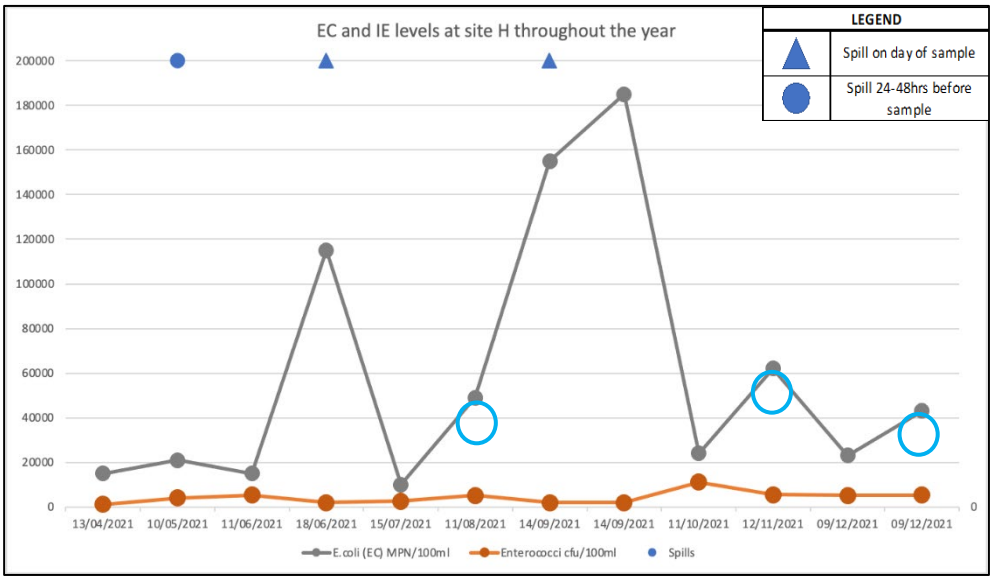


Figure 3: Shows the EC and IE results and correlated spills at sample point H throughout the year

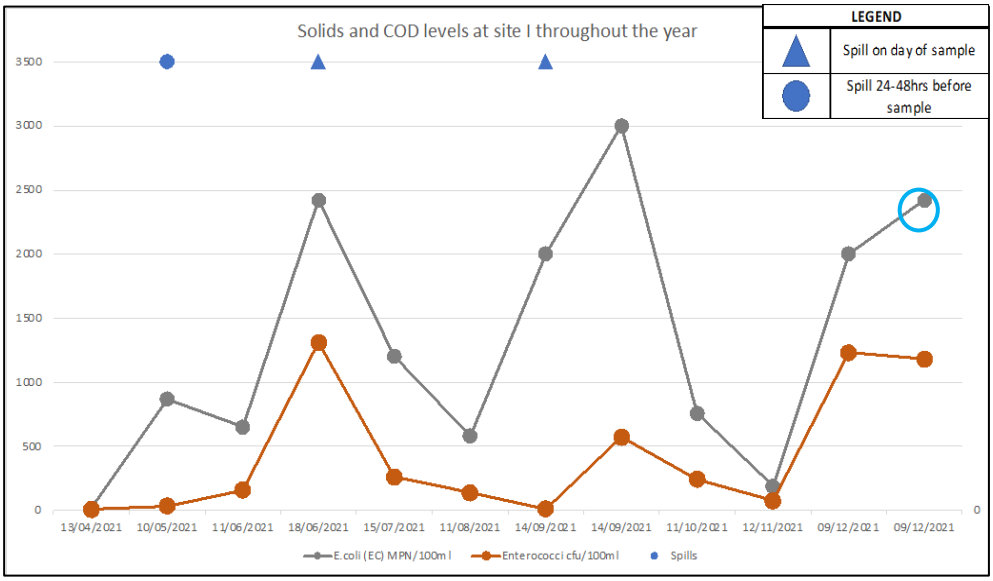


Figure 4: Shows the EC and IE results and correlated spills at sample point I throughout the year

Cherwell Catchment

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458084	20/04/2021	K	41	0	1776.50	2865.85	1225.36	2570.84
F9458106	18/05/2021	K	1120	780				
F9458112	24/05/2021	K	579	98				
F9563079	18/06/2021	K	1203	490				
F9563127	23/07/2021	K	1046	160				
F9562982	19/08/2021	K	219	103				
F9653672	22/09/2021	K	365	127				
F9653685	19/10/2021	K	461	340				
F9796571	17/12/2021	K	44	19				

1. Results

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458085	20/04/2021	L	91	0	4656.83	8615.41	5256.26	13825.06
F9458105	18/05/2021	L	248	36				
F9458110	24/05/2021	L	548	320				
F9563080	18/06/2021	L	20000	12500				
F9563128	23/07/2021	L	205	1000				
F9562981	19/08/2021	L	1046	80				
F9653671	22/09/2021	L	461	600				
F9653691	19/10/2021	L	1733	510				
F9796570	17/12/2021	L	102	59				

Table 6: Cherwell sample point K results and BW status percentiles

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458086	20/04/2021	N	21	0	1524.34	2505.48	982.76	1949.01
F9458104	18/05/2021	N	2000	250				
F9458109	24/05/2021	N	1046	350				
F9563081	18/06/2021	N	1046	810				
F9563129	23/07/2021	N	225	82				
F9562980	19/08/2021	N	308	63				
F9653674	22/09/2021	N	214	160				
F9653690	19/10/2021	N	313	320				
F9653667	15/11/2021	N	86	56				
F9796569	17/12/2021	N	112	35				

Table 7: Cherwell sample point L the tributary River Ray results and BW status percentiles

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458092	29/04/2021	O	649	360	3352.49	4573.74	1024.88	1505.05
F9458113	26/05/2021	O	866	82				
F9563082	18/06/2021	O	2000	1330				
F9458127	22/06/2021	O	579	197				
F9563132	26/07/2021	O	2000	320				
F9562985	23/08/2021	O	5000	1700				
F9653675	30/09/2021	O	3000	300				
F9563026	27/10/2021	O	921	90				
F9796539	23/11/2021	O	432	130				
F9796572	20/12/2021	O	461	133				

Table 8: Cherwell sample point N results and BW status percentiles

2. Evaluation

Spill Correlation

Table 9: Cherwell sample point O results and BW status percentiles

The Cherwell catchment's sample location K has no u/s EDM site and so no spill data for this location. Sample locations L, N and O are affected by Islip STW spills; there was no EDM data supplied for this site by Thames Water for the project but there were no recorded spills from this STW in 2020.
The data for sample points L and K show no occurrence of a significant rise indicative of point source sewage inputs (Figures 5 and 6). The data for sample point N shows 1 occurrence (18/05) of a significant rise that would be indicative of a point source sewage input, this is circled in blue on Figure 8. Sample point O has 3 occurrences (26/07, 23/08 and 30/09) of a significant rise that would be indicative of a point source sewage input this is circled in blue on Figure 9.

3. Conclusion

For sample points K and L there were no occurrences where results indicated point source (sewage) impact (Figure 5 and 6) both sample points data indicates an EC to IE ratio (as detailed in Section 1: Evaluation) more commonly linked to diffuse FIO inputs such as agriculture, septic tanks and misconnections. There is a significant increase in levels for both EC and IE at point L on 18th June that is more commonly associated with a point source sewage input but the level of IE within that increase is more indicative of diffuse inputs. The combination of these impacts on water quality has caused the annual BW status to be Poor overall for both IE and EC at both the 90 and 95 percentile at sample point K and L.

In contrast sample points N and O's data (Figure 7 and 8) despite overall throughout the year being indicative of diffuse inputs as the key cause of the FIO levels, there are significant rises recorded on the 18/05 (N), 26/07, 23/08 and 30/09 (O) that indicate a point source (sewage) input with EC being the dominant FIO within those samples. The combination of these impacts on water quality has caused the annual BW status to be Poor overall for both IE and EC at both the 90 and 95 percentile at sample points N and O.

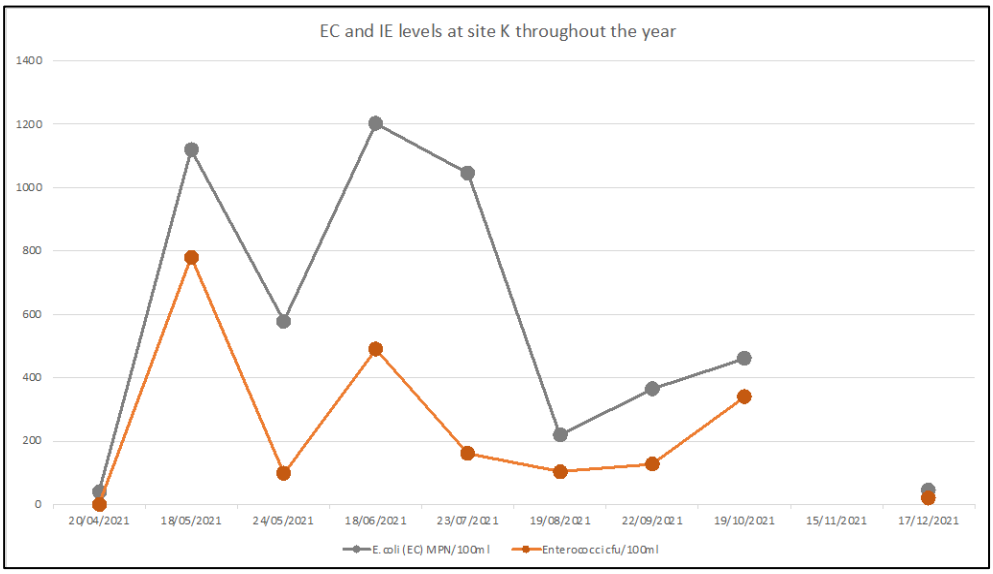


Figure 5: Shows the EC and IE results at sample point K throughout the year

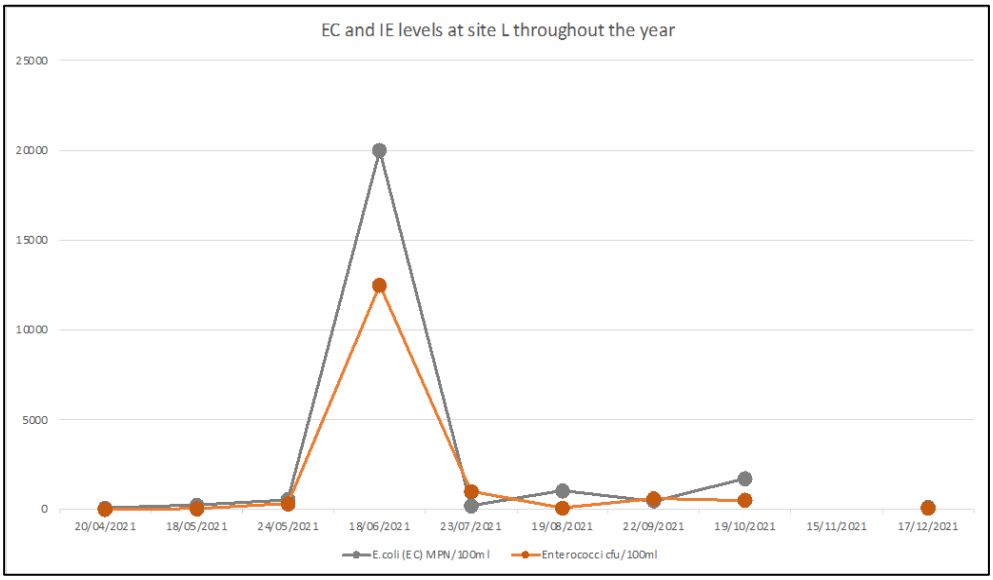


Figure 6: Shows the EC and IE results at sample point L throughout the year

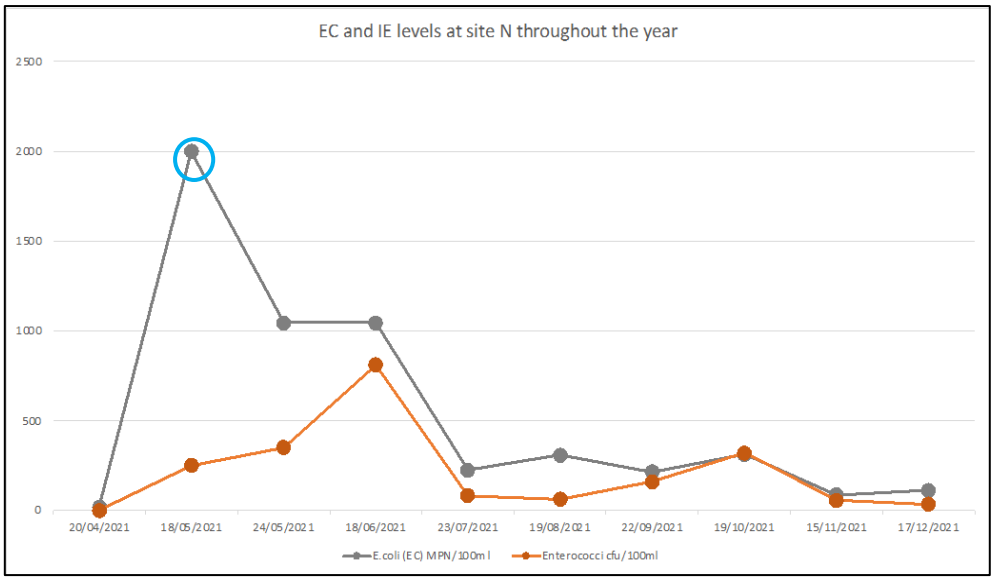


Figure 7: Shows the EC and IE results at sample point N throughout the year

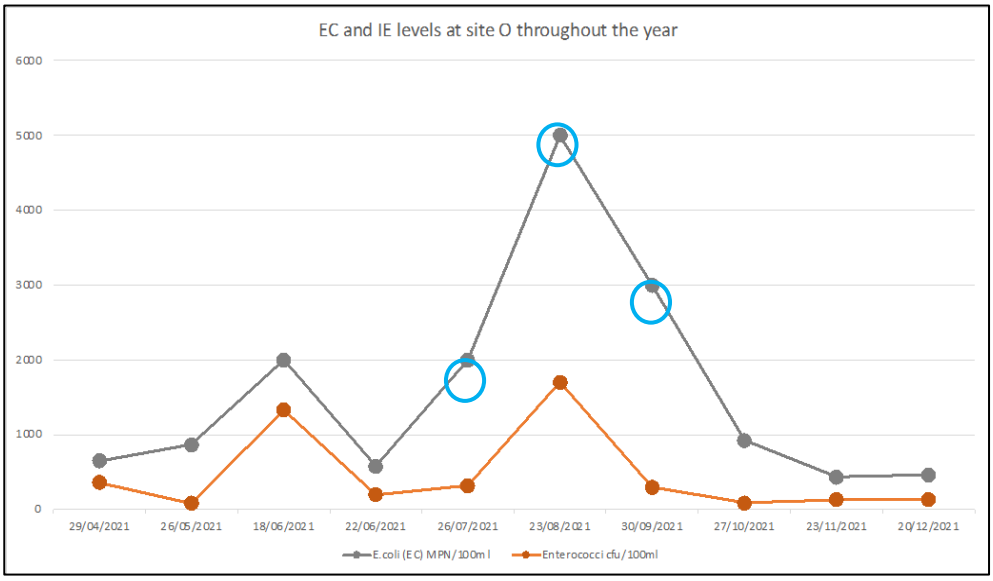


Figure 8: Shows the EC and IE results at sample point O throughout the year

Thames

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458096	07/05/2021	C	204	319	703.50	822.20	717.38	1003.06
F9458121	03/06/2021	C	517	58				
F9563061	18/06/2021	C	210	143				
F9563051	07/07/2021	C	387	1010				
F9563141	03/08/2021	C	579	130				
F9562998	06/09/2021	C	411	81				
F9653682	08/10/2021	C	517	510				
F9653693	04/11/2021	C	439	319				
F9796547	08/12/2021	C	687	300				

1. Results

Table 10: Thames sample point C results and BW status percentiles

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458080	13/04/2021	G	54	12	756.33	1071.78	333.60	544.09
F9458101	10/05/2021	G	435	42				
F9458126	11/06/2021	G	142	31				
F9563075	18/06/2021	G	727	210				
F9563120	15/07/2021	G	91	27				
F9645401	11/08/2021	G	115	5				
F9653664	14/09/2021	G	818	400				
F9653665	14/09/2021	G	1046	410				
F9653686	11/10/2021	G	131	53				
F9653694	12/11/2021	G	205	101				
F7976565	09/12/2021	G	145	61				
F9796566	09/12/2021	G	194	106				

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458079	13/04/2021	F	39	4	375.11	480.80	261.92	396.26
F9458097	10/05/2021	F	308	58				
F9458124	11/06/2021	F	236	63				
F9563073	18/06/2021	F	144	104				
F9563121	15/07/2021	F	86	61				
F9645402	11/08/2021	F	71	18				
F9653662	14/09/2021	F	248	200				
F9653663	14/09/2021	F	276	240				
F9653683	11/10/2021	F	93	36				
f9653695	12/11/2021	F	225	75				
F9796560	09/12/2021	F	272	163				
F6796561	09/12/2021	F	249	90				

Table 11: Thames sample point G the tributary Flichampstead Brook results and BW status percentiles

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458089	29/04/2021	R	138	230	7550.17	13899.43	2575.29	3430.61
F9458093	07/05/2021	D	49	1147				
F9458117	26/05/2021	R	1046	152				
F9458118	03/06/2021	D	387	490				
F9563083	18/06/2021	R	1000	4200				
F9563063	18/06/2021	D	13000	2088				
F9563040	22/06/2021	R	517	87				
F9563043	07/07/2021	D	727	1320				
F9563134	26/07/2021	R	613	91				
F9563138	03/08/2021	D	5000	1280				
F9562988	23/08/2102	R	1300	1130				
F9562990	06/09/2021	D	613	1750				
F9653678	30/09/2021	R	1733	1180				
F9653679	08/10/2021	D	980	1930				
F9653673	27/10/2021	R	1020	14				
F9563029	04/11/2021	D	2420	1147				
F9796542	25/11/2021	R	1046	149				
F9796548	08/12/2021	D	276	158				

Table 13: Thames sample point D the tributary Limb Brook results and BW status percentiles

Table 12: Thames sample point R results and BW status percentiles

Sample ID	Date	Sample Point	E.coli (EC) MPN/100ml	Enterococci cfu/100ml	E.coli		Enterococci	
					90 %ile	95 %ile	90 %ile	95 %ile
F9458081	13/04/2021	E	2000	870	15656.73	30862.40	1964.69	2773.30
F9458098	10/05/2021	E	1733	260				
F9458125	11/06/2021	E	488	560				
F9563071	18/06/2021	E	17000	4500				
F9563122	15/07/2021	E	1414	180				
F9645400	11/08/2021	E	248	810				
F9653658	14/09/2021	E	30000	1000				
F9653659	14/09/2021	E	24000	1200				
F9563009	11/10/2021	E	980	1040				
f9653696	12/11/2021	E	172	320				
F9796556	09/12/2021	E	291	250				

Table 14: Thames sample point E the tributary Limb Brook results and BW status percentiles

2. Evaluation

Spill Correlation

The Thames catchment sample locations C, G and F have no u/s EDM site, so no spill data for these locations. Sample location D is affected by South Leigh STW spills, sample point E is also affected by South Leigh and Stanton Harcourt STW and sample point R is affected by Littlemore SPS and Oxford STW.

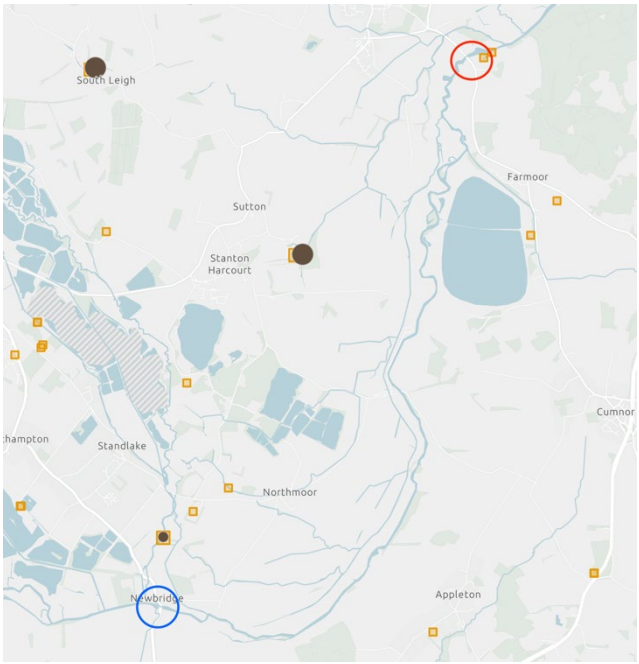
The data for sample points C, G and F show no occurrences of a significant rise indicative of point source sewage inputs (Figures 9, 10

Table 15: Thames sample point R results and BW status percentiles

and 11). At sample point D there was 1 occurrence 03/08 where data indicated a point source input (sewage release) but there was no associated spill notification, this is circled in blue on Figure 12. At sample point E there was 1 occurrence 14/09 where data indicated a point source input (sewage release) but there was no associated spill notification, this is circled in blue on Figure 13. At sample point R there was 1 occurrence 23/11 where data indicated a point source input (sewage release) but there was no associated spill notification, this is circled in blue on Figure 14.

3. Conclusion

For sample points C and G there were no occurrences where results indicated point source (sewage) impact (Figure 9 and 10) both sample points data indicates an EC to IE ratio (as detailed in Section 1: Evaluation) more commonly linked to diffuse FIO inputs such as agriculture, septic tanks and misconnections. The combination of these impacts on water quality has caused the annual BW status to be Sufficient to Good for EC but Poor overall for IE at sample point C and Sufficient to Poor for EC but Poor overall for IE at sample point G. For sample point F (Figure 11) water quality was very good and is more indicative of a river not affected by anthropogenic inputs, resulting in a BW status of Good to Excellent both the 90 and 95 percentile. Further investigation would be required to understand why at this point there is no evidence of anthropogenic input, but as shown in Map 2, there are no inputs in the stretch between Sample point C (blue circle) at Newbridge and Sample point F (red circle) at Swinford. This combined with abstraction from the river at Farmoor Reservoir a short distance upstream, mitigating the upper catchments impact, I believe has a positive impact on water quality.



Map 2: Shows the positioning of Sample point C (Blue circle) and F (Red circle)

Sample point D's data (Figure 12) despite overall throughout the year being indicative of diffuse inputs as the key cause of FIO levels, there is a significant rise recorded on the 18/06 that indicates a point source (sewage) input with EC being the dominant FIO. This correlates with a spill from South Leigh STW. This spill occurred on the sampling day, but the occurrences when a spill was within 24-48 hrs before a sample, showed no or minimal impact which could possibly indicate no lasting impact of a spill on this particular water course. The other occasion when a sample was taken on the day of a spill - 08/12 there was no impact, but this was due to the sample being taken at 09:20 and the spill starting

at 20:23 over 11 hours later in the day. The combination of these impacts on water quality has caused the annual BW status to be Poor overall for both IE and EC at both the 90 and 95 percentile.

Sample point E's data (Figure 13) despite overall throughout the year being indicative of diffuse inputs as the key cause of FIO levels, there is a significant rise recorded on the 18/06 that indicate a point source (sewage) input with EC being the dominant FIO that correlates with a spill from South Leigh STW. The other occasion when a sample was taken on the day of a spill 10/05 there was no impact, but this was due to the sample being taken at 11:22 and the spill which started on the 08/05 ending at 05:00 on the 10/05 over 6 hours earlier in the day. The combination of these impacts on water quality has caused the annual BW status to be Poor overall for both IE and EC at both the 90 and 95 percentile.

Sample point R's data (Figure 14) is indicative of diffuse inputs as the key cause of FIO levels. On the 18/06 (circled red) when there was a correlation between sampling and a spill from Oxford STW, data shows a significant rise for IE only, but this is due to an anomaly in the EC result caused by limits of the testing method (the neat sample was recorded as >2420 cfu/100ml (the Limit of Detection) and a result of 1cfu/100ml from the 1:1000 dilution. This means a result of 1000 cfu/100ml is reported. This shows errors that can result from multiple aliquots being taken from one sample and is a limitation of the method used. It is likely that the true EC result would have been much higher, but we can only use data we have available. On 22/06 when there is correlation between sampling and spills from Oxford STW there is no rise seen but looking at sampling time 12:10 and spill time 10:30-14:26, the spill duration would have been 1hr 40 mins before the sample was taken and due to Oxford STW not discharging directly into the Thames, this would result in a lag of impact on the Thames at sample point R due to residence time within the receiving watercourse.

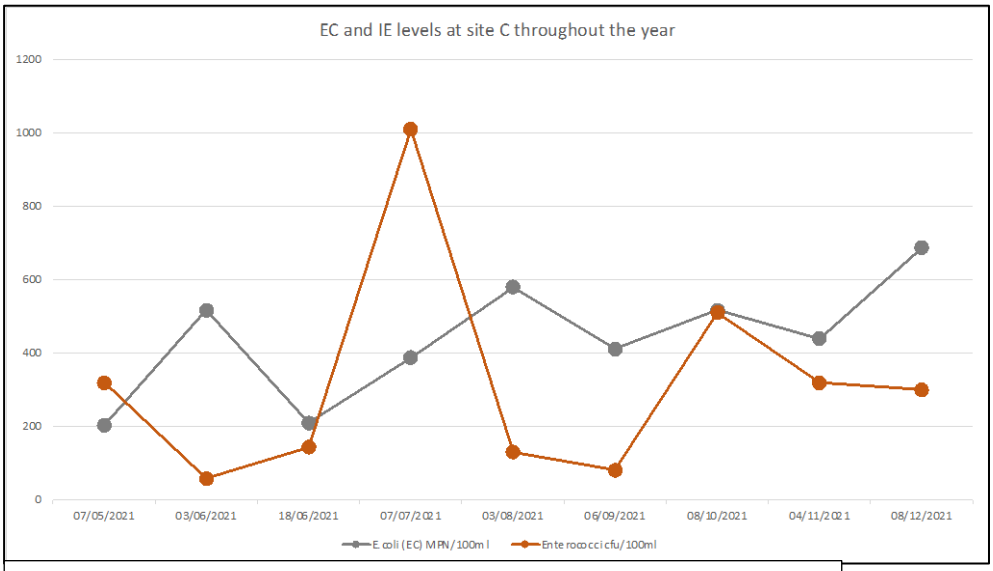


Figure 9: Shows the EC and IE results at sample point C throughout the year

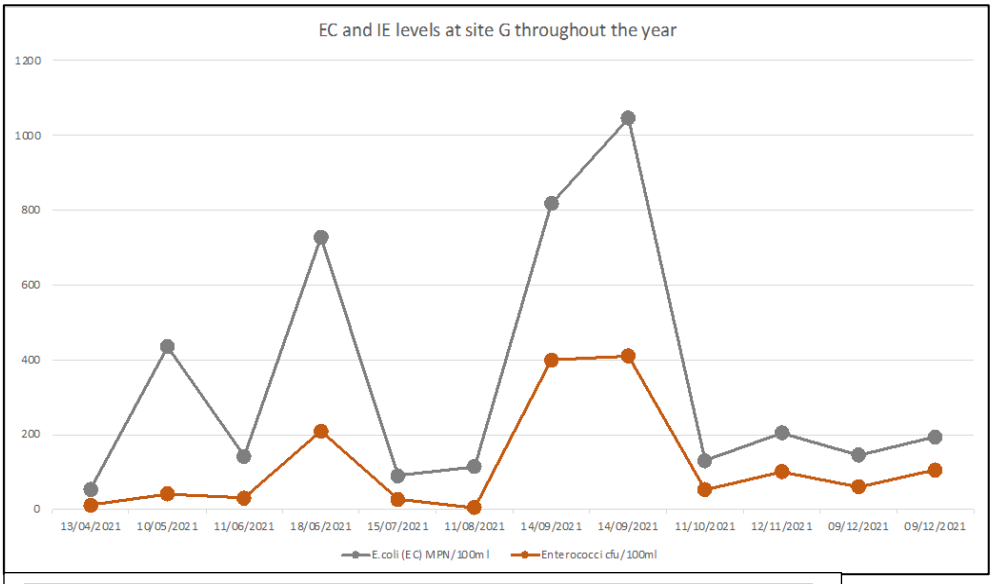


Figure 10: Shows the EC and IE results at sample point G throughout the year

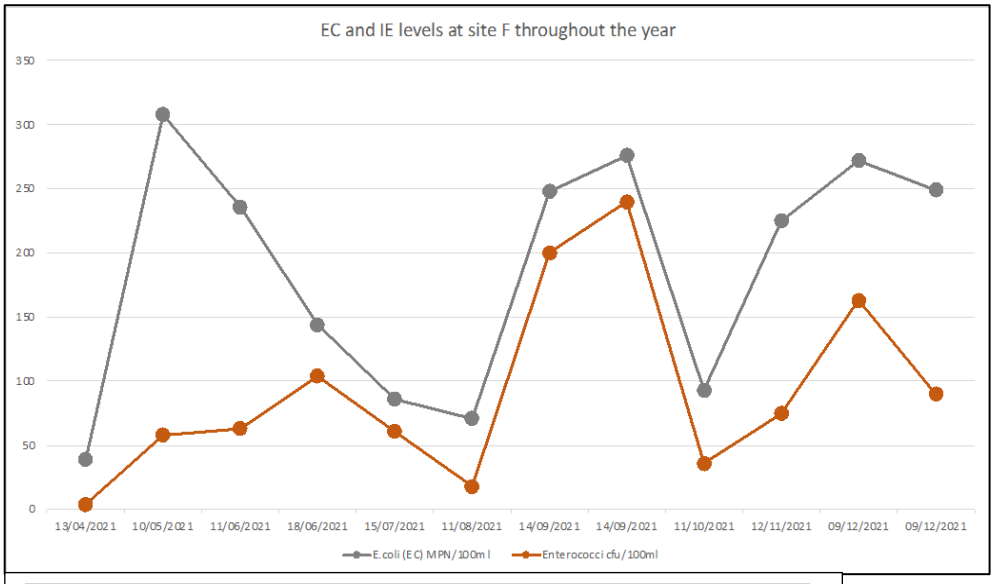
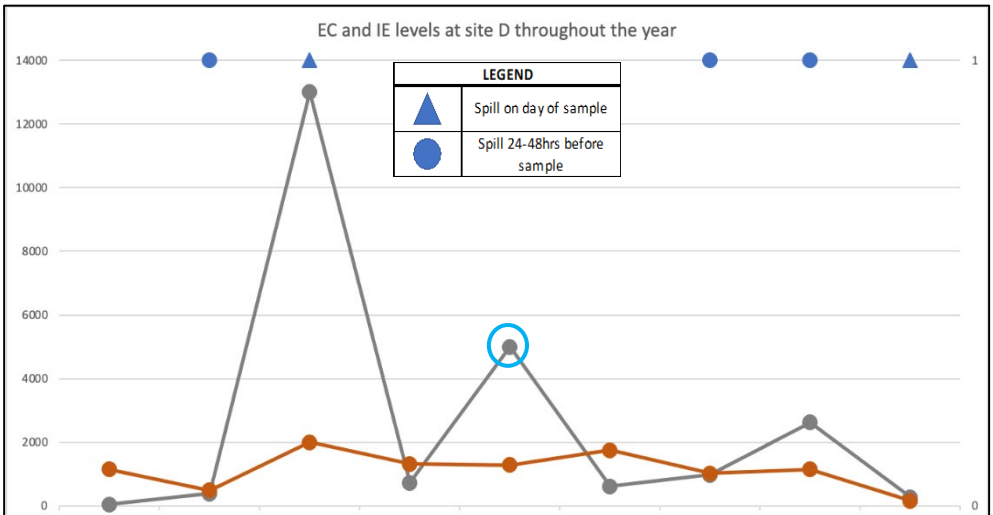


Figure 11: Shows the EC and IE results at sample point F throughout the year



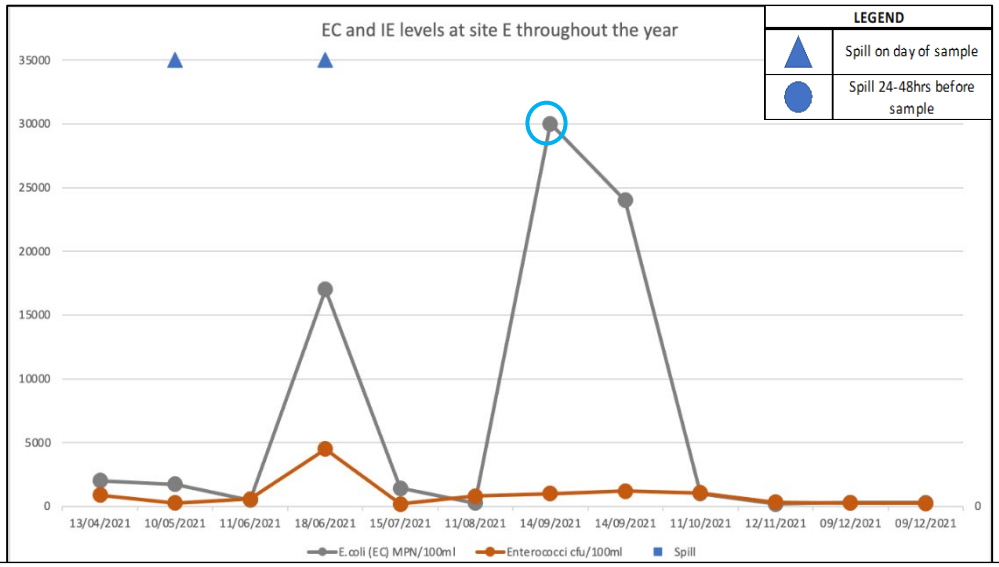


Figure 13: Shows the EC and IE results and correlated spills at sample point E throughout the year

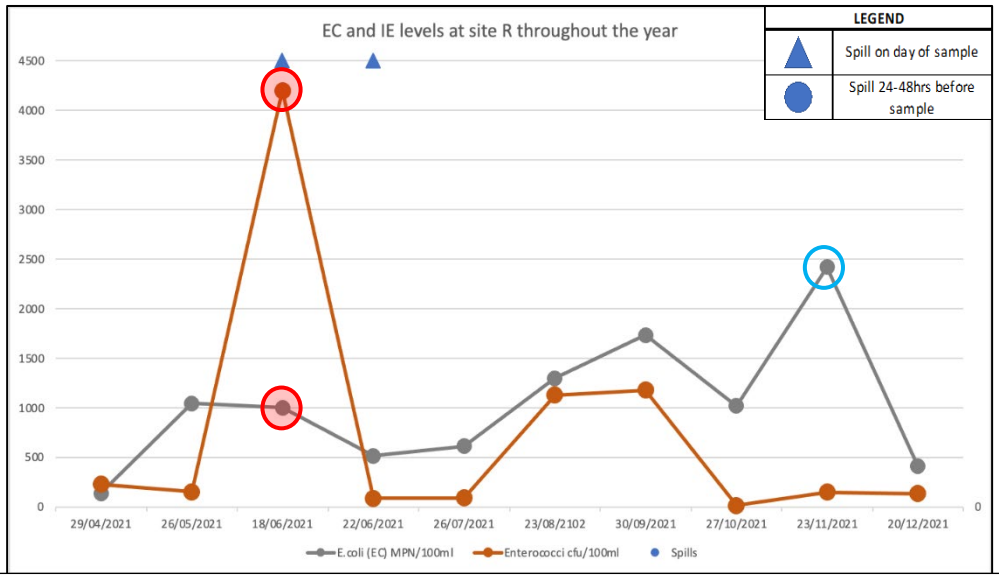


Figure 14: Shows the EC and IE results and correlated spills at sample point R throughout the year

Rainfall Impact

Data Details

The rainfall data has been kindly supplied by The UK Centre for Ecology and Hydrology via there COSMOS-UK project and is a catchment wide (Thames at Sutton Courtney) calculated value collated from rainfall gauges placed around the Oxford area. There will be some localised variation, but it was deemed the best "catch all" data set to use for this catchment.

For this comparison a 3 day average of the total daily rainfall was calculated up to the date of the sample being taken at each of the sample locations, so for example if the sample was taken on the 13th July the total daily rainfall from 11th, 12th and 13th July was used to calculate the average to be used in the rainfall impact assessment.

Windrush Catchment

As already stated, the data for the Windrush catchment indicates the greatest impact is due to diffuse pollution inputs, this pollution proportion requires a conduit to transport it into the River. That conduit is typically rainfall and in Figure 15 there is good correlation between increased rainfall and E.coli levels but the greater impact of rainfall is on the Enterococci levels as can be seen in Figure 16. There are some outliers present but the most significant changes in FIO levels is related to an increase in rainfall.

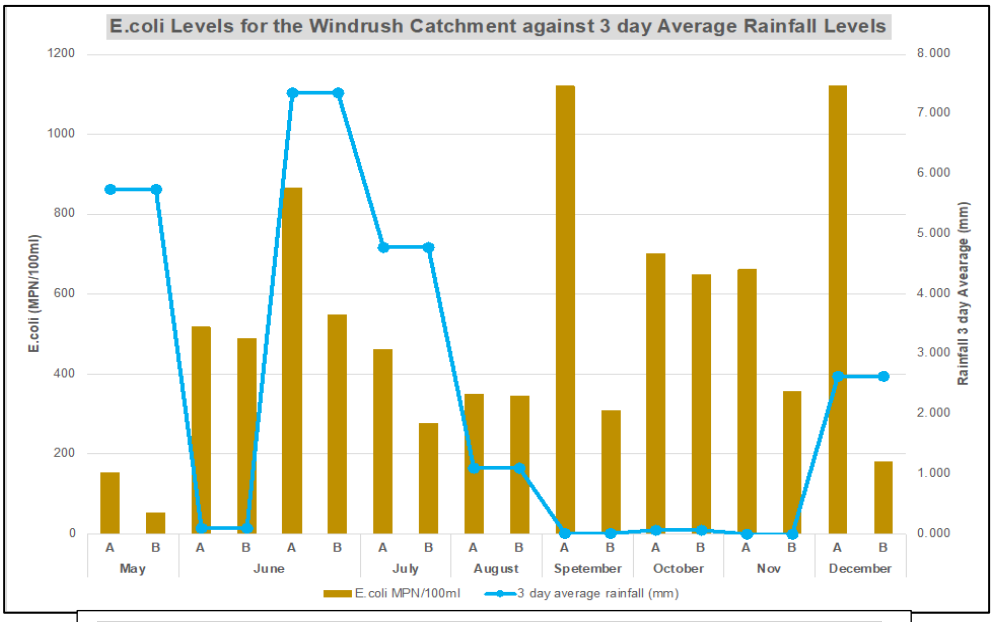
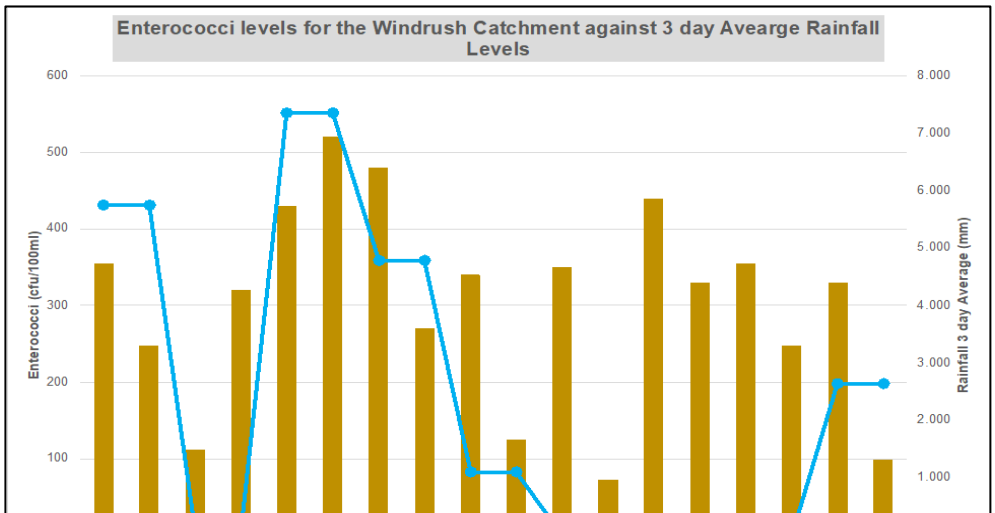


Figure 15: Shows the Impact of Rainfall on E.coli levels in the River Windrush



Evenlode Catchment

Sample point H's data, as already stated is consistent with the flow primarily consisting of Final Effluent from Church Hanborough WwTW and is shown to respond to storm "spills". The principal cause of storm spills is excessive rainfall and as shown in Figure 17 and 18 below there is good correlation between increased rainfall and increased FIO levels particularly E.coli which is consistent with point source (sewage) inputs.
Sample point I shows good correlation between increases in rainfall and FIO levels with the most significant increases present during the highest rainfall events, with E.coli showing the greatest increase this is consistent with point source (sewage) inputs being the main contributor.

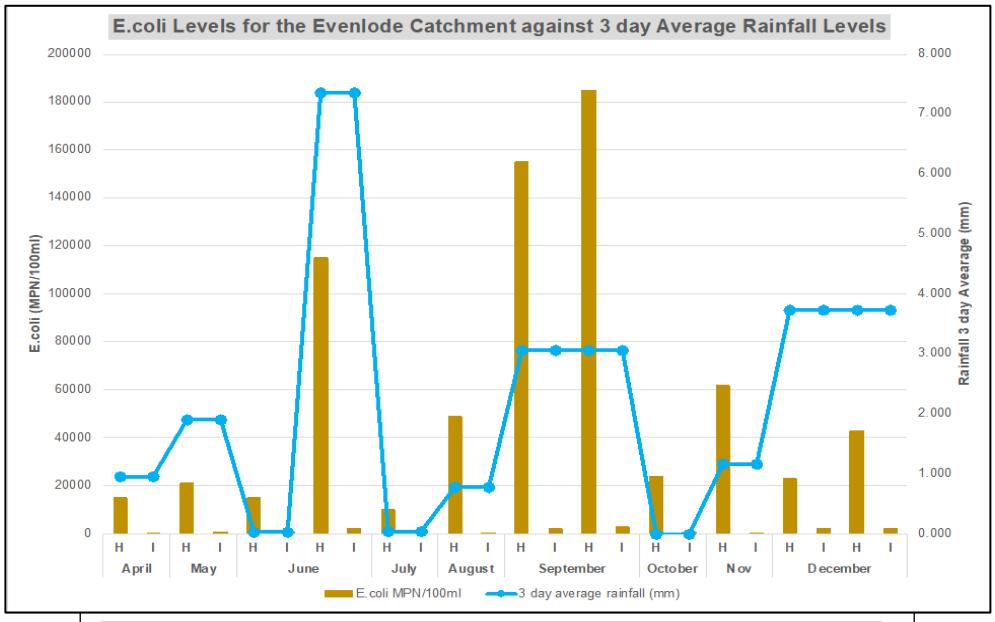
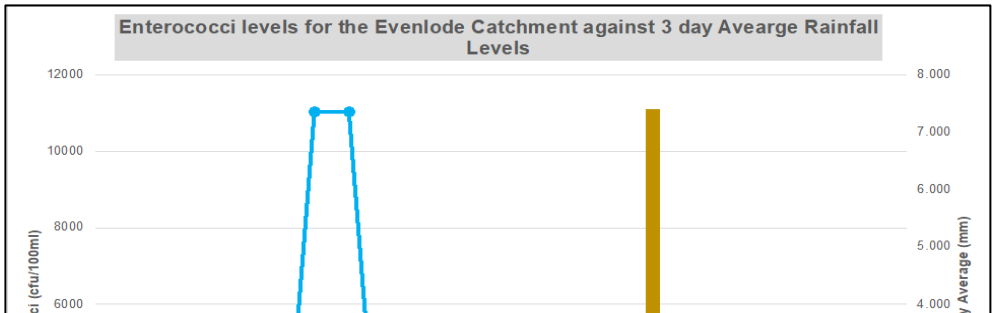


Figure 17: Shows the Impact of Rainfall on E.coli levels in the River Evenlode



Cherwell Catchment

As already stated, the data for Sample points K and L indicates the greatest impact is from diffuse pollution inputs, this pollution proportion requires a conduit to transport it into the River. That conduit is typically rainfall and in Figure 19 there is good correlation between increased rainfall and E.coli levels but the greater impact of rainfall is on the Enterococci levels as can be seen in Figure 20, this is best demonstrated sample point L's results from the "Blitz" event on 18th June with a significant rise in both EC and IE but the greatest change is seen in IE levels.
Sample points N and O's data shows reasonable correlation between rainfall and increases in FIO levels, as already stated these points showed overall an impact from diffuse inputs but did have occurrences when the rises were more indicative of point source (sewage) inputs this is when the correlation is strongest between rainfall and the FIO level rise (May N only, July, August and September O only)

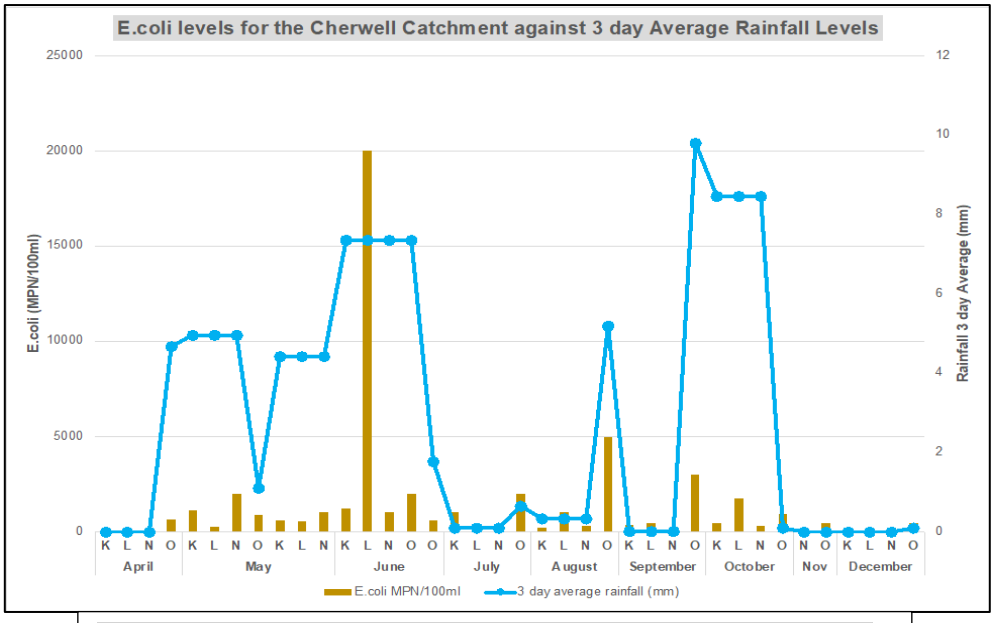


Figure 19: Shows the Impact of Rainfall on E.coli levels in the River Cherwell

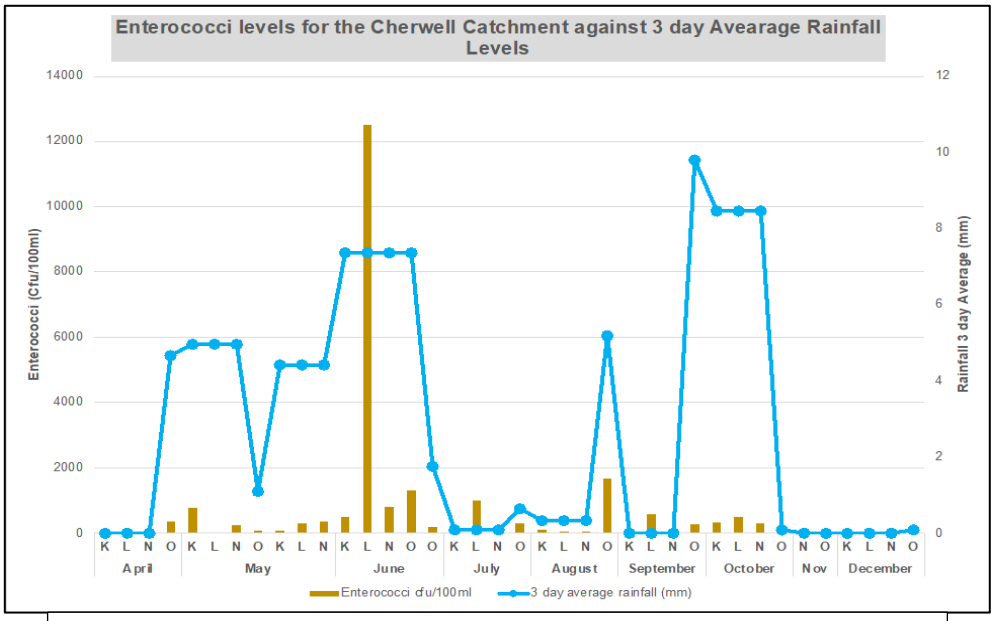


Figure 20: Shows the Impact of Rainfall on Enterococci levels in the River Cherwell

Thames Tributaries

Three sample points G (Flichampstead Brook) D and E (Limb Brook) are tributaries that were sampled, looking at the sample points data G correlated with diffuse pollution. Of the dates G was sampled the rainfall level was low the majority of the time but on the four occasions when rainfall was 2 mm or more (May, June, September and December) sample results showed an increase in FIO levels on 3 of those occasions in correlation with typical diffuse pollution inputs. Sample points D showed good correlation with rainfall increases including a significant increase on 18th June that is typical of a point source (sewage) input overall though the data showed more typical impacts from diffuse pollution. Sample point E showed strong correlation with rainfall increases and the data very strongly shows the impact is from point source (sewage) inputs.

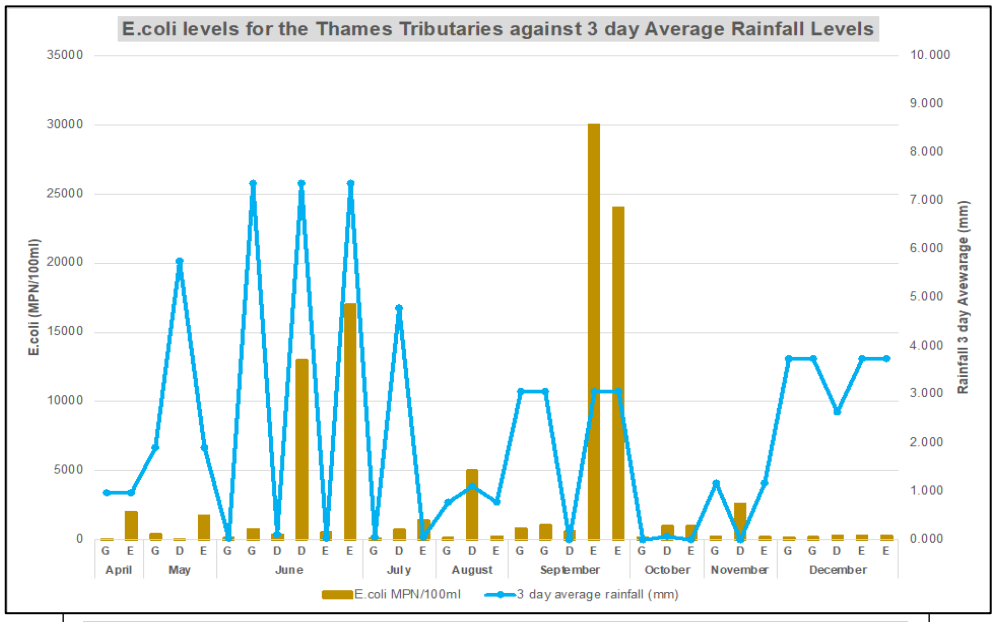


Figure 21: Shows the Impact of Rainfall on E.coli levels in the Thames Tributaries

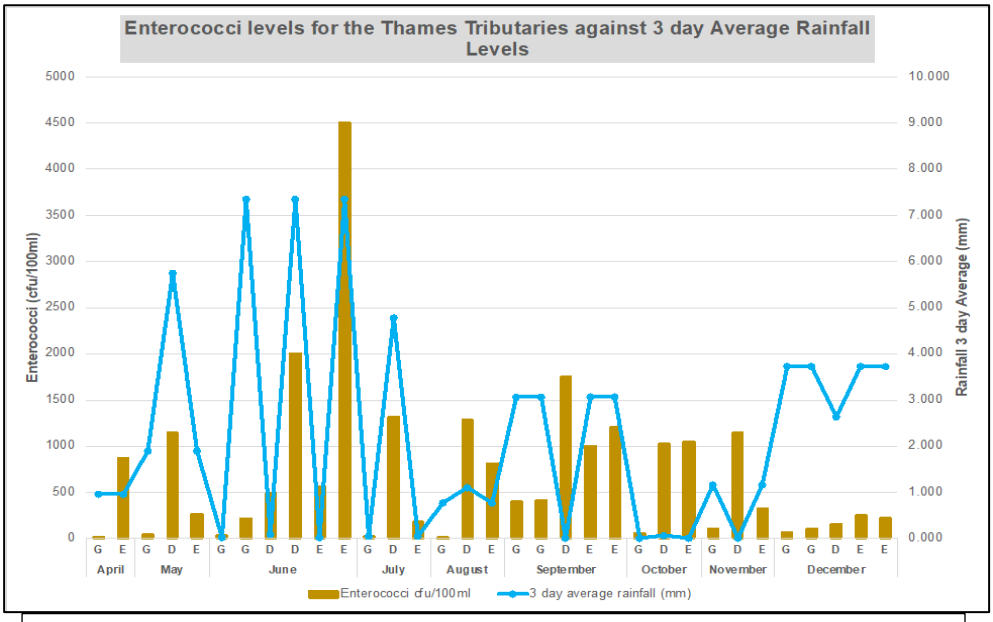


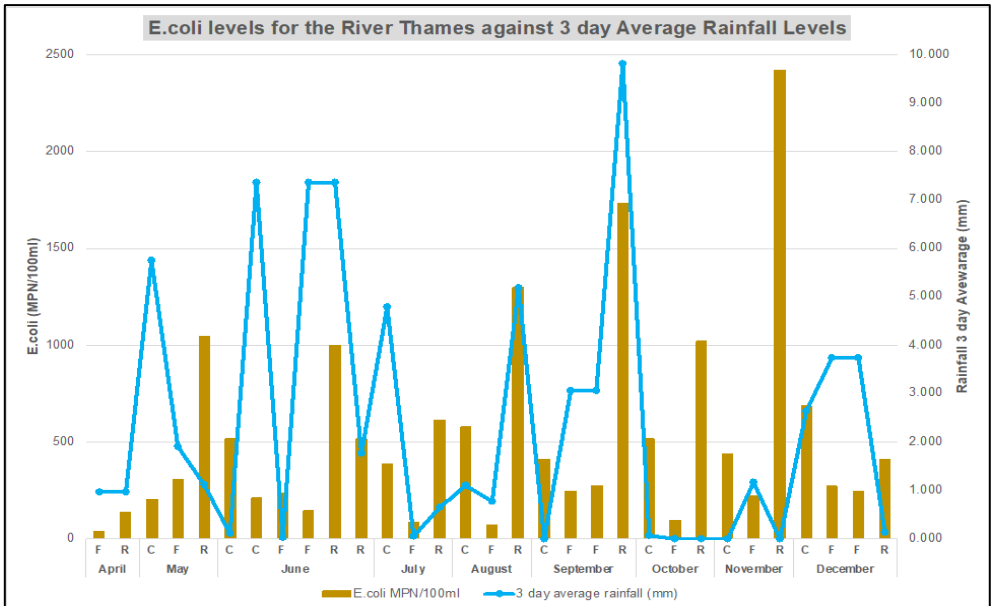
Figure 22: Shows the Impact of Rainfall on Enterococci levels in the Thames Tributaries

Thames – Main River

Sample points C, F and R are the main River Thames sample points tested that were not identified as recreational sites. Sample point F was the shining light in the catchment showing muted response to rainfall and no significant increases that can be correlated to either Diffuse or Point source pollution, I believe this to be due to the land mass that borders the reach that leads up to F with connected flood plains, established wooded areas and buffered field edges mitigating the FIO impact from rainfall events.

Sample point C shows good correlation to rainfall events with an increase in FIO levels that are indicative of diffuse pollution inputs.

Sample point R shows strong correlation to rainfall events with an increase in FIO levels that are indicative of point source (sewage) pollution inputs, this is strongly seen in the months May, June, August and September. One occurrences in November when there was a significant rise in FIO levels indicative of point source (sewage) inputs there was no recorded rainfall event this would require further investigation.



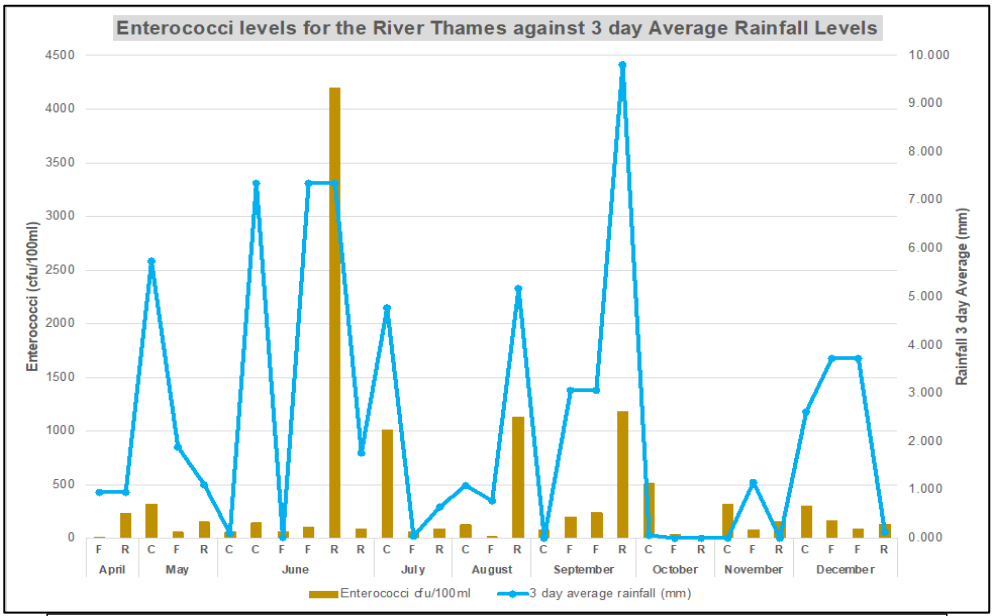


Figure 24: Shows the Impact of Rainfall on Enterococci levels in the River Thames