Westcountry Rivers Trust

River Yealm
Continuous Water Quality Monitoring Report 2023/24

Dr. Holly Pearson

Photo: River Piall - © Julia Bertram .

Westcountry Rivers Trust is an environmental charity established in 1995 to restore, protect and improve the rivers, streams, and water environments in the region for the benefit of wildlife and people.

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1. Introduction

The River Yealm catchment (as defined by the Environment Agency's 'Operational Area') is just over 100km^2 and includes coastal areas in the south to moorland in the north. There is nearly a 500m difference in elevation across the catchment, meaning that a wide variety of habitat types are found here, from the sheltered estuarine habitats where seagrasses can be found, to the blanket bog of Dartmoor, with many other priority habitats providing connections in between. The loss of habitats and ecological networks across the country has led to the UK Government's 25 Year Environment Plan (25YEP)[1] being published, which sets out a series of goals and steps for achieving them. Recognising the value of the natural environment, protecting it and taking measures to enhance it are fundamental elements of the plan.

The aim of the Yealm Estuary to Moor project is to link fragmented habitats, such as wetlands, woodlands and species rich grassland, along the River Yealm from coastal estuary to moorland source, to create a continuous in-river and riparian wildlife corridor. The project will do this through restoring existing habitats currently in poor ecological condition, creating new habitats where possible, improving connectivity in-river by the easement of barriers to migratory species of fish and to increase biodiversity along the course of the River Yealm.

The principal set of evidence that is available to use to assess the water quality in a catchment is the Water Framework Directive (WFD) classification of the waterbodies. For surface waters, such as rivers and lakes, the 'overall status' of a waterbody is comprised of an ecological and a chemical component. The ecological status can be classed as Bad, Poor, Moderate, Good or High and is allocated through assessment of a number of elements, including aquatic invertebrates, fish populations, nutrients, oxygen levels, aquatic plants and specific pollutants. Macrophyte and phytobenthos status (diatom indeces) is a well-established method for assessing water quality. It is widely accepted that a detailed evaluation of the structure and function of phytobenthic communities in a river can provide robust evidence for assessing its ecological condition. Community composition is particularly affected by changes in the pH and nutrient levels in the water and can be used to identify rivers impacted by these types of pollution. Chemical status can be Fail or Good and requires assessment of a range of Priority and Priority Hazardous substances. After the introduction of more stringent tests for the 2019 WFD assessment, every water body in England failed the tests for Polybrominated diphenyl ethers (PBDE) and mercury. This meant that no waterbody could achieve an Overall Status of Good, even if they are classified as Good for ecological status.

The ecological classifications of waterbodies across the Yealm catchment range from moderate (3 water bodies) to good (2 water bodies, https://environment.data.gov.uk/catchment-planning/OperationalCatchment/3555). The reasons for not achieving good (RNAG) in the catchment waterbodies are primarily related to phosphate concentrations derived either from agricultural or sewage pollution impacting the macrophyte and phytobenthos (2 water bodies), and physical barriers or surface water abstraction impacting flow and fish passage in the upper catchment. It is vital to understand water quality in a catchment to gain a clearer picture of the location and temporal character of pollution sources and their potential impacts on ecology and biodiversity.

In January 2023, the River Yealm Water Quality Group (RYWQG) purchased an Aqua Troll 600 which was subsequently deployed in collaboration with the Yealm Estuary to Moor (YEM) project. The Aqua Troll 600 (herein referred to as "the sonde") was deployed at the base of the River Yealm in order to collect continuous baseline water quality data. The sonde was fitted with sensors for measuring simple water quality parameters, that when plotted together against time, can yield information on the way a river responds to rainfall events. Measured parameters included temperature, depth, dissolved oxygen, pH, turbidity and total dissolved solids (TDS, equivalent to electrical conductivity multiplied by 0.67) and the sonde was deployed in conjunction with a VuSitu telemetry unit in order to remotely send data to a server (HydroVu) where it could be viewed in near-real time. This report presents the full (12-month) dataset, summarizing some simple statistics, seasonal trends and parameter correlations, providing some interpretation of the key observations from the data.

2. Methodology

The sonde was deployed at Puslinch Bridge (SX 57074 50997) on 13th January 2023, upstream of the tidal influence. The first measurement was recorded at 15:30 and measurements for all parameters were recorded at 15 minute time intervals for the duration of the deployment. The final measurement to be included in this report was taken on the 1st January 2024 at 12:00.

The sonde was deployed in a vertically inside a length of perforated PVC pipe attached to the river bank via an angle iron and supporting road pins driven into the bank. Regular visits were made by members of the YEM group to check and maintain (clean and calibrate) the sonde and sensors throughout the deployment period. The dataset was downloaded from the YEM group's HydroVu account (the online data hosting platform associated with In-Situ's telemetry products) by a YEM member and cleaned in order to remove obvious outliers and correct for pH sensor drift. The data was sent to Westcountry Rivers Trust (WRT) for analysis, where Microsoft Excel was used to graphically represent the data for analysis. Box plots were made using the in-built chart function and programmed to display the range of values (whiskers), the interquartile range (the 25th through the 75th percentile), the median, mean and any outliers, as displayed in Figure 1.

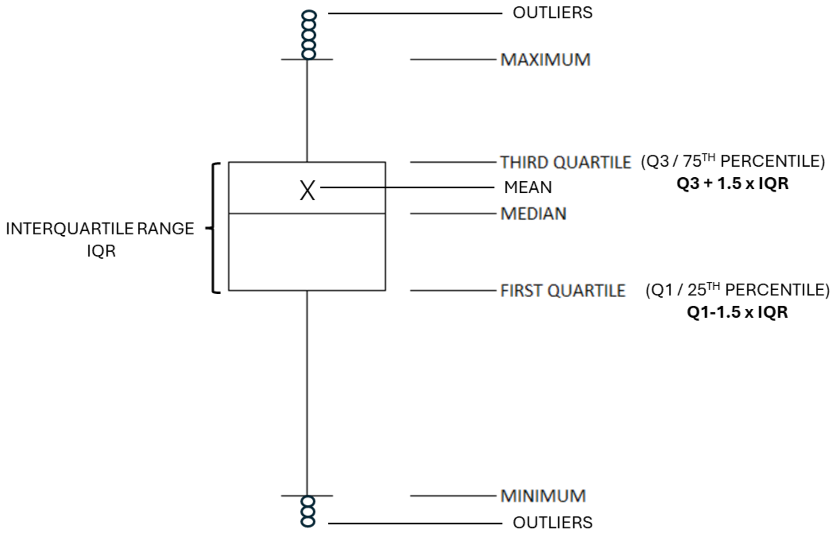

Figure 1: The structure of the box and whisker plots used to display the data distributions in this report

3. Results and Discussion

3.1 General Trends and Statistics

Traces for each water quality parameter measured by the sonde over the 2023 period are shown in Figure 2. Accompanying summary statistics are displayed in Table 1 and box and whisker plots shown in Figure 3.

Temperature, dissolved oxygen (DO), pH and total dissolved solids (TDS) were within the expected ranges for the river type and location, and time of year (Figure 3 and Table 1). These data were also in excellent agreement with the Environment Agency's 2023 spot sampling data (Open WIMS data, freely available from https://environment.data.gov.uk/water-quality/view/landing) and, with the exception of temperature, were within the ranges required for optimum health of sensitive freshwater species such as salmonid fish (Table 1)

Temperatures exceeded an 18°C threshold[1] for a total of ~9 h on 07/09/2023 and ~3 h 08/09/2023 by a maximum of 0.5°C. Despite the summary statistics giving very low turbidity for the River Yealm overall, very large turbidity spikes occurred throughout the 1-year data collection period. Those exceeding the maximum measurable range of the sensor (>4000 NTU) were removed from the dataset for detailed analysis.

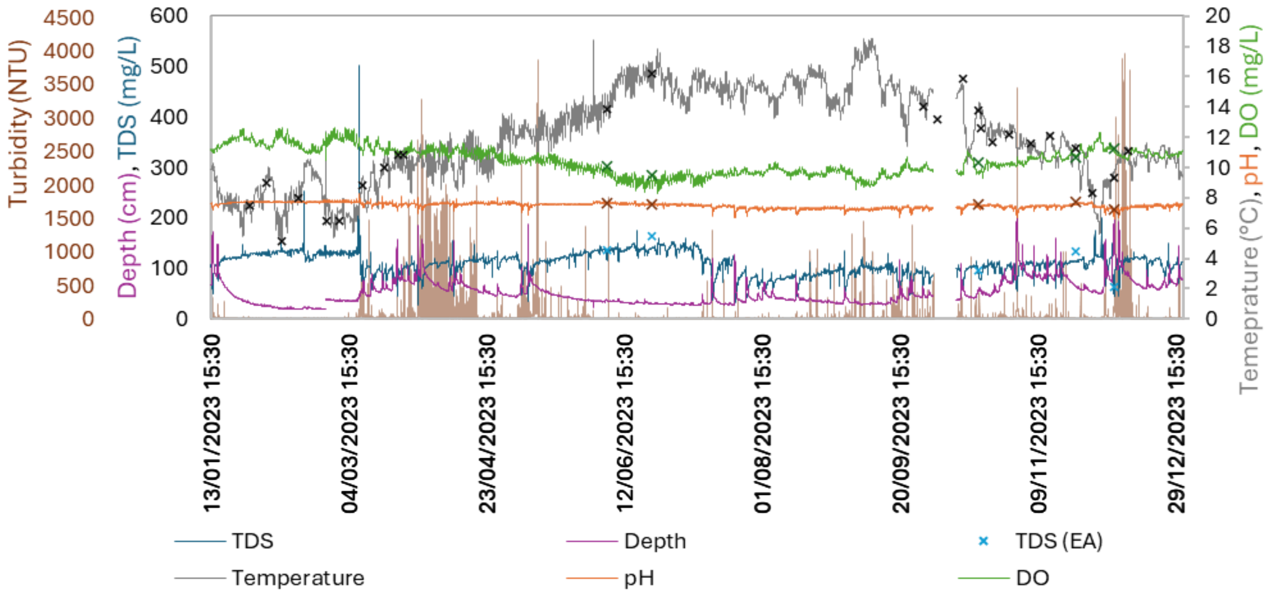

Figure 2: Fifteen-minute timeseries data for the water quality parameters measured by the sonde at Puslinch Bridge during 2023. Environment Agency (EA) spot sampling data from the same location are plotted as crosses (x) for comparison.

Table 1: Summary statistics for the parameters measured on the YEM group's sonde from January 2023-2024. "Healthy range" refers to the range considered optimum for no detrimental effects on salmonid fish species. TDS=Total Dissolved Solids; NTU = nephelometric turbidity units; DO=Dissolved Oxygen.

	Temperature (°C)	pH	TDS (mg/L)	Turbidity (NTU)	DO (mg/L)	Depth (m)
MIN	5.12	6.61	26.14	0	8.32	0.19
MEDIAN	12	7.53	110.4	0	10.51	0.45
MEAN	12.12	7.50	108.89	29.63	10.46	0.52
MAX	18.52	8.29	501.96	3938.26	12.67	2.07
HEALTHY RANGE*	<18	6-9			>5 mg/L	

*for salmonid fish species[2]

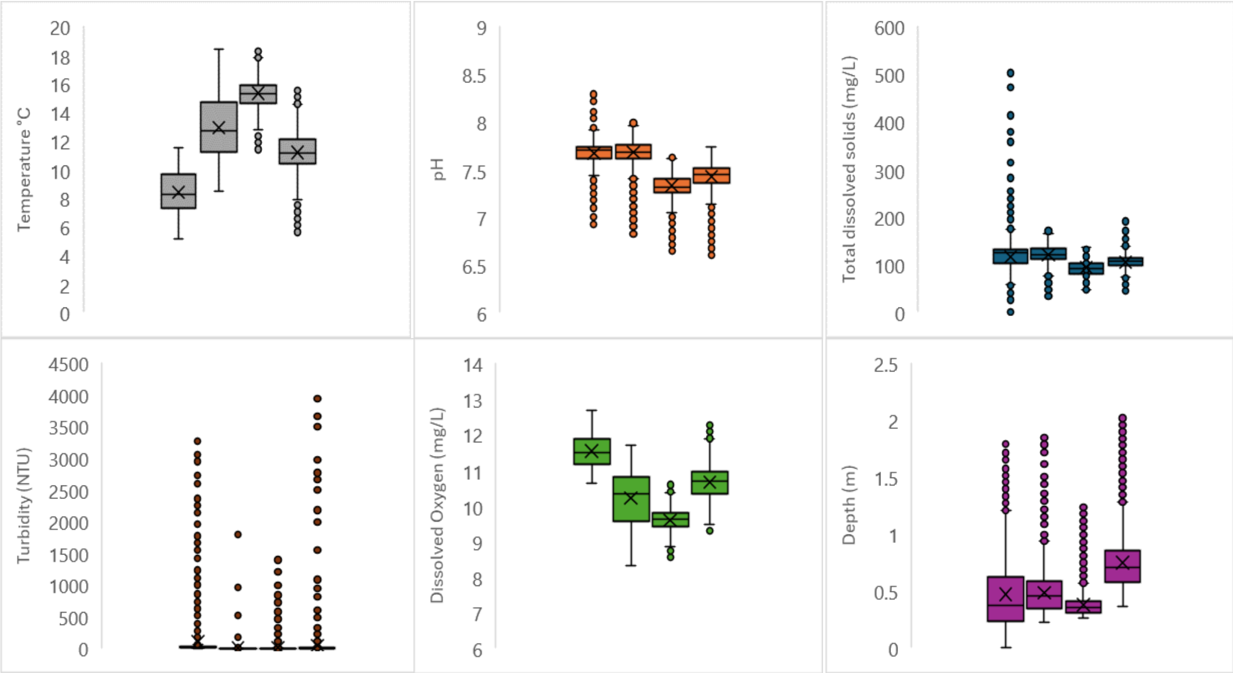

Figure 3: Box and whisker plots displaying the distribution of values for each parameter for each quarter. Q1 of 2023 is represented by the left hand box plot through to Q4 (right hand box plot).

3.2 Total Dissolved Solids

Concentrations of total dissolved solids (TDS) generally show an inverse relationship with depth (Figure 4), reflecting dilution of dissolved ions with increasing water level (and by inference, rainfall). A significant increase in TDS concentration to ~500 mg/L was observed on 8th March 2023 (Figure 5). This event started at around 0600, peaking at 0700 before returning to approximately baseline levels by 1100. The increase appears independent of any changes in level, suggesting it was uncoupled from rainfall, and none of the other measured parameters were affected. A smaller but similar spike in TDS was observed on 16th February 2023 at 0915 of ~250 mg/L, lasting around 4 hours. The reasons for these spikes in conductivity remains unknown, although the gritting of roads with salt during icy weather and subsequent wash-in after thawing of ice/rainfall could be a possibility for the 8th March event. Historic weather records show temperature lows of 1°C were forecast for the early hours of 6th March 2023, with rain forecast for the 8th.

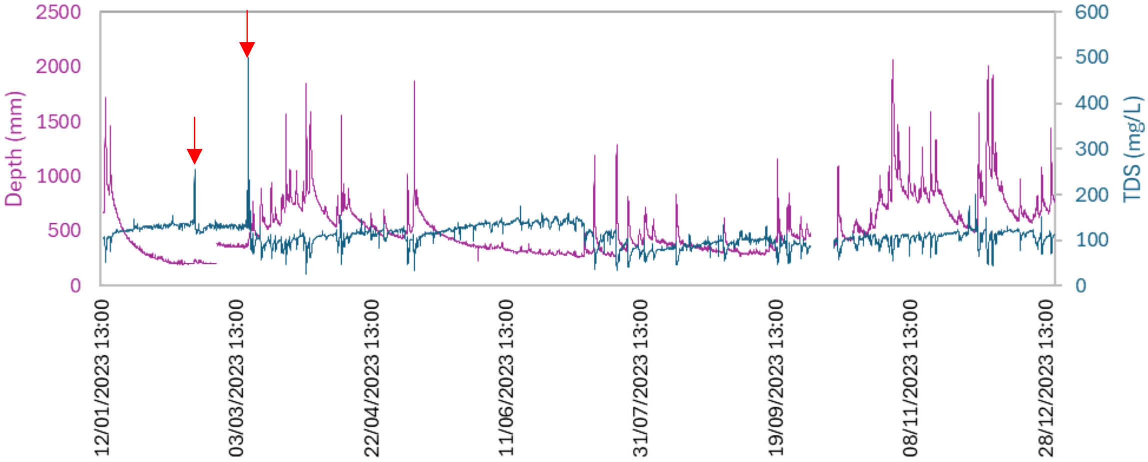

Figure 4: 15 minute depth and total dissolved solids (TDS) timeseries data from the sonde at Puslinch Bridge. The coloured arrows indicate large spikes in TDS concentrations as described in the text and displayed in Figure 5.

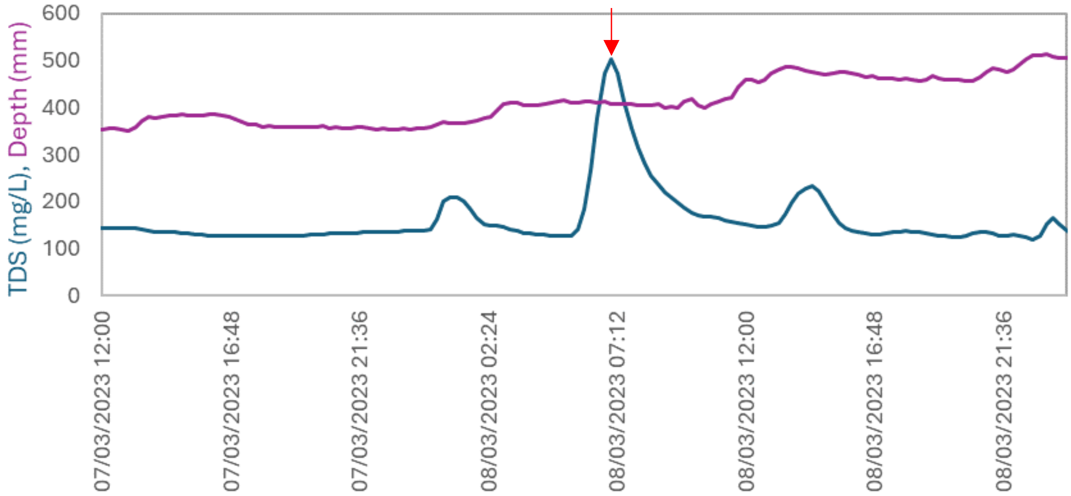

Figure 5: Close-up of the 15 minute timeseries data for the marked increase in total dissolved solids during the morning of the 8th March 2023, indicated by the red arrow in Figure 4.

3.3 Turbidity

Despite cleaning of the turbidity data, notably elevated turbidity measurements were consistently recorded by the sonde throughout the annual monitoring, and particularly during April (Figure 6, yellow highlighted area). These April measurements (Figure 7) span several orders of magnitude and are uncoupled from depth. On close inspection of the data, there is some indication that regular "pulses" of increased turbidity occur throughout the dataset. A plot (Figure 8) displaying turbidity data over a 24 h period in May 2023 shows a repetitive cycle of turbidity fluctuating between 0 and 100-200 NTU every 2 hours, independent of the small (~5cm) increase in level beginning ~0600. As turbidity readings returned to baseline levels between peaks, the data suggest regular discharging of suspended material into the river, consistent with and thus substantiated by associated variation in the range of suspended solids as were observed coincidentally by the EA (Figure 9). The source of such material cannot be given with any certainty, but several possible point sources that could contribute to elevated turbidity exist upstream of Puslinch, such as active and disused quarries, and sewage treatment works.

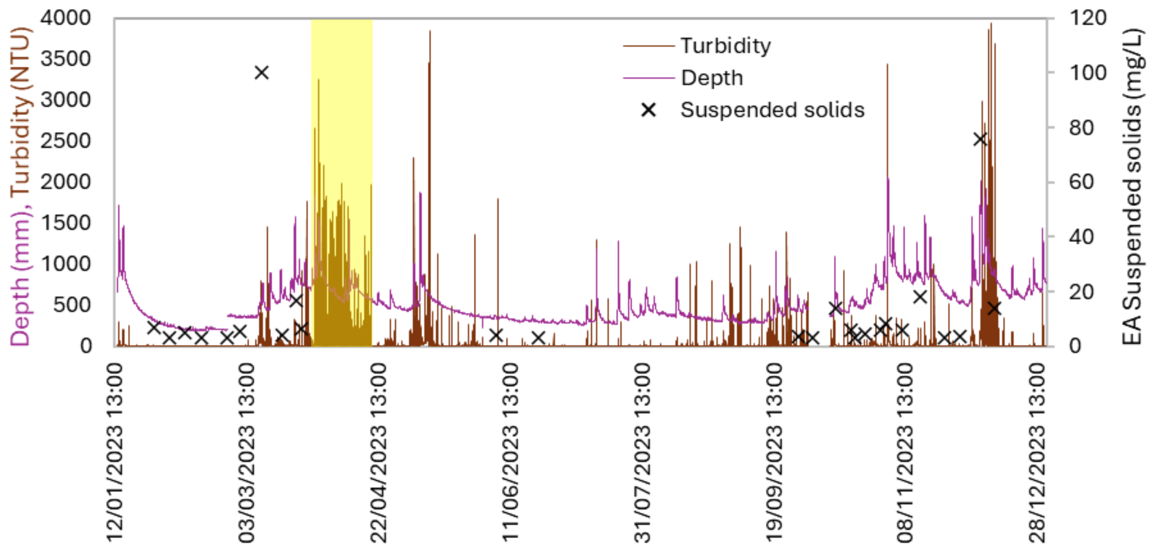

Figure 6: Depth and turbidity timeseries data from the sonde plotted with measurements made by the Environment Agency for suspended solids in spot samples (x) (WIMS open data). The yellow highlighted area is referred to in the text and shown in more detail in Figure 7.

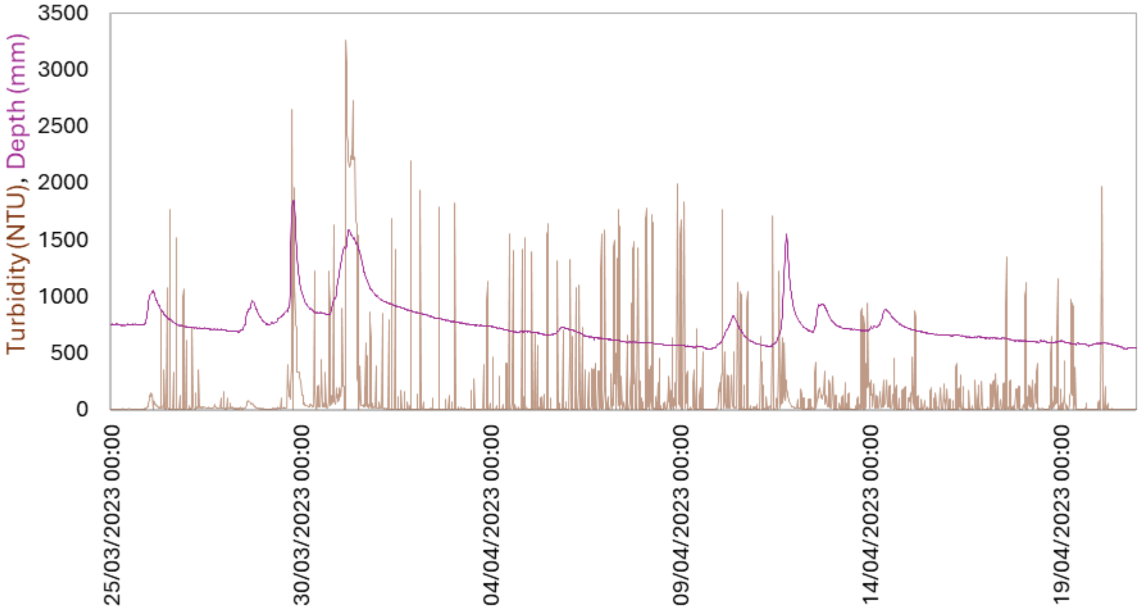

Figure 7: Turbidity and level data from the sonde which is highlighted yellow in Figure 6.

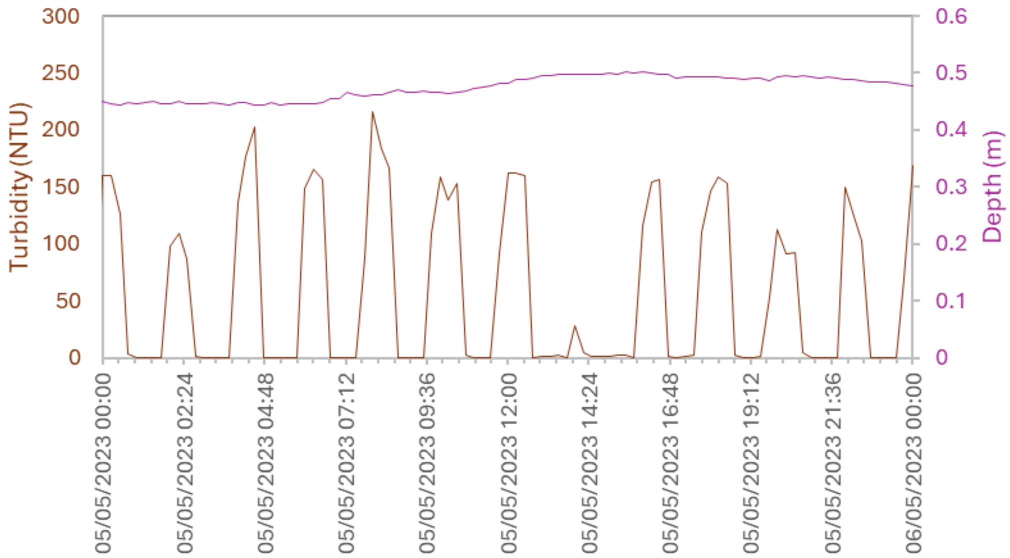

Figure 8: Turbidity measurements made by the sonde over a 24 hour period in May 2023.

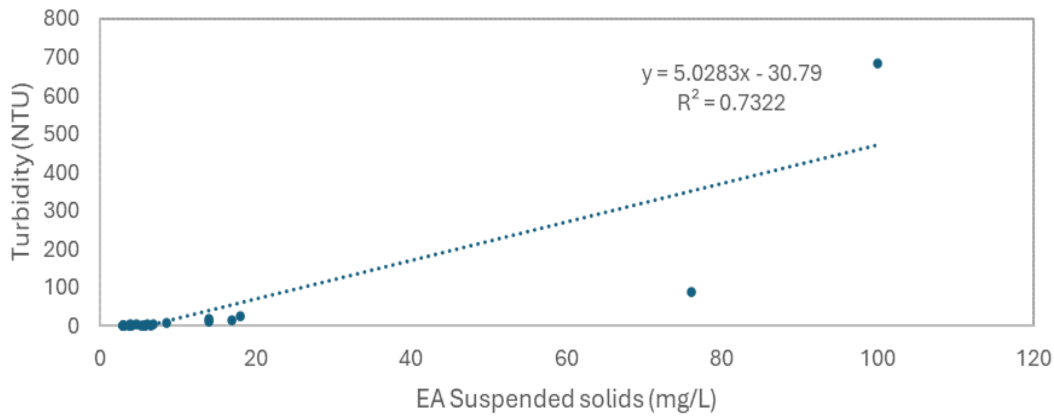

Figure 9: Turbidity measurements made by the sonde plotted against Environment Agency's (EA) suspended solids measurements. The turbidity measurements used were the ones taken as close to the recorded time of the EA sample as possible.

3.4 Dissolved Oxygen

Dissolved oxygen (DO) remained at healthy concentrations throughout the measurement period and showed an inverse relationship with temperature (Figure 10), a common phenomenon demonstrating the reduction in the concentrations of oxygen able to dissolve in warmer waters. The timeseries data show DO concentrations peaking during winter months and troughing during summer, reflecting a normal pattern in seasonal DO trends. Despite this, a closer look at the DO trace shows this parameter decreasing during nighttime hours, when temperatures tend to decrease. This diurnal cycle (Figure 11) is a commonly observed phenomenon in natural waters and is the result of the switching between a net increase in oxygen released by plants during the day when photosynthetic activity is at its peak, vs increased respiration during the night.

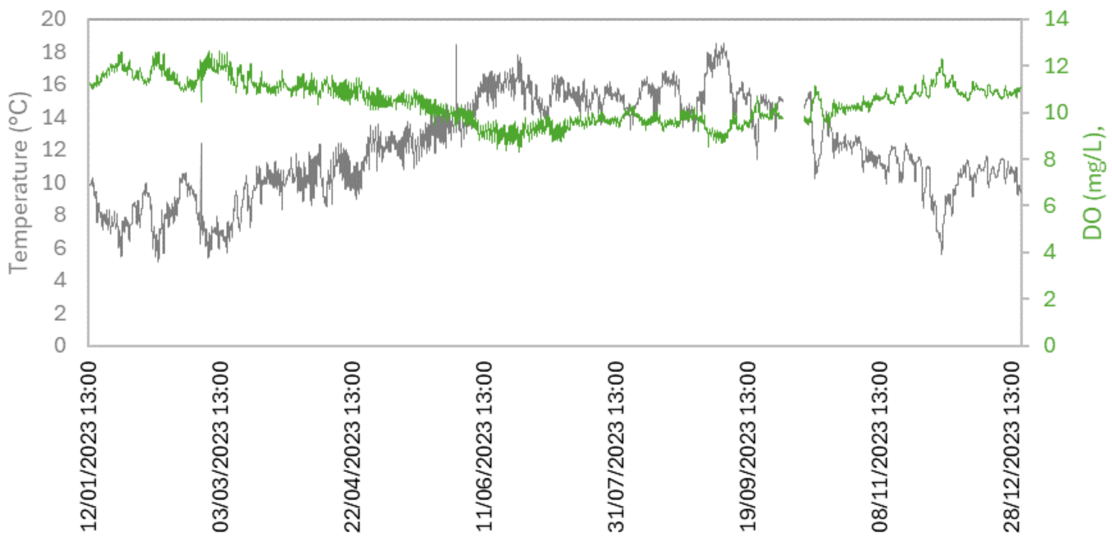

Figure 10: Dissolved oxygen and temperature concentrations recorded by the sonde.

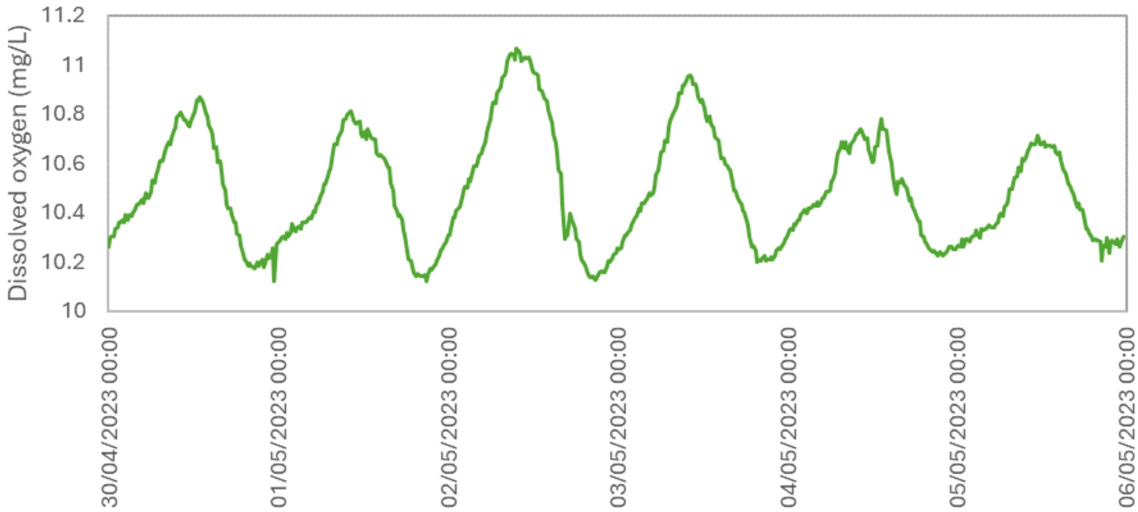

Figure 11: An extract from the sonde data to show the diurnal cycle exhibited in the dissolved oxygen data

3.5 pH

Despite the moorland origin of the Yealm, the mud, silt and sandstones that begin at Dendles Wood and Newpark Waste, in conjunction with the limestone, mudstone and calcareous mudstones that underly the village of Yealmpton just prior to Puslinch Bridge, mean that a neutral to slightly basic pH is not unexpected for this river. The most striking trends in the pH timeseries data are the regular troughs in pH with increased depth (Figure 12), sometimes with a preceding rise in pH (Figure 13) suggesting the occurrence of a "first flush" of dissolved ions (such as carbonates, bicarbonates and hydroxides) entering the watercourse that increase pH before an increase in acidifying material, possibly dissolved humic and fulvic acids from the peaty moorland drive the pH down below baseline. These troughs can last for up to 15 h before recovery to previous pH values and correlate closely to fluctuations in depth. In contrast, the preceding spikes are typically 2 to 3 h in duration, occurring on the rising limb of the depth profile.

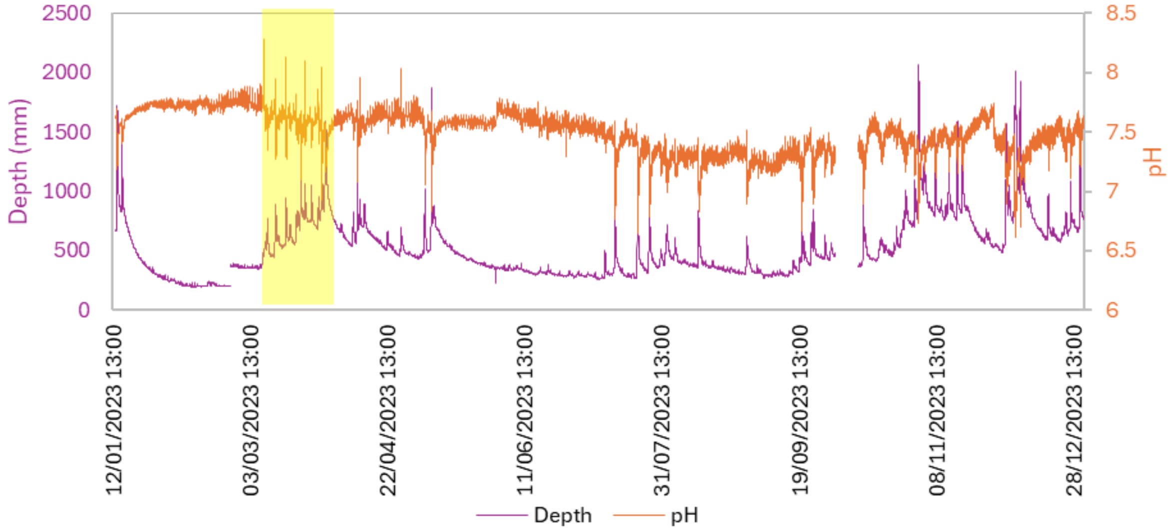

Figure 12: Timeseries pH data with depth from the sonde. The yellow highlighted area indicates the period shown in more detail in Figure 13.

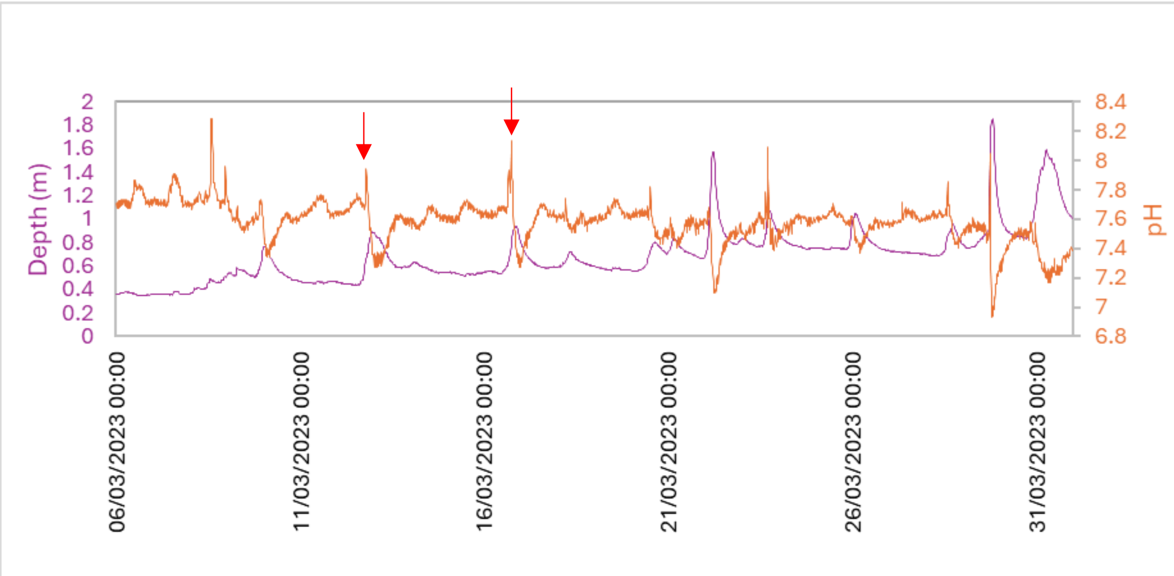

Figure 13: An extract from the data presented in Figure 12 for the period 06/03/23 – 31/03/23. Red arrows mark instances where troughs in pH with increased depth are preceded by rises in pH.

4. Conclusions and Recommendations

The data from the Puslinch Bridge sonde has provided an excellent baseline of the response of the Yealm catchment to changes in hydrology. The data have captured seasonal variations in the measured water quality parameters that are generally in line with expected concentrations and levels for the catchment's geology and location. Events observed in the timeseries data are varied – some driven by natural processes and some by anthropogenic influences. Events included relatively short-lived (4 to 5 hour duration) spikes in concentration (e.g. TDS), as well as prolonged deviations from baseline values (e.g. pH), regular, more rhythmical trends (e.g. the diurnal oxygen cycles) through to sporadic increases that appear uncoupled from depth/rainfall (e.g. turbidity). Such observations suggest a complex catchment with many factors contributing to the overall water quality signal with time.

Future work to expand knowledge of the catchment response could include additional sondes placed on main tributaries further upstream, in order to pinpoint more accurately where the sources of pollution are, and how these are diluted with time and distance from the source. Citizen Science Investigations can also be undertaken at strategic locations upstream for a similar outcome, and for the collection of further data that are not possible to capture using the sonde (e.g. phosphate, photographs and other contextual information). Meanwhile, utilisation of the threshold alarm system in HydroVu is enabling citizen scientists to undertake event sampling, towards identifying potential pollution sources.

5. References

[1] Defra, 2018. The 25 Year Environment Plan. https://assets.publishing.service.gov.uk/media/5ab3a67840f0b65bb584297e/25-year-environment-plan.pdf

[2] Cowx IG & Fraser D (2003). Monitoring the Atlantic Salmon. Conserving Natura 2000 Rivers Monitoring Series No. 7, English Nature, Peterborough