CONCLUDING REMARKS AND FUTURE RESEARCH

Over the past 5 years, scientists at the University of Exeter have monitored the impact of Upstream Thinking, SWW's award winning catchment management project, on water quality. Investigating the impact of 30 different types of interventions on eight water quality parameters in 11 catchments over five years was by no means an easy task. Throughout the project, a wealth of different types of data and information have been gathered, requiring a number of analytical approaches, and giving us some of the answers to the questions initially posed. Of course, the research has also raised new questions, as well as challenged some of the general assumptions about catchment management that prevail, ensuring that continued work in the Upstream Thinking catchments is required to study long-term impacts of the interventions that are now in place.

Changes in water quality in feeder streams to reservoirs: the importance of high flow conditions

Using an analytical approach that considers pollutant inputs during either rainfall events or high flow conditions, we were able to identify some change due to Upstream Thinking interventions. For instance, turbidity (which illustrates the sediment in water) input to Upper Tamar Lake has been significantly reduced during high flow (i.e. flow reached or exceeded 5% of the time, Q5). Such a change is yet to be detected in the reservoir, but potentially shows the positive impact of Upstream Thinking in the tributary which supplies this important drinking water reservoir.

The approach used has also highlighted differences between sub-catchments and confirmed high contributions of diffuse pollution from agriculture from specific locations. Such work is invaluable to justify the need for increased interventions, which target specific agricultural problems in the catchment. This was, for example, the case for the Antron Stream in the Argal catchment that, despite lower stream flow, demonstrated higher contributions of nutrient loadings to the water body, and thus is an area that should be prioritised for future Upstream Thinking interventions.

Data show that algal blooms are the main water quality issue in drinking water reservoirs in the south west of England. We observed discrepancies in the timing and extent of blooms between reservoirs, highlighting the importance of local environmental and meteorological conditions in driving the growth of blooms. Nutrient concentrations during rainfall events (i.e. the main contaminant contribution) were also generally found to be above desired thresholds during a large proportion of the time, thereby contributing to the existing nutrient loading problem already present in the reservoir. Overall, these results highlight the complexity of algal bloom dynamics, especially the need to reduce both the loss of diffuse nutrients from farmland as well as the recycling of nutrients in reservoirs.

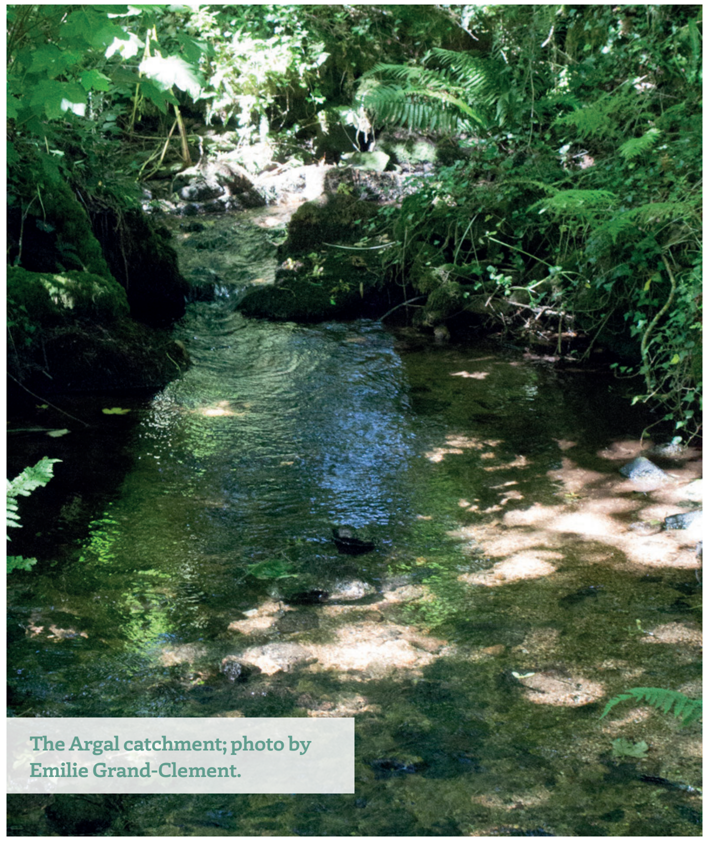
River sites and continuous data: the use of rainfall events to understand change

Investigation of water quality changes at river sites was mostly based on continuous data routinely collected by SWW as a regulatory requirement for their water treatment operation. Across all sites, results highlighted the need for an essential step of critical examination of the quality of the data prior to any analysis. A number of automated and manual data cleaning stages enabled us to identify and effectively remove sensor drift, erroneous data and other sensor issues that may have otherwise biased the conclusions that could be drawn. The quality control approach that we have developed can now be applied to other water quality data collected and across new catchments.

Differences between types of flow in rivers highlighted water quality changes at low flow in certain conditions. For instance, in the River Fowey, turbidity (indicative of suspended sediment levels) at low flow decreased significantly from an annual mean of 5.2 NTU in 2012-2013 to 3.9 NTU in 2017-2018. Although low flow conditions are usually not the main contributor to contaminants in rivers, such change is encouraging for catchment management initiatives, as it shows that interventions can deliver good water quality, wherein sediment pollution is not an issue.

The use of hysteresis loops to study the behaviour of pollutant concentrations in relation to flow during rainfall events has also proven to be an invaluable tool to gain some understanding of the potential origin of pollution at different times. For example, the difference in the direction of hysteresis loops of Soluble Reactive Phosphorus during two distinct rainfall events at Upper Tamar Lake suggest the contribution of two different sources of pollutants.

Finally, seasonal variation has been observed in a number of parameters across multiple catchments, such as the Lower Exe or the Cober. This stresses the importance of considering natural variability in data analysis. Without doing so, the impact of Upstream Thinking approaches might either not be quantified, or might be overstated.



The Argal catchment; photo by Emilie Grand-Clement.

Contamination of water with pesticides and herbicides

The use of passive sampling to monitor acid herbicides and pesticides, such as metaldehyde or mecoprop, has given a good understanding of the extent of pesticide issues in each catchment. Because of the nature of the sampling (i.e. passive samplers deployed over a 6 week period in the spring and 6 week period in the autumn) and the variability in the timing of pesticide usage between years (dependent on weather conditions and crop growth), it is difficult to identify clear change precisely over the course of the Upstream Thinking programme. It was reassuring to observe that, during the monitoring period, the majority of the catchments experienced low concentrations, which are below the target threshold; high concentrations (> 100 ng L^{-1} per compound) were, however, detected in the Cober, Exe and the Tamar catchments. In addition, the use of 'Time Weighted averages' to measure concentrations might also hide the occurrence of short-lived peaks. Therefore, the overall benefit of this work has been in the identification of the compounds detected. Differences between locations within each catchment might also help pinpoint specific issues and help partners address herbicide and pesticide issues, leading to optimal interventions in the next phase of the project.

Predicting change in water quality

Overall, both the SimplyP and SPARROW models have estimated marginal water quality improvement as a result of in-catchment interventions. These results are, to some extent, in agreement with the water quality monitoring conclusions that we drew. There are, however, a number of caveats associated with this modelling work that may have contributed to these low values. First, the difficulty in identifying and classifying interventions in a fixed structure and terminology using the Farmscoper software means that not all interventions could be used in the modelling, thereby leading to a likely underestimation of the coverage, and, in turn, on the modelled water quality changes that might be delivered. A number of interventions also focused on biodiversity improvements, with limited quantifiable impact on water quality, even if this might have occurred. This might have affected certain catchments more than others. In addition, the interventions used to tackle specific on-farm issues might not address parameters included in the modelling.

Extent of the impact of catchment management on water quality

The change in water quality presented in this report is modest. This could be partly due to a number of factors that need highlighting. The duration of the monitoring on the ground by the University of Exeter covered approximately 3.5 years, which is a relatively short amount of time. Additionally, the interventions were not implemented at the same time in all catchments. For instance, they started in 2010 in Upper Tamar, but only in 2016 in the Argal catchment. For these latter catchments, the measured water quality might therefore be more a snapshot of the current situation rather than the result of recent land management change. Upstream Thinking is also only one of the funding streams available for catchment management, which means that the overall extent of the work in each catchment might be larger than what has been quantified in this study and vary between locations. However, this could not be captured within the scope of this study. Finally, no control catchment could be used, as there are no similar catchments (i.e. land use and climate) where no interventions were taking place through any other funding streams that water quality could be compared to.

As improvement in water quality due to Upstream Thinking is generally slow to be noticed, the small changes monitored and predicted across the region highlight the need for cumulative interventions and high coverage within each catchment, and make the case for sustained efforts and continued funding for this work.

CONCLUDING REMARKS AND FUTURE RESEARCH

Future work: 2020-2025 and beyond

The success of Upstream Thinking in working with project partners to invest in improving water quality and environmental conditions has led to the continuation of the project, now into its third phase. The ambitious new phase over the 2020-2025 period aims to deliver 50,000 ha of interventions in a total of 15 catchments. In addition to improving raw water quality, the project also focuses on promoting landscape restoration and ensuring the long-term resilience of water supply under changing climates. Looking forward, this new phase will be matched by a new monitoring programme that will continue to investigate the impact of in-catchment interventions on water quality and improve the current way of working. Additionally, the results presented here have led to the identification of other avenues to explore, as explained below.

Improved recording of intervention mapping

As presented in the work here, quantification of interventions required their re-classification into the specific Farmscoper software mitigation measures. Due to the wide range of options available and the different definitions used by project partners this proved challenging. To address this and to develop a more unified method moving forward, a change in practice has been developed across the project for the next phase of Upstream Thinking (2020-2025). Through the NERC-funded SWEEP programme, the **Whole Catchment Water Management project** is working with SWW and the UsT Delivery Partners to develop a new on-line spatial recording tool and associated methodology for recording and reporting the location and extent of interventions within catchments. The tool will provide a unique and unified method for all partners to record their activities and provide integrated, spatially explicit data on interventions that will facilitate efficient analysis of their impact on water quality and quantity throughout the next phase of Upstream Thinking, as well as the planning and modelling of the next business plan activities and outcomes (PR24).

Dynamics of reservoir water quality

The bulk of the monitoring work and sample collection in Upstream Thinking 2 has focused on the nutrient inputs to reservoir sites for a number of sites affected by eutrophication and algal blooms. Whilst this approach enabled us to identify changes in the inputs to the reservoir as a result of catchment management, reservoir dynamics ultimately impact on water quality in the water body, and therefore on treatment. In light of the work presented here, increased research on within reservoir dynamics in Southwest England where algal blooms and taste and odour compounds are recurrent issues, is essential to ensure the resilience of the water supply in the region, and will be an important focus of the work carried out in the next phase of Upstream Thinking. This work will also benefit from the addition of a number of catchments in the project.

Emerging contaminants

One of the issues of concern highlighted by the Upstream Thinking programme was herbicide and pesticide detections and usage in catchments. Our work highlights the need for further monitoring of these chemicals and development of this field of research to expand our understanding of a wider breadth of compounds, such as the use of new, emerging contaminants. These compounds are chemicals that have been detected in water bodies, that may cause ecological or human health impact, but that are not yet regulated for and, therefore, do not yet need to be treated out of drinking water. However, as awareness is raised and detection methods improve, it is likely that such compounds will need to be removed during treatment in the future. An understanding of the extent of the problem in the South West would facilitate that step.

Understanding the water treatment process including cost:benefit analyses

One of the concepts behind Upstream Thinking is the idea that investing in catchment management upstream can deliver a number of environmental benefits and improve water quality downstream. Such improvements have the potential to lead to a cost saving for the water industry, as less treatment, energy and chemicals are required to produce drinking water. The few attempts at such estimation[1,2] have highlighted the complexity of such evaluation. This is partly due to the number and variety of parameters to consider (e.g. specific operational factors, uncertainty in quantifying water quality change, regulatory context). We therefore aim to use and build upon our existing knowledge to gain a better understanding of such change in support of cost:benefit analyses of the future Upstream Thinking programmes.

Long-term changes in water quality

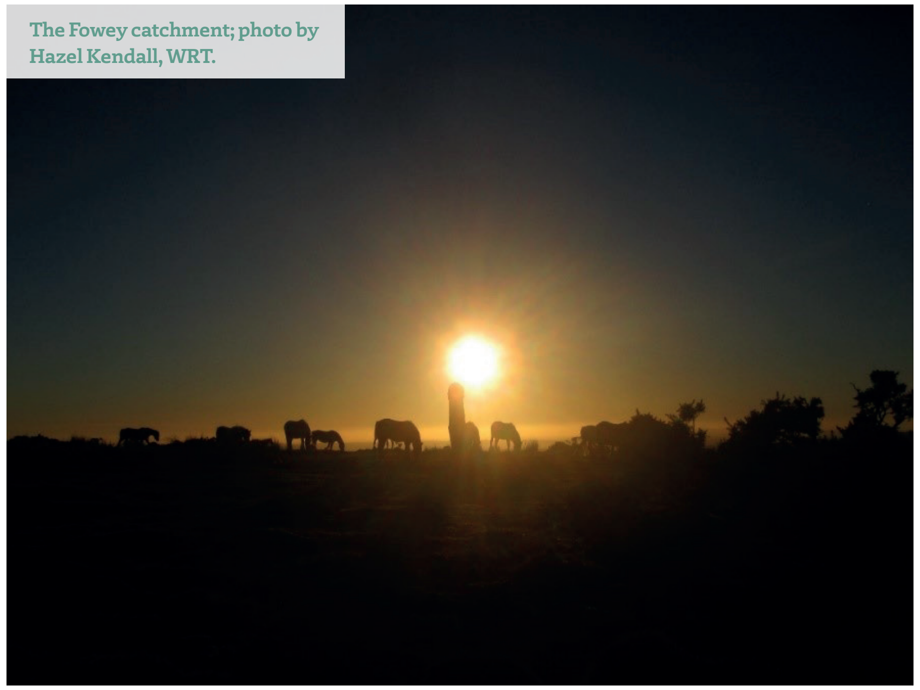
The focus of the project has been to investigate the impact of interventions occurring over a relatively short timescale, i.e. the past 5 years. However, previous research has shown that water quality change may occur at a scale occurring well beyond the scope of the project. For instance, most parameters show a delayed response in their recovery: certain parameters may take decades[3,4], whilst some may get worse initially before getting better[5,6]. Inter-annual variability might also blur the picture, i.e. what is perceived as change might actually reflect the impact of a dry year or of climate change.

The work presented here makes a very strong case for both continuation of interventions to ensure best-practice in the catchment and cumulative benefits, but also for long-term monitoring to identify change at the appropriate timescale. This work will take place in the next phase of the project that will see continued efforts in the current catchments with an additional 5 catchments, and an investigation of the change of a wider number of contaminants delivered through a planned £14.5m of interventions.


Devon sunset; photo by DWT.


A stream in the Argal catchment; photo by Emilie Grand-Clement.


The lower Exe; photo by DWT.


The Fowey catchment; photo by Hazel Kendall, WRT.

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