Report No.1: Water quality monitoring and testing in the Cam and its tributaries: bacterial indicators of faecal contamination, and phosphate and nitrate status

Cam Valley Forum's Bruce Huett, sampling river water at Grantchester Meadows for bacterial indicators of faecal contamination

Mike Foley, Cam Valley Forum

24th August 2021

The Cam Valley Forum is an unincorporated association, registered with HMRC as a charity.
info@camvalleyforum.uk
https://camvalleyforum.uk

Chairman: Stephen Tomkins
Secretary: Alan Woods
Treasurer: Bruce Huett

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Contents

Notes:
- Our data are derived from just one batch of samples and the results must be treated with caution. Further sampling is needed to check for any sampling or testing errors.
- At this early stage, this report should not be used to guide water users on the bacteriological safety of any specific stretches of the river; this may be possible if repeated sampling shows that there are consistent patterns in bacterial abundance.
- Please do not publish data from this report without our prior permission.

Dr Mike Foley
24 August 2021

1 Summary

1.1 As part of our aspirations to safeguard and improve the River Cam, Cam Valley Forum (CVF) undertook its first batch of tests on river water from Haslingfield to Cambridge City on 14th June 2021, in order to monitor the **faecal indicator bacteria *E. coli* and intestinal enterococci** (hereafter called enterococci). Also included in the sampling was the effluent discharge into the river from the Haslingfield Wastewater Treatment Works (WwTW). Stretches used by swimmers were also included in the twelve sampling sites. Our aim is to better understand faecal contamination in the river by evaluating counts of faecal indicator bacteria in water samples by seasonality, distance, under varying conditions of river flow, natural UV intensity, and agricultural operations. We intend to look for significant, mainly point sources which might then be addressed and improved by remedial action where feasible.

1.2 There has been a recent public groundswell of opinion for the river to be ‘cleaned up’. CVF has responded by initiating a proposal to create a Designated Bathing Water in the Cambridge locale (see https://camvalleyforum.uk/cam-safer-swim/), which if successful would enable the Environment Agency to take statutory indicator bacterial samples. If high levels of bacteria were found there and were linked to the Haslingfield Wastewater Treatment Works, Anglian Water would need to treat the discharged wastewater to higher standards to reduce the pollution, using methods such as ultra-violet (UV) disinfection.

1.3 CVF also sampled for concentrations of inorganic phosphorus (as **soluble reactive phosphorus**), and inorganic nitrogen (**as nitrate**). Unionised ammonia was not tested. Raised levels of nutrients, particularly phosphate, in rivers can trigger the growth of algae and larger plants in a process called **‘eutrophication’**. Their decomposition can lead to severe drops in dissolved oxygen levels with major impacts on freshwater biodiversity. It can also adversely impact on a range of water uses and societal benefits – drinking water abstraction and treatment, water contact sports, angling, wildlife and conservation interest, livestock watering, navigation, general amenity, tourism and waterside property values.

1.4 Samples were taken with great care, and analysed at the **UKAS-accredited laboratory** of South East Water Scientific Services. The main findings from the first batch of tests are as follows. **The results are based on a single batch of samples and therefore need to be treated with caution.**

a) The Haslingfield WwTW discharged high numbers of both types of indicator bacteria (e.g. 38,700 *E. coli* per 100ml of effluent). These were in treated effluent, and were the highest count of all the samples.

b) Numbers of *E. coli* and enterococci dropped markedly within 1.9 km downstream of the WwTW, and the general pattern of counts over longer distances was similar for both types. One aim of further sampling will be to better understand why counts can decline rapidly over distance.

c) Natural disinfection of bacteria by the action of ultra violet sunlight is well-known phenomenon. It probably occurred to an unknown extent on the day of sampling both within the WwTW and in the river. Natural UV light intensity will vary substantially and thus lethal effects on bacteria will vary.

d) Some of the variation over distance might have occurred due to localised recharge along the way resulting perhaps from faeces from animals, birds or other sources. Sampling error (i.e., bacteria not being uniformly blended within the water) is another possibility.

e) Relatively low numbers of the two bacterial types were found at **Sheep's Green** (5.5 km from the WwTW) **and Jesus Green.** Just one *E. coli* and no enterococci were counted in the sample from Bourn Brook. The Granta-Cam and Vicar's Brook contributed some faecal bacteria, in moderate numbers.

f) Vicar's Brook had higher numbers of *E. coli* than did the Cam at Sheep's Green just downstream of it, and had a disproportionately high number of enterococci. Faecal matter from cattle grazing in Coe Fen was the most likely source of bacteria but the sampling procedure was unable to eliminate other possible causes further upstream.

g) **No sampling** was undertaken at **the Rush**, where children and cattle intermingle intimately.

h) The presence of the two indicator bacteria in moderate numbers (relative to other counts in the batch) <u>above</u> the WwTW requires further investigation (which is being undertaken in Batch 2 sampling).

i) A **'storm discharge',** via settlement overflow tanks, of untreated sewage did **not** occur at Haslingfield WwTW on the day of sampling. Information published by Anglian Water documented **88 CSO events (1009 hours duration) and 49 events (428 hours duration)** in 2019 and 2020 respectively.

j) In the second batch of samples to be taken on 24th August 2021, seven additional sampling sites will be Meldreth (Rhee), Barrington (Rhee), Newnham Riverbank Club (Cam), upstream of Cambridge Water Recycling Centre (WRC) (Cam), Cambridge WRC (pure effluent), Baits Bite Lock (Cam) and Clayhithe (Cam).

k) **CVF noted that both nitrate and phosphate were present at high levels** in the Rhee/Cam, Grant-Cam, Bourn Brook, and in the WwTW effluent. The phosphorus level was low in Vicar's Brook, as expected because it flows from Hobson's Brook with springheads at Nine Wells sourced from aquifer groundwater.

1.5 Our data show that all sites – **other than Vicar's Brook – had 'poor' status for phosphorus** according to the EA Water Framework Directive standard.

1.6 There is no definitive threshold for nitrate, other than 50 mg/l nitrate for drinking water at the tap. **The high levels CVF found are well above those that start to contribute to eutrophic conditions.**

1.7 Observations of high water turbidity levels are also a source of concern. Comparative turbidity measurements using a standard method such as a Secchi disk tube were not performed but could become part of CVF's ongoing monitoring.

1.8 Cam Valley Forum funded the first batch of samples. We are grateful to Anglian Water and Waitrose for their funding contributions. The second and third batches of sampling will be fully funded but beyond that we would be grateful for additional funding from organisations interested in the health of the Cam.

2 Background

2.1 The Forum is an association of local individuals with diverse environmental, recreational, academic and business interests, concerned directly or indirectly with the River Cam. Our mission is to defend the health and wellbeing of the Cam for its wildlife and environment and for people; safeguard its historical and cultural importance; and seek, through a reasoned and evidence-based approach, changes in policy and practice to enhance the water environment of the entire catchment.

2.2 Bacterial studies

2.2.1 Earlier this year CVF was involved at the initial stages of a proposal to apply for a local Defra Bathing Water designation, through its 'Cam Safer Swim Initiative' (CSSI), set up to examine actions to improve water quality for all river users. The initial proposals (see https://camvalleyforum.uk/cam-safer-swim/) followed on from local concerns raised about water quality and health. There is an increasing perceived concern that the water quality of the Cam is being compromised by forms of bacterial or viral pollution derived from sewage treatment works which, if ingested by swimmers, paddlers, rowers or boaters may cause gastroenteritis or a range of skin, eye, ear and respiratory tract infections. Less well-recognised is that some of these organisms occur in wild birds, wild mammals and livestock. These illnesses occur in a minority of participants and are usually minor, with diarrhoeic and vomiting symptoms lasting up to a day or two. Some infections are potentially more serious. The level of concern has heightened as river flows have become regularly lower during the summer months, thus increasing the concentrations of pollutants having entered the water. There is also concern that sources of harmful organisms may release more during the winter months.

2.2.2 **CVF's objective is to undertake citizen science monitoring of levels of faecal indicator bacteria in the Cam local to Cambridge,** with the aim to inform relevant organisations of significant sources and patterns of distribution. This may lead on to appropriate actions being considered to reduce the faecal bacterial load and thus to help reduce the risk of illnesses to river users.

2.2.3 Levels of faecal contamination can be determined easily by testing for 'indicator bacteria' – ***E. coli*** **(*Escherichia coli*) and enterococci** – in the river water. CVF recently proposed to undertake their own sampling for testing this summer at several locations including tributaries (initially 12 with 19 for the second batch of samples) from Meldreth on the Rhee to the lower Cam to Clayhithe, to improve our understanding of the abundance of bacteria over time and place.

2.2.4 Thus, testing will help to identify sources of contamination from point sources such as Wastewater Treatment Works (WwTW), and other sources such as agriculture, cattle, misconnected or broken sewer pipes, and leaking septic tanks. Samples from the river will need to be taken over several months in benign conditions with low rainfall, during or after a period of heavy rainfall, when the ground becomes saturated in the winter, ditches fill, and greater movement of pollutants can occur, and during or after Combined Sewage Overflow (CSO) event at Haslingfield WwTW and other CSOs along the river.

2.2.5 The UKAS- accredited laboratory South East Water Scientific Services (SEWSS) are undertaking the analyses on our samples.

2.2.6 Results from CVF's testing for the presence of indicator bacteria are not intended to be used formally and definitively to classify stretches of the river as 'safe' or otherwise with regards to faecal contamination. **They will however be very useful as a broad indicator.** The EA protocol for testing of Designated Bathing Waters comprises taking an entire summer's data from up to 20 samplings (CVF will sample far fewer times than this) to provide a classification for the following year, rather than for the current season.

2.3 Nutrient studies

2.3.1 CVF also wants to see future reductions of phosphate and nitrate in the river water so that our unique Chalk stream ecosystem is supported towards recovery. For that reason, the samples for bacterial testing are being analysed for nitrate and soluble reactive phosphorus to provide us with easily obtained but valuable information on nutrient quality, **from samples taken on the same day**. This project links to another important CVF activity, focusing on the devastating effects of over-abstraction on summer river flows, and the extent and health of our watercourses and wetlands, as set out in our 2020 Report ***Let it Flow!*** [reference[1]]

3 Methods

3.1 Sampling on 14th June 2021 was done in sequence from sites 12 to 1 (exception - site 5 sampled last), the next site being visited several minutes after the previous one. With sampling limited to just 12 tests, sites had to be selected strategically. The site map can be viewed online [reference[2]]

3.2 There are comments and some photos – click on the pointers. The zoom level can be changed. Click on arrow at 'base map' to change to satellite image. Also, see map below (Figure 1).

3.3 A comparison of counts, for instance just below a potential discharge / pollution point and further downstream before the next potential discharge point, will allow a check on bacteria losses caused by settling into the bed silt, natural losses, flow, and UV kill. It was deemed important to test the tributaries Granta-Cam, Bourn Brook and Vicar's Brook before they join the Cam.

3.4 The Yorkshire River Wharfe citizen science bacterial project [reference[3]] reported that duplicate samples at each site were not necessary. Thus, in order to achieve our aims and limited to 12 samples overall, CVF took only one bacterial sample at each site.

[1] *Let it Flow!* Cam_Valley_Forum_Let_it_Flow_Full_report_26-05-20-compressed.pdf

[2] https://www.google.com/maps/d/edit?mid=10ECdga6hFW6WFFXqqIk-rUGiIHqiEtpe&usp=sharing.

[3] https://sites.google.com/view/cleanwharfeilkley/home?authuser=0

3.5 **Figure 1: Map showing the 12 sites sampled 14th June 2021**

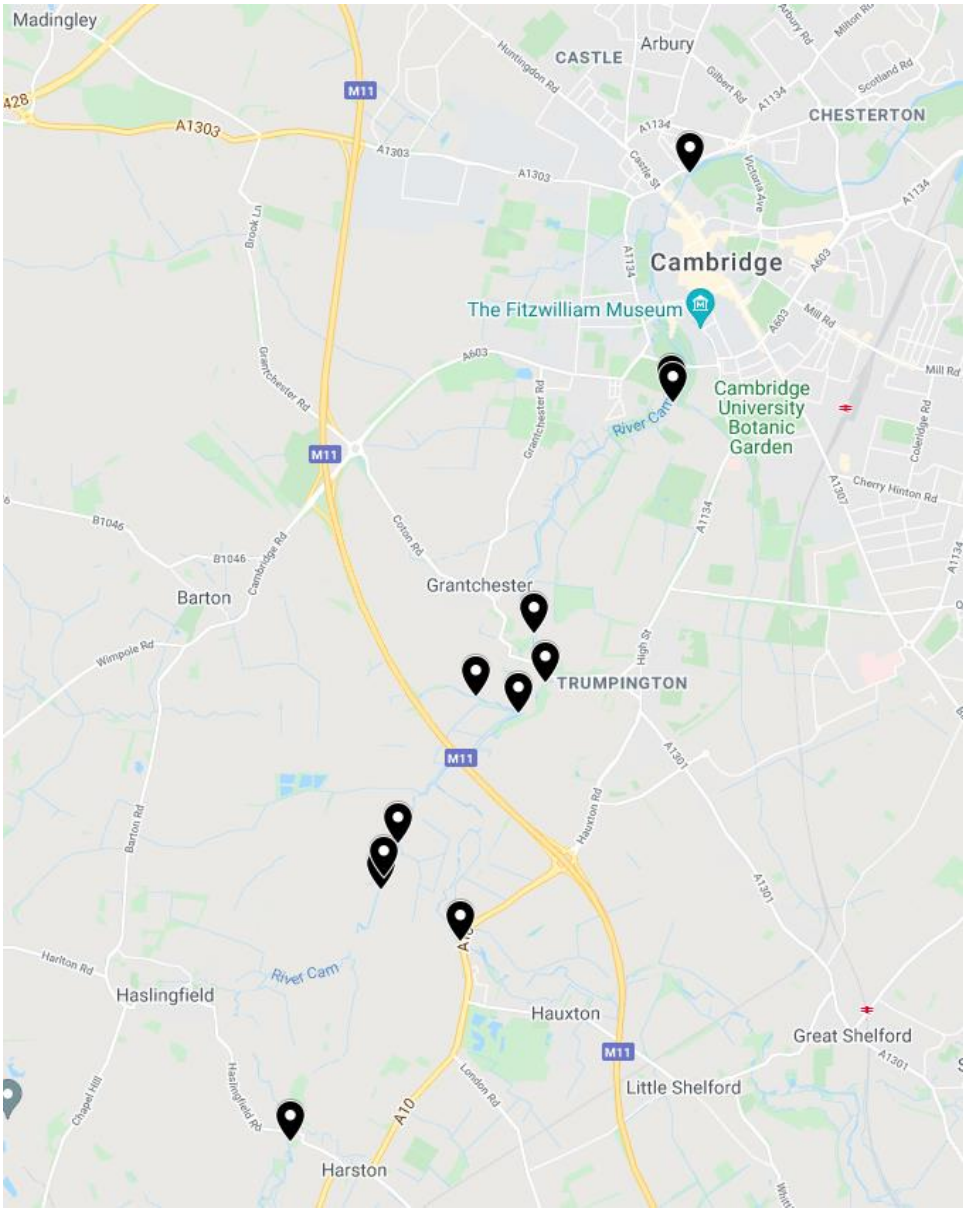


Table 1: Location of sampling points

Site	Location of sampling points 14th June 2021	Distance from Haslingfield WwTW	Reason for location selection
[1]	Rhee - Harston-Haslingfield road, bridge	–3.1 km	Important to have two sites above WwTW. This is upstream of [2]
[2]	Rhee - Just above Haslingfield WwTW	–0.08 km	(a) One of two sites above WwTW (b) direct comparison of points above and below the works. Taken 80m above discharge point to be clear of works site.
[3]	Rhee- Haslingfield WwTW	±0 km	Pure effluent, taken from discharge point, Critical, to know what is present at WwTW source.
[4]	Rhee - just below Haslingfield WwTW	+0.27 km	Direct comparison with above the works; far enough down to allow mixing.
[5]	Granta	n/a	Upstream of confluence with Rhee, to evaluate Granta's bacterial input. At A10 road bridge.
[6]	Cam – just above confluence with Bourn Brook	+1.9 km	Cam water without Bourn Brook input
[7]	Bourn Brook, Cantelupe Farm bridge	n/a	Upstream of confluence with Cam, to evaluate Bourn Brook's bacterial input; Coincides with EA nutrient testing site.
[8]	Cam – below Byron's Pool, Trumpington-Grantchester road	+2.35 km	Below Bryon's Pool and just above private sewer effluent discharge from cottages; [Bourn Brook + 0.420 km]
[9]	Cam - top of Grantchester Meadows- cricket field	+2.8 km	After Mill Stream joins, and before long cattle grazing/dog walking/swimming stretch.
[10]	Vicar's Brook,	n/a	Above exit into Cam, to evaluate Vicar's bacterial input
[11]	Cam -Sheep's Green, Coe Fen footbridge	+5.5 km	After confluence with Vicar's Brook, coincides with EA nutrient testing site, at popular swimming stretch.
[12]	Cam – Jesus Green	+7.6 km	Bottom end of Middle River above Jesus Lock and just above moored narrowboats; below city centre.

3.7 General Procedure

1. The samples are analysed at SWESS under contract to B. A. Hydro Solutions Ltd, The Sidings, Station Rd, Shepreth, Royston SG8 6PZ (01763 262726) who arrange delivery. The samples have to be taken after 0900 to comply with the laboratory's 24 hour transit regulation and delivered by 1400, preferably 1300. Our contact there was Rio Small, now Patrycja Malinowska.
2. At base, label all bottles with a permanent marker pen.
3. Add 2+ frozen cool-packs to the polystyrene storage box. Keep this box within the blue box.
4. Wash hands thoroughly backed up with alcohol hand gel (to remove any faecal bacteria accidentally picked up from surrounding area).
5. Attach the white-capped 500ml 'Bacti' bottle firmly to a Wolf Garten 19cm rake head (see photo). Use 4+ elastic bands.

6. Attach to a telescopic 220-400cm pole.
7. Carefully remove the cap and put aside on a clean surface without touching the cap or bottle rims.
8. Apply the pole at full stretch so that the water sampled is at least 2m from the bank and preferably 3m.
9. With the pole near to horizontal as possible, hold the bottle upside down (neck down) just above the water surface then lower the bottle vertically into clean water. Wait for any floating clumps of plant material or other debris to pass by.
10. When the opening is at 20 cm depth below the water surface turn the bottle to about 45 degrees from the vertical with the opening facing downstream. Maintain the depth at 20cm minimum ensuring the river bed is not disturbed.
11. Allow the bottle to start filling and on four or so occasions tilt the bottle towards the vertical for several seconds to reduce inflow. The intention is to sample water over 30 seconds so that a greater volume of water is sampled.
12. Do not rinse out the white-capped bottles unless it is absolutely necessary. When filled, remove and inspect for obvious clumps. Only if any is present, empty and resample.
13. If the sample is satisfactory, flick the bottle to expel water creating an air gap down to the base of the neck of the bottle. This allows the sample to be mixed in the lab before extractions.
14. Hygienically screw down the bottle cap ensuring tightening is sufficient to prevent leakage.
15. <u>Repeat procedure</u> with the green-capped 250ml PET bottles for nutrient analysis.
16. At all sites, but especially effluent, take appropriate hygiene precautions.
17. Place bottles in the polystyrene box immediately after each site visit (keep in car boot).
18. Take the samples to BAHS Ltd.
19. BAHS will keep the box of samples under appropriate holding conditions until it is couriered to SEWSS, Farnborough. The samples will be delivered within 24 hours to arrive at SEWSS before 0900 the following day.

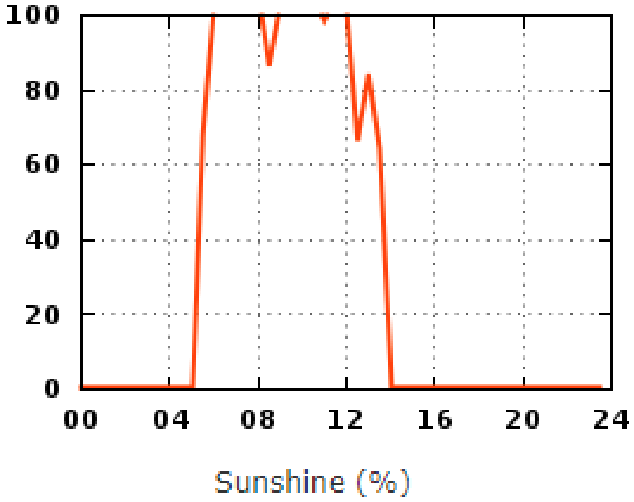
3.8 **Batch 1 sampling, 14th June 2021**

3.8.1 Stephen Tomkins and Mike Foley sampled at all 12 sites on 14th June. Sampling commenced at site [12] at 0900 and sites were visited in reverse number order, except that the Granta [5] was tested last.

3.8.2 Conditions on and prior to the day of sampling are being recorded. Air temperature was 20-25^{O}C; sunshine was intense until 1200 and reduced by 1330 by a veil of light cloud, though it was still remained very bright. Only sample [5] was taken after 1330 (taken at 1335), but if the source was some distance upstream, UV kill would have occurred earlier on while the bacteria were still travelling.

3.8.3 The graph shows the percent sunshine on 14th June 2021 (Digital Technology Group (DTG), University of Cambridge (amateur-maintained weather station), William Gates Building, 15 JJ Thomson Avenue, Cambridge CB3 0FD, 6 km from Haslingfield WwTW). Below is a screenshot of their web page [Reference[4]]

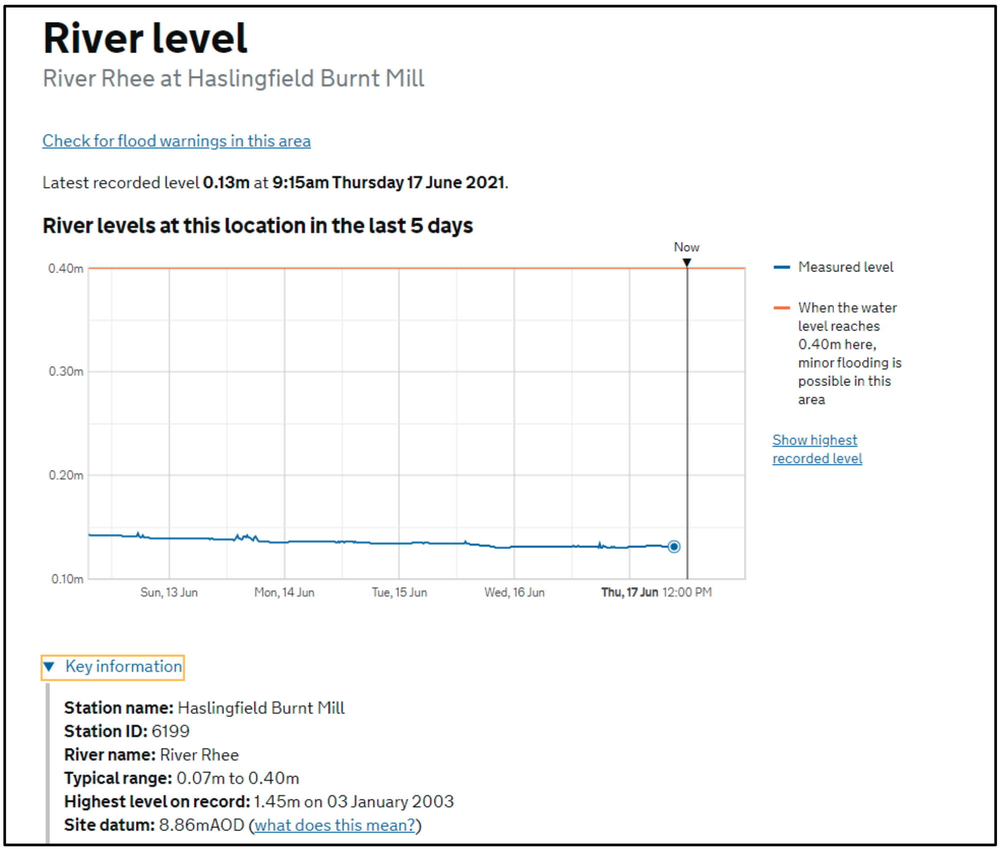
Figure 2: Sunshine intensity of 14th June



[4] https://www.cl.cam.ac.uk/research/dtg/weather/daily-graph.cgi?2021-06-14

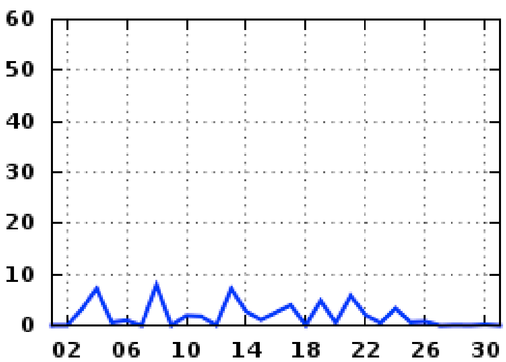
3.8.5 A screenshot of the river level at Burnt Mill, Haslingfield is shown below [reference[5]]. The level was dropping slightly immediately before the sampling date.

Figure 3: Level of River Rhee at Burnt Mill, Haslingfield in the period



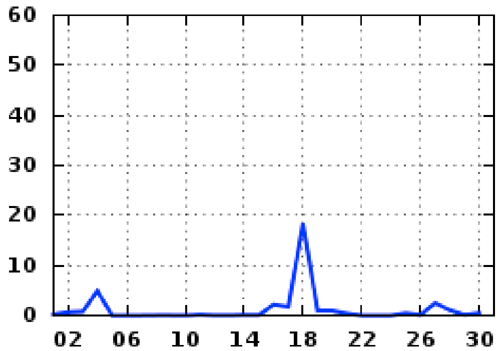
3.8.7 For rainfall in the period preceding the sampling date, the daily rainfall in May and June 2021 was captured as a screenshot of DTG data. Other than 5mm rainfall over 3rd and 4th June, a 19-day period prior to 14th June was dry, and it was dry for 10 days prior to the sampling date.

Figure 4: Rainfall May 2021



[5] https://flood-warning-information.service.gov.uk/river-and-sea-levels

Figure 5: Rainfall June 2021



3.8.8 The samples were tested at South East Water Scientific Services (SEWSS) for the indicator bacteria (*E. coli*, and enterococci), and total coliforms, the coliforms (*E. coli* is one) by the Colilert Most Probably Number (MPN) method and enterococci by the MGLA (colony-forming units) method. The samples were also analysed for nitrate-N and SRP (= soluble reactive phosphorus (= P in orthophosphate). The reporting limit for nitrate is 2mg/l and for Phosphorus-SRP is 84 ppb (0.084 mg/l). The limit 0.084 was sufficient for our needs, as it is within the 'high' status according to the Water Framework Directive.

3.9 Sampling technique

Figure 6: S**ecured bacterial sampling bottle on extendible (4m) Wolf Garten pole with attached rake head**

Figure 7: Below Bryon's Pool: sampling bottle immersed in river away from bank, attached to extendible pole; rate of air bubbles exiting bottle aiding judgment to adjust flow into the bottle

Figure 8: Sampling at Jesus Green on a wide part of the river; from a moored punt facilitating sampling further out from the bank

Figure 9: Haslingfield WwTW discharge point

3.9.1 At the Haslingfield discharge point, the treated effluent appears clear to the eye. It flows in an arc partly across river, according to the flows of the effluent and the river (Figure 10). An uneven blend of river water and effluent will occur immediately below the discharge point. Note that water turbidity was similar below and above the discharge point.

Figure 10: Effluent arcing across the Rhee

3.9.2 Several fish, identified as Dace from a photograph (Rob Mungovan, Wild Trout Trust) were feeding (or at least moving actively) along the upstream edge of the effluent flow.

4 Results

Table 2: Bacterial counts and nutrient concentrations

Site #	Location of sampling point	Distance from Haslingfield WwTW	Reason for selecting location	Count of faecal indicator bacteria (coliforms inc. *Escherichia coli* – most probable number (MPN) per 100ml; enterococci – colony forming units (CFU) /per 100ml)			Nutrient concentrations	
				E. coli	Total coliforms	Enterococci	P – Soluble Reactive Phosphorus (= P in orthophosphate) (mg/l)	N – Nitrate (mg/l)
[1]	Rhee - Harston-Haslingfield road, bridge	–3.1 km	Important to have two sites above WwTW. This is upstream of [2]	326	2420	48	0.438	58.4
[2]	Rhee - Just above Haslingfield WwTW	–0.08 km	One of two sites above WwTW It provides a direct comparison above and below the works. Taken 80m above discharge point to be clear of works site.	205	1733	24	0.347	48.8
[3]	Rhee-Haslingfield WwTW	± 0 km	Pure effluent, taken from discharge point, Critical, to know what is present at WwTW source.	38700	155,300	6200	0.313	65.1
[4]	Rhee - just below Haslingfield WwTW	+0.27 km	Direct comparison with above the works; far enough down to allow mixing with discharge.	1080	6870	62	0.336	53.0
[5]	Granta-Cam	n/a	Upstream of confluence with Rhee, to evaluate Granta's bacterial input. At A10 road bridge	126	1986	6	0.368	37.9

Site #	Location of sampling point	Distance from Haslingfield WwTW	Reason for selecting location	Count of faecal indicator bacteria (coliforms inc. *Escherichia coli* – most probable number (MPN) per 100ml; enterococci – colony forming units (CFU) /per 100ml)			Nutrient concentrations	
				E. coli	**Total coliforms**	**Enterococci**	**P (mg/l)**	**N (mg/l)**
[6]	Cam – just above confluence with Bourn Brook	+1.9 km	Cam water without Bourn Brook input.	167	2420	18	0.379	48.1
[7]	Bourn Brook, Cantelupe Farm bridge	n/a	Upstream of confluence with Cam, to evaluate Bourn Brook's bacterial load; coincides with EA nutrient testing site.	1	54	0	0.600	23.7
[8]	Cam – below Byron's Pool, Trumpington-Grantchester road	+2.35 km	Below Bryon's Pool and just above private sewer effluent discharge from cottages; [Bourn Brook + 0.420 km]	261	2420	20	0.399	46.4
[9]	Cam - top of Grantchester Meadows-cricket field	+2.8 km	After Mill Stream joins, and before the stretch of cattle grazing/dog walking/swimming.	160	2610	32	0.391	45.7
[10]	Vicar's Brook,	n/a	Above exit into Cam, to evaluate Vicar's bacterial load	400	3080	220	<0.084	46.9
[11]	Cam -Sheep's Green, Coe Fen footbridge	+5.5 km	After confluence with Vicar's Brook, coincides with EA nutrient testing site, at popular swimming stretch.	29	317	3	0.349	46.3

Site #	Location of sampling point	Distance from Haslingfield WwTW	Reason for selecting location	Count of faecal indicator bacteria (coliforms inc. *Escherichia coli* – most probable number (MPN) per 100ml; enterococci – colony forming units (CFU) /per 100ml)			Nutrient concentrations	
				E. coli	Total coliforms	Enterococci	P (mg/l)	N (mg/l)
[12]	Cam – Jesus Green	+7.6 km	Bottom end of Middle River above Jesus Lock and just above moored narrowboats; below city centre / colleges.	29 (same as [11])	326	5	0.343	43.4
	Reference EA sampling points for N and P							
[1]	Rhee - EA Haslingfield-Harston road		Rhee - Haslingfield Road bridge, AN-30M07 10 samples Same site as [1], 2/7/19-12/3/20	Same as [1]			0.509	56.1
	Cam-Granta - EA M11 U/S Hauxton		Cam-Granta - M11 road bridge AN-29M09 U/S Hauxton 10 samples 6/12/16-31/10/18	Sample point [5] -2 km			0.351	40.6
[7]	Bourn Brook - EA Cantelupe Farm bridge		Bourn Brook - Cantelupe Farm bridge. AN-32M02 Same site as [7], 10 samples 13/6/19-7/6/21	Same as [7]			0.575	35.8
	Vicar's /Hobson's Brook - EA Long Road		Vicar's / Hobson's Brook, Long Road bridge, AN-33M24 10 samples 11/10/17-15/1/20	Above sampling point [10] by 2 km			0.033	36.3
[11]	Cam - EA Coe Fen		Coe Fen footbridge AN-33M02 Same site as [11], 10 samples 1/2/17-9/1/20	Same as [11]			0.456	47.3

5 Discussion - bacterial counts

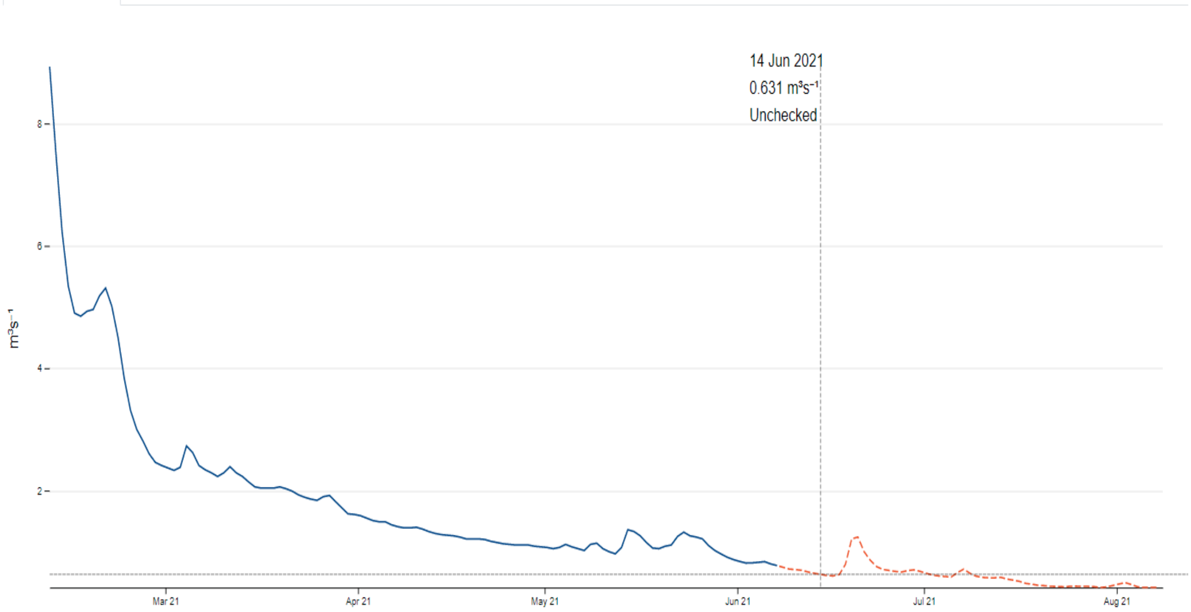
5.1 <u>Converting effluent counts to river water counts</u>

5.1.2 The highest count of *E. coli* (per 100ml sampled water) was 38,700 in the WwTW's pure effluent. There is a way of converting the effluent count to a river water count after discharge of the effluent into the river. Anglian Water data show that the effluent flow at the 'inlet' at 12.40pm (sampling time) on 14th June was 37.4 l/s which is being used as the best estimate of flow.

5.1.3 [Interestingly, approaching the estimation in a different way, the mean effluent flow for 2016-2020 was 1,168,942 m^3 per year (Anglian Water data), equivalent to 37.1 l/s if flow was constant throughout the year. These two figures are surprisingly close]. However, Anglian Water states that flow varies through a 24-hour period, so clearly basing the flow on a mean annual figure is prone to error.

5.1.4 On 14th June the flow at Burnt Mill, Haslingfield was 0.631 m^3/s (unchecked, recent EA data. However, data up to 7th June have been checked and 'good' (blue line) and the trend towards slightly less flow continued to 14th June).

Figure 11: River Flow, Burnt Mill, Haslingfield, 14th June



5.1.5 The flow will be very similar at the WwTW (1.6 km downstream), so 14,473,800 *E. coli* from the effluent per second mixed with and were diluted in 0.668 m^3 of water per second (0.0374 m^3 effluent + 0.631 m^3 river water). The figure obtained for *E. coli* and the other indicators is 2167 bacteria / 100ml of river water (see Table 3).

Table 3: Conversion of effluent count of *E. coli* to a 'river water' count using estimated flows of effluent and river.

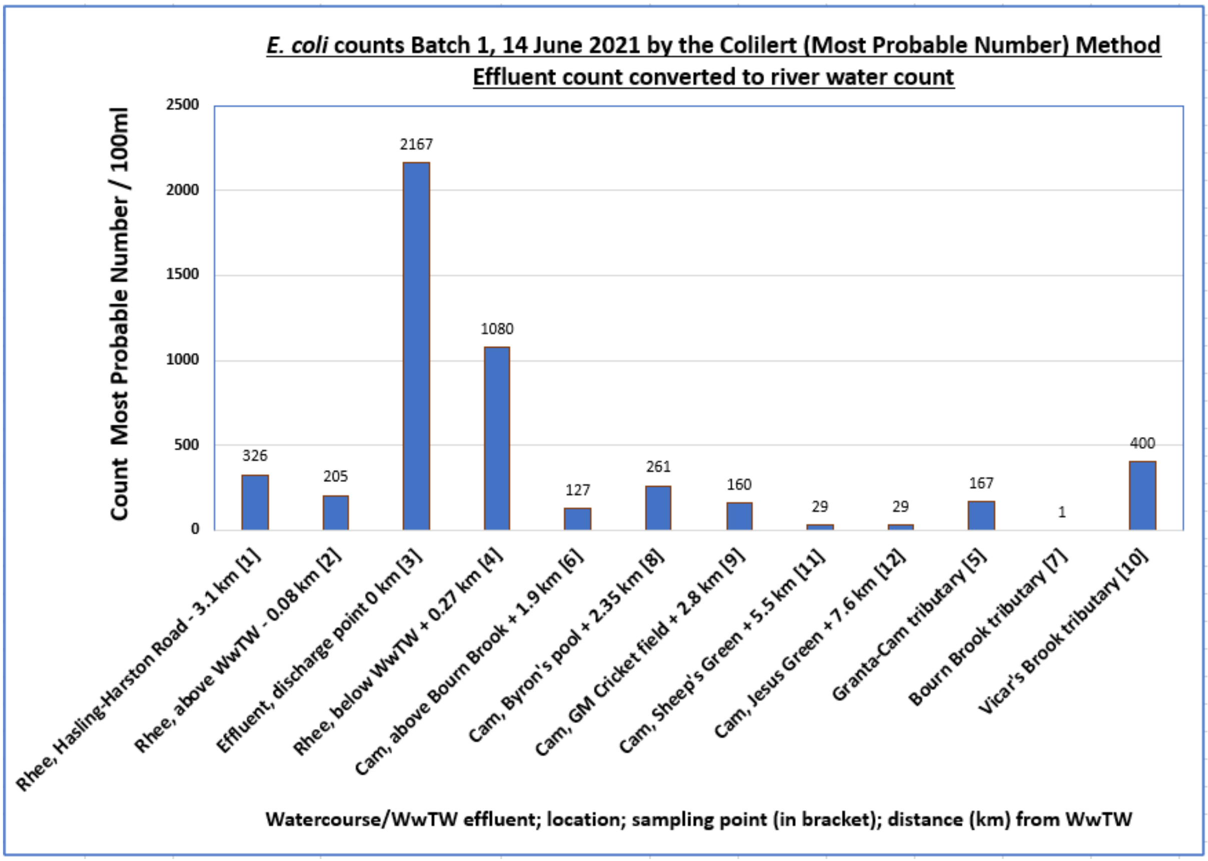
	Effluent count/100 ml	Effluent count expressed as a 'river water count'/100 ml
E. coli	38700	2167
Total coliforms	155300	8696
Enterococci	6200	347

5.1.6 On the day of sampling applying available effluent and river flow rates, concentrations of organisms and nutrients in the effluent were estimated to have been diluted by a factor of 17.9 after discharge into the river.

5.2 Counts of *E. coli*

5.2.1 The converted effluent count can now be included in the sequence of counts on the river (Figure 12).

Figure 12: Counts of *E. coli* at the 12 sampling points (effluent count converted to a river water count)



5.2.2 The calculated count of *E. coli* in the river after effluent was mixed with river water forms an important part of the overall picture. Counts at eight sites along the river can be compared between each other but valuable information is gained by having a river water count from the WwTW's discharge. The count of *E. coli* immediately above the WwTW at point [2] was 9.4% of the effluent 'river count' at the WwTW and was 15% higher further upstream at point [1]. Both counts above the WwTW were higher than at point [6] which is 1.9km below the WwTW, suggesting that there is either a moderate source close to and above point [1], or a much more potent source further upstream. Potential sources of *E. coli* further upstream need to be investigated.

5.2.3 Sampling only 270m downstream from the WwTW at point [4], the count dropped by 38%. No dilutive water discharges from the fields are known to occur between the two points during summer months, suggesting that the marked drop over such a short distance was caused by some lethal factor, such as UV radiation, which was high on the day.

5.2.4 Counts were lower still at 1.9 km downstream from the WwTW (point [6], 93% drop) and thereon. Bourn Brook upstream of its confluence with the Cam had an *E. coli* count of just one. The doubling in numbers just below Byron's Pool (point [8]) might have been due simply to variability, or a recharge from a local, natural faecal source. At +5.5 km from the WwTW, at Sheep's Green the count was still very low and precisely the same was found at Jesus Green 2.1 km further downstream. The Vicar's Brook count was higher than most.

5.2.5 Bathing Water Directive implications

5.2.5.1 As mentioned before, it is not CVF's intention to use the counts from this first batch of samples and to try to relate them to the Bathing Water Directive's thresholds (Figure 13) and so state if a river section is poor to excellent for bathing. The EA thresholds involve multiple sampling with up to 20 results in a season [reference[6]].

Figure 13: Bathing Water Directive 2006/7/EC

Excellent	EC: ≤500 cfu/100ml ; IE: ≤200 cfu/100ml	95th percentile
Good	EC: ≤1000 cfu/100ml ; IE: ≤400 cfu/100ml	95th percentile
Sufficient	EC: ≤900 cfu/100ml ; IE: ≤330 cfu/100ml	90th percentile
Poor	means that the values are worse than the sufficient	

Key EC: Escherichia coli, IE: Intestinal enterococci, cfu: Colony Forming Units

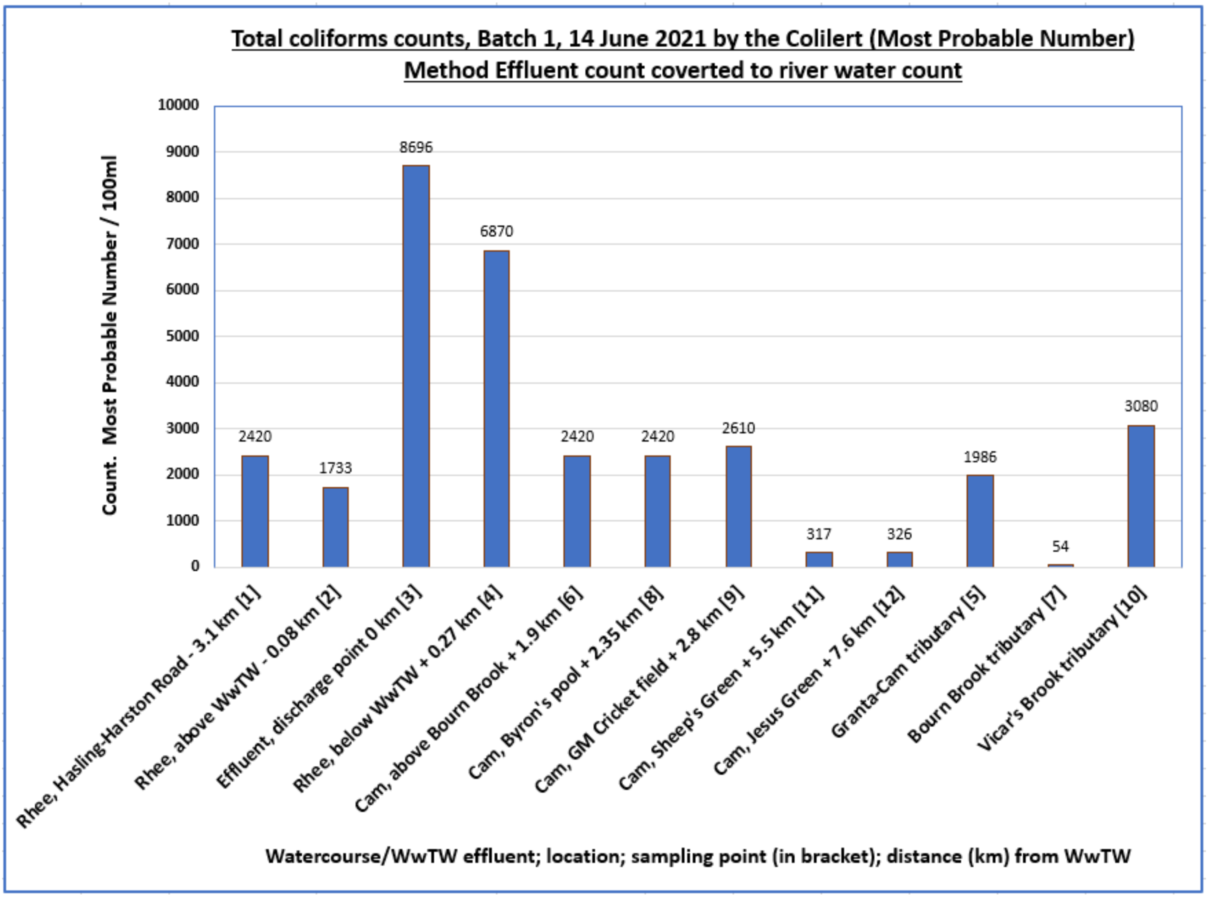
5.2.6 Note that tests on batch 1, due to an error by SEWSS, CVF's *E. coli* and total coliforms counts were obtained using the Colilert **MPN (Most Probable Number) method** rather than the CFU (colony-forming unit) method. At SEWSS the CFU method provides an actual count up to a ceiling of 10,000 bacteria per 100ml, and above that figure the count is presented as >10,000. Fortuitously, SEWSS's use of the MPN method enabled us to show that there were numbers much higher than 10,000 / 10ml in the effluent. The use of the MPN method will continue. Enterococci were counted by SEWSS using the CFU method, as counts are generally much lower than *E. coli*.

5.2.7 The pattern of counts over distance indicates that there were probably no profound sampling errors. However, variability in bacterial load in the river over very short time periods is certain to occur and might cause the differences between some smaller counts. Equally, slightly raised counts could be due to a recharge of fresh faecal matter from wild animals or birds which might be continuous or occasional. Considerable practical investigative work would be required to test this further.

[6] https://environment.data.gov.uk/bwq/profiles/help-understanding-data.html

5.3 <u>Counts of total coliforms</u>

Figure 14: Counts of total coliforms at the 12 sampling points, effluent count converted to a river water count



5.3.1 Although they are not primary indicator bacteria for our project, the 'total coliform' group of bacteria are counted by the lab as part of the overall analysis. This group was originally believed to indicate the presence of faecal contamination, however total coliforms can be both faecal and non-faecal in distribution and have been found to be widely distributed in nature, and not always associated with the gastrointestinal tract of warm-blooded animals. The number of total coliform bacteria in the environment is nonetheless still widely used as an indicator for potable water, but is now not used formally in the UK by the EA. Nevertheless, in the original EEC Directive on Bathing Waters (CD 76/160/EEC, December, 1975; superseded), abundance of total coliforms was included as a measure.

5.3.2 The pattern of counts above and below the WwTW was roughly similar to that for *E. coli* with numbers always markedly higher than for *E. coli*. Much lower counts were found at the three sites mentioned above.

5.3.3 A count of total coliforms after excluding the inclusion of *E. coli* in the count can be calculated by subtracting the *E. coli* count from the total coliforms count. Ratios of the amended total coliforms count to *E. coli* counts at each site are listed in Table 4, and included as a possible future point of reference.

Table 4: Ratios of the counts of total coliforms to *E. coli* (first excluding *E. coli* from the total coliform count)

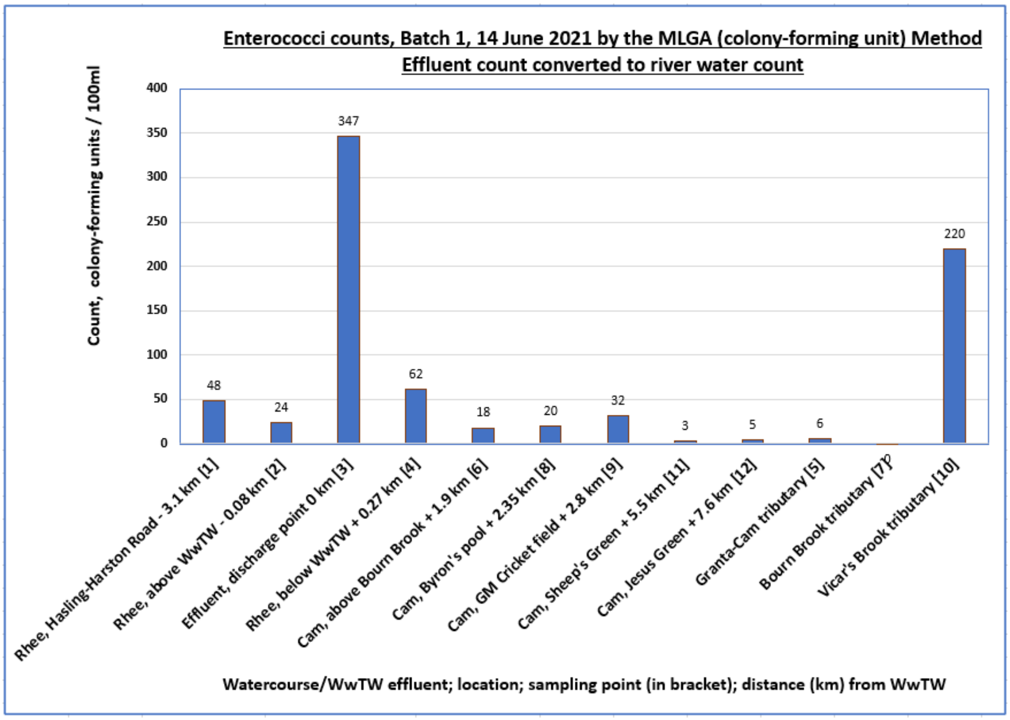
Sampling site	A. Count *E. coli*	B. Count total coliforms with *E. coli* count subtracted	Ratio of B:A
1	326	2094	6.4
2	205	1528	7.5
3 (effluent)	**38700**	**116,600**	**3.0**
4	1080	5790	5.4
6	127	2293	18.1
8	261	2159	8.3
9	160	2450	15.3
11	29	288	9.9
12	29	297	10.2
5	167	1819	10.9
7	1	53	53.0
10	400	2680	6.7

5.3.4 In the pure effluent the ratio was 3.0. The ratio at other sites is variable, probably due to a combination of factors. This could become an important issue in interpretation of results and use of total coliforms as a measure of risk, if the survival rate of one bacterial type (non-faecal coliforms) was better or worse than faecal coliforms (e.g. *E. coli*) over distance and time.

5.4 Counts of enterococci

5.4.1 Formerly called faecal streptococci, [intestinal] enterococci are the second group of bacteria measured by the EA to classify bathing waters.

Figure 15: Counts of enterococci at the 12 sampling points, effluent count converted to a river water count



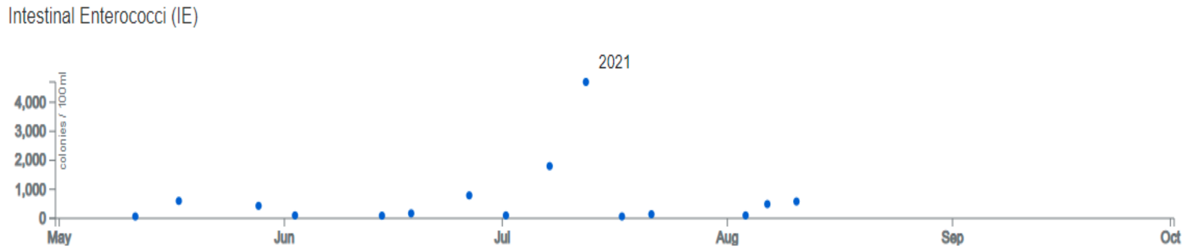
5.4.2 6200 CFUs/100ml were counted in the pure effluent. Again, the pattern of counts over distance was broadly similar to the other groups. The count at Vicar's Brook stands out as much higher than at any site except for the WwTW effluent.

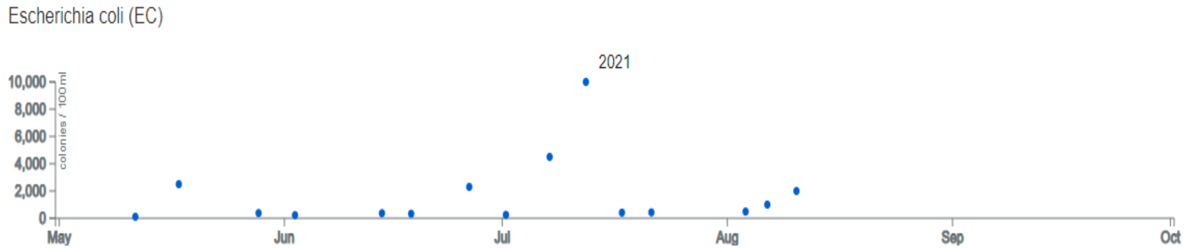
5.4.3 A comparison of the abundance of *E. coli* and enterococci in this batch of samples shows that numbers of *E. coli* were consistently higher.

5.5 Bathing water quality, examples of monitoring by the EA

5.5.1 As mentioned above, CVF's bacterial results will have no formal standing. An interpretation of CVF results is unwise after just one batch of samples.

5.5.2 It is the EA who undertake statutory testing at designated bathing waters. An example of their procedure and publication of the data are shown below at 'Cromwheel' [reference[7]]in Ilkley on the River Wharfe in a stretch given approval as a Designated Bathing Water in December 2000.





5.6 Comparison with River Wharfe citizen science projects 2019-20

5.6.1 In 2018 the Ilkley Clean River Group (ICRG) was formed to draw attention to problems of untreated sewage discharged into the River Wharfe in Ilkley from the Ashlands Sewage Treatment Works. In 2019 there were 136 storm discharge events. The overall objective of the project was to assess the level of health risk to citizens using the river when exposed to storm-related discharges of untreated sewage.

5.6.2 The iWHARFE project of 2020 ran alongside the Ashlands project by extending bacterial sampling geographically to include the full length of the river, to provide a snapshot of river health [reference[8]]

5.6.3 Point 1: The iWHARFE project sampled for *E. coli* and enterococci at each site, and found that, except in five cases, the counts of *E. coli* were higher and often considerably higher.

- The CVF sampling found a similar pattern, also with variability.

[7] https://environment.data.gov.uk/bwq/profiles/profile.html?site=uke1200-08901
[8] https://www.ydrt.org.uk/what-we-do/projects/current-projects/iwharfe

Figure 16: River Wharfe faecal indicator bacteria monitoring, 24th August 2020 ('iWHARFE')

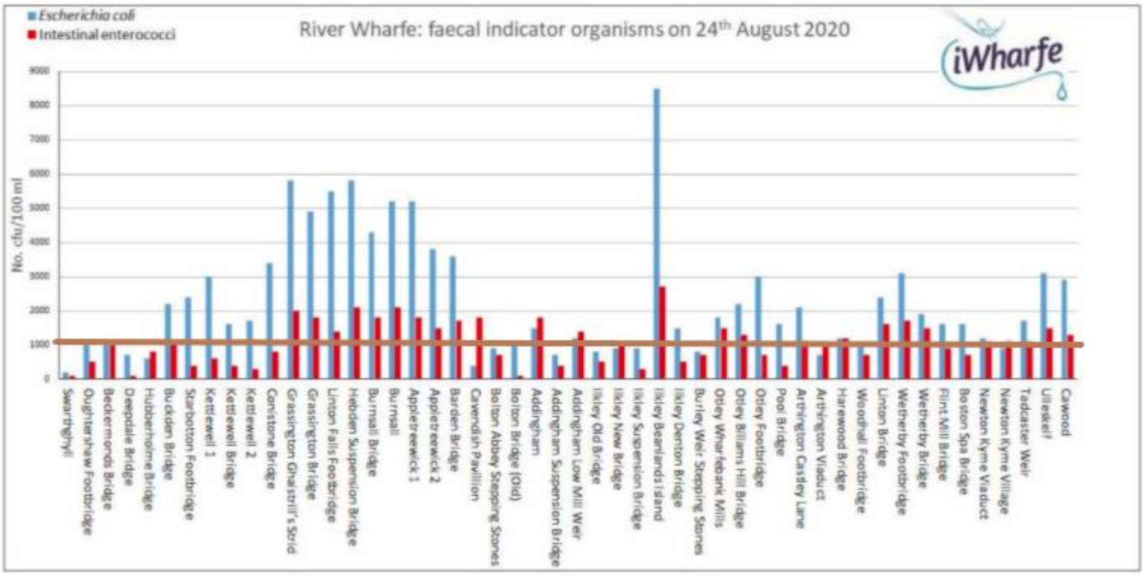


Figure 2. E. coli and IE data for 50 sampling sites on the R. Wharfe

5.6.4 Point 2: ICRG found a strong (but not perfect) relationship between concentrations of *E. coli* and total coliforms in both high and low flow conditions.

- CVF results perhaps showed more variability in the relationship (Table 4), and we shall explore this further in future samplings.

5.6.5 Point 3: ICRG undertook deliberate trampling of the bed sediment followed by water sampling and this action showed no enhancement in counts. They did however add a caveat that sediment with high organic matter just below a storm outfall should be further investigated for resuspension into the flow in high flows.

- In order to standardise between sampling sites, CVF is being careful not to disturb the bed at each site or let clumps of organic matter get into the sampling bottle.

5.6.6 Point 4: ICRG's observation that treated effluent at Ashlands had a very high *E. coli* count of 43,000 00 ml '*indicated that contamination downstream would always be high and not just related to CSO storm spill frequency*'.

- CVF sampling occurred without an CSO and the CVF count of *E. coli* in the discharged treated effluent was 38,700 MPN/100ml, somewhat similar. The catchment populations for the Ilkley (Ashlands) and Haslingfield works are not known. However, the population of Ilkley was 14,809 in 2011 and for Haslingfield was 1,520.

5.6.7 Point 5: ICRG found that during an overflow, the *E. coli* count could reach 240,000 CFU/100ml.

- CVF has not yet encountered an overflow to sample.

5.6.8 Point 6: ICRG found that coliform counts decreased downstream quite rapidly in both high and low flow conditions, indicating a need to understand the rate of downstream die-off.

- CVF found a roughly similar pattern **and has a similar aim to understand why and check for consistency between batches of results**.

5.6.9 Point 7: ICRG noted that in conditions of low flow and with no storm spills, upstream of a sewage treatment works, counts of *E. coli* were in the region of 100-350 CFU/100ml. These were not identified precisely with a source but could arise from small sewage works and/or from agricultural land.

- These levels are roughly similar to CVF's counts in the samples upstream of the WwTW, taken during benign conditions.

5.6.10 Point 8: ICRG noted relatively high concentrations in some tributaries. These are of local concern and pointed to the need to track down the sources and differentiate between coliforms / enterococci derived from livestock and those derived from people via septic tanks or leaking sewers.

- CVF results over time should provide indications of sources of bacteria not clearly related to a Wastewater Treatment Works.

5.6.11 Point 9: When comparing the Wharfe at Ilkley with the Rhee/Cam, 'low' and 'high' flows are not similar in volumes of water per second.

- A low flow quoted as such by ICRG can be many times higher than a low flow in the Rhee.

6 Conclusions from bacterial results

6.1 The sampling is the first in a series, and was undertaken under conditions of relatively low river flow and high UV intensity. It cannot be assumed that the bacterial load in the WwTW effluent will be similar at other times, and the survival of bacteria in the river over time and distance may vary considerably on different dates. Data from just one batch of samples must therefore be treated with caution, and further testing is needed to check for consistency. Although this report presents all the raw bacterial data, it should not be used to guide water users on the bacteriological safety of any specific stretches of the river.

6.1.1 Natural disinfection of bacteria by the action of ultra violet sunlight is well-known phenomenon. It may have occurred both at the WwTW and in the river. Natural UV light intensity will vary substantially and thus lethal effects on bacteria will vary according to the conditions on the day of sampling.

6.1.2 The Haslingfield WwTW discharged high numbers of all three groups of bacteria. These were found in the discharged treated effluent. No 'Combined Storm Overflow' (CSO) of only partially processed sewage occurred on the day of sampling.

6.1.3 Numbers of *E. coli* and enterococci dropped markedly within 1.9 km downstream from the WwTW, though with numbers of total coliforms dropping less to that point. The general pattern of counts of all three groups over longer distances was similar.

6.1.4 Relatively low numbers of the two faecal indicator bacterial groups were found at Sheep's Green (5.5 km from the WwTW) and Jesus Green. Just one *E. coli* bacterium and no enterococci were counted in the Bourn Brook.

6.1.5 Some of the changes over distance might have occurred due to sampling error (bacteria not being uniformly blended within the water), or recharge from natural faecal sources. The occasional presence of natural faecal sources downstream of the WwTW is a possible factor in counts remaining stable over a considerable distance from the WwTW, after the first large drop in counts near the WwTW.

6.1.6 Vicar's Brook had higher numbers of *E. coli* and a disproportionately high number of enterococci, compared to the other two tributaries sampled. Faecal matter from cattle grazing in Coe Fen was the most likely source of bacteria. However, the sampling procedure was unable to eliminate other possible causes further upstream.

6.1.7 The presence of the two indicator bacteria in moderate numbers (relative to other counts in the batch) above the WwTW requires further investigation (which is being undertaken in Batch 2 sampling).

6.1.8 Lower relative survival rates of E. coli over distance and time, compared to some other organisms originating from the same contamination source, **cannot be discounted**.

7 Further monitoring

7.1 The entire programme of sampling needs to be repeated at intervals, and the next batch will be taken on 24th August. Additional sampling sites will be visited, two more further upstream from Harston/Haslingfield, and three more downstream from Jesus Green and including Cambridge Water Recycling Centre (discharged treated effluent). Also, a site immediately below the Grantchester Meadows cattle fields, at Newnham Riverbank Club, will be sampled to obtain additional bacterial counts upstream of Sheep's Green.

7.2 Storm water spillage needs to be monitored by sampling the river water during its occurrence. As the *E. coli* concentration of untreated sewage is in the order of 7,000,000 CFU/100 ml (reference [9]), that alone is able to seriously elevate coliform concentrations in the river during such periods. This would be relevant **if wholly untreated sewage were to be discharged**. However, the site manager (pers. comm.), says, **'there will be no 'raw sewage' in the outlet flow from the** Haslingfield WwTW **site into the Rhee. There is a storm tank which can discharge screened, settled storm sewage under certain conditions (e.g., following prolonged heavy rain)'**. Thus, the sewage in those conditions would have been at least partially processed before being discharged.

8 Discussion of phosphate and nitrate levels

8.1 Raised levels of nutrients, particularly phosphate, in rivers can trigger the growth of algae and larger plants in a process called **'eutrophication'**. Their decomposition can lead to severe drops in dissolved oxygen levels with major impacts on freshwater biodiversity.

8.2 Phosphorus sources

8.2.1 Natural low-level background sources of phosphorus include atmospheric deposition, soil weathering, river bank erosion, riparian vegetation and migratory fish.

8.2.2 Human-caused inputs come from point and diffuse sources.

8.2.3 Point sources of phosphorus include wastewater, septic tank and industrial effluents, and these generally contain a high proportion of bio-available phosphorus (as soluble phosphate).

[9] Kay, et al., 2008. Faecal indicator organism concentrations in sewage and treated effluents. Water Research, 42, 442-454

8.2.4 Diffuse sources include agriculture and rural land management, in particular where phosphate is adsorbed to the surface of soil particles washed into rivers from fields and farm gateways. Also, urban and road runoff which contains a higher proportion of particulate phosphorus.

8.2.5 Sewage treatment works contribute up to 90 per cent of the non-agricultural phosphorus load [reference[10]]

8.2.6 National estimates for England and Wales have until recent years suggested industrial, human and household sources (point and diffuse) accounted for around 65-76 per cent of total phosphorus in rivers, mostly from sewage treatments works, while agriculture accounted for 18-28 per cent, and background sources made up about 4.5- 6.5 per cent [reference[11]]

8.2.7 More recently there has been a swing towards agricultural sources contributing more than sewage treatment works. Agriculture and rural land management has now overtaken water industry STWs as the most common cause of water bodies not achieving good status for P. [reference[12]]**.** Phosphorus loadings to English rivers from water industry sewage treatment works have reduced dramatically since 1995, and the Narrative states that by 2020 the load will have been cut by 66%.

8.3 Nitrate sources

8.3.1 Key sources of nitrate pollution are fertilisers (including artificial, inorganic fertilisers, compost, animal manure and slurry (liquid manure), sewage sludge (and other materials spread on land), and domestic and industrial sewage. Farming is now the main source of ammonia, some of which converts to nitrate.

8.3.2 Historic conversion of grassland to arable land, and poor management of dressings of manure and artificial fertiliser on crops has led to nitrate pollution in many of our groundwater sources. **This is evident in the aquifer from which Cambridge Water Company draws nearly all its drinking water**. Manure and artificial fertiliser applications should these days be better targeted on the crop (avoiding field margins and ditches) and related closely to crop needs (so that what is applied is effectively taken up by the crop).

8.3.3 Recent modelling undertaken by the Environment Agency estimates the national loading to rivers from diffuse sources (predominantly agriculture) to be 75%, with point sources (predominantly sewage treatment works) contributing 25% [reference[13]]. The agricultural contribution is estimated as 69% of the total nitrate-N loading to rivers.

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[10] Environment Agency, May 2012, Review of phosphorus pollution in Anglian River Basin District https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291507/scho0512buwf-e-e.pdf

[11] Environment Agency, Version 12: 02/02/10, Diffuse Pollution Programme Strategic Assessment Report – Phosphorus.

[12] Environment Agency, 2019, Phosphorus and Freshwater Eutrophication Pressure Narrative, page 4 https://consult.environment-agency.gov.uk/++preview++/environment-and-business/challenges-and-choices/user_uploads/phosphorus-pressure-rbmp-2021.pdf

[13] Environment Agency, 23/10/2019, 2021 River Basin Management Plan: Nitrates https://consult.environment-agency.gov.uk/environment-and-business/challenges-and-choices/user_uploads/nitrate-pressure-narrative-021211.pdf

8.4 Chalk stream nutrient levels in near-pristine conditions

8.4.1 The following (Figure 17) is extracted from Chalk Rivers Nature and Conservation [reference[14]].

Figure 17: Key water quality parameters including phosphorus and nitrogen

Indicative values of key water quality parameters that might be expected in chalk rivers in near-pristine conditions are given in Table 2.1, drawing heavily on observations by Robach *et al.* (1996) in French examples but also including subjective judgement of historical UK conditions. These should be used as a broad guide only, and are not intended for use in evaluations of specific rivers or river reaches without more detailed assessment of local circumstances. Significant differences might be expected between rivers on the basis of the nature of drift deposits and the influence of other geologies. Values for upper, middle and lower reaches take some account of nutrient spiralling and the tendency to encounter non-chalk geologies further down the catchment, and also admit some low-level anthropogenic impact from extensive agriculture and low population levels.

Table 2.1 Indicative values (annual means) of key water quality parameters in chalk rivers under near-pristine conditions.

Parameter	Upper reaches	Middle reaches	Lower reaches
Suspended solids (mg l^{-1})	<2	4	6
SRP (mg P mg l^{-1})	<0.01	0.02	0.03
Total Phosphorus (mg P l^{-1})	0.02	0.04	0.06
Nitrate (mg NO_3-N l^{-1})	0.2	0.5	1.0
Total Ammonia (mg NH_3-N l^{-1})	0.01	0.03	0.05
pH	7.8-8.0	7.8	7.4

8.4.2 Unionised ammonia is hazardous due to its toxic and sub-lethal impacts on fish and macroinvertebrates. This compound is not being investigated in the project.

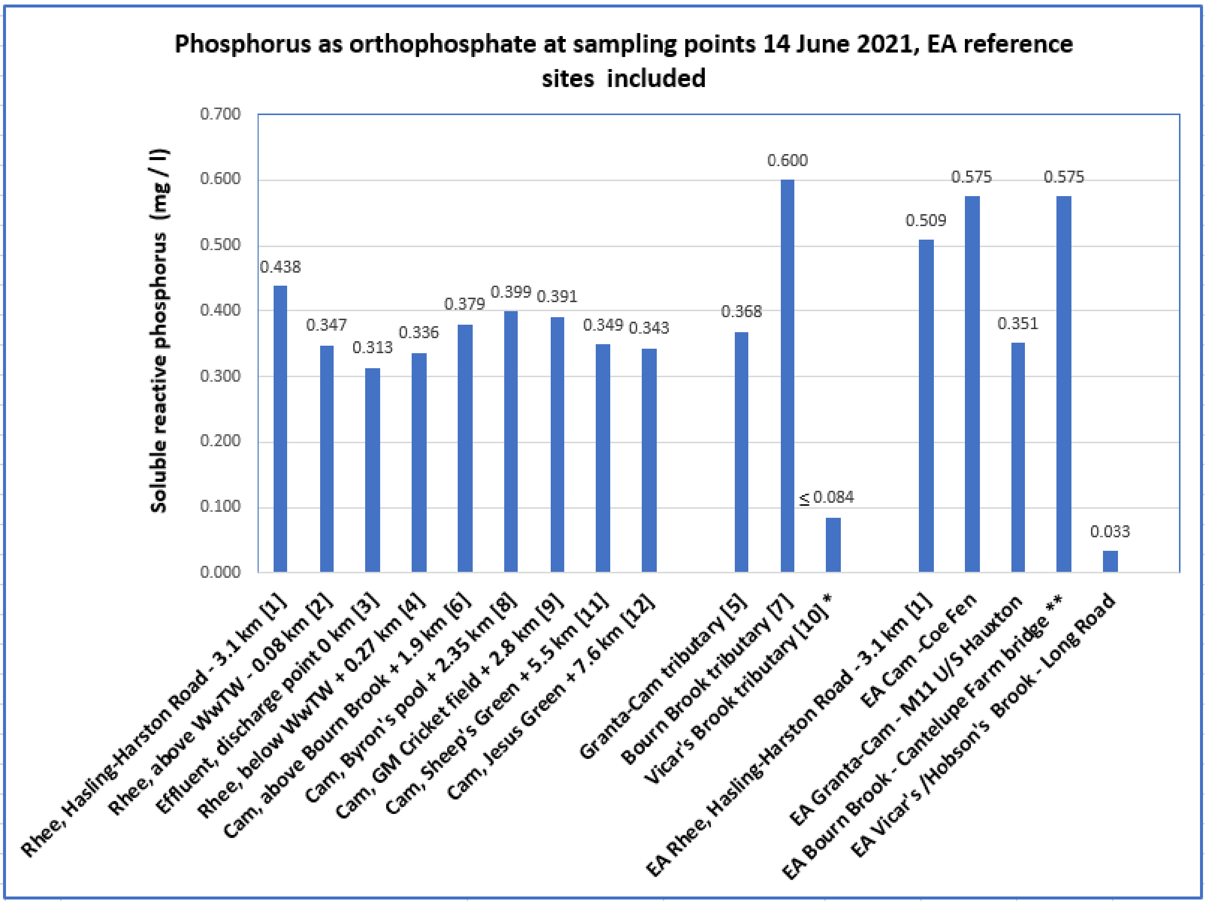
9 Phosphorus results

9.1 Figure 18 below shows phosphorus levels, in orthophosphate, at eight Rhee/Cam sampling points, also in the WwTW effluent, and in three tributaries (Granta-Cam, Bourn Brook and Vicar's Brook). Also included are the means of the last ten measurements made by the EA at five relevant sites. For statutory purposes, the EA would mean the measurements over the last three years but the mean of the last ten measurements is sufficient for our purposes.

9.1.2 Note that the figures are phosphorus as phosphate. Total phosphorus levels in a sample are normally greater than phosphate-P.

[14] Mainstone C. P. 1999, Chalk Rivers Nature and Conservation, page 18.
http://publications.naturalengland.org.uk/publication/5981928

Figure 18: Phosphate-P concentrations at all sampling points, with mean concentrations at EA sample points included for reference



The measurement of phosphate-P concentration refers to sampled pure effluent prior to any dilution in the river.

9.1.3 Note: the EA reference data were extracted from WIMS (Water Quality Archive) the online Defra Data Services Platform. The EA figures are means of the last ten measurements as at June 2021.

9.2 The main issue is that, excluding Vicar's Brook, the samples failed to reach the WFD standard for a 'good' river (to be good a specified section of the river requires the phosphorus level to be equal to or less than 0.089 mg/l.) They were in the range 0.336 – 0.600, the '**poor**' category - see the standards below.

Table 5: Water Frame Directive standards for phosphate-phosphorus in lowland (<80m AOD), high-alkalinity rivers

	Status				
	High	**Good**	**Moderate**	**Poor**	**Bad**
Bands, P (ppm)	0.00 - 0.05	0.051- 0.089	0.090 - 0.211	0.212- 1.089	> 1.089

9.3 It is gratifying to note that the EA measurement of SRP on 7th June was 0.600, precisely the same as our measurement seven days later at the same sampling point. There will be variation over time, but these two similar results validate our sampling procedure. Similarly, the CVF reading for Vicar's Brook of ≤ 0.084 stands out from the other CVF readings and fits well with the EA mean reading of 0.033 on the same watercourse.

9.4 The figure of 0.313 mg/l phosphate in the WwTW effluent is much lower than in earlier years. According to this single measurement, there has been a 90% reduction since 2008/2009 when phosphate levels were last reported (Table 6). The phosphorus stripping treatment at the works will have contributed to the reduction, as will have regulations to limit phosphorus in washing detergents etc. However, although levels in the effluent will be diluted after discharge into the river, the **cumulative effect of discharges** from this and the several other treatment works upstream will be considerable.

Table 6: Published data on phosphorus levels in final effluent at Haslingfield WwTW (EA WIMS data)

Haslingfield WwTW Phosphorus (mg/l), in effluent [1]										
Earliest published orthophosphate 30 March 2000	30-Mar 2000	04-May 2000	30-May 2000	20-Jun 2000	25-Jul 2000	21-Aug 2000	06-Oct 2000	23-Oct 2000	20-Nov 2000	04-Jan 2001
Orthophosphate, reactive as P	6.98	5.8	3.28	8.2	8.01	8.9	9.2	4.12	3.06	2.77
Latest published orthophosphate 16 March 2009	05-Nov 2008	18-Nov 2008	03-Dec 2008	01-Jan 2009	19-Jan 2009	25-Jan 2009	18-Feb 2009	16-Mar 2009		
Orthophosphate reactive as P	4.05		2.92		4.06		1.97	3.28		
Earliest published Total P was 14 Jan 2020	21-Oct 2019	08-Nov 2019	21-Nov 2019	26-Nov 2019	01-Jan 2020	14-Jan 2020	28-Jan 2020	07-Feb 2020	14-Feb 2020	04-Mar 2020
Phosphorus, Total as P						0.8			0.47	
Most recent analyses	**09-Jan 2021**	**27-Jan 2021**	**25-Feb 2021**	**02-Mar 2021**	**03-Mar 2021**	**16-Mar 2021**	**06-Apr 2021**	**23-Apr 2021**	**05-May 2021**	**10-May 2021**
Phosphorus, Total as P		**1**		**1.52**		**1.31**		**2.38**	**1.09**	
Iron µg / l in effluent [1]	09-Jan 2021	27-Jan 2021	25-Feb 2021	02-Mar 2021	03-Mar 2021	16-Mar 2021	06-Apr 2021	23-Apr 2021	05-May 2021	10-May 2021
Earliest published iron 27 April 2000 (1110 µg / l)	2260		1510		1540		1170			1940

Note **1**: A phosphorus stripping treatment which uses iron in its process was installed at the WwTW in 2019.

9.4.1 Note that the EA-derived data used may arise from sampling dates which sometimes are historic as there are no recent data available. As for all comparisons of nutrient concentration, sampling dates over a season may not be the same between sites. Also, any degree of interpretation that discharges from a sewage treatment works of phosphorus are implicated in the raised levels in the river water needs to be tempered by the lack of direct data on all other possible sources.

9.5 CASE STUDY ONE – Sequencing phosphorus measurements along the River Rhee / Cam

9.5.1 Please note that comparisons of nutrient levels at the various sites below were often made using data collected at individual sites on different dates.

9.5.2 At Ashwell Springs, the **phosphate-P level** is generally very low and the groundwater has a 'high' status (Table 7). It is still lower in borehole groundwater samples nearby.

Table 7: Rhee – Ashwell Springs - groundwater, most recent three samples – 'high' status

SAMPLING POINT				
R.Rhee Ashwell Springs				
Sampling point ID	AN-30M01			
Type	Groundwater – Spring			
Determinand	Units	10-Jan	13-Feb	04-Mar
		2020	2020	2020
Orthophosphate, reactive as P	**mg/l**	**0.013**	**0.01**	**0.017**

9.5.3 At Ashwell sewage treatment works, the most recent analyses of **total P** are much lower than at some other works. The analysis of iron suggests that the works has a phosphorus stripper [to be checked].

Table 8: Ashwell Sewage Treatment Works – effluent, most recent three samples

Description	**ASHWELL STW FINAL EFFLUENT**				
Sampling point ID	**AN-ASHWELL**				
Type	Sewage Discharges – Final/Treated Effluent – Water Company				
Notation	Determinand	Units	12-Mar	15-Apr	13-May
			2021	2021	2021
348	**Phosphorus, Total as P**	**mg/l**	**1.56**	**0.581**	**0.595**
6051	Iron	µg/l	426	426	409

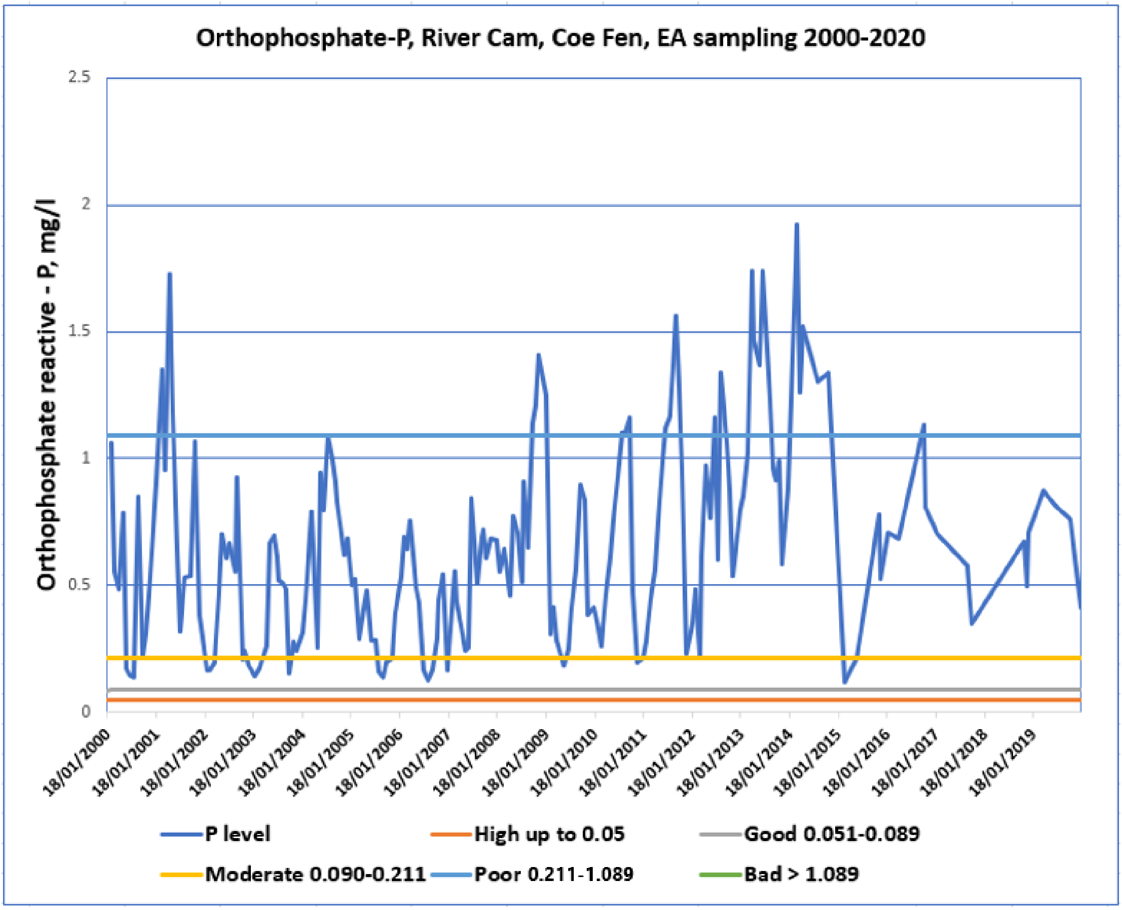
9.5.4 Further downstream (Wendy) the Rhee has become 'poor' for phosphate-P (Table 9).

Table 9: Rhee – Wendy Road Bridge, Wendy, most recent three samples – 'poor' status

R.Rhee Wendy Rd.Br.					
Sampling point ID	AN-30M24				
Samples from 23 Nov 2016 to 19 Sep 2017					
Notation	Determinand	Units	12-Apr	20-Jun	27-Jul
			2017	2017	2017
180	**Orthophosphate, reactive as P**	**mg/l**	**0.657**	**0.937**	**0.885**

9.5.5 Even further downstream at Coe Fen (Cambridge), levels of phosphate-P have been high for many years ('poor' to 'bad' status), with a downward trend recently but still at **'poor'** levels.

Figure 19: Phosphate concentration at a single sampling point in Cambridge over a period of 21 years



9.6 CASE STUDY TWO – site-sequencing phosphorus measurements along the Granta

9.6.1 Table 10 shows that at Linton Road bridge, levels of orthophosphate are very low, and that section has a 'high' to 'good' status.

Table 10: Granta, Linton Road Bridge, 'high' to 'good' status for phosphate-P

R. Granta Linton Rd.Br.												
Sampling point ID	**AN-28M03**											
Notation	**Determinand**	**Units**	**25-Jun**	**19-Jul**	**08-Aug**	**19-Sep**	**16-Oct**	**08-Nov**	**19-Dec**	**22-Jan**	**25-Feb**	**06-Mar**
			2019	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2020**	**2020**	**2020**
180	**Orthophosphate, reactive as P**	**mg/l**	**0.030**	**0.024**	**0.024**	**0.078**	**0.039**	**0.018**	**0.078**	**0.057**	**0.078**	**0.07**

9.6.2 Table 11 below shows that at 4.5 km downstream the concentration of orthophosphate in the river is about 36 times higher than at Linton Road bridge when comparing the mean of all ten measurements, and about 54 times by comparison of measurements only in 2019-20.

Table 11: Granta, Hildersham Ford, 'poor' to 'bad' status for phosphate-P

R.Granta Hildersham Ford												
Sampling point ID	AN-28M04											
Notation	Determinand	Units	17-Aug	23-Nov	21-Mar	06-Jun	10-Sep	18-Dec	23-Apr	19-Jul	16-Oct	22-Jan
			2017	2017	2018	2018	2018	2018	2019	2019	2019	2020
180	Orthophosphate, reactive as P	mg/l	1.38	1.76	0.574	0.4	1.82	1.91	2.25	3.5	4.9	0.56

9.6.3 Located in-between the two sampling points and just 1.5 km from the Hildersham sampling point is the Linton Sewage Treatment Works with historic high concentrations of phosphate-P in the effluent. The data in Table 12 are the latest published that show any forms of P.

Table 12: Linton sewage treatment works final effluent

Linton Stw F/E						
Descriptic	LINTON STW FINAL EFFLUENT					
Sampling	AN-LINTON					
Notation	Determinand	Units	18-Dec	07-Feb	13-Mar	16-Apr
			2012	2013	2013	2013
180	Orthophosphate, reactive as P	mg/l	5.55	4.37	5.17	6.44

9.7 CASE STUDY THREE – Swaffham Bulbeck Lode, poor water quality

Figure 20: Swaffham Bulbeck Lode, 31st May 2021

Credit: Elizabeth Thompson

9.7.1 The thick, heavy benthic layer of green material in this section of the lode is largely filamentous algae which covers the bed silt and other macrophytes, reducing light availability.

9.7.2 The data in Figure 21 show high levels of nitrate throughout 2109, peaking in September. Ammonia is well below a harmful level. Phosphate-P clearly peaks during summer, being of 'poor' status earlier in the year and becoming 'bad'.

Figure 21: Swaffham Bulbeck Lode nitrate-N, orthophosphate-P and ammonia-N

Swaffham Bulbeck Lode S.Bulbeck Rd.Br.															
Sampling point ID															
		11-Mar	08-Apr	22-May	20-Jun	18-Jul	12-Aug	19-Sep	15-Oct	08-Nov	03-Dec	14-Jan	28-Jan	18-Feb	05-Mar
		2019	2019	2019	2019	2019	2019	2019	2019	2019	2019	2020	2020	2020	2020
Nitrate as N	mg/l	14.5	14.8	14.3	14.7	17	16	20	16	17.3	17.9	15		14	15
Ammonia un-ionised as N	mg/l	< 0.0005	< 0.00028	< 0.00048	< 0.00026	0.00028	< 0.00061	< 0.00043	< 0.00037	< 0.00021	0.00088	< 0.00031		< 0.00022	< 0.00021
Orthophosphate, reactive as P	mg/l	0.468	0.598	0.696	1.24	1.6	1.1	1.5	1	1.2	0.97	0.49	0.35	0.3	0.34

9.7.3 The Environment Agency have made the following observations (EA, pers. comm).

9.7.3.1 The WFD status for phosphate-P in the Lode is ‘poor’ (‘bad’ in 2019, after which concentrations reduced in 2020).

9.7.3.2 EA apportionment modelling estimates that **92% of the phosphate input into the waterbody is from Bottisham WRC**. Arable contribution is estimated at 4%.

9.7.3.3. Particularly high phosphate concentrations observed in 2019 were almost certainly due to the prolonged dry weather and particularly hot summer temperatures. During this time, river flows were much reduced, resulting in reduced dilution of the Bottisham sewage effluent.

9.7.3.4. An Anglian Water Asset Management Programme (AMP) P-removal scheme has now been confirmed for Bottisham WRC – the permit limit will be 1 mg/l P (current effluent quality is very variable, but averages ~7 mg/l P). The delivery deadline is 22nd December 2024.

9.7.3.5 The AMP scheme is expected to result in an improvement to ‘good’ phosphate status in the lode, which in turn should much reduce the eutrophication effects observed.

10 Nitrate results

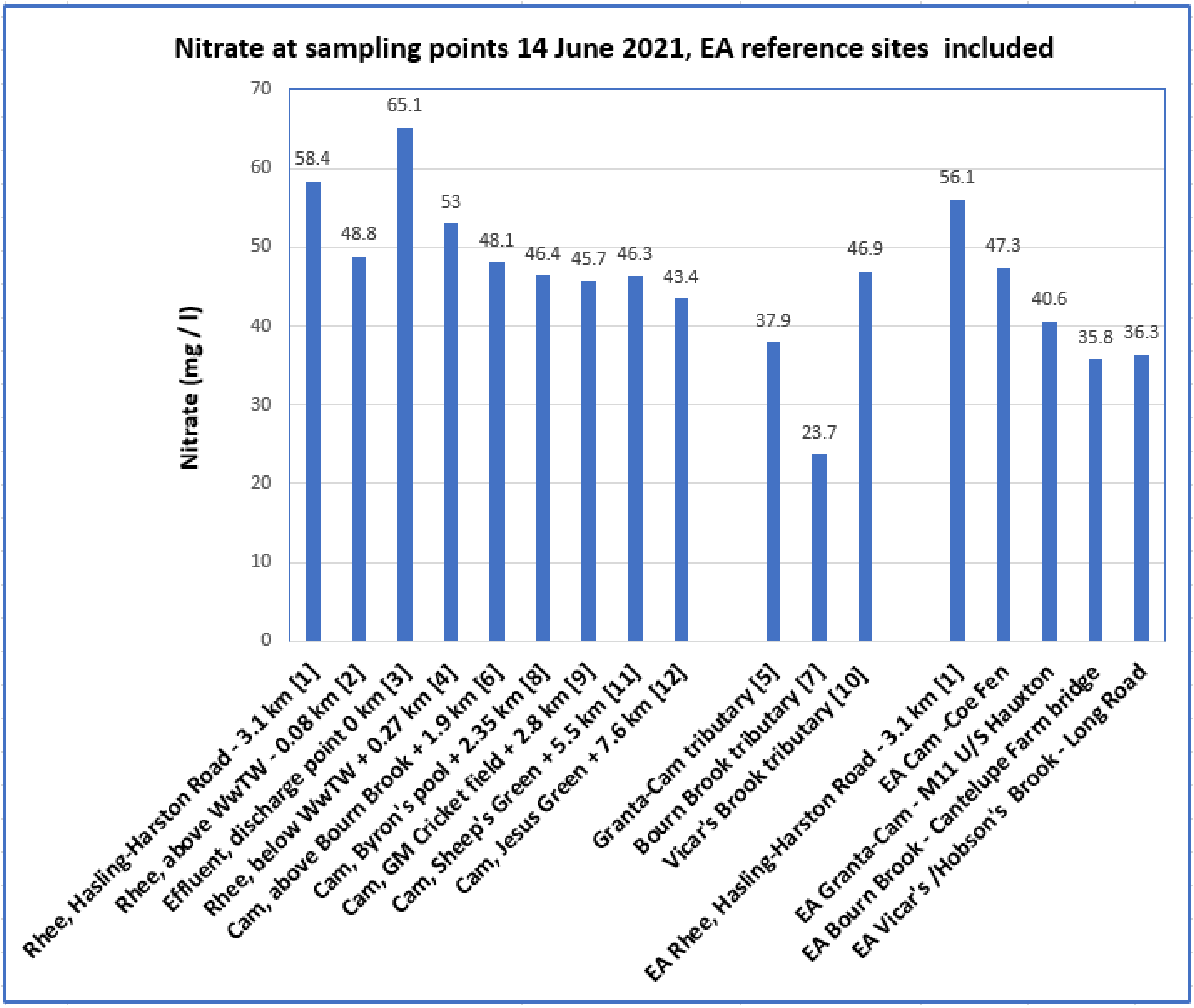
10.1 According to the House of Commons Environmental Audit Committee, ‘*The poor ecological status of our water systems continues to be problematic for our wildlife and pollution of groundwater sources affects a major source of our drinking water. Nitrates are one of the key nutrients involved in the pollution of rivers and streams and are the main pollutant in groundwater sources.* ***They are predicted to worsen for some time to come***’ [reference[15]].

10.2 CVF results of nitrate concentrations are shown in Figure 22. They are all high. Bourn Brook stands out for having a level about one-half of some sites on the Rhee/Cam. On this occasion, the level is 66% of the mean of the most recent ten EA measurements.

10.3 All these concentrations are high enough to exacerbate eutrophication attributable to raised and high phosphate levels.

[15] *UK Progress in Reducing Nitrate Pollution, Eleventh Report of Session 2017-19).* *https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/656/656.pdf*

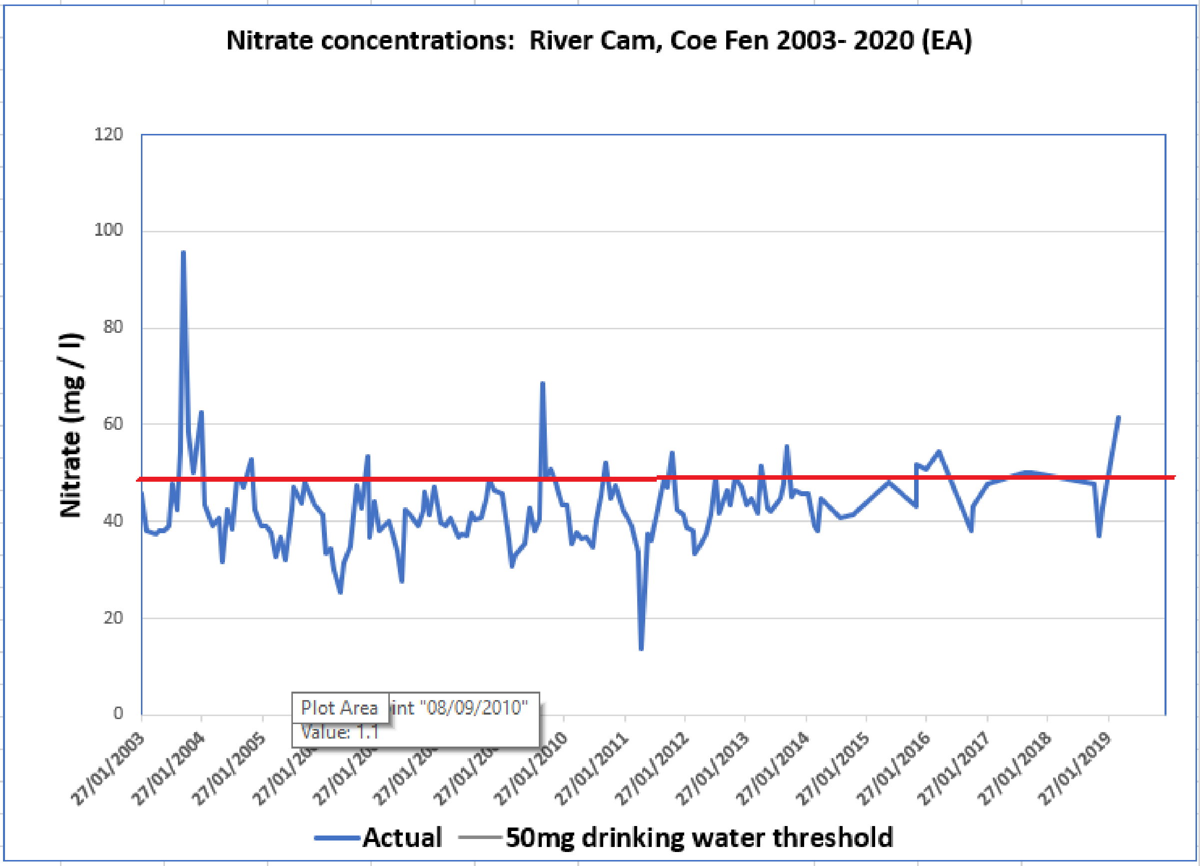
Figure 22: Nitrate concentrations of all sampling points, with mean concentrations at EA sampling points included as reference data.



The measurement of nitrate concentration refers to sampled pure effluent prior to any dilution in the river.

10.4 Nitrate concentrations have been historically high in many sections of the Cam catchment. The analysis of samples taken at Coe Fen (Cambridge) over many years shows a typical pattern of nitrate concentration (Figure 23).

Figure 23: Nitrate concentration at a single EA sampling point in Cambridge over a period of 17 years



10.5 Table 13 shows clearly that the source of nitrate at Ashwell is the groundwater, and that the nitrate concentration is high. The most recent measurement of 13 mg/l nitrate-N is equivalent to 58 mg/l nitrate, and if this groundwater were to be used for drinking water the nitrate would need to be reduced by treatment or by blended with other water sources with lower levels.

Table 13: Nitrate-N concentrations at Ashwell Springs 20-19 –2020, headwater of the Rhee

SAMPLING POINT											
R.Rhee Ashwell Springs											
Sampling point ID	AN-30M01										
Type	Groundwater – Spring										
Determinand	Units	12-Jun	18-Jul	01-Aug	06-Sep	18-Oct	14-Nov	09-Dec	10-Jan	13-Feb	04-Mar
		2019	2019	2019	2019	2019	2019	2019	2020	2020	2020
Nitrate as N	**mg/l**	**10.9**	**11**	**11**	**11**	**11**	**11.1**	**11**	**12**	**12**	**13**

10.6 <u>Cambridge Water Company quality reports</u>

10.6.1 Cambridge Water Company publishes data on analyses of their drinking water. An example can be viewed here, for City South water quality zone (Z2, [reference[16]].

[16] Water quality report 2020) https://www.cambridge-water.co.uk/household/my-water-supply/water-quality/water-quality-standards/cambridge-city-south-water-quality-zone-z2

10.6.2. In the example linked to above, nitrate measurements have a mean of 39.51 mg/l.

11 Effects of low river flows on pollutant levels

11.1 Table 14 illustrates the typical seasonality observed in phosphate-P, at a high concentration in summer at the time of minimum river dilution despite being the time of highest biological uptake. '*In a low-flow year a lower minimum dilution gives rise to higher phosphorus concentrations*' *[reference[17]].*

11.2 High levels in the Rhee occurred June – November 2019, with much lower concentrations January –March. This is a similar situation to that in the Swaffham Bulbeck Lode also in that year.

Table 14: Rhee – Wimpole, A1198 road bridge, most recent 10 samples – 'moderate' or 'poor' status

R.Rhee Wimpole "A14" Rd.Br.												
Sampling	AN-30M05											
Samples from 17 Jun 2019 to 11 Mar 2020												
Notation	Determinand	Units	17-Jun 2019	19-Jul 2019	01-Aug 2019	23-Sep 2019	18-Oct 2019	07-Nov 2019	04-Dec 2019	15-Jan 2020	10-Feb 2020	11-Mar 2020
117	Nitrate as N	mg/l	9.42	8.48	7.67	13	13	9.81	13	18	15.9	16
180	**Orthophosphate, reactive as P**	**mg/l**	**0.561**	**0.61**	**0.6**	**0.75**	**0.62**	**0.589**	**0.42**	**0.14**	**0.18**	**0.1**

11.3 Low flows of several rivers in the catchment have been associated with over-abstraction from the aquifer (see *Let it Flow!*).

11.4 Data from Anglian Water on effluent discharges per annum are used in Table 15 to provide a mean effluent flow per second from all STWs. The proportion of effluent in the flow of the flow of the Rhee for a particularly low-flow situation can then be estimated.

Table 15: Effluent flow into the Rhee from STWs above Burnt Mill, Haslingfield gauging station as litres per second, based on meaned 2016-2020 data

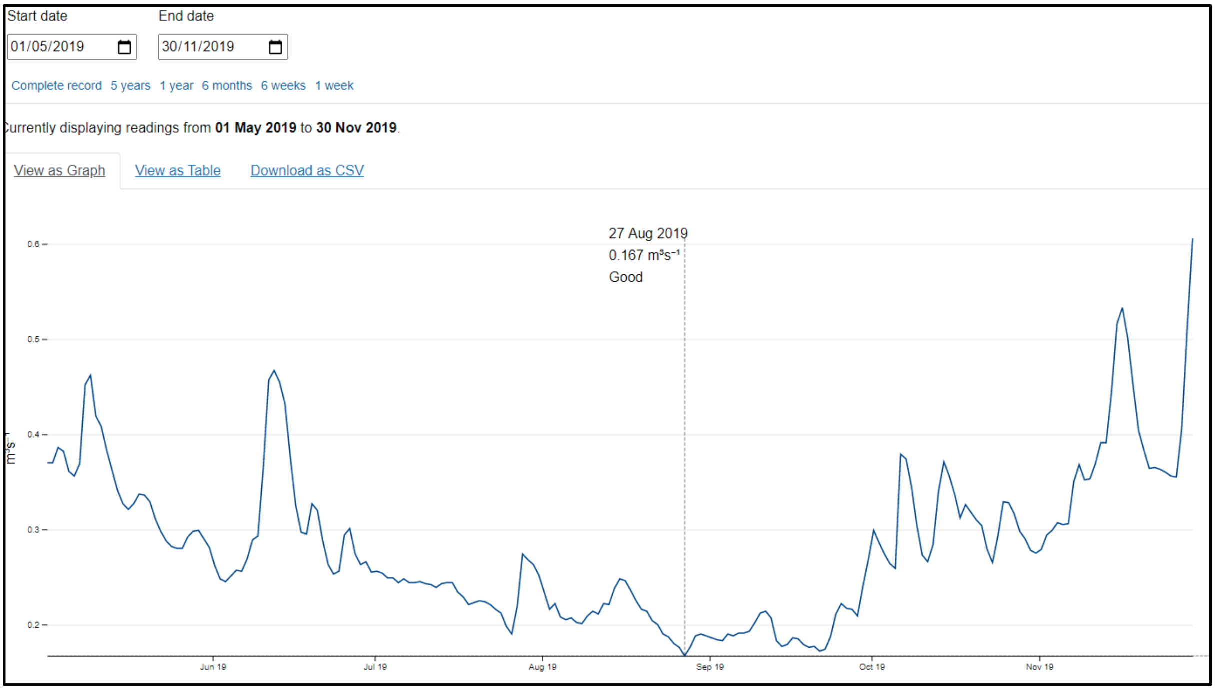
STW	Average flow m3 /annum	Litres per second
Arrington	50566	1.6
Ashwell No data		
Barley	97,001	3.1
Bassingbourn	394,382	12.5
Foxton	693,831	22.0
Guilden Morden	163,012	5.2
Melbourn	839,740	26.6
Royston	947,752	30.1
Total l/sec		**101.0**

Notes: The Rhee as the final discharge river to be confirmed for Barley. There are no data for Ashwell STW. See 11.4.2 and 11.4.3 for comment on incoming dilutive water from tributaries.

11.4.1 In 2019 the lowest flow at the Burnt Mill gauging station, Haslingfield was on 27th August – 167 litres / sec (Figure 24).

[17] Mainstone C. P. 1999, Chalk Rivers Nature and Conservation, page 107. http://publications.naturalengland.org.uk/publication/5981928

Figure 24: River flow at Burnt Mill gauging station, Haslingfield.



11.4.2 Thus, the proportion of river flow at Burnt Mill made up from effluent from the various sewage treatment works upstream is estimated at 60%. The proportion just above the Granta-Cam, with Haslingfield effluent flow included, would be 68%. **This is a crude estimate**, for instance the figures of effluent flow may be too high on that day, and some incoming flows from tributaries such as the River Mel are not included, though of course the River Mel flow would be made up of a substantial amount of effluent in high summer.

11.4.3 Thereafter, downstream, there will be dilutive effects from the Granta-Cam and Bourn Brook etc. However, the Granta flow at Stapleford on 27th August was **zero,** the Cam at Dernford being 152 l/s. More data would be needed to model the flow in the Cam at the approaches to Cambridge city, but the flow might have been made up in the order of **39% effluent on that date**.

11.4.4 This approach should be expanded and modelled more accurately, so that the apportionment of sewage effluent to total river flow can be shown over a range of conditions and time of year.

11 Water turbidity

11.1 Turbidity is the clarity of water and it is an important factor in water quality. Materials that can cause water to be turbid include: clay colloids, silt, sediment from bank erosion, tiny inorganic matter and coloured, dissolved organic matter, algae, waste discharges, chemical precipitates, zooplankton, phytoplankton, and other microscopic organisms. Turbidity reduces photosynthetic rates, and fine sediment can clog fish gills and lower an organism's resistance to disease and parasites. Settlement of such fine suspended materials on the bed further downstream coats gravel and fish spawning grounds.

11.2 It is generally noted that the Rhee, and thus the Cam too downstream of it, is turbid over long periods. This problem is very obvious at Hauxton Junction, at the confluence with the clearer Granta-Cam

Figure 25: Confluence of Granta-Cam and Rhee (Rhee flows right to left, from bottom right), October 2015

Credit: Alan Coulson

11.3 Our own investigations in different locations have shown that it is very difficult to get an objective view of turbidity with the naked eye, or with photographs, as so much depends on the angle of view, shading, strength of sunlight, depth of water, etc. Hence any further investigations will depend on the acquisition by CVF of a turbidity meter or Secchi Tube.

11.4 At the time of sampling effluent and river water at and near the Haslingfield WwTW on 14th June, there was no apparent difference with the naked eye in river water turbidity immediately below and above the discharge point. The bottled sample of treated effluent appeared to have good clarity by eye.

12 Funding

12.1 Cam Valley Forum funded the first batch of samples. We are grateful to Anglian Water and Waitrose for their funding contributions. The second and third batches of sampling will be fully funded but beyond that we would be grateful for additional funding from organisations interested in the health of the Cam.

13. Amendments (8 September 2021) to Report No. 1 after issue on 24 August.

5.2.1 The vertical axis of the E. coli chart was originally titled log_{10} scale of *E. coli* counts. This has been changed to counts on a non-log scale.

5.2.2 The amendment is emboldened below: The calculated count of *E. coli* in the river after effluent was mixed with river water forms an important part of the overall picture. Counts at eight sites along the river can be compared between each other but valuable information is gained by having a river water count from the WwTW's discharge. The count of *E. coli* immediately above the WwTW at point [2] was 9.4% of the effluent 'river count' at the WwTW and was 15% higher further upstream at point [1]. **Both counts above the WwTW were higher than at point [6] which is 1.9km below the WwTW, suggesting that there is either a moderate source close to and above point [1], or, more likely, a much more potent source further upstream.** Potential sources of *E. coli* further upstream need to be investigated.

5.2.1 Figure 12: E. coli count was 2167 MPN / 100ml, not 1733. The count was first calculated using a lower estimated effluent flow before Anglian Water provided a more accurate figure.

5.4.3 Original figure 17 deleted.