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A Qualitative Approach to Combined Sewer Overflow (CSO) Modelling on the WATERVERSE Project †

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Abstract: In the UK, combined sewer overflows (CSO) 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 an historic lack of CSO-related data collection. This paper looks to build a model of water quality to capture and different key CSO verses 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. For this project, we (UNEXE & SWW), are investigating the performance of combined sewer overflows (CSO) with UNEXE. As part of this project, we have worked together to develop approaches for modelling 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 causing events, typically agricultural runoff [3] for the largely rural SWW, there is a need to educate 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 is available.

In this paper, we have 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 South West England. The resulting model has then been used to simulate novel water scenarios

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concerning CSO performance in typical extreme or unusual conditions: CSO blockages during dry weather, flash summer storms and prolonged winter storms, and agricultural run-off.

It is hoped that this work will help to develop a concept understanding of the drivers of river water quality within the data science team at SWW and lead to 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 location of existing water quality sensors and installed and planned CSOs. Totnes is a relatively small town (c9,000 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 collects water quality data from a network of water quality sensors provided by Meteor Communications [4] and the Environment agency [5], with the Meteor sensors collecting water temperature, conductivity, ammonium, turbidity, dissolved oxygen, chlorophyll, and pH, whilst the Environment Agency (EA) provides water level and rainfall data. For both providers, data is collected as time series and can be accessed historically through appropriate APIs.

2.2 A Model of Water Quality

On their own, the properties collected from the Meteor and EA do not provide a huge amount of value, and this is 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.

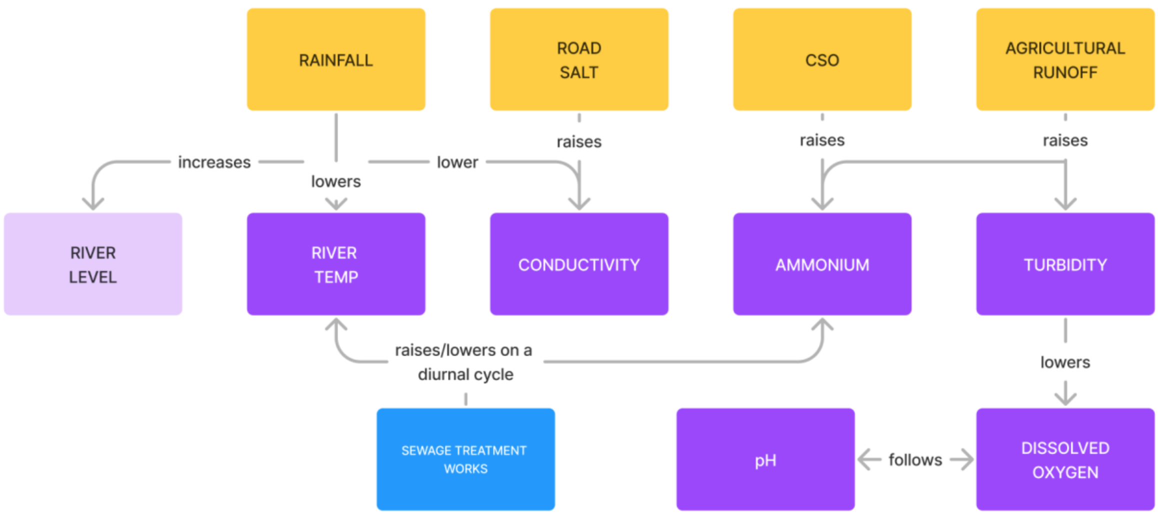


Figure 1. A model of water quality

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 will increase river level and lower 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 will lead to a rise in ammonium levels, though the agricultural runoff will also increase turbidity, something that CSO overtopping generally doesn't 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 are located such that quality alerts can be raised for given swimming locations when the sensor to the left (upstream) of the location report quality issues, regardless of whether the issues are caused by CSO or AG RUNOFF.

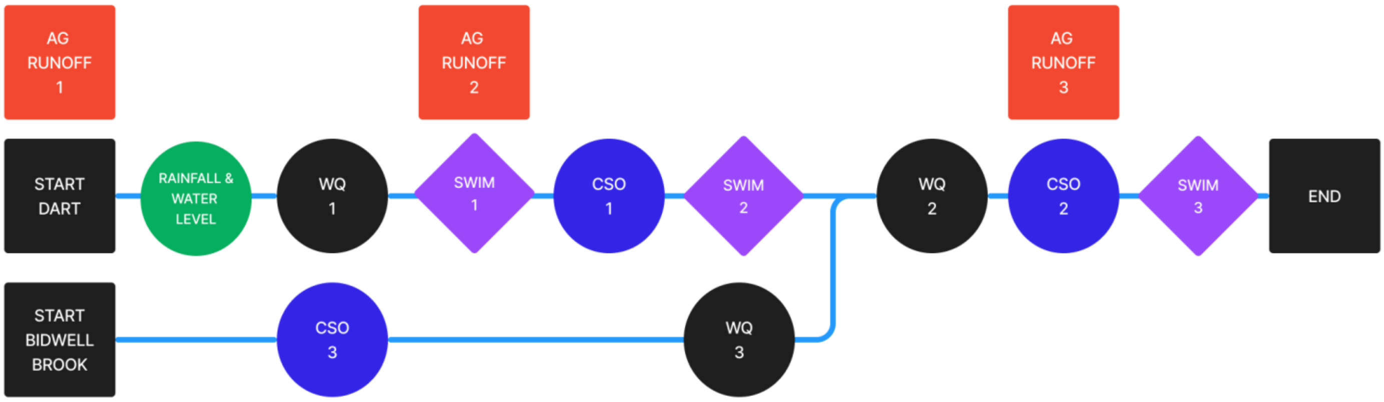
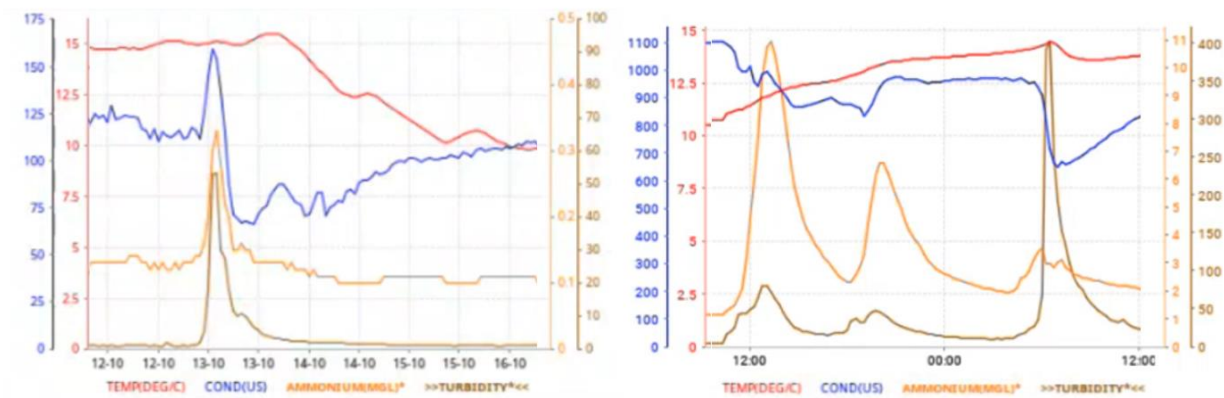


Figure 2. Our conceptual model of the river Dart at Totnes

2.4 Scenario Creation

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



(a) **(b)**

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 has been to create a shared body of water quality knowledge. This has enabled the multi-domain research team engaged on a shared platform with 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 the 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 ball-park quantitative data but, moreover, the shape of the shape of traces, with fast attacks and slow releases being key attributes of the properties to model.

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The authors declare no conflicts of interest.

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