Proceeding Paper

A Qualitative Approach to Combined Sewer Overflow Modelling on the WATERVERSE Project [†]

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Abstract: In the UK, combined sewer overflows (CSOs) are currently a hot topic, with the UK's water regulator (OFWAT) mandating greater visibility and reporting on such incidents. However, there is often little existing support for this given a historic lack of CSO-related data collection. This paper looks to build a model of water quality to capture different key CSO versus agricultural runoff events and to develop a digital twin for Totnes and swimming areas of the river Dart.

Keywords: CSO; open channel model; agricultural runoff; water quality; wild swimming

1. Introduction

The University of Exeter (UNEXE) and South West Water (SWW) are partners in the WATERVERSE project [1], a project concerned with the development of a water data management ecosystem (WDME) for six European partners. UNEXE and SWW have worked together to develop approaches for modelling combined sewer overflows (CSOs) and water quality within the Totnes region of the UK.

The drivers for this work come from several considerations: firstly, the UK's Office for Water Services (OFWAT) PR24 [2] mandates the publication of CSO operation; secondly, there is a broad need to differentiate between CSO events and other pollution events, typically agricultural runoff [3] for the largely rural areas; there is a need to support SWW data scientists in river-based water quality modelling to give them insight into the river data they are working with; and finally, there is a desire within SWW to develop a safe wild swimming app for the river Dart.

Typically, open channel water networks of this nature are modelled using either quantitative modelling approaches such as EPA SWMM or data-driven approaches typified by big data and machine learning. Whilst these approaches can work well, they can run into limitations, in that quantitative modelling normally requires an understanding of the theory of water quality, and data-driven approaches are limited by the real-world data that are available.

In this paper, we developed a qualitative approach based on the experiences of in-the-field water quality engineers to capture tacit knowledge relating to causality and co-occurrence in limited and small-scale scenarios based in the Totnes area of southwest England. The resulting model was then used to simulate novel water scenarios concerning CSO performance in typical extreme or unusual conditions: blockages during dry weather, flash summer storms and prolonged winter storms, and agricultural runoff.

It is hoped that this work will help develop a conceptual understanding of the drivers of river water quality within the data science team at SWW and lead to the improved analysis of sensor data.

2. Method

For this project, we took the approach of developing a digital twin of the river Dart around Totnes based on the locations of existing water quality sensors and installed and planned CSOs. Totnes is a relatively small town (c9000 population) in rural South Devon. As the town has expanded in recent years, new housing estates have been constructed, resulting in the installation of CSOs, particularly in the Bidwell Brook region of the town, a valley to the north of Totnes, feeding into the river Dart.

2.1. Sensor Properties

SWW collected water quality data from a network of water quality sensors provided by Meteor Communications [4] and the Environment Agency (EA) [5], with the Meteor sensors collecting water temperature, conductivity, ammonium, turbidity, dissolved oxygen, chlorophyll, and pH, whilst the EA provided water level and rainfall data. For both providers, data were collected as time series and could be accessed historically through appropriate APIs.

2.2. A Model of Water Quality

On their own, the properties collected from the Meteor and EA did not provide a huge amount of value, and this was a typical data-information-knowledge issue. We therefore met with an expert from the EA to provide context on the sensor properties and add meaning, resulting in Figure 1.
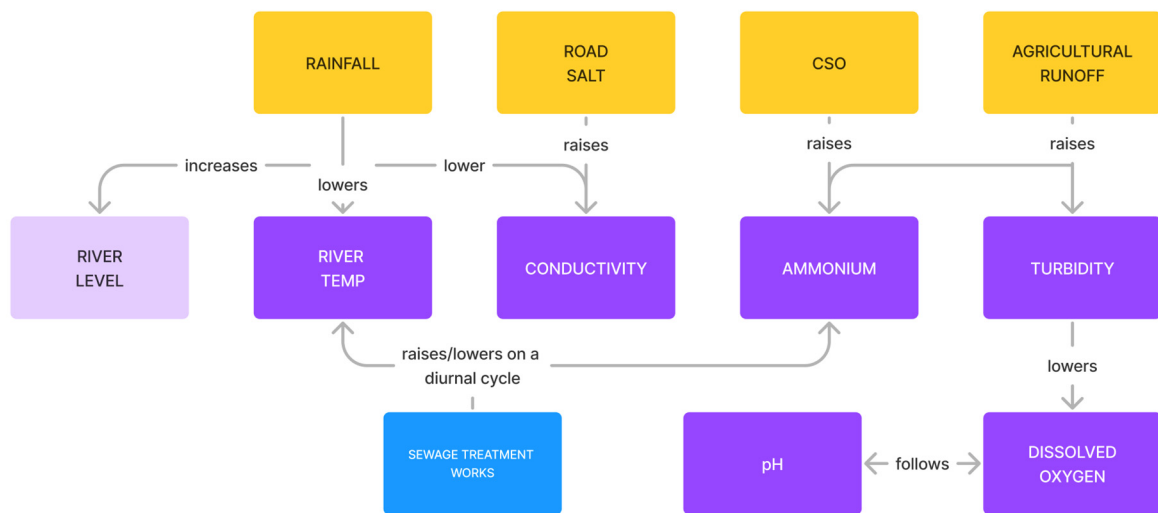
Figure 1. A model of water quality.

The model has four inputs (gold) that drive the Meteor and EA properties (dark and light purple) with the sewage treatment works (blue) acting as an internal node. As expected, rainfall increased the river level and lowered its temperature. Generally, rainfall has no conductivity, so it will lower the conductivity of the river. However, in the UK rock salt is spread on the roads in winter to combat icing, so winter rainfall will often cause a rise in conductivity.

For our CSO modelling work, both CSO and agricultural runoff led to a rise in ammonium levels, although the agricultural runoff also increased turbidity, something that CSO overtopping generally did not achieve. In addition, although not mentioned on this static model of water quality, agricultural runoff events generally have a far longer duration than CSO overtopping.

2.3. Model of the River Dart at Totnes

Figure 2 details our conceptual model of the river Dart at Totnes, with the Bidwell Brook showing as a tributary to the main river. The model is a collection of water quality (WQ) sensors, wild swimming locations (SWIM), CSOs, and sites for agricultural runoff (AG runoff). Water quality sensors were located such that quality alerts could be raised for given swimming locations when the sensor to the left (upstream) of the location reported quality issues, regardless of whether the issues were caused by CSO or AG runoff.
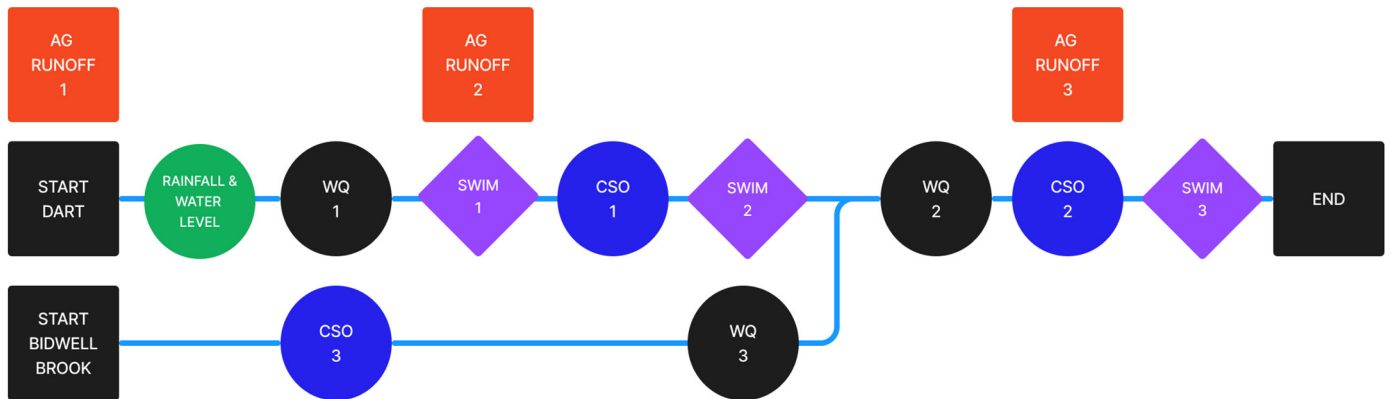

Figure 2. Our conceptual model of the river Dart at Totnes.

2.4. Scenario Creation

Scenarios were created using sequences of time series data, with each property modelled as a separate trace. Figure 3 demonstrates two potential scenarios. Whilst the scenarios looked similar, in the sense that both had peaks of ammonium turbidity suggesting an agricultural runoff event, it was case (b) that was the actual event, having multiple peaks compared with the single event of a CSO overtopping (a). Moreover, ammonium and turbidity for (b) were an order of magnitude higher than those for (a): 11 vs. 0.3 for ammonium and 400 vs. 65 for turbidity.
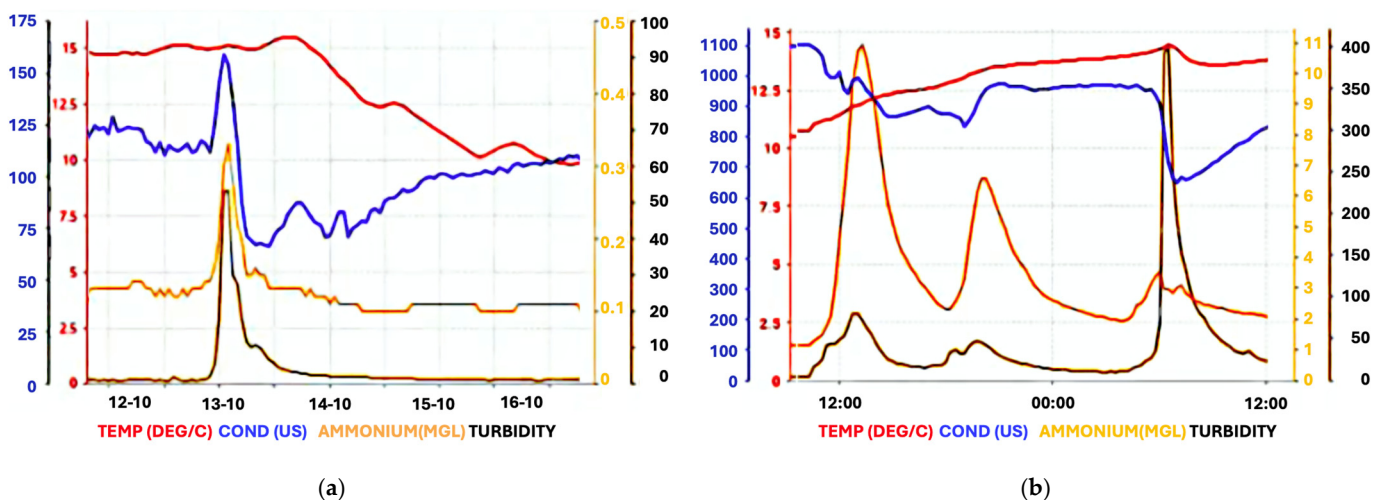

Figure 3. Sensor time series data showing CSO overtopping (**a**) and agricultural runoff (**b**).

3. Results and Next Steps

3.1. Shared Understanding of Water Quality

The primary positive outcome from our current activities was to create a shared body of water quality knowledge. This enabled the multi-domain research team engaged on a shared platform to have a clear understanding of the relationship between the inputs and outputs of the water system, as defined in Figure 2, and its broad interactions with the

users of the water system, in particular the wild swimmers, farmers, and citizens of the local Totnes area.

3.2. Implementation of Scenarios

The next stage of this work is to create software to model and iterate through the sequences of time series data on demand. From discussions with our water quality expert, the resulting traces need to capture both the ballpark quantitative data and, moreover, the shapes of the traces, with fast attacks and slow releases being key attributes of the properties to model.

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References

1. Waterverse Home Page. Available online: https://waterverse.eu/ (accessed on 30 March 2024).
2. Ofwat. PR24 and Beyond: Creating Tomorrow, Together. [Online]. Available online: https://www.ofwat.gov.uk/regulated-companies/price-review/2024-price-review/framework-and-methodology/pr24-and-beyond-creating-tomorrow-together/ (accessed on 30 March 2024).
3. BBC News. Cornwall: 'Unbearable' Stench of Sewage on Beauty Spot Beach. [Online]. Available online: https://www.bbc.co.uk/news/uk-england-cornwall-63456417 (accessed on 30 March 2024).
4. Meteor Communications Home Page. Available online: https://meteorcommunications.co.uk/operational-water-quality/ (accessed on 30 March 2024).
5. Environment Agency: Check for Flooding Service. Available online: https://check-for-flooding.service.gov.uk/?v=map-live&lyr=mv,ts,tw,ta&ext=-10.529528,49.93027,6.574741,55.84093 (accessed on 30 March 2024).