Strategy to address water pollution in Teign Catchment

James Garling

Introduction

Freshwater pollution is a growing concern in the UK. This study focused on water pollution, specifically the pollutants; phosphates, total dissolved solids and turbidity in the Teign catchment area. The Teign catchment was chosen as an area to study as it's home to many iconic British species, including; kingfishers, otters, Atlantic salmon, herons, cormorants, Brown trout and Sea trout. Atlantic Salmon are experiencing a population decline in the Teign catchment, with egg deposition rates dropping (M, T, 2020). The rapidly growing population in the Teign catchment increased the artificial pressures caused by road use, farming, sewage and mining is another reason the catchment was chosen. Poor water quality within these rivers will directly impact these species. Through the analysis and mapping of the pollutants' potential sources can be inferred, and possible nature-based solutions can be suggested. The Westcountry Rivers Trust provides the data for this report through their Citizen Scientist scheme.

Background information

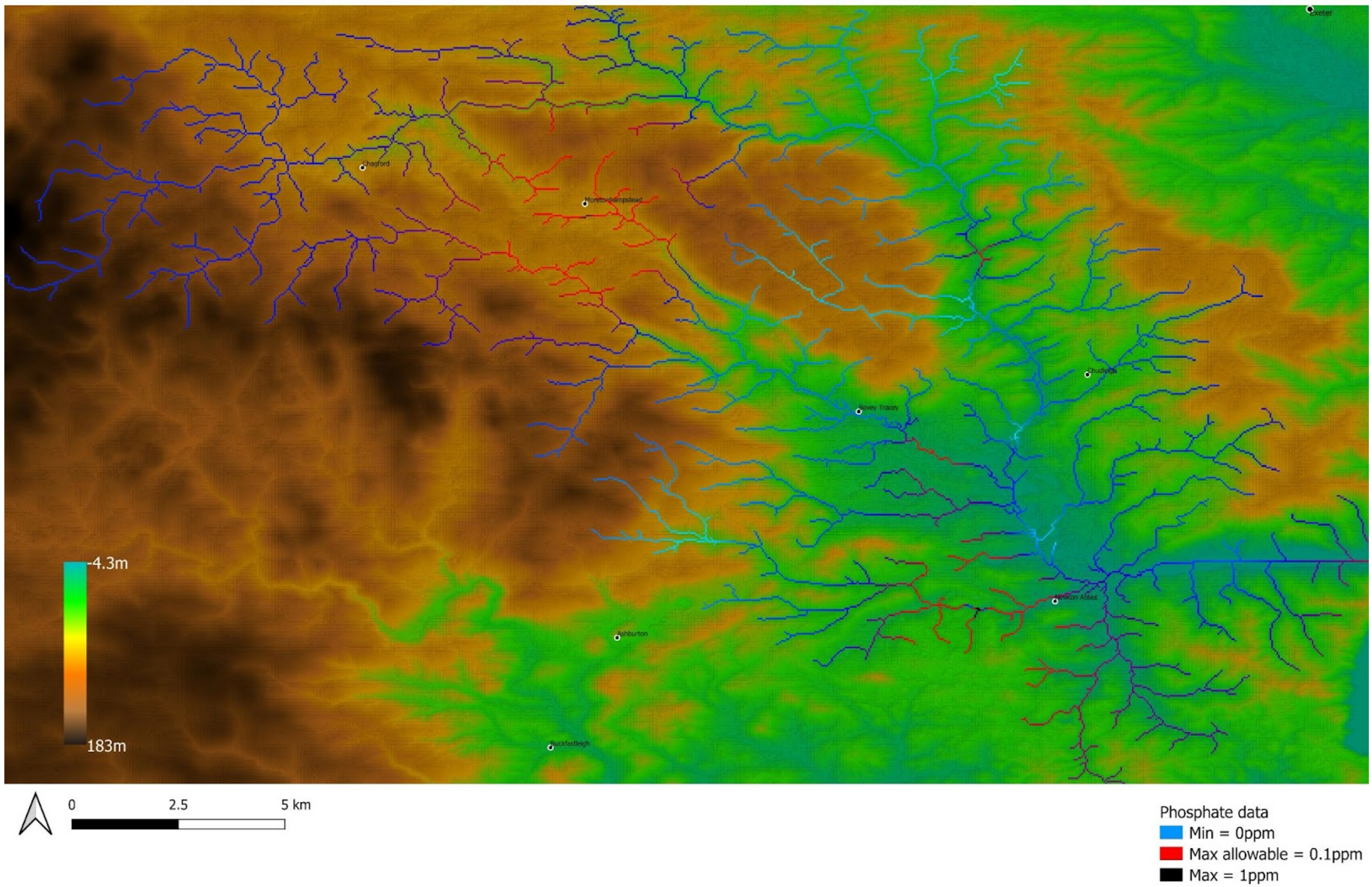
Phosphate is a chemical that contains the mineral phosphorus. Too much phosphate in one area will leave the water with a too high density of nutrients, leading to an algal bloom and eutrophication. Eutrophication will stop light from entering the water, therefore stopping the aquatic plants from photosynthesising, killing the plants and stopping the input of oxygen into the water. The lack of food and oxygen in the water will kill off any life under the water, creating anaerobic dead zones. Dead zones will directly impact the salmon and trout and indirectly affect the otter and all predatory birds who will lose their food sources. The dead zones support parasites that can cause illnesses including cholera, salmonid whirling disease, and malaria(J, 2007). The maximum allowable phosphate is 0.1ppm. (DEFRA, 2014)

Total dissolved solids (TDS) measure all inorganic salts and organic matter present in a water solution. If the TDS becomes too high in the river, it could cause the Brown trout, a freshwater fish, to undergo reverse osmosis hence killing the fish. The Atlantic salmon and Sea trout, both anadromous fish, will not directly kill the fish but will stop them from spawning as both species only spawn in freshwater. With anadromous fish populations in decline and Atlantic salmon populations in decline, it is essential that the spawning of these species is protected. There are no official standards for TDS in freshwater, but after 400ppm, the increase in TDS shows a decreased survivability rate in freshwater fish, so 400ppm is the maximum allowable concentration. (Scannel, Jacobs, 2001)

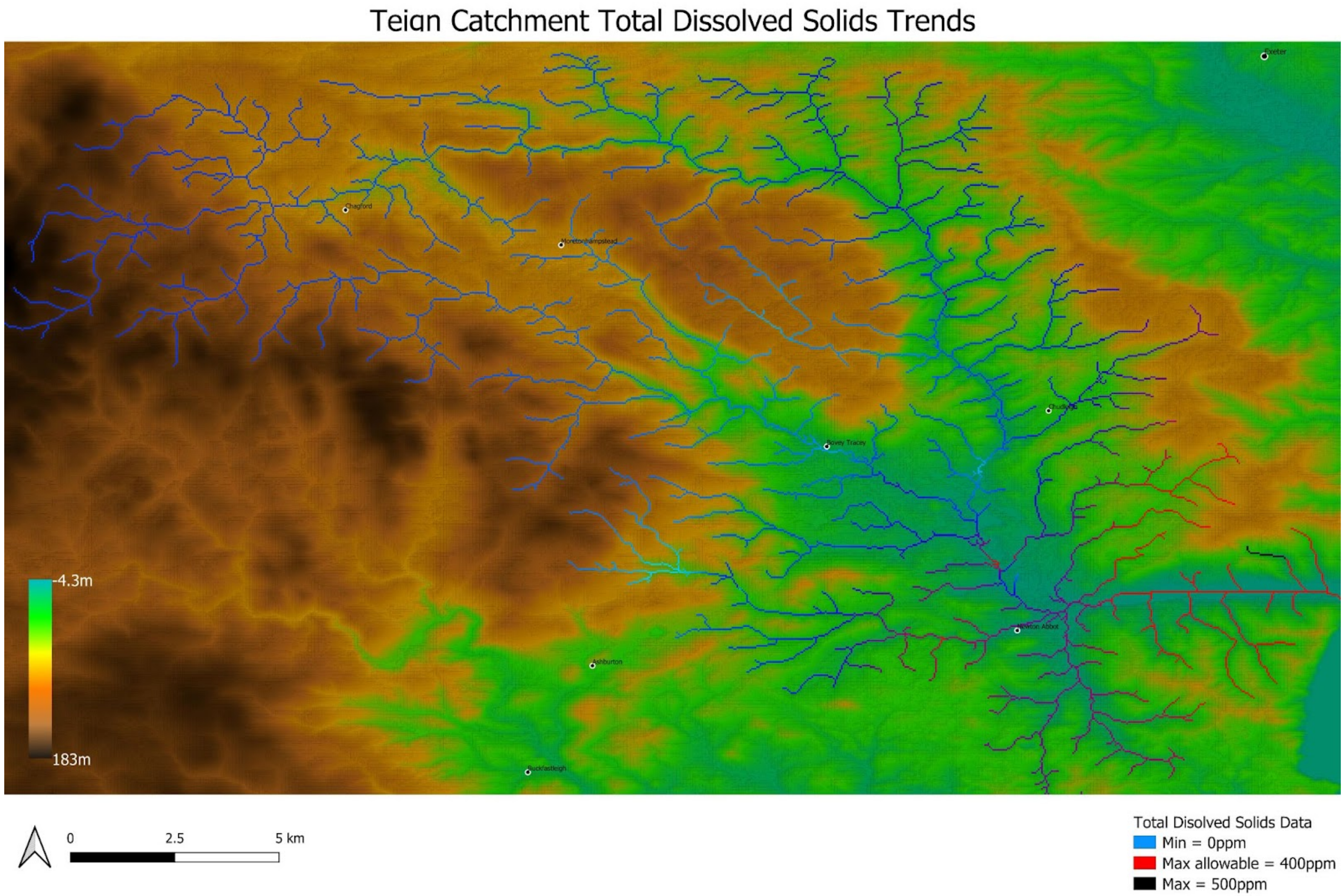
Turbidity is the measure of the cloudiness of the sample. The cloudiness is caused by larger particles being suspended in the solution. This can be caused by ground disturbance or the direct input of larger particles. If turbidity becomes too high, it can limit light from entering the river, causing the same effect as eutrophication. It will restrict visibility for all predatory fish, mammals and birds relying on the river. Highly turbid water can also clog fish gills, stopping respiration and causing them to die. Similar to TDS, there is no official limit. Highly turbid water, defined as between 40-68NTU, caused a significant increase in time taken to forage for food and behaviours associated with stress for smaller fish. (N, P, P, 2021). Therefore, 70 NTU will be used as the max allowable turbidity. NTU stands for Nephelometric Turbidity unit and is used to measure the turbidity of fluids.

The primary sources of pollutants in rivers are agricultural waste and run-off, affecting 40% of water bodies, sewage and wastewater overflow affecting 36% of water bodies and urban run-off affecting 18% of water bodies(Environmental Audit Committee, 2022). The data has been mapped using QGIS. The maps below will be used to infer the pollution sources, which will enable the choice of the best fitting nature-based solutions. The maps are shown below.

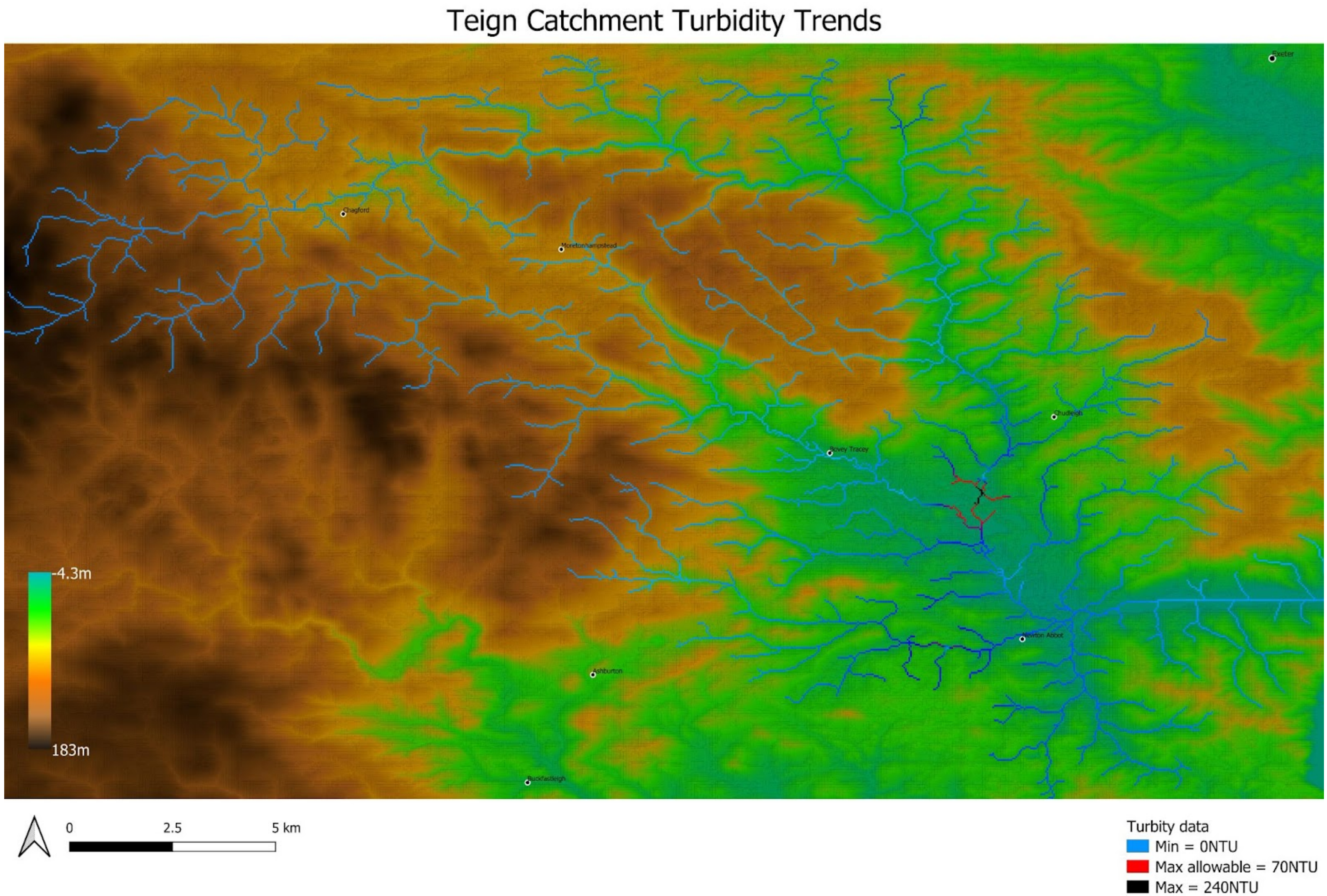
Teign Catchment Phosphate Trends



(Figure 1: showing the river water phosphate concentration trends in the Teign catchment created on QGIS)



(Figure 2: showing the river water TDS concentration trends in the Teign catchment created on QGIS)



(Figure 3: showing the river water Turbidity trends in the Teign catchment created on QGIS)

Inferred pollution sources

It is important to note that none of these suggested pollution sources is a suggestion of any wrongdoing or unlawful act by any company or party involved. Further and regular pollution checks would need to be conducted to confirm a specific source.

The maps above identified any areas with an average pollution level above the set permissible level. To infer the pollution sources, the regions upstream of these high readings were then investigated using Google Earth, Google Maps, Is my river fit to play in? and land use maps. A map showing the highlighted areas is available here: Pollutant map

Potential sources of phosphate

Locations A-C are in the Moretonhampstead area.

Location A is 600m downstream from a Trout fishery. Fisheries can increase phosphate levels in rivers as phosphate input from fish food and faecal matter. As fisheries are within the water body, any excess input phosphate will leach directly into the river.

Location B is 800m downstream from an active farm which could lead to increased phosphate from fertiliser leaching. Location B is also 100m downhill from a graveyard which can lead to increased phosphates due to the decomposition of the deceased (Heath, 2015). It is hard to state with any certainty which is the more significant cause without knowing more about the practices of either potential source.

Location C is after the confluence of the brooks Wadley and Wray which A and B are contained, respectively. Therefore, it is likely that the concentration at C is due to the two upstream concentrations.

Location D is 250m north of Ogwell village. There is a sewage overflow at this location. In 2020 this sewer storm overflow spilt 142 times for a total of 3024 hours. Sewage overflow can lead to an increased phosphate level as human excreta, household detergents and some industrial and trade effluents contain heightened levels of phosphate that would increase phosphate concentrations.

Potential sources of increased TDS

Location D, 250m North of Ogwell village, also has a high TDS(total dissolved solids) average. Sewage overflows can increase TDS as it is an input of material into the river. In addition, faecal matter, household detergents and industrial effluents will all dissolve into the river, increasing the TDS of the river.

Location E is 2.9km south of Chudleigh Knighton. This high reading is 100m from the active quarries. Quarries can input TDS into river systems due to run-off from mined materials. However, due to the quarry having sedimentation ponds (visible on Google Earth), this will likely only occur during heavy rain events.

Location F is the north side of the Teign river estuary. There is heavy road usage in this area. Roads can be a significant contribution to river TDS. When poorly drained, roads can contribute high amounts of often toxic chemical run-off into rivers. Heavy metals in exhaust fumes, breakdown of tires and road tarmac, and other smaller sources like antifreeze and oil drips accumulate over time and can significantly contribute to run-off into rivers. (Greater London Authority, 2019) There is also a golf course upstream on the east of Location F, golf courses can lead to an increased TDS through the use of recycled municipal water used to water the grass (Harivandi, 2004).

Potential sources of increased turbidity

Location G is 700m south of Chudleigh Knighton downstream of quarries. There is an active clay quarry 70m from the stream. Excess material from the quarry could run into the river system, which would increase the concentration of suspended solids in the water and hence increase the water's opacity. Similarly, sedimentation ponds are visible in this quarry, so this would likely occur only during high rainfall events.

Nature-based solutions

Nature-based solutions are actions to protect, sustainably manage, and restore natural or modified ecosystems, address societal challenges effectively and adaptively, and simultaneously provide human well-being and biodiversity benefits. For the context of this report, the solutions to the problems should; Lower the pollution readings, be sustainable, and either have no impact or a positive impact on the ecosystem and biodiversity. The chosen solutions are below.

Comfrey

(Figure 4: comfrey flower image - Image link)

All plants intake phosphate but some intake phosphate from their surroundings faster than others. Comfrey is a plant with a rapid intake of phosphates and nitrates. This is due to mycorrhizal fungi that have a symbiotic relationship with the comfrey plant, which increases uptake, and comfrey is an annual plant which means it will rapidly intake all nutrients to grow fast. Comfrey is a suitable plant for this as it's native, grows very easily in all light levels, has an expansive root spread, and comfortably grows along river banks. To remove the phosphates comfrey must be collected annually, taking the stored phosphates to new locations where it can be used for animal feed or as a very potent natural fertiliser(O, R, K, B, M, M, P, W, 2020).

Fat Hen

(Figure 5: fat hen image -Image link)

Halophytes are plants that can live in high sodium environments. Halophytes with a salt bladder effectively lower TDS by absorption of inorganic salts and sequestering them in the salt bladder. (Lokhande and Suprasanna, 2012). Most halophytes are coastal, and many do not have salt bladders, so few options are available. Fat Hen is a halophyte with a salt bladder; it is the only native halophyte with a salt bladder that can live above the coastal altitude zone (0-20m) inland, making it suitable for this project. It can survive up to 3600m. Similar to the comfrey management, Fat Hen has to be collected annually and either eaten, having a taste similar to that of Chard or can be used as animal feed.

Oak

(Figure 6: Oak tree image -Image link)

The rate of infiltration is the rate at which water can enter a soil. Low infiltration rates in the soil cause high run-off. Run-off is the flow of liquid over the soil, which will carry pollutants directly into the water. The higher a soil's infiltration rate, the less run-off there will be, hence the less water pollution there will be. When wet clay has a very low infiltration rate, evidence has shown that planting trees with dense root distribution will increase soil infiltration rates(X, C, Y, T, L, C, 2020). The common oak tree has a dense root distribution, can grow on steeper inclines and is native to the area, so it is chosen. Reduction of run-off will lower all 3 of the studied pollution measurements. Oak also has mycorrhizal fungi on its roots like comfrey and will also increase phosphate uptake.

Sedimentation pools

(Figure 7: Sediment trap image -Image link)

Turbidity can be lowered via sedimentation. Sedimentation is the process of particles settling in the water. The reduced level of sediment would decrease the opacity of the water. Sedimentation often does not happen in rivers due to the fast water speed and nowhere for the sediment to build up, causing high turbidity. Sedimentation pools trap and slow water on its path to the river allowing sedimentation to occur, removing the larger particles from the water without an energy input.

Both Comfrey and Fat Hen will function best in narrow and shallow waterways like brooks. This is because the smaller waterways like brooks have a greater contact surface area, in contact with the soil, to water volume ratio. Roots will not grow far into the water when soil is present. This means that the roots will spread to a far more significant proportion of the water in a waterway with a high surface area to volume ratio. A greater surface area to volume ratio will also increase the amount of phosphate and salt deposited into the clay soil compared to the quantity in the water body. This deposited phosphate and salt will usually be washed downstream when the stream erodes the clay. Using these plants to uptake the phosphate and sodium will prevent them from being transported downstream.

A map of where best to implement these solutions is shown below. In addition, there is more information on the dimensions and type of solution used at each location available by following the link provided below the map.

(figure 8; Locations and proposed methods of solutions available at; [Nature-based solution implementation])

Viability

Before implementing any of these solutions, multiple requirements must be met. The person or group implementing these will either need to be the landowner or have permission from them to work on the land. As the work is in streams/ ditches, the lead local flood authority will need to be contacted, which in the Teign catchment is the Devon County Council. They would also need to check for each site if any of the following is required; an environmental permit, a licence for felling trees, planning permission, environment impact assessment and consent on a protected site.

Costing this project is difficult as it's unknown who would be carrying out the work as the company's scale or the need to hire workers will vary depending on who implements these. However, for the sake of the project, the planting could be done by volunteers, and the sedimentation pools dug out by a groundwork contractor.

The average price of a sedimentation basin is £13.8 per m^3 (DEFRA, 2007). The required basin size as of Carex's Suggested sediment trap dimensions based on the width and water velocity of the waterway is 15m long, 4.5m wide and 1m deep. Requiring an excavation of 67.5, m^3 costing £931.5. To account for inflation since the 2007 study, this would equate to £1,374.45.

Fat Hen requires a $0.3m^2$ space, Oak requires $5m^2$ space when planting and comfrey requires $1m^2$. Therefore, to cover the area set out in the plan above, the costs incurred would be; £215.73 for the 75,300 fat hen seeds required, £215.59 for the 7,700 comfrey plants required and £420.24 for the 444 40-60cm tall oak tree saplings. In addition, the saplings will need tree guards to protect them from wildlife, costing £141.60 and stakes for keeping them upright, costing £106.56.
This would put the total implementation costs at £2474.17.
Depending on conditions, storm-water ponds should be renovated every 1-10 years (Whatcom BMP, 2009). The comfrey and fat hen will need annual collection but will grow back from the roots. The oak trees can be left alone to grow. Annual collection of plants could be done via volunteer projects.

Efficacy

It is hard to comment on the actual effectiveness of this project without further in-depth tests into how these specific species interact under the specific conditions and concentrations of pollutants in this area. CAREX - Canterbury Water Rehabilitation Experiment has stated that using the suggested dimensions, the sediment trap will capture 50-60% of the sediment in the water, which will lower turbidity. (CAREX, 2020)

Per m^2 comfrey will produce between 0.85g and 3.4g of phosphorus(T, P, D, K, O, U, O, 1992); given the area covered in this project, this would equate to 26.18kg-104.72kg of phosphorus removed annually between March and October.
There is no current data on fat hen salt yield or their percentage proportion of salt, so it is impossible to calculate how much will be removed. Therefore, I can only use prior studies to state that Halophytes are the species that can be used to desalinate and restore saline soils and withstand highly saline water irrigation (Lokhande and Suprasanna, 2012). However, this will only occur between March and December when the plants grow.
Similarly, there is no data on the uptake of minerals by Oak trees, so I will not comment on this. The infiltration rate increase has been researched. The closer the infiltration measurement is taken to a tree, the greater the infiltration rate in clay. The soil showed a 75.87% increase in infiltration from 10cm to 2m away from the tree. (R, L, R, B, 2022)
Risks - one risk of this project is the proliferation of the Comfrey or Fat Hen, as they are both hardy weed species and will grow very well in these areas. During the annual collection of these plants, it is likely the vast majority of seeds will be removed, thus mitigating this risk.

Limitations

This project has a few limitations that are important to mention briefly.
- The pollution data provided by WRT has a location sample size of 1-9 per location; this size makes it hard to remove outliers and reduces the repeatability of the data.
- Is my river fit to play in? data is from 2020, not 2021, meaning the same patterns had to be assumed.
- The flow direction and velocity were not included when mapping the pollution, which may have given some more precise results.
- Only Oak trees were planted to simplify the viability assessment and due to the added benefit of mycorrhizal presence. Trees with extensive dense root systems could also be used in combination with Oak similarly increasing infiltration. This would include; Elm, Poplar and Willow trees.

- Location D has an inferred source of sewage overflow. Due to the low contact time and being on the river bank with a smaller surface area to volume ratio than brooks, Fat Hen and Comfrey may not have the desired impact on the phosphate and TDS. In this instance, stopping at the source is required. Based on the frequency and total duration of overflow at this sewage overflow, it is very likely that increasing the capacity of the wastewater system to keep up with the new usage demand is required and would remedy the situation.
- Location F is within the Coombe Valley Nature Reserve, managed by the Teignbridge District Council rangers. As the area is a nature reserve, it is potentially unlikely that the planting of Fat Hen would be authorised as it may impact the ecosystem there. If that were the case, the pollution would need to be stopped at the source. Sources are inferred and not confirmed. Once the source is known, planting native trees with expansive dense root distributions would aid the situation by increasing infiltration rates and stopping the solids from reaching the Bitton Brook.

Furthering the project

There are many ways to further the project.

- More data sampled within the catchment and at different locations would allow for more precise and in-depth mapping.
- Direct assessment and regular monitoring of any of the inferred sources would help confirm if there is any fault. This would allow for better evaluation of what nature-based solutions to implement and discussion of better management practices to stop the pollution at the source.
- Further research on the efficacy of nature-based solutions and their actual intake is required.
- Producing a pollution mixing model of this data would be helpful to create a clearer view of the pollutants in the catchment. A mixing model is a model of the predicted spread of matter (pollution) in water-based on pollutant concentrations and velocity.
- This exact methodology could be repeated for any catchments or pollutants to infer sources and identify ways of managing that pollutant.

What you can do to help

If this report compels you to help, these links below are provided.

How to report pollution incidents, River Teign Restoration Project, Westcountry CSI, Get involved with Surfers Against Sewage, Campaign for local swimming spots to get bathing water status. If you can further this project through the means discussed above or if you're a landowner in these areas, think about implementing some of the suggested solutions.

Some papers and documentaries are listed below for further information on this topic.

https://rivercide.tv/, BBC iPlayer - Panorama - The River Pollution Scandal, Ethical Consumer, South West Water EPA data report 2020 - GOV.UK, Water quality in rivers - Environmental Audit Committee.

By mentioning how you can help, I am not trying to place any blame for these pollutants on the reader. Instead, it is likely a combined effect of individuals and companies causing these pollutants.

I also wanted to mention that whilst it's hard to know one company's impact without extensive research, the impact of South West Water sewage overflows was under discussion in this report. For example, there were 5193 total spills in the Teign catchment area with a total annual duration of 53,000hrs. This equates to having 6 overflows constantly going into the catchment at one time. (Is my river fit to play in?)

In the water and sewerage companies in England environmental performance report, Southwest water was the worst performing in England for both sewage pollution incidents and serious sewerage pollution incidents (EPA, 2020). This impact on the environment cannot be ignored and needs to be further researched.

Closing statements

Thank you for reading. Whilst this project is not the end of the process of remedying these pollutants, I hope it can act as a platform for further research, data collection and moving towards the use of nature-based solutions. This report is a shortened version of my full project written for my dissertation. If you have any questions or would like to send me any additional information concerning this, feel free to contact me at JamesWateryProject@gmail.com.

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