Upstream Thinking: Catchment Investigations

Littlehempston Water Treatment Works

Group 2 – March 2013

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The Westcountry Rivers Trust is an environmental charity (Charity no. 1135007, Company no. 06545646) established in 1995 to secure the preservation, protection, development and improvement of the rivers, streams, watercourses and water impoundments in the Westcountry and to advance the education of the public in the management of water.

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1. Introduction

1.1. SWW PR09 NEP Catchment Investigations (CIs)

In 2014 South West Water will undertake another strategic Periodic Review (PR14) of their water pricing and investment programme. As part of this new strategic plan they would like to see a second phase of investment as part of the Upstream Thinking initiative, but in order to secure this they need to evaluate the condition of a further 17 water supply catchments that may be targeted as part of the new programme.

South West Water has engaged the Westcountry Rivers Trust to undertake all 17 of South West Water's National Environment Programme (NEP) Catchment Investigations between 2011 and 2013. The objective of these investigations is to provide SWW with detailed pollution risk assessment and source apportionment evidence to inform any potential future catchment management projects that are designed to achieve water quality improvements.

The Catchment Investigations will also provide, for each catchment, a targeted and fully costed catchment intervention strategy designed to achieve the most significant improvements in water quality using the most cost-effective and resource-efficient approach.

1.1.1. CI Study Catchments

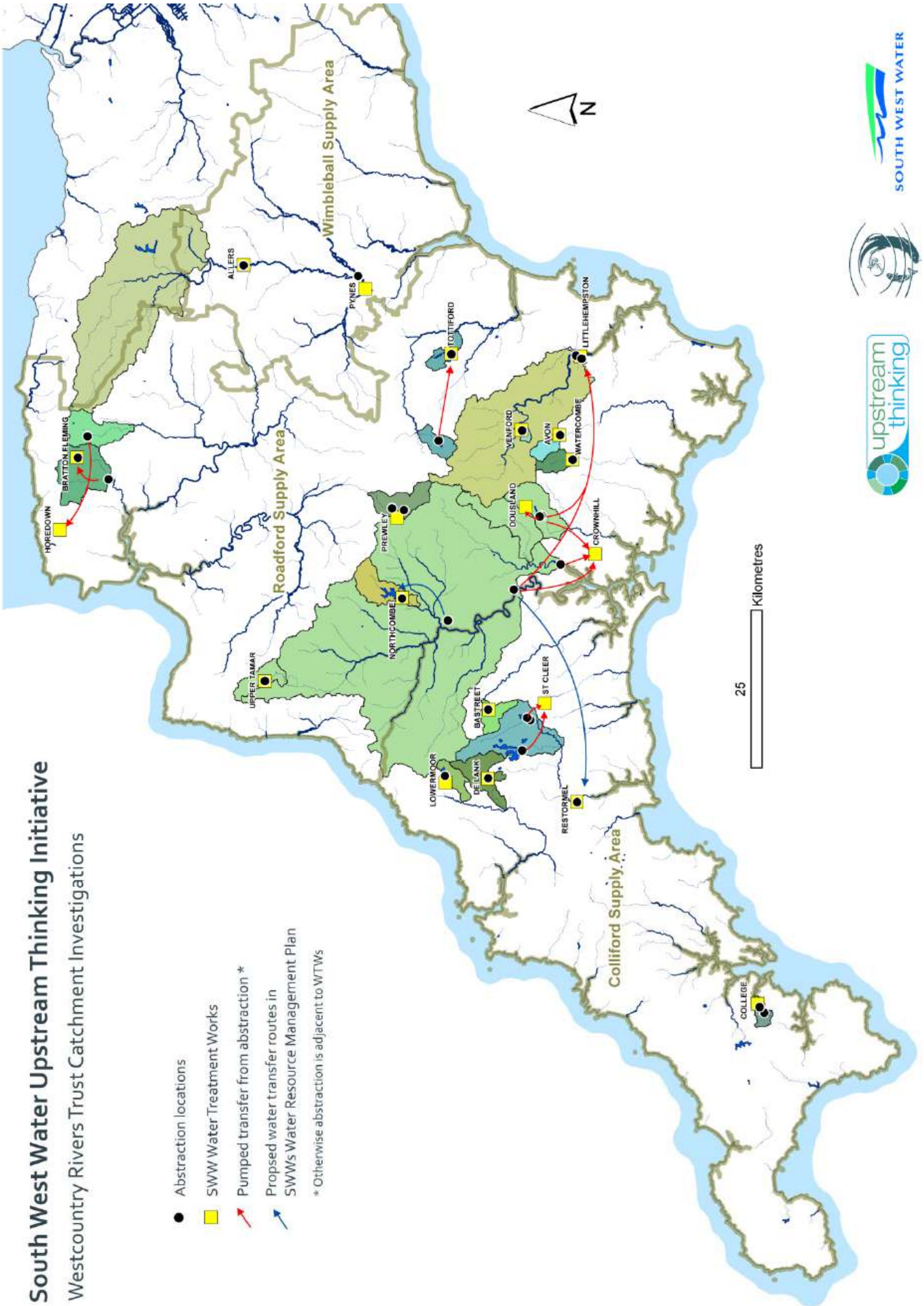
The study catchments for this programme of investigations are listed below (Table 1) and approximately delineated in Figure 1.

In a number of catchments the final raw water used at a particular Water Treatment Works is a blend of water derived from a number of different sources. As a result, the catchment delineated for a works can extend across a number of different river catchments and there can be considerable overlap between them where raw water sources are shared.

Table 1. The 17 Water Treatment Works (WTWs) catchments to be assessed as part of the South West Water National Environment Programme (NEP) Catchment Investigations between 2011 and 2013. * *It should be noted that Watercombe WTWs has now closed and that the raw water intake now supplies Littlehempston via the South Devon Spine Main*

Group I	Group II	Group III
Crownhill	**Littlehempston**	Avon
Tottiford	St Cleer	Dousland
Bratton Fleming	Bastreet	Prewley
College	De Lank	Watercombe*
Allers	Lowermoor	Venford
Northcombe	Horedown	

Figure 1. (Following page). Map delineating the 17 study catchments for the SWW NEP Catchment Investigations. The map shows the locations of the various Water Treatment Works (WTWs), the principle abstraction locations used to obtain raw water for each works and where water transfer is undertaken form one source or catchment to another.


South West Water Upstream Thinking Initiative
Westcountry Rivers Trust Catchment Investigations
Abstraction locations
SWW Water Treatment Works
Pumped transfer from abstraction *
Propsed water transfer routes in SWWs Water Resource Management Plan
* Otherwise abstraction is adjacent to WTWs
Wimbleball Supply Area
Roadford Supply Area
Colliford Supply Area
HOREDOWN
BRATTON FLEMING
ALLERS
PYNES
TOTTIFORD
LITTLEHEMPSTON
VENFORD
AVON
WATERCOMBE
DOUSLAND
CROWNHILL
PREWLEY
NORTHCOMBE
UPPER TAMAR
ST CLEER
BASTREET
LOWERMOOR
DE LANK
RESTORMEL
COLLEGE
N
25
Kilometres
upstream thinking
SOUTH WEST WATER

2. Methodology

In order to deliver the NEP Catchment Investigations we have developed a scalable methodology that can be adapted to meet the specific requirements of each study catchment. Every study catchment has been subjected to a core suite of investigation and planning approaches, which have been tailored to the catchment according to its size and the challenges faced at the WTWs.

2.1. Water treatment works overview

A full characterisation of the processes adopted at the WTW has been undertaken. The various sources and methods used to derive the combined raw water presented to the treatment process have been examined in detail and the effect that pressure on the different sources at certain times has on the contribution of each source to the final raw water has also been characterised.

2.2. Pollutant source apportionment

In order to develop tailored and targeted catchment management interventions, we have, through the integration of data and modelling outputs with targeted field survey methods, developed a programme of catchment investigations to diagnose the causes and sources of the degraded raw water quality challenges experienced at the WTWs.

2.2.1. Pollution risk modelling

We have adopted a variety of approaches to model landuse- and other human-derived pollution risks across each of the study catchments. These approaches include the use of the SCIMAP fine sediment erosion risk model, the spatial modelling of consented and un-consented sewage discharges, the development of a pesticide risk modelling method based on the i-MAP WATER tool, and the analysis of the PSYCHIC phosphate load risk assessment model (Davison et al., 2008).

The outputs of these models have been combined with additional spatial data and evidence to pinpoint the highest risk areas for each pollutant in each catchment or sub-catchment.

2.2.2. Monitoring data review

Having assessed pollution risk across each catchment, they have then been subjected to a comprehensive historical and spatial evidence review encompassing data collated from SWW, the Environment Agency and a variety of additional 3rd party sources. This review of the evidence has, where suitable data exists been used to examine the actual pollutant loads contributed by various sections of the catchment.

2.2.3. Water quality monitoring programme

Where deemed to be useful we have undertaken supplementary monitoring. We have developed a flexible and scalable water quality monitoring programme that can be adjusted depending on the geographic scale of the study catchment and, in some catchments, a targeted invertebrate monitoring programme has also been undertaken. Invertebrate assemblages can be used to examine the levels of pollution to which a river is being subjected (e.g. two newly developed invertebrate indices allow the sediment and pesticide load in a river to be examined).

2.2.4. Catchment walkover surveys & pollution risk assessments

In each study catchment a series of targeted farm visits have been undertaken to identify activities or issues that are contributing to the pollution load in the river or which represent a significant risk of pollution.

In sections of the catchment that have been identified through source apportionment monitoring or risk assessment modelling approaches to represent areas of elevated risk, and which are therefore thought to be making significant contributions to the pollutant load at the outflow of the catchment, we have attempted to assess the impacts of all of the farming practice being undertaken.

Furthermore, where potential threats to the water quality in the catchment have been recorded, the potential interventions and behavioural changes have then also been identified that could be implemented to mitigate the risks of pollution posed. Estimates have also been made of what the delivery of these interventions would cost, and the potential savings that the land-manager or farmer would realise as a result of implementing them.

2.2.5. Fluvial walkover surveys

In sections of the catchment that have been identified through source apportionment monitoring or risk assessment modelling approaches to represent areas of elevated risk, we have also undertaken riparian corridor walkover surveys to examine the structural condition of key sections the river and to identify potential diffuse or point source pollution problems that may be contributing sediment, phosphate or organic pollution downstream. These surveys have also allowed us to identify locations where diffuse and point source pollution may be having a deleterious impact on the ecological condition of the river.

2.3. Intervention strategy development

2.3.1. Assessment of current mitigation measures in the catchment

Before a full catchment management plan can be developed it is necessary to have a clear understanding of what mitigation measures have already been put in place or are in the process of being implemented. We have therefore attempted to summarise the previous and on-going approaches adopted in each catchment to mitigate the risks and impacts of pollution derived from a variety of sources. The measures assessed include the presence of naturally occurring mitigation in the landscape, the protection of the landscape through the designation of protected areas, the uptake of Countryside/Environmental Stewardship schemes, interventions delivered through Catchment Sensitive Farming and any other environmental work being done in the catchment.

2.3.2. Proposal for delivery of future intervention

Based on all of our findings, we have, for each study catchment, developed a detailed and fully costed intervention strategy, which we believe could remediate the problems found and mitigate the risk to raw water quality at the point of abstraction. These plans will outline which areas and activities represent the greatest pollution risk in the catchment and what interventions and resource allocation would be required to mitigate those risks.

2.4. Assessment of potential outcomes

It is vital that we collect sufficient evidence to provide an objective and scientifically robust assessment of the effectiveness of our interventions. Ultimately, we must be able to justify that the money we have spent and the interventions we have made across the landscape have either delivered significant improvements in raw water quality (and have therefore made significant contributions to the delivery of good ecological status of river catchments) and have generated significant secondary financial, ecological and social benefits.

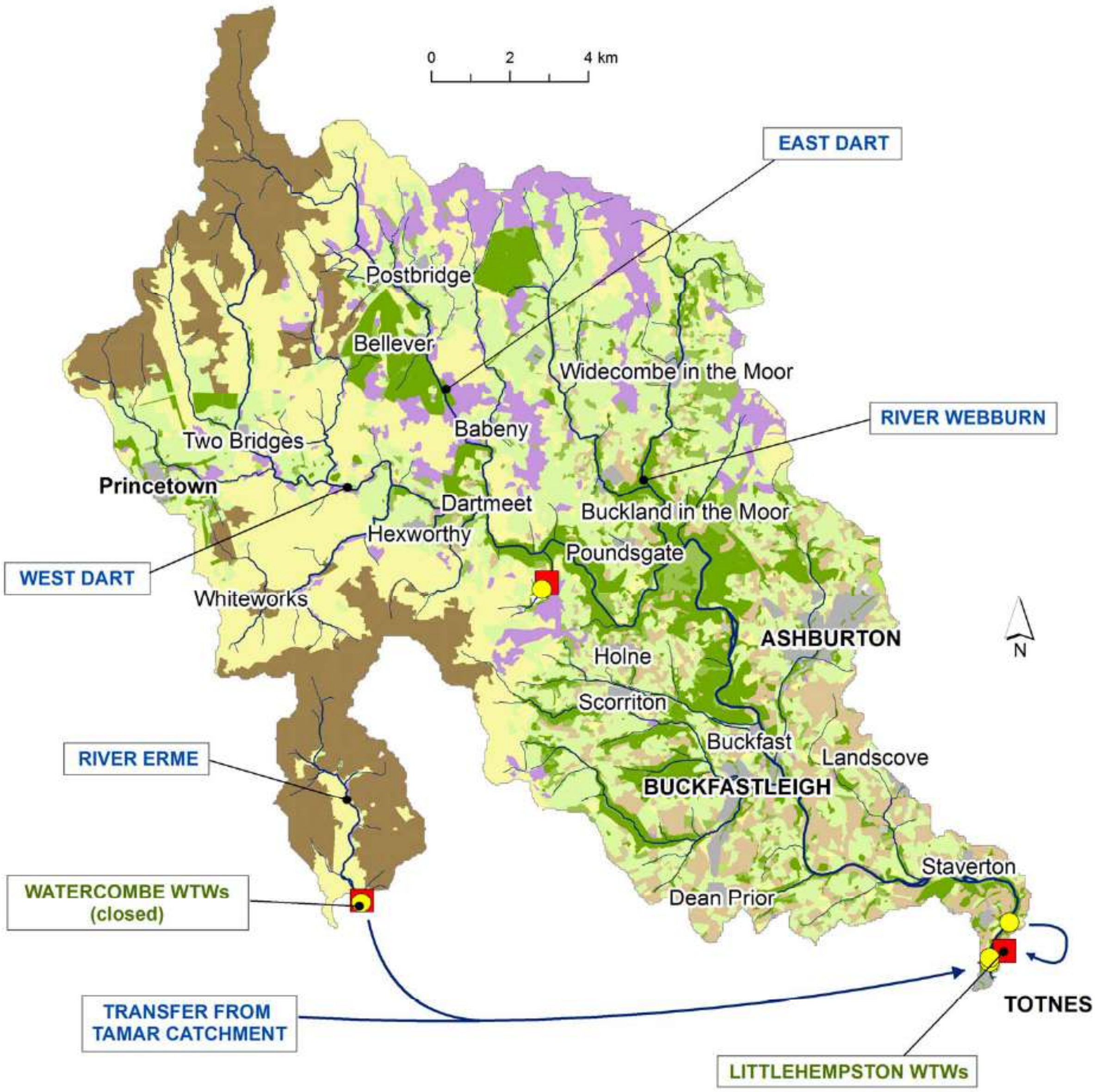
3. WTW overview

3.1. Raw water sources & catchment areas

The water treatment works at Littlehempston WTW treats around 35-65 Ml of water a day (up to a maximum of 84 Ml/day) for supply to the towns of South Devon including Totnes, Torbay, Kingsbridge, Newton Abbot and Teignmouth. There are nine concessionary supplies in the catchment and, while there is no major industry in the Littlehempston supply area, there are a number of small cottage industries including yarn spinning, wine manufacturing and a number of farm industries. The predominant industries for the area are tourism and farming: the Littlehempston supply area in South Devon is a major tourist destination, which generates significant increases in the demand for water during the tourist seasons.

Raw water for the Littlehempston WTW is served by 6 separate sources (see Figure 2): three are from within the River Dart catchment (River Dart, Dart Boreholes and Rannies Groundwater) and three are in other catchments (Burrator Reservoir and the River Tamar via the Roborough Tank and the Watercombe abstraction on the River Erme – both via the South Devon Spine Main).

Figure 2: The Littlehempston WTW catchment showing abstraction locations and the pumped movement of water.



The main Littlehempston WTW catchment lies largely within the boundary of Dartmoor National Park and is essentially comprised of the River Dart catchment above the town of Totnes, including the three main tributaries of the Dart: the River Webburn, the East Dart and the West Dart.

The upper reaches of the Dart catchment are dominated by the moorland of Dartmoor and, while the lower reaches of the Dart catchment are a largely rural landscape, they do contain the towns of Buckfastleigh and Ashburton and a 10km stretch of the A38 trunk road (see examples in Figure 3).

Figure 3: Photographs showing the general form of the Littlehempston WTWs catchment. The typical land-cover on the open moorland of the upper catchment (top left), the meeting of West and East Dart at Dartmeet (top right), a typical landscape found in the south of the catchment (middle) and the A38 as it runs through the catchment (bottom).

3.2. Raw water quality: challenges, risks & cost implications

In order to assess the challenges faced by South West Water as they attempt to treat raw water derived from the variety of different sources at the Littlehempston WTWs, it was first necessary to characterise the quality of the raw water obtained from each source and examine the effect that its use has on the final combined raw water.

This was particularly difficult in Littlehempston, due to the number of sources contributing to the combined water and the fact that the Littlehempston catchment has no significant water storage capacity in the form of a strategic impounding reservoir.

Through detailed discussions with South West Water scientists and subsequent examination of the water quality data for each of the raw water sources, it has been possible to characterise the challenges faced by SWW when attempting to treat drinking water at Littlehempston WTWs. We have also, where data is available, attempted to identify any significant trends in the raw quality from each of the sources. Data analysed was collected by South West Water and/or the Environment Agency between 2006 and 2012, although at many sampling locations data was only available for part of this time.

The Drinking Water Safety Plan risk assessment for Littlehempston WTWs was last updated in September 2009 and identified the following as the most significant risks; ***bacteria***, ***cryptosporidium*** and ***pesticides***.

The waterbody around the Littlehempston abstraction has been classified as a Drinking Water Protected Area under Article 7 of the WFD in which the following parameters were specified as 'high priority' for action; ***Atrazine***, ***Diazinon***, ***Dichlobenil***, ***Isoproturon***, ***MCPA***, ***MCPB***, ***Propetamphos*** and ***Sulcofuron*** (notably all pesticides).

The Drinking Water Safety Plan risk assessment for the Watercombe raw water abstraction on the River Erme was last updated in September 2009 and identified the following as the most significant risks; ***cryptosporidium***, ***biological wastes***, ***bacteria*** and ***pesticides***.

•

It should be noted that the quality of the raw water brought into Littlehempston WTWs from the Tamar catchment through the South Devon Spine Main has already been the subject of an extensive study as part of the Crownhill WTWs Catchment Investigation undertaken in 2012.

The potential threat that this raw water poses to the treatment processes at Littlehempston WTWs will be considered in this study, but the main focus has been to assess the risk from the sources within the River Dart catchment and above the Watercombe abstraction on the River Erme.

4. Catchment overview

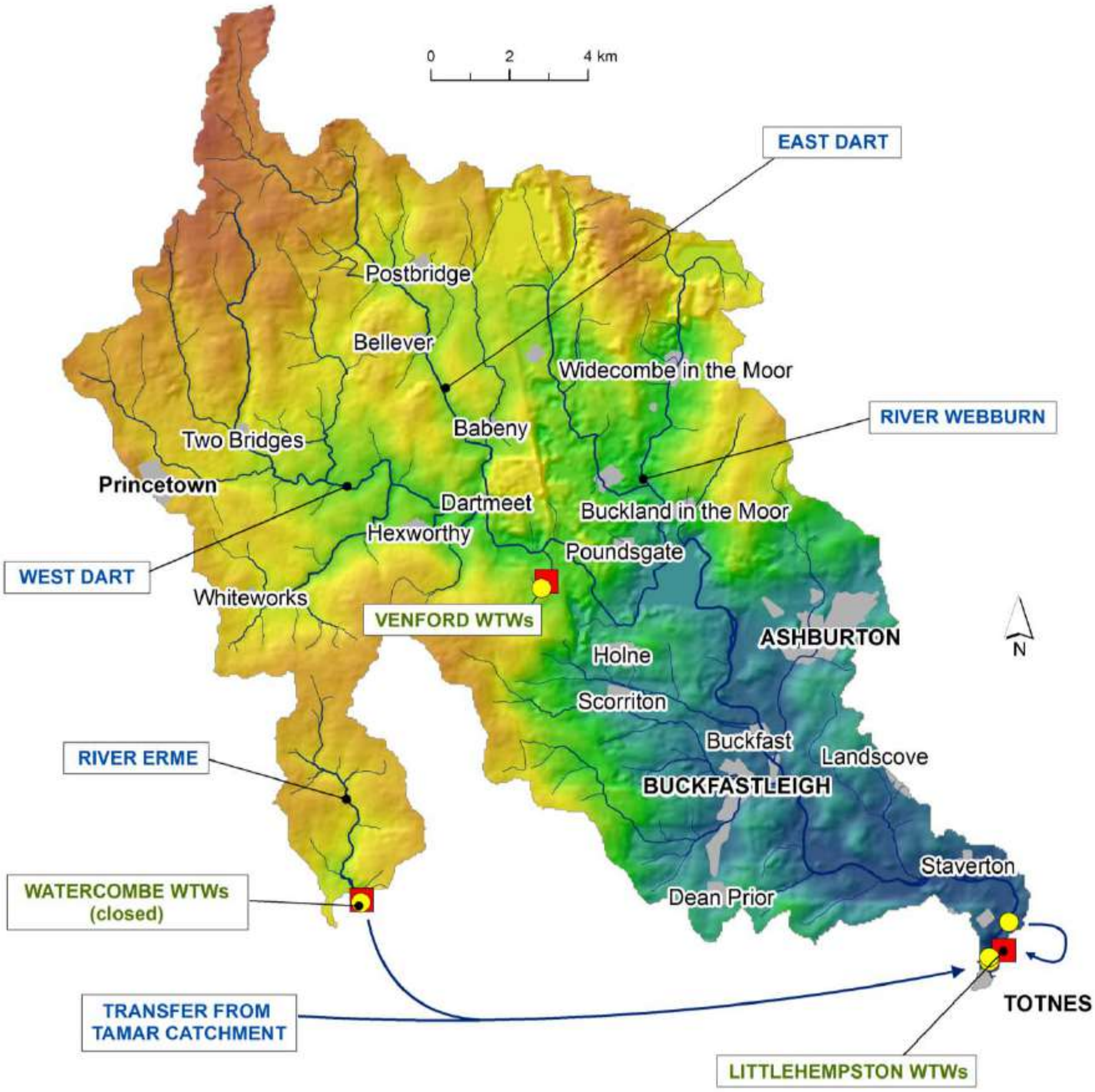
4.1. Morphology & hydrology

The Littlehempston WTWs catchment covers around 28,700 Ha of the Dart catchment plus 1,450 Ha above the Watercombe abstraction on the River Erme. In the headwaters of the Dart the two main tributaries, the East and West Dart, join at Dartmeet to form the main river, which meets the River Webburn around 8km further downstream.

The headwaters of these streams rise at an altitude of approximately 540m in open moorland before descending rapidly into steep wooded valleys, the lower reaches of the River Dart consist of low lying undulating land which is primarily used for a mixture of arable and lowland grazing agriculture.

According to data from the National Soil Resources Institute (NSRI, Cranfield University) the very upper areas of the Dart catchment are almost entirely covered in 'very acid loamy upland soils with a wet peaty surface' and some areas of 'slowly permeable wet very acid upland soils with a peaty surface' in the western headwaters. However, the majority of the central catchment area is 'freely draining acid loamy soils over rock (granite)' giving way to 'freely draining slightly acid loamy soils' in the lower reaches around the A38 and down to Totnes.

Figure 4: Morphology of the Littlehempston catchment showing key hydrological features and abstraction locations.



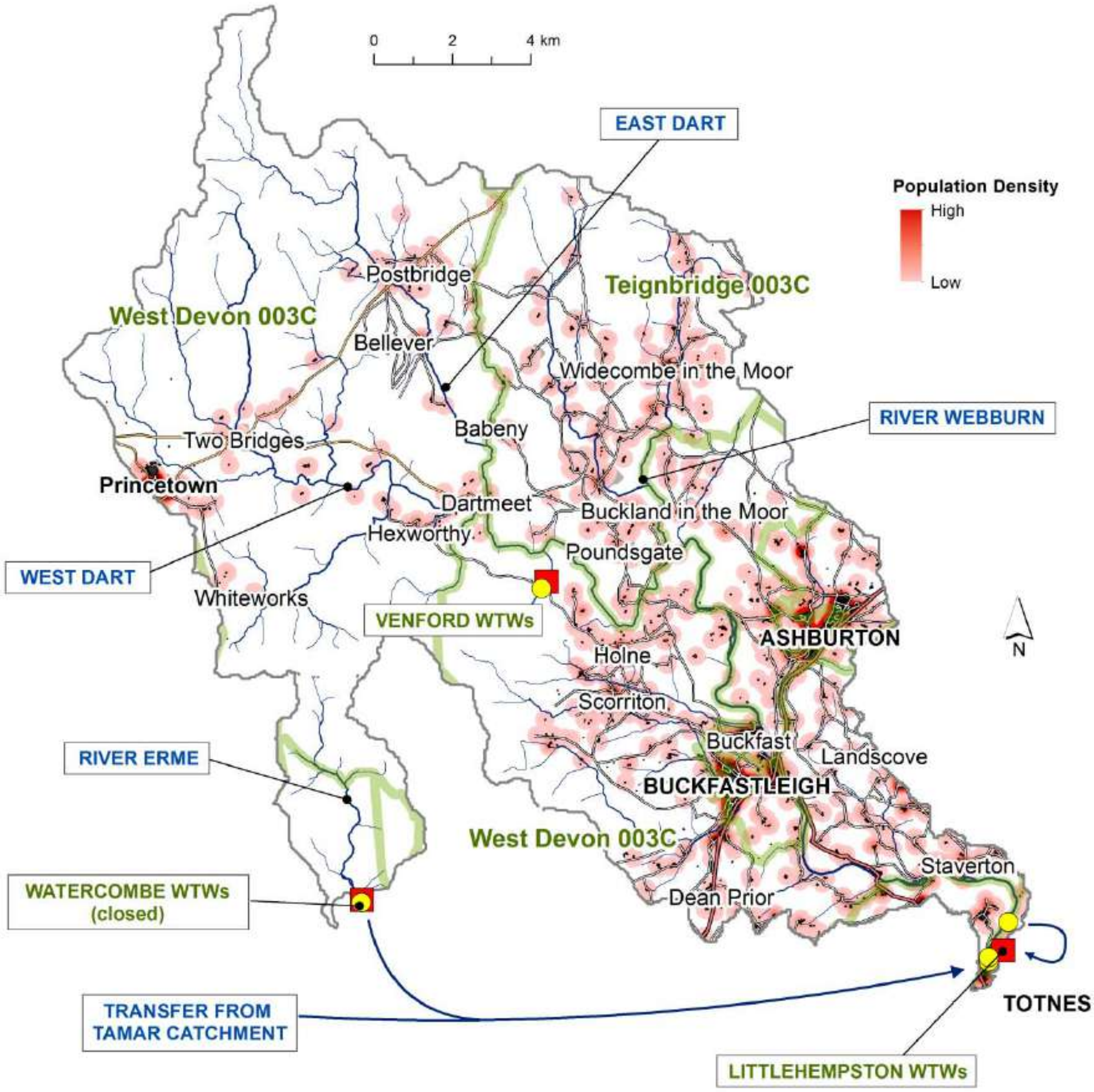
There are approximately 646 km of watercourses in the Littlehempston WTWs catchment (25 km of these are in the Watercombe catchment) and data from the Environment Agency hydrometric gauging station at Austin's Bridge at Buckfastleigh reveal that the average daily discharge from the river is 12 cumecs (~1,000 Ml/day) and that the flow exceeds this 30% of the time and is below this level 70% of the time.

When flow at Austin's Bridge is 0.789 cumecs (68 Ml/day) or less, not more than 9 Ml/day can be abstracted and alternative sources must be used. When river flow at Austin's Bridge rises above 0.789 cumecs, for each unit increase in flow above this figure a like unit may be abstracted, up to a maximum of 27.28 Ml. This permitted abstraction volume can constitute as much as 30% of total flow in the river during periods of low flow.

4.2. Social & economic

The 287 km^2 Littlehempston catchment itself has a population of approximately 12,557 (at an average density of 2.4/km2) (see Figure 5). There are no properties in the Watercombe catchment. The two major towns in the catchment are Buckfastleigh (3,661 residents) and Ashburton (3,909 residents), both in the south of the catchment, and it is also here where the highest concentration of roads is found including the A38, which is a major trunk road connecting Exeter with Plymouth.

Figure 5: Population density and infrastructure in the Littlehempston catchment.



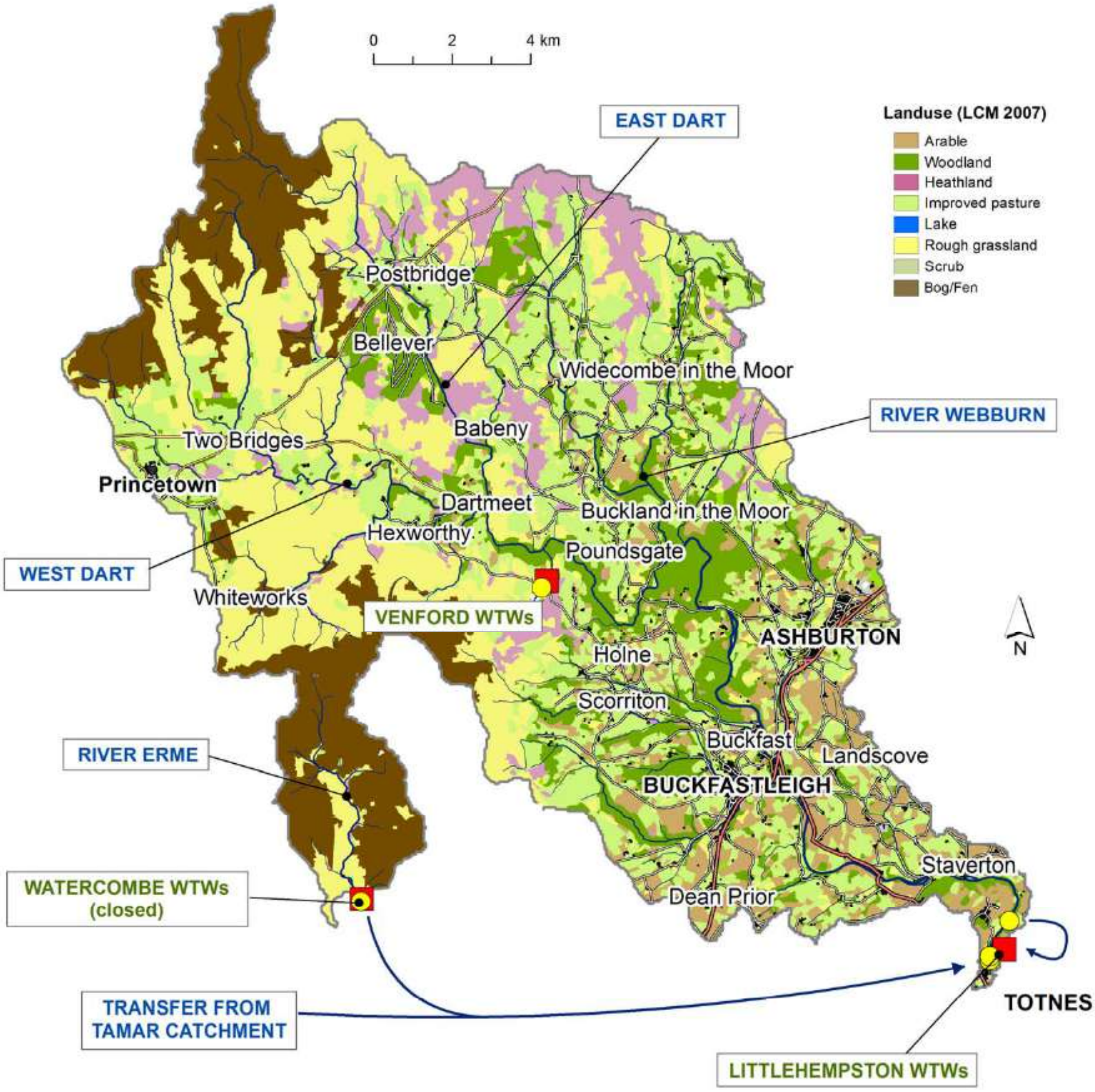
Social and economic data also indicate that the economy of the catchment is particularly dominated by the agriculture, forestry and fishing industries with approximately 7.9% of the working population employed in that sector (over four times the national average). The main industry in the catchment is tourism, with many facilities catering for this with a multitude of bike routes, walking trails and country parks around the catchment.

4.3. Farming & land-use

Data on agricultural practice and landuse derived from the Rural Payments Agency in 2012 and the Agricultural Census of 2000 indicate that there are around 250-300 individual farm holdings in the catchment which cover around 19,735 Ha (68%) of the catchment area (Figure 6). These farm holdings include large areas of common land and moorland grazing in the upper reaches of the catchment.

Of this farmed area in the catchment; ~4,500 Ha (18% of the farmed area) are under temporary or improved grassland and 3,500 Ha (14% of the farmed area) have been used to grow any form of crops. The remainder, which totals 17,500 Ha (69% of the farmed area) in the catchment, is under rough/permanent pasture or woodland/forestry. The total area of woodland/forestry in the catchment is 2,738 Ha (10% of the catchment area). In the Watercombe catchment there are just 3 farm holdings and the landuse is entirely comprised of rough grassland and moorland grazing.

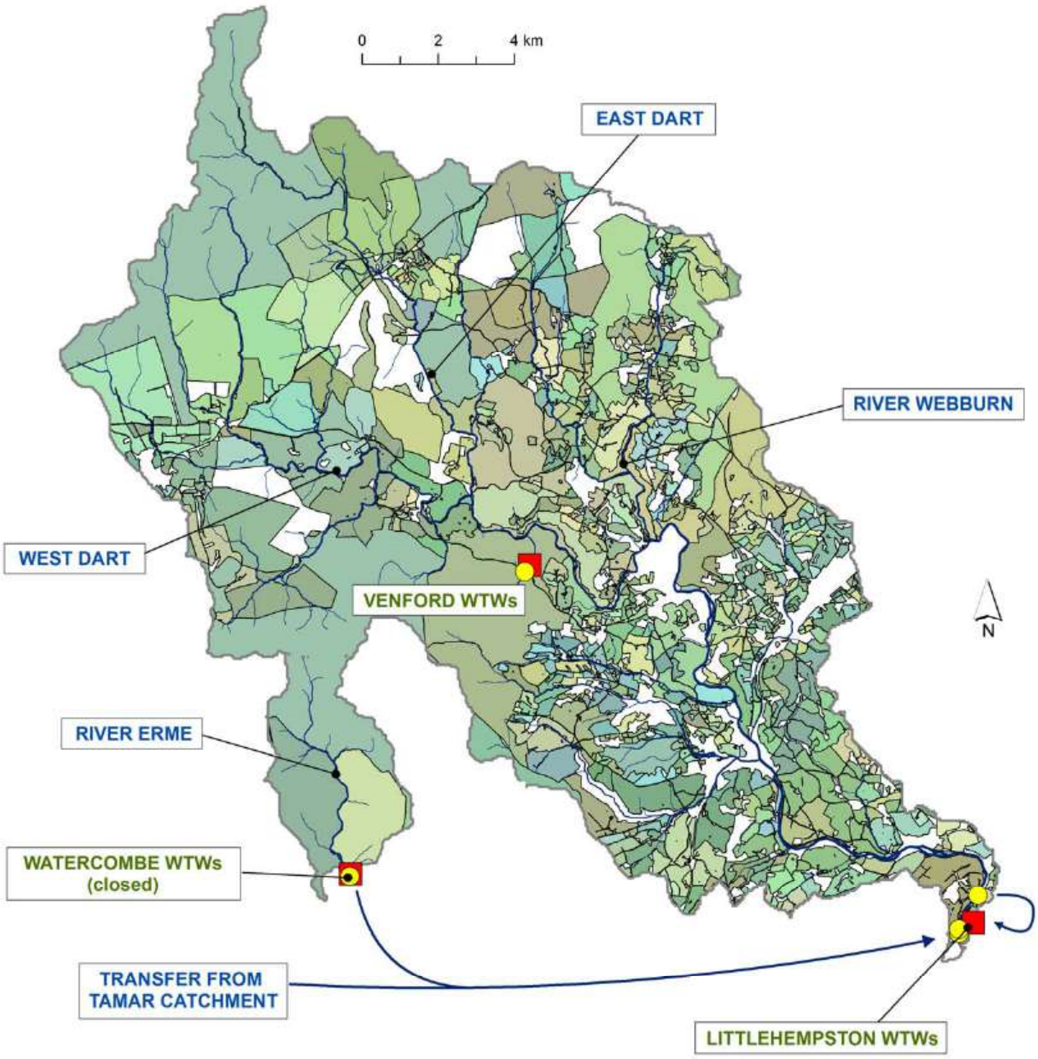
Figure 6: Landuse data from Land Cover Map 2007 (CEH, 2010).



The Rural Payments Agency data (Figure 7) indicates that ~120 of the farm holdings are over 30 Ha in size and, while only offering a coarse indication of numbers, the Agricultural Census data for the catchment in 2000 indicates that there are 20 arable/horticultural, 4 pig/poultry, 17 dairy, 152 beef and sheep and 13 mixed practice farms in the catchment area (100 are classified as 'other').

It is perhaps interesting to note that, as the landuse data in Figure 6 indicates, the vast majority of the arable, horticulture and dairy farms in the catchment are found around of below the line of the A38, with the farming practices higher up the catchment almost entirely dominated by lower intensity livestock farming practices.

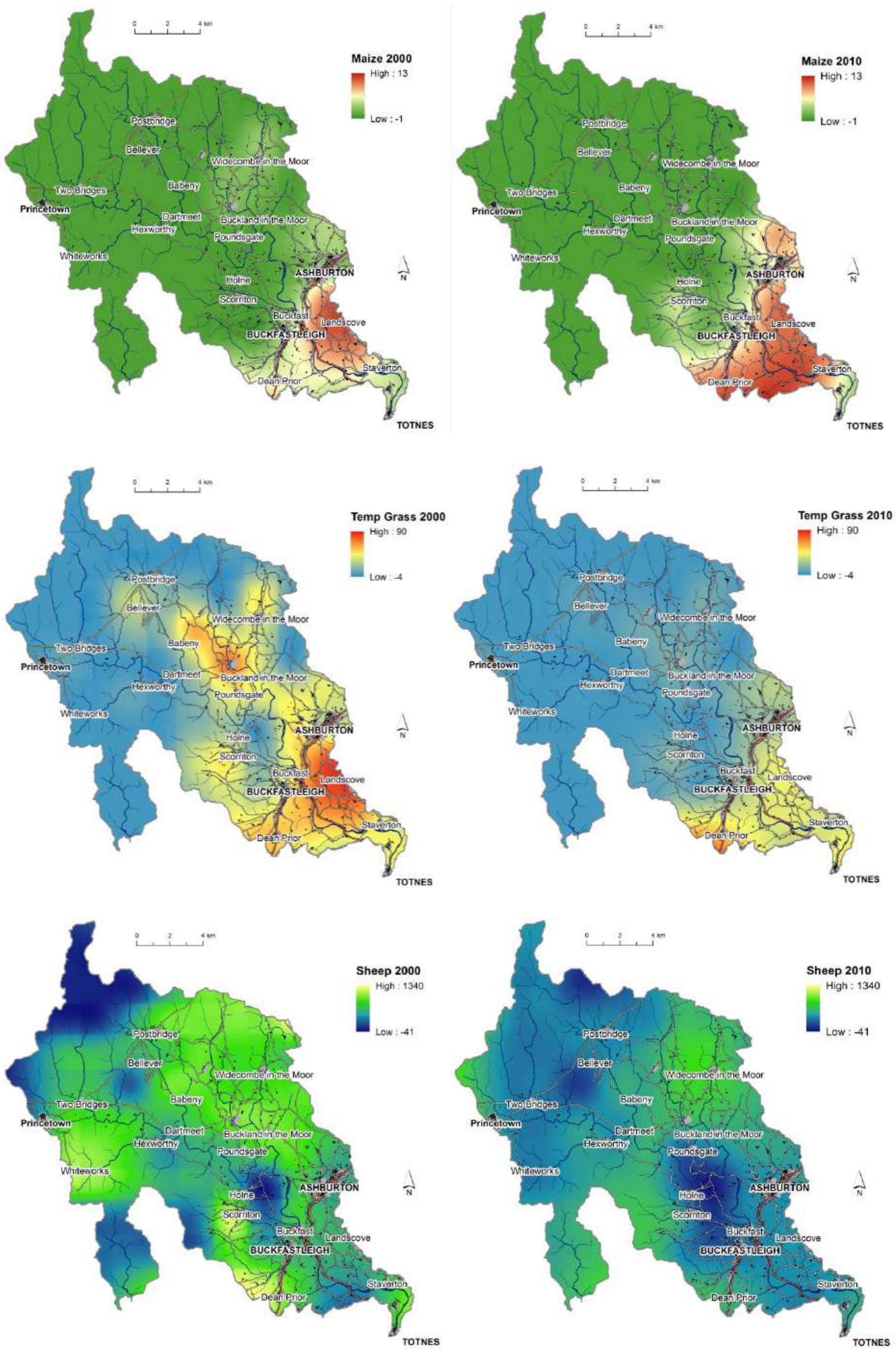
Figure 7: Farm boundary data from the Rural Payments Agency (2012) for the Littlehempston catchment.

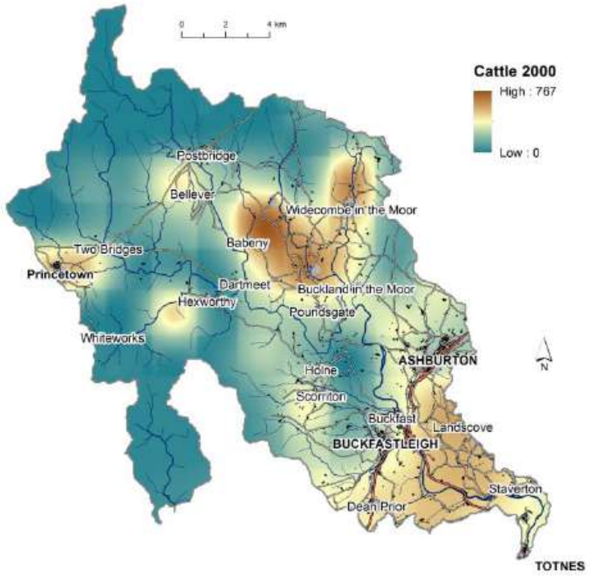


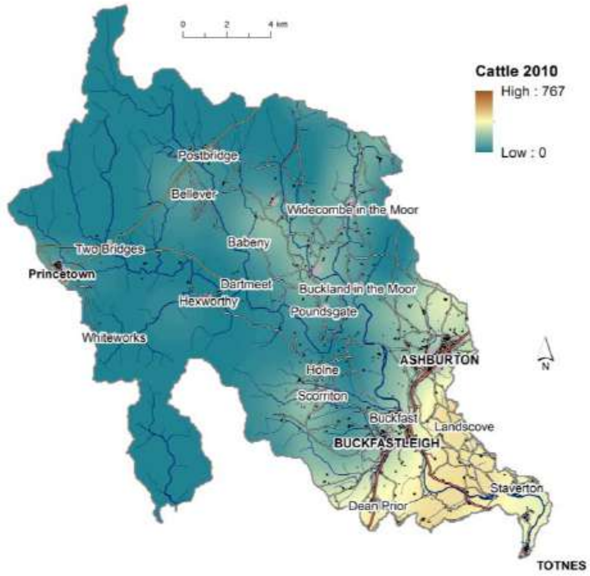
By examining the Agricultural Census from 2000 and 2010 we can explore whether there have been any changes in agricultural practices undertaken in the Littlehempston WTWs catchment over that 10 year period. The results of these analyses for: (1) the area of maize cultivated; (2) the area of temporary grassland under 5 years old; (3) the number of sheep, and (4) the number of cattle, are shown in Figure 8.

These data clearly show that there have been some significant changes in the farming practices undertaken in the catchment. It shows that maize growing is restricted to the area below the A38, but that the level of production has intensified within this area. In contrast, the amount of temporary grassland has reduced significantly and shrunk in its extent. There have also been (perhaps corresponding) falls in the number of sheep (↓33%) and cattle (↓57%) in the catchment.

Figure 8 (*continues over page*): Agricultural Census data from 2000 and 2010 showing the changes in the total area of land being cultivated for maize or temporary grassland and for the numbers of sheep and cattle.







5. Pollutant source identification & risk assessment

Having assessed the diversity and relative levels of pollutants found in the raw water treated at the Littlehempston WTWs, we then undertook a series of studies to identify their likely sources in the catchment. Only when we had identified the sources of pollutants in the catchment, and their relative contribution to the pollutant load at the WTWs, could we then develop a fully targeted, effective and costed catchment management intervention strategy.

All of our investigative work in river catchments is undertaken in accordance with the 'source-pathway-receptor' principle of pollution.

SOURCE — PATHWAY — RECEPTOR

Pollutant Availability + Mobilisation + Connectivity = Pollution risk

As stated previously, our discussions with SWW scientists and our examination of a variety of data and evidence have revealed that there are a number of potential risks that may occur in the raw water abstracted from the Littlehempston WTWs catchment/s. If these pollutants were to arise in the raw water abstracted for treatment they could pose a significant challenge to the treatment of raw water at the WTWs and/or increase the risks associated with that treatment process.

The Drinking Water Safety Plan risk assessment for Littlehempston WTWs was last updated in September 2009 and identified the following as the most significant risks; ***bacteria***, ***cryptosporidium*** and ***pesticides***.

The waterbody around the Littlehempston abstraction has been classified as a Drinking Water Protected Area under Article 7 of the WFD in which the following parameters were specified as 'high priority' for action; ***Atrazine***, ***Diazinon***, ***Dichlobenil***, ***Isoproturon***, ***MCPA***, ***MCPB***, ***Propetamphos*** and ***Sulcofuron*** (notably all pesticides).

The Drinking Water Safety Plan risk assessment for the Watercombe raw water abstraction o the River Erme was last updated in September 2009 and identified the following as the most significant risks; ***cryptosporidium***, ***biological wastes***, ***bacteria*** and ***pesticides***.

In this study we have used a combination of field- and desk-based assessments to identify any potential sources of pollution in the raw water supply catchment for the Littlehempston WTWs. In some cases these pollutants are already being experienced in the raw water abstracted for treatment, but in many cases the assessment is to identify where there is a potential risk posed that could result in them arising in the raw water. Pollutants assessed are listed in Table 2 (*below*).

Table 2. Principle pollutant types examined in this source apportionment study.

Nutrients & algae	Physico-chemistry
• Phosphorus compounds • Nitrates/Nitrites • Algae • Ammonia compounds	• Dissolved oxygen • Colour • Turbidity / suspended solids • Taste & odour compounds
Pesticides	**Microbiology**
• Acid herbicides • Neutral herbicide • Insecticides	• Faecal coliforms • Other bacteria • Cryptosporidium

5.1. Suspended solids & turbidity

Numerous methods have been developed to identify the sources of suspended solids and the dynamics of sediment transport in rivers. Overall these studies reveal that the sediment load in rivers is primarily derived from point or diffuse sources in three principal locations: material from the river channel and banks, soil and other organic material from the surface of surrounding land and particulate material from anthropogenic sources (e.g. roads, industry and urban areas).

5.1.1. Water quality assessment

South West Water scientists have indicated that turbidity and suspended solids do not represent a significant risk to the quality of the raw water treated at the Littlehempston WTWs. Data obtained from South West Water indicates that, between 2004 and 2008, the average level of turbidity in the raw water at Littlehempston was actually very low at just 1 NTU and the maximum recorded level between over the same period was 2.5 NTU.

Despite this low level of turbidity in the raw water it remains possible that sediment could become mobilised from a number of sources in the catchment and we have undertaken a risk assessment to identify the areas with the most potential to generate pollution of this type.

It is also important to recognise that, as described in great detail in the Crownhill Catchment Investigation Report, there is a high risk that water of high turbidity or suspended sediment pollution could be imported into the Littlehempston WTWs through the spine main from the Tamar catchment to the west. Thus, if water resources in the Dart catchment remain sufficient throughout the year the need to use this alternative raw water source can be obviated along with the risk of pollution being imported.

5.1.2. Fine sediment risk analysis

In addition to the mobilisation of sediment and other suspended material from within the riparian corridor, these pollutants can also be mobilised from land-surface sources. We can identify potential sources of this kind through field surveys (*see below*), but to get an initial broad assessment of the risk we can use a spatial modelling approach to assess the fine sediment erosion and mobilisation risk across the Littlehempston WTWs catchment.

A simple, robust fine sediment risk model can be extremely beneficial as it helps us to target and tailor both further monitoring work and catchment management interventions going forward.

To achieve this goal we have developed a spatial model based on the SCIMAP fine sediment risk model, which was developed through a collaborative project between Durham and Lancaster Universities. The SCIMAP Project has been supported by the UK Natural Environment Research Council, the Eden Rivers Trust, the Department of the Environment, Food and Rural Affairs and the Environment Agency.

The SCIMAP model gives an indication of where the highest risk of sediment erosion risk occurs in the catchment by (1) identifying locations where, due to landuse, sediment is available for mobilisation (pollutant source mapping) and (2) combining this information with a map of hydrological connectivity (likelihood of pollutant mobilisation and transportation to receptor).

(1) In our model we create a map of sediment availability using land cover, soil type (where available) and agricultural practice data. Both arable and livestock farming have an intrinsic ability to mobilise fine sediment, but this risk is significantly higher in arable systems. The sediment mobilisation risk inherent in these agricultural practices is likely to be increased with increasing farming intensity.

    The land-use data on the distribution of grassland and arable farming practices (Land Cover Map 2007, CEH) are then weighted using Agricultural Census data on stock density and arable crop production respectively as indicators of farming intensity.

(2) The SCIMAP risk mapping framework produces a map of hydrological connectivity based on the analysis of the potential pattern of soil moisture and saturation within the landscape. For each point in the landscape, the probability of continuous flow to the river channel network is assessed. This is achieved through the prediction of the spatial pattern of soil moisture and hence the susceptibly of each point in the landscape to generate saturated overland flow.

The sediment availability map resulting from this analysis is shown in Figure 9A. The resulting Surface Flow Index map created from this analysis is shown in Figure 9B.

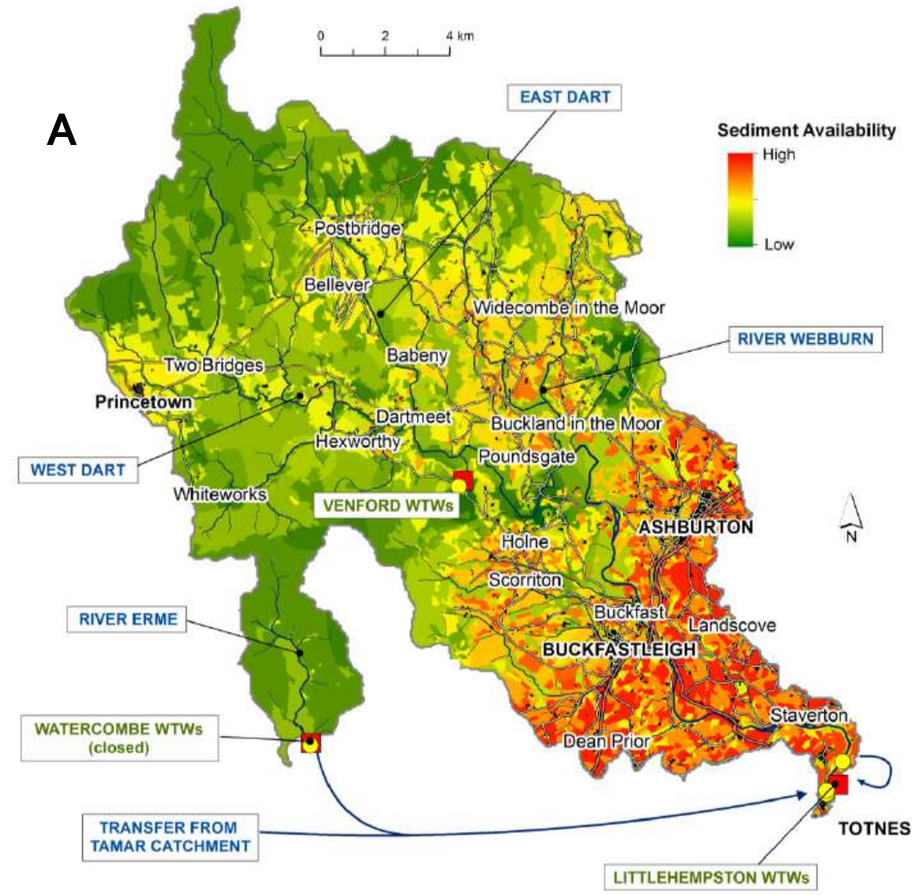
The combination of the sediment availability and hydrological connectivity maps results in a final fine sediment erosion risk model which is shown in Figure 9C.

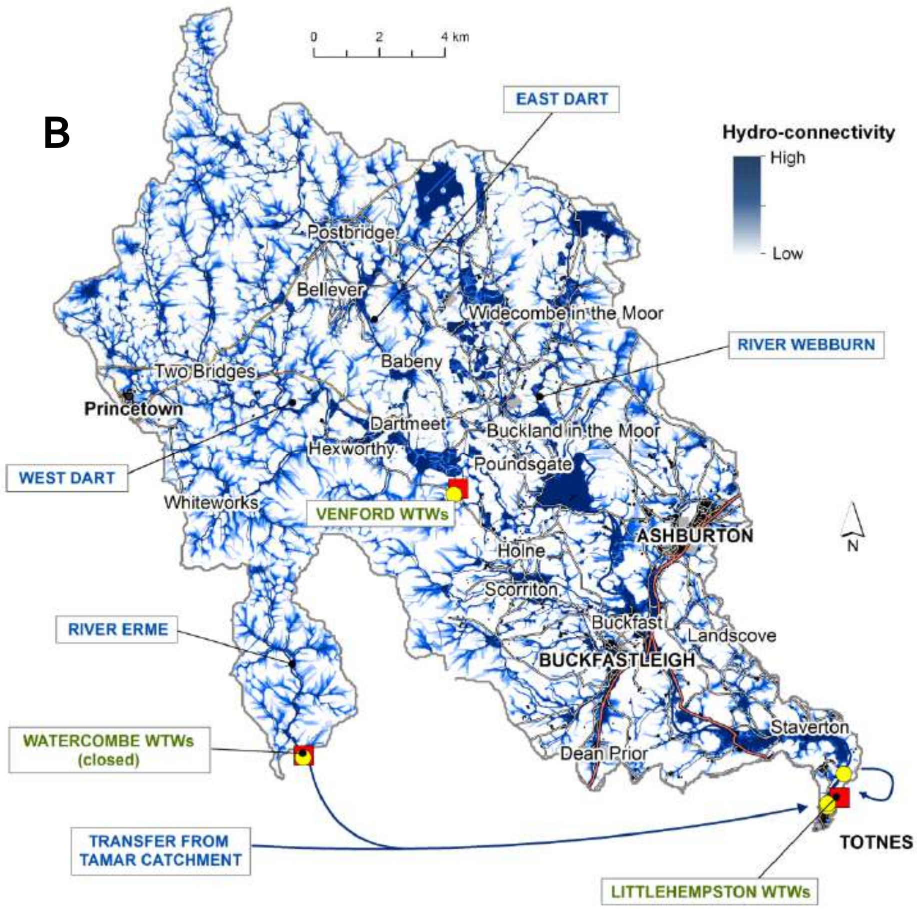
The data in Figure 9 clearly show that there are a number of areas where there may be a fine sediment mobilisation risk in the Littlehempston WTWs catchment. These are areas of land where cultivation or improvement of grassland and/or the action of livestock may increase the availability of sediment for erosion and there are a number of areas where there is an elevated likelihood of run-off occurring during periods of high rainfall.

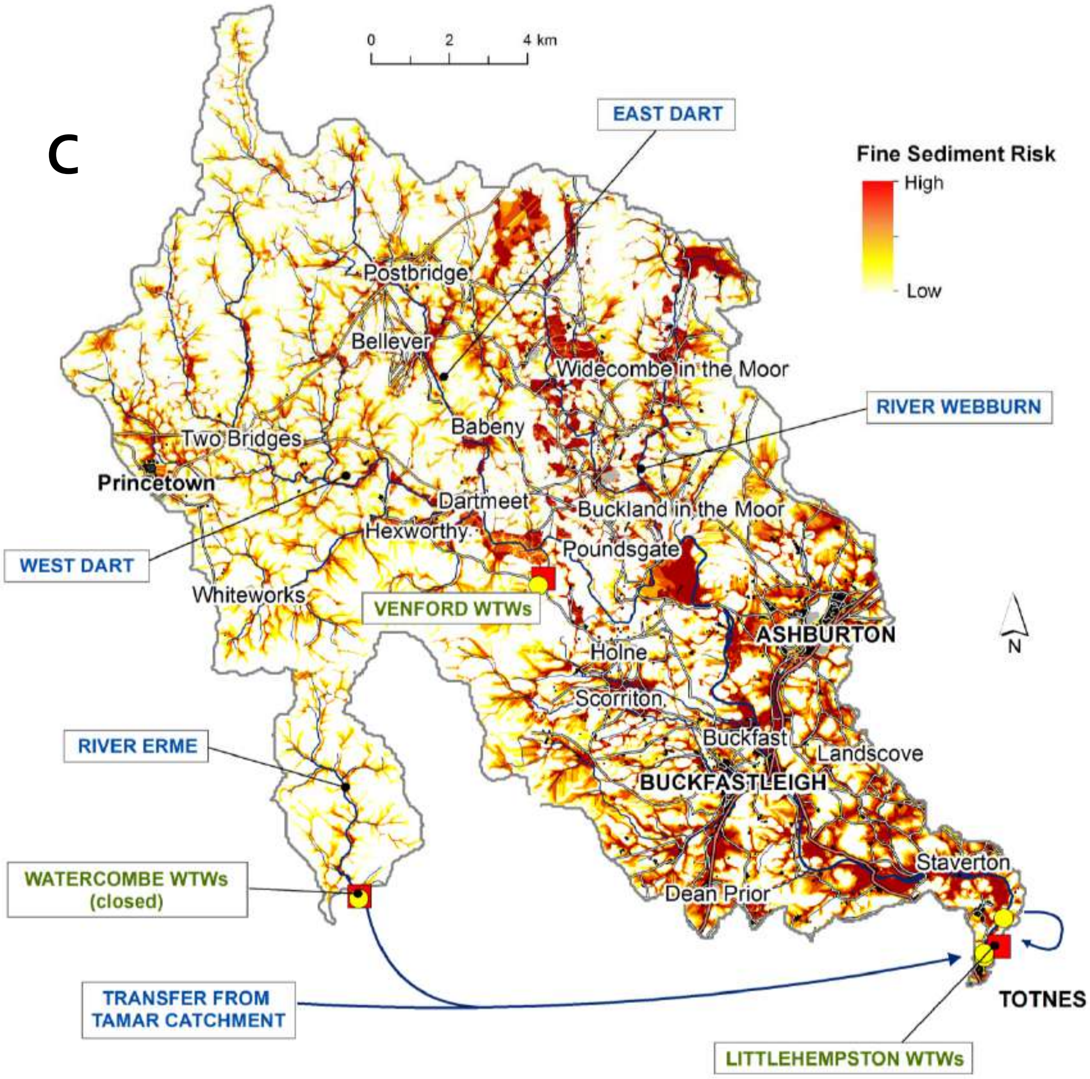
The areas of greatest risk appear to be concentrated in the sub-catchments of the River Webburn, the River Ashburn (around Ashburton), the River Mardle (south and west of Buckfastleigh) and along the main stem of the River Dart.

Now that these areas have been identified they can be examined in more detail to determine whether they are already generating sediment pollution and, if they are found to be, then interventions can be targeted into them to mitigate these impacts.

Figure 9. Fine sediment erosion risk maps derived using the SCIMAP modelling approach. (A) Fine sediment erodability or availability model. (B) Surface Flow Index model derived from rainfall and topographic data in the SCIMAP modelling framework. (C) The final fine sediment erosion risk model.







5.1.3. Pollutant load analysis

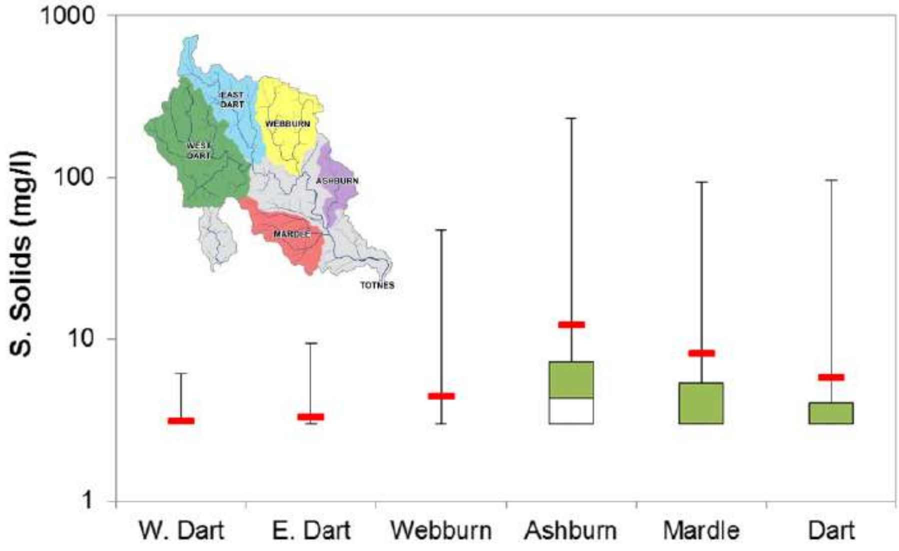
Having characterised where the greatest fine sediment erosion risk may be present in the Littlehempston WTWs catchment, we next undertook a study of water quality monitoring data collected at strategic locations in the catchment that would allow us to identify which areas were contributing the greatest amount of suspended solids. For this study we examined 8 years of Environment Agency water quality monitoring data for the catchment at 6 key locations across the catchment (shown in Figure 10; *inset*).

Figure 10 shows the average suspended solids concentration recorded by the Environment Agency over an 8 year period between 2005 and 2012. Samples were taken at the outflow of each of the 5 main sub-catchments of the River Dart above Totnes and the River Dart at Totnes with a sampling frequency of once a month. There is no monitoring site on the River Erme above Watercombe.

The data shown in Figure 10 clearly shows that there is huge variation in the levels of suspended solids recorded in all of the rivers. In line with the findings of our risk mapping analysis, the mean concentrations in samples taken from the West Dart and East Dart are very low (just ~3 mg/l).

However, the concentrations in the Webburn and especially the lower tributaries of the Rivers Mardle and Ashburn and the main river Dart were not only higher on average, but these rivers also experienced much higher spikes in their sediment concentrations at certain times (maximum recorded concentrations of suspended sediment of 47, 92, 229 and 96 mg/l respectively).

Figure 10. Variation in suspended sediment concentration in 6 locations in the Dart catchment.



5.1.4. River corridor & landscape sediment risk assessments

Fine sediment or suspended solids pollution in rivers can be derived from natural geomorphological processes, such as bank and channel erosion, and through erosion of the soil and materials from the land surface during run-off events. These inputs can be significantly increased if river banks and channels become damaged or excessively disturbed due to the actions of livestock given unrestricted access to the watercourse or if soil condition is degraded due to the farming practices being undertaken upon it.

The likelihood of sediment being mobilised from either of these sources can best be identified through field-based surveys of the watercourses in a catchment. A detailed survey of the watercourses, agricultural land and forestry in the Littlehempston WTWs catchment was undertaken to identify any locations where there may be a risk that the practices or activities occurring could generate suspended sediment or turbidity in the raw water treated at the WTWs.

The survey of the upper catchment revealed that the landscape and the river corridors were in very good condition and there were few if any apparent sources of sediment mobilisation. The farming practices are extensive hill farming of beef and sheep often on open moorland (see examples in Figure 11).

Overall, the streams that feed into the Dart River appear very clear, with gravel and sand substrates that are clean with healthy macrophyte growth. However, it should be noted that, due to the topography of these upland areas, which receive high rainfall, the streams are 'flashy' in response to rainfall and that this may increase the risk of sediment mobilisation from both the river banks and the land surface.

There are some large areas of confer plantation in the upper catchment and the forestry practices undertaken in these areas could generate sediment pollution. However, the middle and lower reaches of the River Dart are actually quite well buffered by broadleaved woodland and it is possible that these areas may reduce the likelihood that mobilised sediment will enter the watercourses.

In the lower reaches of the catchment, where the intensity of the agricultural practices increases, a number of potential sediment sources were found during the survey. While the soil characteristics in these areas are more resilient to activities that could lead sediment run-off occurring, the problems that were found were primarily associated with intensive livestock or arable farming (especially maize cultivation) on steeply sloping ground (see examples in Figure 12).

Figure 11. Examples of the extensive farming practices and healthy river corridors of the tributaries of the Upper Dart catchment as they flow over the open moorland of Dartmoor and through the heavily wooded valleys of the middle catchment.

Figure 12. Examples of the more intensive farming practices in the lower tributaries of the Dart catchment and some of the locations found where sediment mobilisation was more likely to occur due to livestock or cropping practices.

5.2. Nutrients & algae

For the purposes of this study we have focused on phosphorus-containing compounds, which are thought to play a key role in driving the growth of algae in the river system, in reservoirs and in raw water supply and storage infrastructure. Nitrates do occur at elevated levels in many South West Water WTWs catchments, but generally they are not considered to represent a significant threat to the drinking water treatment process, to the cost of treatment undertaken at the WTWs or (on their own) to the ecology of the rivers in those catchments.

There are two principal measures of phosphorus-containing nutrients: soluble reactive phosphate (SRP) and total phosphorus (TP), and each are derived from different point and diffuse sources across the landscape. The soluble reactive form is regarded as being biologically available and is the limiting nutrient that facilitates the growth of algae. The insoluble fraction of total phosphorus is often associated with suspended solids in the water and is often ignored, but it can rapidly become biologically active through decomposition or solubilisation and there are many who believe that total phosphorus is the best measure of nutrient load in rivers and especially lakes.

There are three principal sources of phosphorus compounds in a river catchment: (1) point agricultural sources, (2) diffuse agricultural sources and (3) point anthropogenic sources. The potential for these sources to generate nutrient pollution in the Littlehempston WTWs catchment are described in the following sections.

5.2.1. Water quality analysis

Due to the absence of a major impounding reservoir in the Littlehempston raw water catchment the threat posed by nutrient enrichment at the WTWs is significantly less than that experienced at other works. Having said this, however, elevated levels of nutrients in raw water can still have an impact on the water treatment process through its enhancement of algal or plant growth in the water storage and supply system and they can also have a significant impact on the general ecological health of the aquatic ecosystem of the river (especially at a localised scale).

Water quality monitoring data obtained from South West Water and the Environment Agency indicate that, while not on average exceeding the standards for raw drinking water or the Water Framework Directive, the levels of phosphorus-containing nutrients in the raw water at Littlehempston WTWs are consistently moderate but, on occasion, quite high.

The average level of total phosphorus in the combined raw water at Littlehempston WTWs between 2009 and 2010 was 27 µg/l, but the average concentration in the River Dart at Totnes was higher at 35 µg/l between 2005 and 2012. Of more interest is the fact that, at certain times, the level of phosphorus rose significantly to reach a maximum of 251 µg/l – a level far more capable of having a significant impact on both the ecological health of the river and on the water treatment processes undertaken at Littlehempston WTWs.

5.2.2. Phosphorus risk analysis

To assess the distribution of phosphorus pollution risk across the Littlehempston WTWs catchment we have used the **P**hosphorus and **S**ediment **Y**ield **CH**aracterisation **I**n **C**atchments (**PSYCHIC**) model developed by a consortium of academic and government organisations led by ADAS Water Quality.

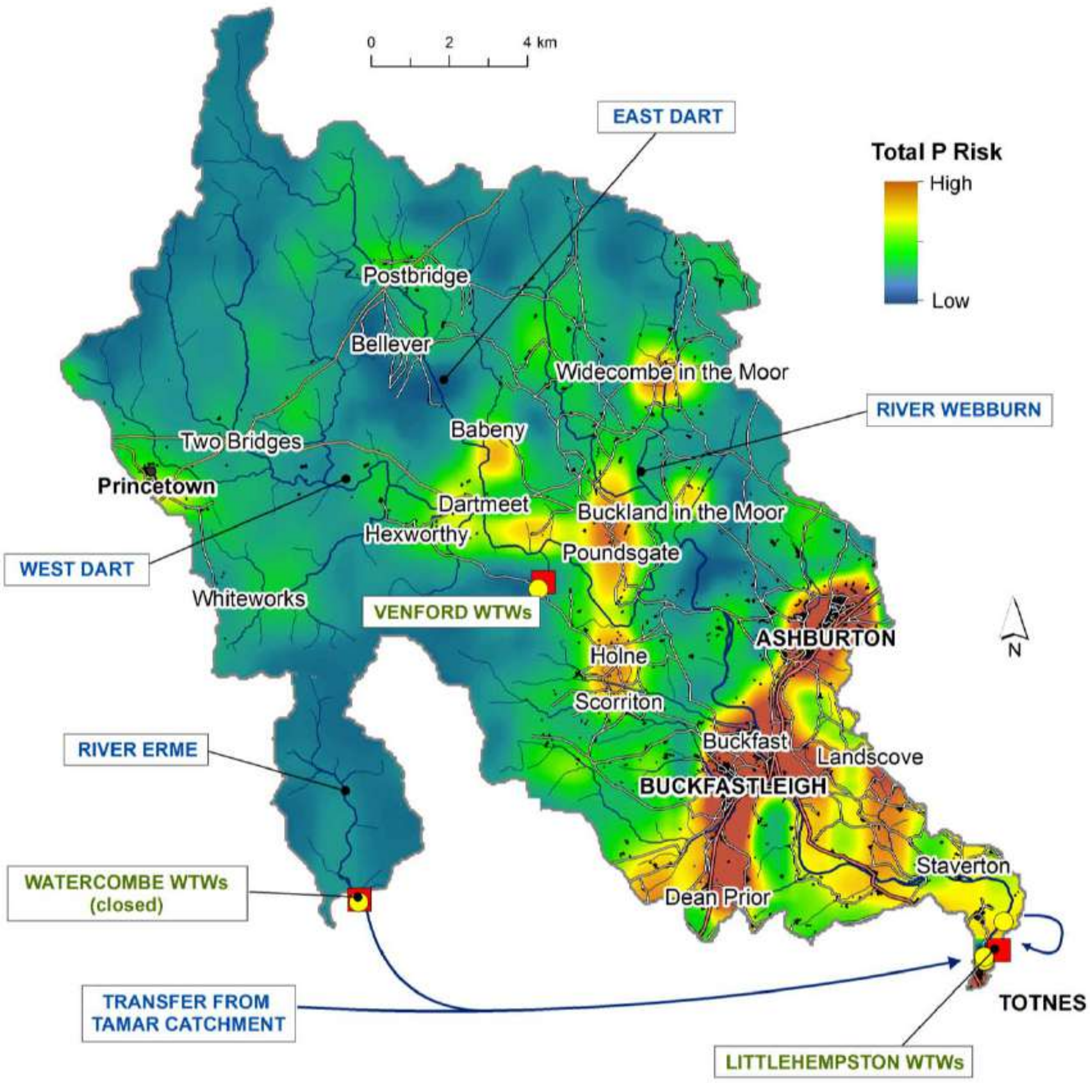
PSYCHIC is a process-based model of phosphorus and suspended sediment mobilisation in land runoff and subsequent delivery to watercourses. Modelled transfer pathways include release of desorbable soil phosphorus, detachment of suspended solids and associated particulate phosphorus, incidental losses from manure and fertiliser applications, losses from hard standings, the transport of all the above to watercourses in under-drainage (where present) and via surface pathways, and losses of dissolved phosphorus from point sources.

The model can be used at two spatial scales: the catchment scale, where it uses easily available national scale datasets to infer all necessary input data, and at the field scale, where the user is required to supply all necessary data. The model is sensitive to a number of crop and animal husbandry decisions, as well as to environmental factors such as soil type and field slope angle. The catchment-scale model is designed to provide the first tier of a catchment characterisation study, and is intended to be used as a screening tool to identify areas within the catchment which may be at elevated risk of phosphorus loss.

The PSYCHIC model output shown in Figure 13 shows the spatial distribution of total phosphorus pollution risk across the Littlehempston WTWs catchment. This model clearly shows that there are a number of areas across the catchment where the risk of phosphorus mobilisation occurring is elevated.

Further examination of the PSYCHIC model outputs indicates that these higher risk areas may be due to the more intensive livestock farming practices that are undertaken in some of these areas, but it is more likely that a number of point sewage effluent discharges may also be making a significant contribution to the elevated risk of nutrient pollution (data not shown).

Figure 13. Interpolated risk maps derived from the PSYCHIC phosphorus risk model.



5.2.3. Point sources – agriculture

Point sources of nutrient pollution from agricultural sources include farm infrastructure designed to store and manage animal waste and other materials such as animal food.

Key infrastructure includes dung heaps, slurry pits, silage clamps and uncovered yards. Animal access point to the watercourse can also lead to the direct delivery of phosphorus compounds to the water and to their mobilisation following channel substrate disturbance.

The field survey undertaken did discover a number of potential agricultural point sources, which had the potential to release nutrients in to the watercourses in the catchment. These sources were not numerous, but taken together they could be making a significant contribution to the moderate level nutrient load found in the raw water at the Littlehempston WTWs.

5.2.4. Diffuse sources – agriculture & landuse

When large amounts of manure, slurry or chemical phosphorus-containing fertiliser are applied to land and this coincides with significant rainfall it can lead to run-off and the transfer of phosphorus into a watercourse. This is a particular where heavy soils are farmed intensively and run-off is more likely to occur.

The largely extensive farming practices undertaken in the upper reaches of the Dart catchment mean that there is unlikely to be a significant risk of nutrient pollution occurring in this area. However, the landuse data shown previously and the findings of our field survey do indicate that there are more significant areas of improved/temporary grassland and arable production in the lower catchment and it is possible that manure, slurry or chemical phosphorus-containing fertiliser applied to this land could be mobilised and carried into a watercourse.

The level to which this practice is undertaken on the catchment is currently unknown, but, if done in high risk, hydrologically connected areas prior to rainfall, there is every chance that nutrients will be washed or leached from this material and then carried into a watercourse.

Indeed, we encountered several locations where there were large volumes of highly nutrient enriched material available for mobilisation in the event of prolonged or extreme rainfall occurring (see Figure 15 for an example of this).

Figure 15. An example of a potential agricultural source of nutrient pollution found in the Littlehempston catchment.

5.2.5. Point sources – consented & unconsented discharges

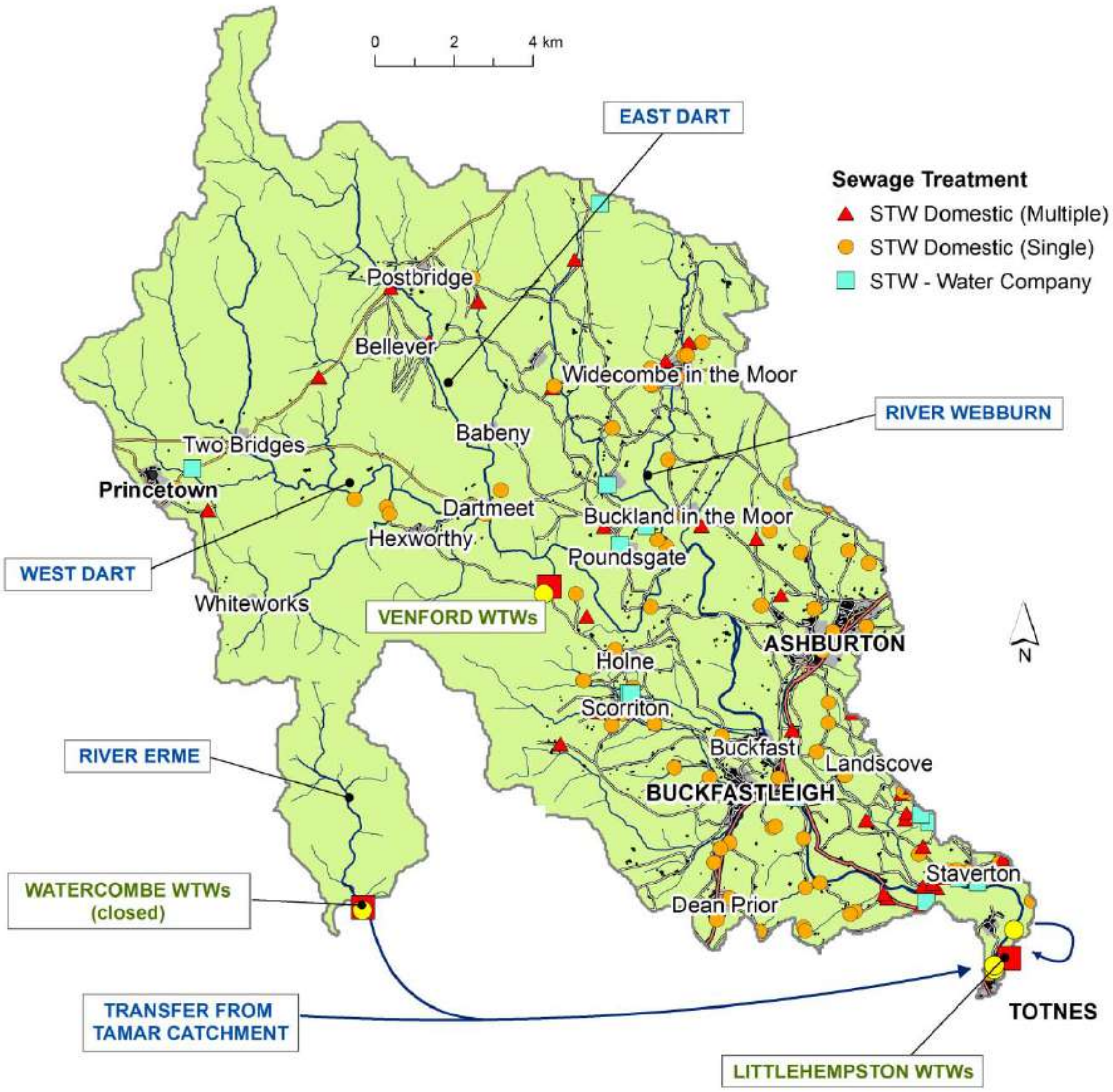
A considerable fraction of the phosphorus in river water may be derived from inputs of sewage effluent (which may or may not have been treated), the drainage systems in urban areas and from roadside drains.

The principal sources of phosphates in sewage are human faeces, urine, food waste, detergents and industrial effluent that has been discharged to the sewers. Typical sewage treatment processes generally remove 15-40% of the phosphorus compounds present in raw sewage, but there are many small sewage treatment facilities (sewage treatment works or septic tanks) in rural areas which could still be making significant contributions to the phosphorus load in rivers and reservoirs.

The effluent discharge points of many sewage treatment facilities now have an environmental permit or discharge consent associated with them, but there are still many small STWs and septic tanks which are not registered and which do not have a discharge consent.

As the data in Figure 16 shows there are a total of 137 sewage effluent discharge consents in the Littlehempston WTWs catchment ranging from large South West Water works in the towns of Ashburton and Buckfastleigh down to small facilities serving individual residential properties or commercial premises.

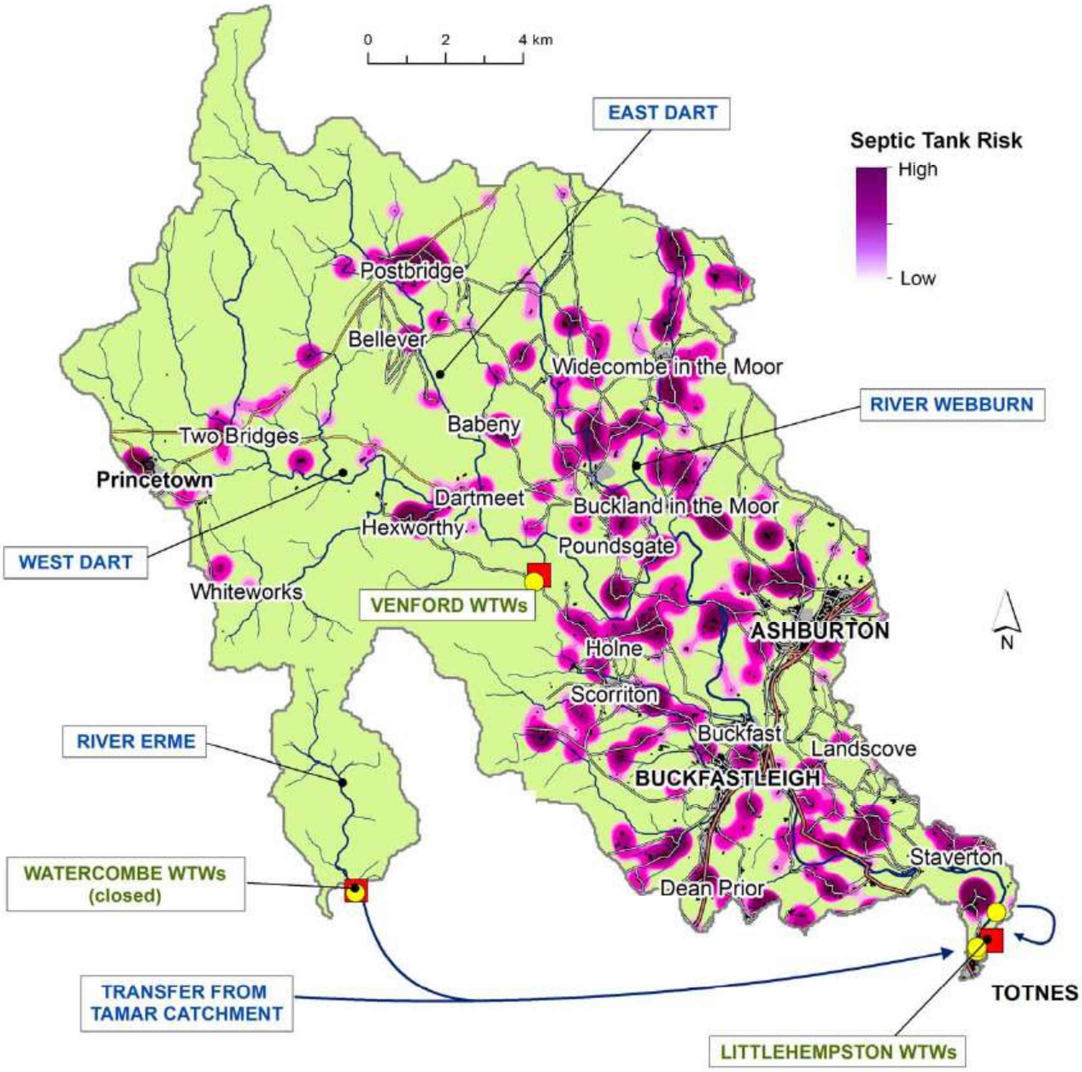
Figure 16. Distribution of consented discharges in the Littlehempston WTWs catchment.



In addition to the consented sewage effluent discharges, property data from Ordnance Survey, when compared to the sewer network and discharge consents in the catchment, indicate there may be a further 800 properties which can be assumed to have a septic tank sewage treatment system that discharges to the watercourse (see Figure 17).

It is possible that these potential inputs of nutrient pollution could not only be having an impact on the ecological health of the small streams in the catchment at a localised scale, but they could also be combining to make a significant contribution to the elevated levels of nutrients recorded in the River Dart at Totnes and in the raw water at Littlehempston WTWs.

Figure 17. Distribution of properties with and without a consented discharge and not on the sewer network.

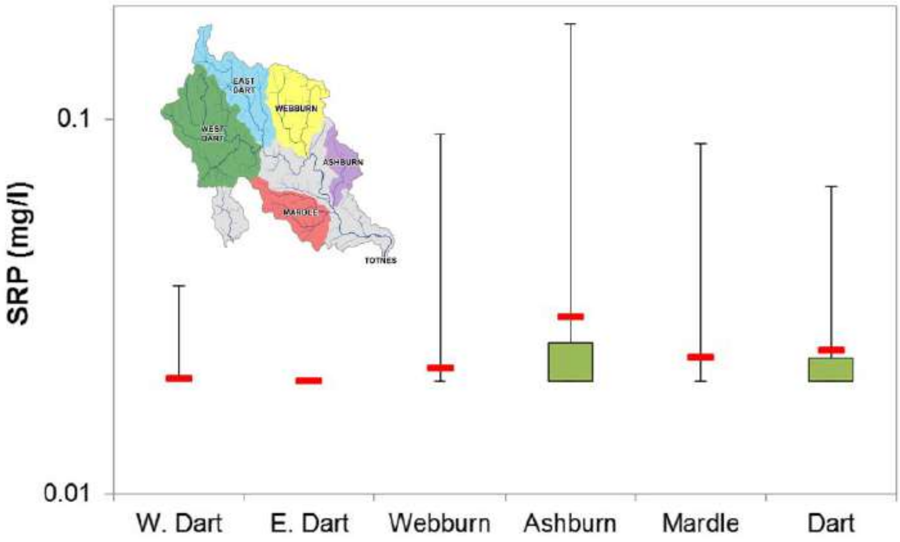


5.2.6. Pollutant load analysis

Having characterised where the greatest phosphorus export risk may be present in the Littlehempston WTWs catchment, we next undertook a study of Environment Agency water quality monitoring data collected at 6 locations in the catchment between 2005 and 2012 that would allow us to identify which areas were contributing the greatest amount of phosphorus (Figure 18; *inset*).

Figure 18 shows the average soluble reactive phosphate (SRP) concentration (the measure used by the Environment Agency for their WFD assessment of nutrient load) recorded between 2005 and 2012 (the Environment Agency do not routinely measure total phosphorus in their monitoring programme). These data clearly confirm that the average levels of SRP are very low across all of the monitoring locations in the catchment, but also that the levels are elevated in the Ashburn and Mardle streams and that the Webburn, Ashburn and Mardle streams all experience very high levels of nutrients at certain times. The elevated levels of nutrient in the main River Dart could therefore have the potential to be reduced though the targeted delivery of intervention measures into these sub-catchments.

Figure 18. Variation in soluble reactive phosphorus concentration at 6 locations in the Dart catchment.



5.3. Bacteria & cryptosporidium

When animal and human faecal material, and the microbes it contains, enter a river system they can pose a significant threat to the health of people who rely on that water for drinking water, recreational bathing or the sustenance of fisheries and shell fisheries downstream.

This material can also make a significant contribution to the turbidity and suspended solid load in the raw water, which can increase the cost of coagulation and sludge management at the WTWs.

The total level of microbial contamination in the water and the level of different faeces-derived bacteria are both used as indicators of the potential pathological risk posed by that water. In addition, faecal material may also contain other pathogenic organisms, such as Cryptosporidium, which cause gastrointestinal infections following ingestion or others which cause infections of the upper respiratory tract, ears, eyes, nasal cavity and skin.

There are three principle mechanisms via which faecal material or faeces-derived substances, such as ammonium, can make their way into a watercourse. These include: (1) direct 'voiding' into the water by wildlife or livestock in the river, (2) wash-off and leaching of manure or slurry on the land surface or accumulated on yards or tracks, and (3) from consented or un-consented discharges of untreated human sewage.

5.3.1. Water quality assessment

Data obtained from South West Water indicate that have been occasions when faecal coliforms were recorded at a very high concentration in the combined raw water abstracted for treatment at Littlehempston WTWs (maximum 10,600 per 100ml from 2009-2010). Furthermore, the average levels of faecal coliforms in the raw water at Littlehempston is also quite high (1,020 per 100mls from 2009-2010).

In addition, the raw water quality monitoring undertaken by South West Water also detected cryptosporidium oocysts on 55 occasions between 2004 and 2008 (34% of samples taken).

It has been speculated that this cryptosporidium contamination is due to the presence of imported water from the Tamar catchment in the combined raw water at Littlehempston WTWs, but closer examination of the data reveals that this is not always the case.

As Figure 19 shows, between 2009 and 2010 the water from the South Devon Spine Main and the combined raw water in Littlehempston WTWs were sampled on the same day on 94 occasions. On 10 occasions (11% of samples) both were positive, indicating that the spine main water could be the source in the combined raw water, but on 29 occasions (31% of samples) the combined water was positive while the water from the spine main was clear of contamination.

Interestingly, on 10 other occasions (11% of samples) the spine main was contaminated, but this did not appear in the samples taken from the combined raw water. This could be due to the large dilution of this water when blended into the combined raw water.

Figure 19. Frequency of positive (+) and negative (-) cryptosporidium detections at the same time in the combined raw water and raw water pumped into the works from the Tamar catchment via the South Devon Spine Main.

Combined + Spine main – **29**	Combined + Spine main + **10**
45 Combined – Spine main –	**10** Combined – Spine main +

5.3.2. Microbial contamination risk assessments

The field survey of the Dart and Watercombe catchments revealed that in the headwaters and across most of the upper catchment area there is open ground with extensive, unrestricted grazing of livestock. As a result animals can access and drink from numerous points along the watercourses and this could be one cause of the microbial pollution reported (e.g. Figure 20).

It should be noted that the nature of the landscape and the use of the land for 'common' grazing would make the exclusion of livestock from the watercourses with fencing both impractical and difficult. However, it may be possible to reduce direct inputs being concentrated and channelled into the watercourses at specific locations through careful management and targeted livestock management measures.

Figure 20. Examples of livestock having unrestricted access to watercourses in the Littlehempston catchment.

It is also possible that microbial contaminants could be washed from animal waste, manures or slurry applied to the land as fertiliser. If applied at high concentration, in high risk areas, there is every chance that material of this nature could be washed into a watercourse or reservoir and give a resulting spike in microbial contamination in the raw water.

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In addition to some potential livestock sources, it is also possible that the anthropogenic point sources (the ~800 un-consented and 137 consented sewage treatment facilities described previously and shown in Figures 16 and 17) could generate microbial contamination at certain times if they were not operating optimally.

More detailed investigation of each individual facility would be required to assess their condition and determine whether they pose a threat to water quality. We would recommend that a programme of septic tank advice and management should be delivered across the catchment to mitigate any potential contributions of nutrient or microbial pollution from these sources.

The final source of microbial contamination in the catchment that may need to be considered is the potential inputs from wildlife, such a birds and mammals, residing on the catchments large areas of wetland and woodland habitats. Several studies have linked microbial pollution found in rivers with wildlife sources (e.g. Jellison et al., 2009).

In a catchment the size of the Littlehempston WTWs catchment it is very challenging to determine the likelihood that wildlife sources do contribute to the microbial loads recoded in the raw water. However, while the presence of birds, deer or other wildlife in the woodlands and wetlands of the catchment are unlikely to generate large quantities of faecal material, they could be the source of specific microbial pollutants such as cryptosporidium and should therefore be considered when attempting to quantify and mitigate the risk.

5.4. Colour, taste & odour

There are two main groups of soluble species that can cause colour, taste and odour problems: soluble organic compounds and metal ions.

On most occasions when colour, taste or odour problems do occur the impacts are on the aesthetic quality of the water and, with the resulting increase in the risk of customer dissatisfaction, there is also an increase in the intensity and cost of treatment required to remove it from the water. In addition, however, there are occasions when soluble colour, taste and odour causing compounds do occur that can pose a serious threat to the condition of water supply infrastructure and, in some circumstances, to human health.

The level of colour, taste and odour compounds in the raw water can have a direct impact on the dose of coagulant required in the treatment of the raw water at the WTWs and if it is not removed it can impinge on the aesthetic quality of the final drinking water and cause the discolouration of drinking water infrastructure (for example manganese).

In addition to these problems, soluble organic compounds, such as humic substances and geosmin, can cause further problems at the WTWs as they can be converted into disinfection by-products (DBPs) when chlorine is used during water treatment (Krasner et al., 1989). These DBPs can take the form of trihalomethanes (THMs), haloacetic acids (HAAs) and a host of other halogenated DBPs, many of which have been shown to cause cancer in laboratory animals (Singer, 1999; Rodriguez et al., 2000).

The sources of taste, odour and colour causing compounds are not easy to identify, but they are often the bi-product of natural phenomena in the landscape. Having said this, the production and release of these substances into watercourses is often significantly exacerbated through human activities such as mining, forestry or agricultural practice and remedial interventions have been shown to be successful in mitigating these effects.

5.4.1. Water quality analysis

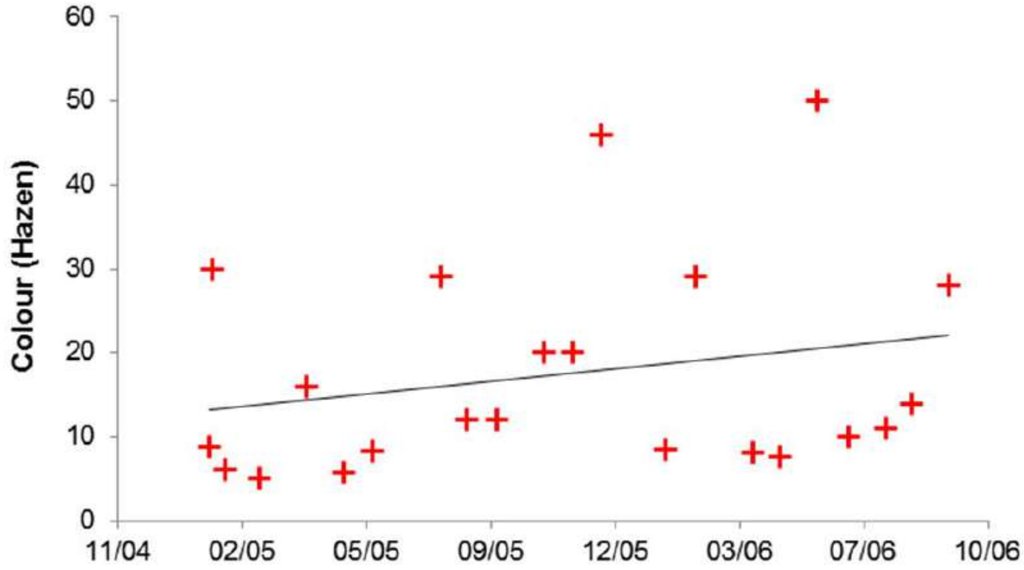
Data obtained from South West Water and the Environment Agency indicate that the level of colour in the raw water abstracted for treatment at Littlehempston WTWs is typically quite high (the average of 14.5 Hazen from 2009-2010 exceeds the minimum guidance level stipulated in the EC's Directive on the Quality Required of Surface Water Intended for the Abstraction of Drinking Water 1975 (75/440/EEC)).

Furthermore, the data also indicate that there have been a number of occasions when the level of colour in the raw water abstracted for treatment at Littlehempston WTWs has been recorded at a far higher level (the maximum of 35.3 Hazen from 2009-2010 is approaching the intermediate guidance level stipulated in the EC Directive).

These findings in the raw water at the WTWs are in accordance with the levels of colour recorded in the River Dart at Totnes between 2005 and 2006, which had an average of 17.5 Hazen and a maximum recoded level of 50 Hazen.

It is also important to note that in both the combined raw water at the WTWs (2009-10) and the river water sampled there was an increasing trend in the levels of colour recorded (Environment Agency data shown in Figure 21).

Figure 21. Levels of colour recorded in the River Dart at Totnes between 2005 and 2006.



5.4.2. Pollutant load analysis

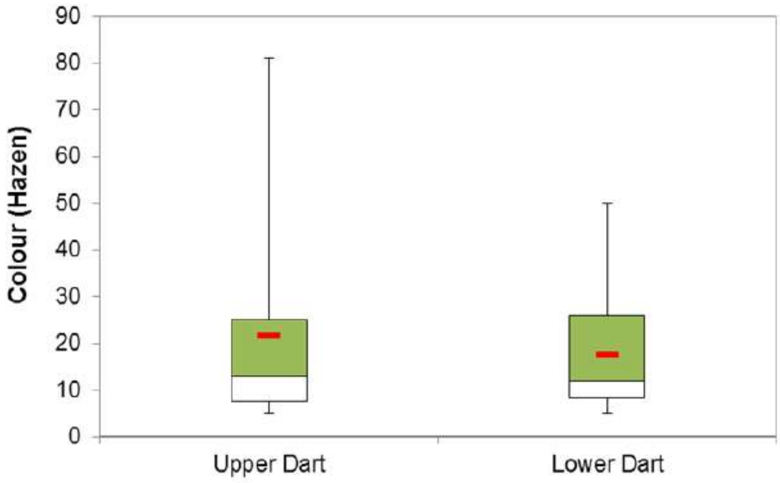
Elevated levels of colouration in river water are a common phenomenon in catchments with large areas of peat-based soils, such as those which dominate the upper reaches of the Littlehempston catchment landscape.

Furthermore, the drainage and over-exploitation of peat wetlands and other upland habitats is known to enhance the loss of dissolved organic carbon (DOC) to watercourses and to significantly increase water discolouration through contamination with colour-causing organic compounds such as humic acids (Worrall et al., 2007; Wallage et al., 2006; Armstrong et al., 2010).

Figure 22 (*top*) shows how the average level of colour recorded in the upper Dart at Two Bridges of 21.8 Hazen was higher than the average level in the Lower River of 17.5 Hazen between 2005 and 2006.

In addition the maximum levels of colour recorded in the upper catchment (81 Hazen) were also much higher than those in the lower river (50 Hazen); an observation that is entirely in accordance with our field observations that the upper river does become highly coloured at certain times (see Figure 22; *bottom*)

Figure 22. Variation in the levels of colour recorded in the upper River Dart at Two Bridges and the lower River Dart at Totnes between 2005 and 2006.



In addition to the colour-causing compounds derived from peat and peaty soils, it has also been shown that leaf litter is another important source of natural dissolved organic carbon (DOC) in forested catchments (Hongve, 1999).

Chemical characterisation using DOC fractionation and tests of biodegradability show that natural litter percolates contain significant fractions of coloured and highly refractory hydrophobic acids (humic substances) and variable fractions of biodegradable compounds.

Furthermore, rainwater percolating through fresh litter is known to obtain higher concentrations of DOC and colour than is derived from older forest floor material and organic soils. Interestingly, deciduous leaf litter has been shown to impart high DOC concentrations in the autumn, while coniferous litter and organic soils release DOC more evenly.

It is clear that the effect of land improvement and increased land drainage, coupled with the increased availability of DOC and colour-causing compounds in the soil due to the decomposition of leaf litter and the degradation of the peat, could partly explain the elevated levels of colour recorded in the raw water at Littlehempston WTWs at certain times.

Many metal ions, and especially manganese, if not removed from the final treated drinking water, can discolour drinking water supply infrastructure and can also produce taste and odour problems that lead to customer dissatisfaction.

Data from South West Water and the Environment Agency indicate that the levels of manganese in the raw water at Littlehempston WTWs and in the River Dart at Totnes are, on average, low (average concentrations of 17.4 and 10.9 µg/l). However, while the samples from the River Dart have had a maximum recorded level of just 31 µg/l (2005-2012), the combined raw water in the WTWs had recorded levels of 134 and 58.8 µg/l between 2009 and 2010. It is possible that these spikes of manganese have been missed during 7 years of Environment Agency sampling, but it seems more likely that these very high levels in the combined raw water are derived from another source (perhaps the imported water from the South Devon Spine Main).

Manganese is released naturally from land with underlying geology where it occurs at high levels and it can therefore be leached at quite significant levels into watercourses. However, this leaching can be significantly enhanced where geological disturbance has been caused through human activities such as mining.

It has also been shown that upland peaty soils such as those found in the Littlehempston WTWs catchment, with their inherently acidic nature, particularly favour the mobilisation of manganese and, furthermore, conifer afforestation has also been demonstrated to increase manganese levels in surface waters immediately following felling.

Interestingly, the Littlehempston catchment also has significant areas of coniferous woodland and large areas of this have been (and continue to be) clear-felled on a regular basis. It is possible that this forestry activity could act at various times to elevate the levels of manganese in the watercourses of the Littlehempston catchment.

5.5. Agro-chemicals (pesticides)

Pesticide pollution occurs primarily through two routes: point sources (such as leakage, spillage or accidental direct application to a watercourse) and diffuse sources (active ingredients washed or leached from the soil following application).

The threat posed by an individual pesticide is also dependent on the unique intrinsic properties of the active ingredients, which determine the specific risk they pose in terms of water pollution and the ease of their subsequent removal from drinking water. These intrinsic properties include:

- ***Pesticide half-life:*** The more stable the pesticide, the longer it takes to break down. This can be measured in terms of its half-life, the longer it takes to break down, the higher its persistence.
- ***Mobility & solubility:*** All pesticides have unique mobility properties, both vertically and horizontally through the soil structure. Many pesticides are designed to be soluble in water so that they can be applied with water and be absorbed by the target, but a pesticide with high solubility also has a far higher risk of being leached out of the soil and into a watercourse.

  In contrast, residual herbicides are generally of lower solubility to facilitate their binding to the soil, but their resulting persistency in the soil can cause other problems.

In addition to the intrinsic characteristics of each pesticide, there are also several extrinsic factors that can determine whether a pesticide poses a risk in a particular situation:

- **Rainfall:** High levels of rainfall increases the risk of pesticides contaminating water. Water moving across or through the soil can wash pesticides into watercourses or they can be transported into the water bound to treated soil via soil erosion.
- **Microbial activity:** Pesticides in the soil are broken down by microbial activity and this degradation is expedited where the levels of microbial activity are high due to the presence of high numbers of microbes or elevated soil temperature. Pesticide residues can also be degraded through evaporation and photodecomposition.
- **Application rate:** The more pesticide that is applied, the longer significant concentrations remain available to be transported into the water.
- **Treatment surface:** Pesticides are generally designed to be applied to soil-based systems where they are held before being taken up by the target organism. When pesticides are applied to non-porous surfaces (such as concrete or tarmac) or to soil that is degraded, they are not absorbed by the soil and are therefore particularly vulnerable to mobilisation into watercourses following rainfall.

5.5.1. Pesticide risk assessment

The Littlehempston WTWs Source and Treatment Risk Review, undertaken by South West Water in 2009, concluded that the highest residual risk to the raw water quality at this works was pesticide contamination.

Monitoring undertaken by South West Water has recorded the presence of pesticides in the raw water abstracted for treatment at the Littlehempston WTWs on 907 occasions since 1992 with 44 different active ingredients detected over this period (summarised in Figure 24).

The most commonly detected pesticides in the catchment were the organophosphate insecticides Diazinon (271 detections) and Propetamphos (106), the organochlorine insecticide Sulcofuron (206) and the triazine insecticide Cyromazine (95). In addition, there have also been large numbers of detections of acid and neutral herbicides.

Of these pesticide detections, 575 (63%) were at a concentration over 10 ng/l and 49 (5%) were over the statutory limit of 100 ng/l (summarised in Figure 23).

Figure 23. Frequency and maximum concentration recorded for pesticides detected above the statutory limit of 100 ng/l in raw water at Littlehempston.

PESTICIDE	No samples > 100ng/l	Max conc. (ng/l)
Atrazine	2	242
Diazinon	5	212
Dichlobenil	5	175
Dichlorprop	1	141
Isoproturon	3	140
MCPA	1	429
MCPB	3	208
Mecoprop	1	461
Propetamphos	3	123
Sulcofuron	25	400
Grand Total	**49**	**461**

Figure 24. Types of pesticides and frequency of their detection in the raw water sources, combined raw water and final treated water at Littlehempston WTWs († = acid herbicide, ◊ = neutral herbicide, # = insecticide).

PESTICIDE	River Dart	Spine Main	Combined	Total
2,4-D †	6			6
2,4-DB †	2			2
Atrazine ◊	4			4
Benazolin †	1	1		2
Bentazone †	2			2
Bromoxynil †	4			4
Carbendazim ◊	1		1	2
Chlorfenvinphos #	5			5
Chlorotoluron ◊	3			3
Chlorpropham ◊	1			1
Chlorpyriphos #	4			4
Clopyralid †	6	1		7
Cyromazine #	55		40	95
Diazinon #	258	2	11	271
Dicamba †	12			12
Dichlobenil #	5	7	2	14
Dichlorprop †	5			5
Diflufenican #	2			2
Diuron ◊	3		1	4
Fluroxypyr †	1			1
Flusilazole	3			3
Ioxynil †	2			2
Isoproturon ◊	10		1	11
Kresoxim-methyl #	1			1
Lindane #	3			3
Linuron ◊	1			1
MCPA †	23	1	2	26
MCPB †	17			17
Mecoprop †	37	1		38
Metaldehyde	9	1	1	11
PCP†	8		1	9
Pendimethalin #	4			4
Propetamphos #	94		12	106
Sulcofuron #	204	1	1	206
Terbuthylazine ◊	1			1
Triclopyr †	16		1	17
Trifluralin ◊	4		1	5
Grand Total	**817**	**15**	**75**	**907**

The i-Map Water pesticide risk assessment application is considered to represent the best value for money and provide us with suitably robust data on which to base our analysis of pesticide pollution risk across the landscape.

The i-MAP Water system estimates that around 11,272 kg of pesticides were applied to around 50,181 Ha of agricultural land in the Littlehempston WTWs catchment in 2011/12. Figure 25 shows the 10 pesticides that the i-MAP Water system estimates had the greatest usage in the Littlehempston WTWs catchment in 2011 and what landuse they were thought to be applied to.

Figure 25: The 10 pesticides most heavily applied (in kg) to the Littlehempston WTWs catchment and their usage. AIs that have been detected at Littlehempston are shown in red text.

Pesticide	Total (Kg)	Temp. grass	Perm. grass	Rough grazing	Cereals	Seed Oils	Veg
Glyphosate	**1,457**	241	341		774	55	36
MCPA	**1,442**	**143**	**1,246**		**50**		**1**
Chlormequat	**1,072**				1072		
Mecoprop-P	**640**	**152**	**114**		**374**		
Pendimethalin	**554**				**481**		**70**
Chlorothalonil	**536**				456		76
Triclopyr	**426**	**23**	**395**	**8**			
Prosulfocarb	**420**				360	4	56
MCPB	**300**	**294**					**6**
Chlorotoluron	**276**				**276**		

Interestingly, of these top 10 most used active ingredients, only the more mobile acid herbicides MCPA, Mecoprop and Triclopyr have been detected regularly at Littlehempston WTWs.

Other pesticides in the top 10, such as Chlormequat, Chlorothalonil, Pendimethalin and Prosulfocarb are all either less mobile in the environment or degraded more readily and, perhaps as a result of this, they have never been detected in the raw or final treated water at Littlehempston WTWs.

As an example of this, the University of Hertfordshire ***Pesticide Properties Database*** (sitem.herts.ac.uk) states that Chlormequat has low leaching potential and breaks down quickly in soil and these physicochemical properties probably explain why it has not been detected despite its high predicted application rate in the catchment.

It is also interesting to note that the most commonly detected insecticides in the raw water at Littlehempston WTWs are not among the most heavily used in terms of application rate. In light of this, it is also interesting to use the i-MAP Water system to rank the pesticides according to the actual risk they pose to water quality by taking the application rate, the area of land treated and the physicochemical properties of the active ingredient into account.

The top 10 most 'risky' pesticides in the Littlehempston catchment, according to i-Map Water are shown in Figure 26.

Figure 26: The 10 pesticides posing the greatest risk to the raw water at the Littlehempston WTWs. AIs that have been detected at Littlehempston are shown in red text.

Ranking	Active ingredient	Relative overall score
1	Triclopyr	100.00
2	Glyphosate	44.22
3	MCPA	43.69
4	Chlormequat	33.24
5	Prothioconazole	29.79
6	Clopyralid	27.92
7	Mecoprop-P	27.12
8	Chlorothalonil	22.65
9	Epoxiconazole	20.87
10	Pendimethalin	17.28

The i-MAP Water risk assessment performs moderately well in predicting contamination by the highly mobile herbicides that have been detected at Littlehempston WTWs, but it does not predict the high frequency and very high levels of insecticide pesticides that are recorded in this catchment.

This observation, combined with the typical application method of these low mobility – low application rate active ingredients, suggest that these contaminations are more likely to be occurring either during of immediately after their application to the treated animals.

5.5.2. Insecticide risk assessment

In the UK, the insecticides Diazinon, Propetamphos, Sulcofuron and Cyromazine are primarily used either as a sheep-dip or pour-on treatments for livestock or for the domestic control insect pests (see examples of Diazinon-containing products in Figure 27.

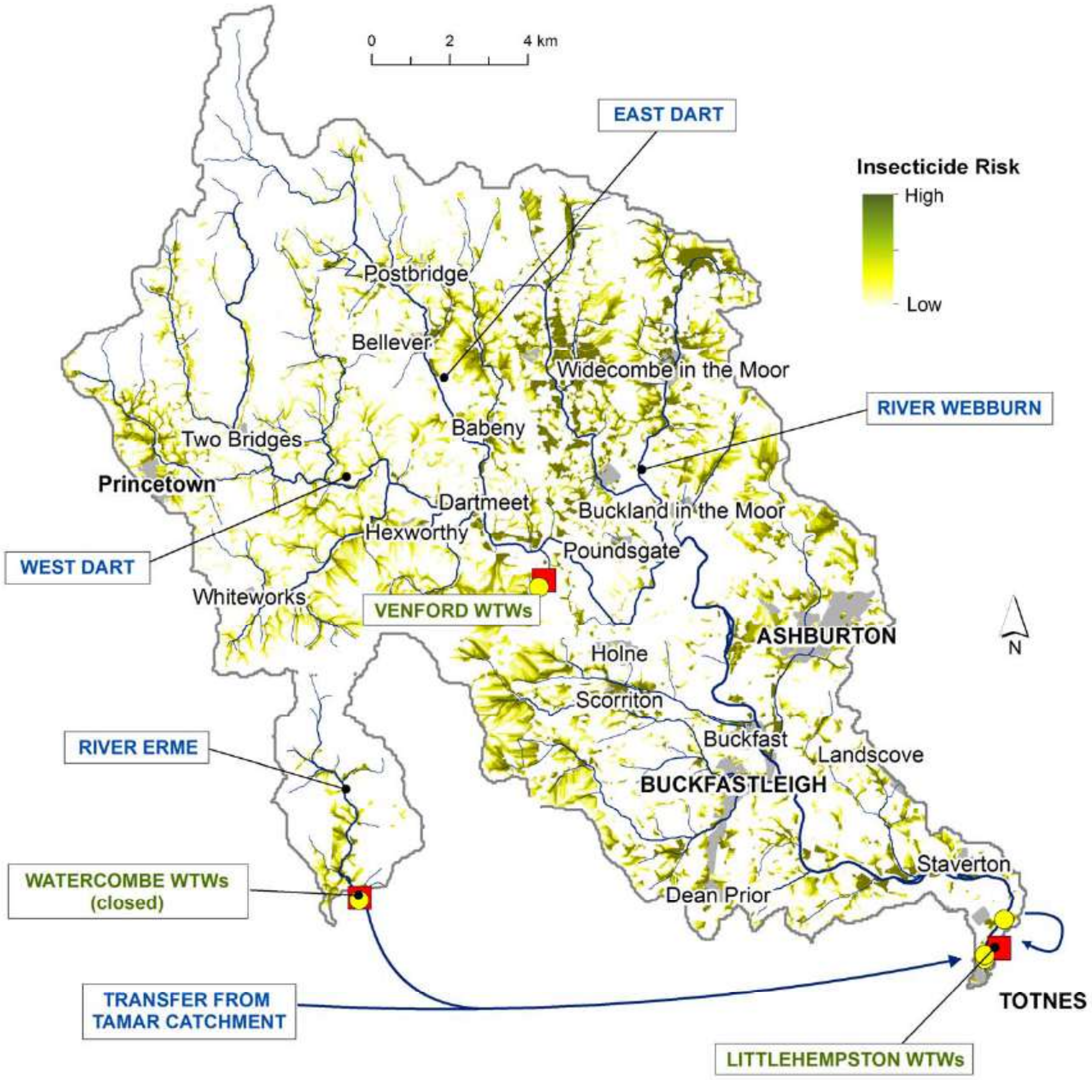
Although it is largely extensive in nature, the presence of large numbers of beef and sheep livestock farms in the Dart catchment clearly results in an increased risk that these pesticides may be mobilised during or following their application and enter a watercourse in the catchment.

Figure 27. Examples of sheep dip and other insecticide pesticides that contain Diazinon.

While it is not possible to predict where point-source pesticide contamination may occur during preparation or storage of these active ingredients, we can assess the risk that they may be mobilised after their application using a spatial modelling approach. The principal aim of this approach is to identify areas where the use of pesticides applied to livestock may be mobilised (washed off) and transported through or over the soil and into a watercourse.

For these insecticide treatments we believe that the greatest risk occurs in hydrologically connected areas where the highest intensity livestock farming is undertaken on grassland landuse areas. As the risk map in Figure 28 shows, these areas are particularly concentrated in the Webburn sub-catchment and in the headwaters of the Mardle and West Dart on the west side of the catchment.

Figure 28. Spatial risk map showing areas where there is the greatest risk of insecticide water contamination.



5.5.3. Herbicide risk assessment

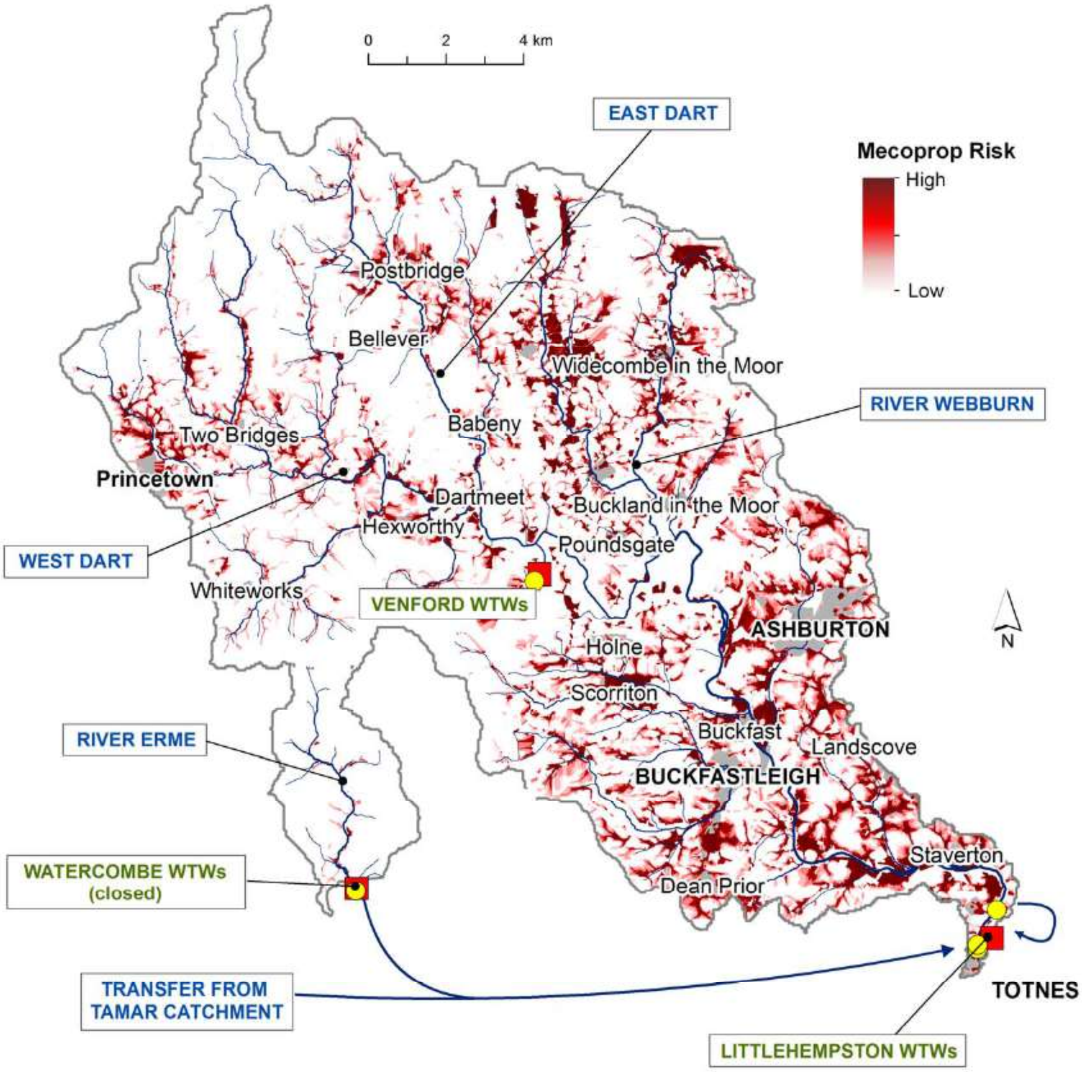
The most commonly occurring herbicide detected in the raw water at the Littlehempston WTWs is the acid herbicide Mecoprop (38 detections), while the herbicide that has exceeded the 100 ng/l statutory limit most often was MCBP (3 detections over 100 ng/l up to a maximum of 208 ng/l).

The acid herbicide ***Mecoprop*** (2-methyl-4-chlorophenoxyacetic acid) is a common general-use herbicide found in many agricultural and household weed killers. It is primarily used to control broadleaf weeds and is often used in combination with other chemically related herbicides such as 2,4-D, Dicamba and MCPA.

The i-Map Water system estimates that, in 2011, 152 kg of Mecoprop were applied to 294 Ha of temporary grassland (0.52 kg/Ha), 114 kg were applied to 621 Ha of permanent pasture (0.18 kg/Ha) and 374 kg were applied to 550 Ha cereal crops (0.68 kg/Ha) in the Littlehempston catchment. We can use these application rates, in combination with the maps of landuse and hydrological connectivity for the catchment to identify areas where there is an elevated risk of Mecoprop being mobilised following its application.

The resulting risk map, shown in Figure 29, indicates that the greatest risk of Mecoprop pollution is localised in the Webburn sub-catchment in the north east and in the southern half of the catchment. This is entirely in accordance with the high concentration of the cultivated land and temporary grassland in these sections of the catchment.

Figure 29. Pesticide pollution risk model for the acid herbicide Mecoprop.

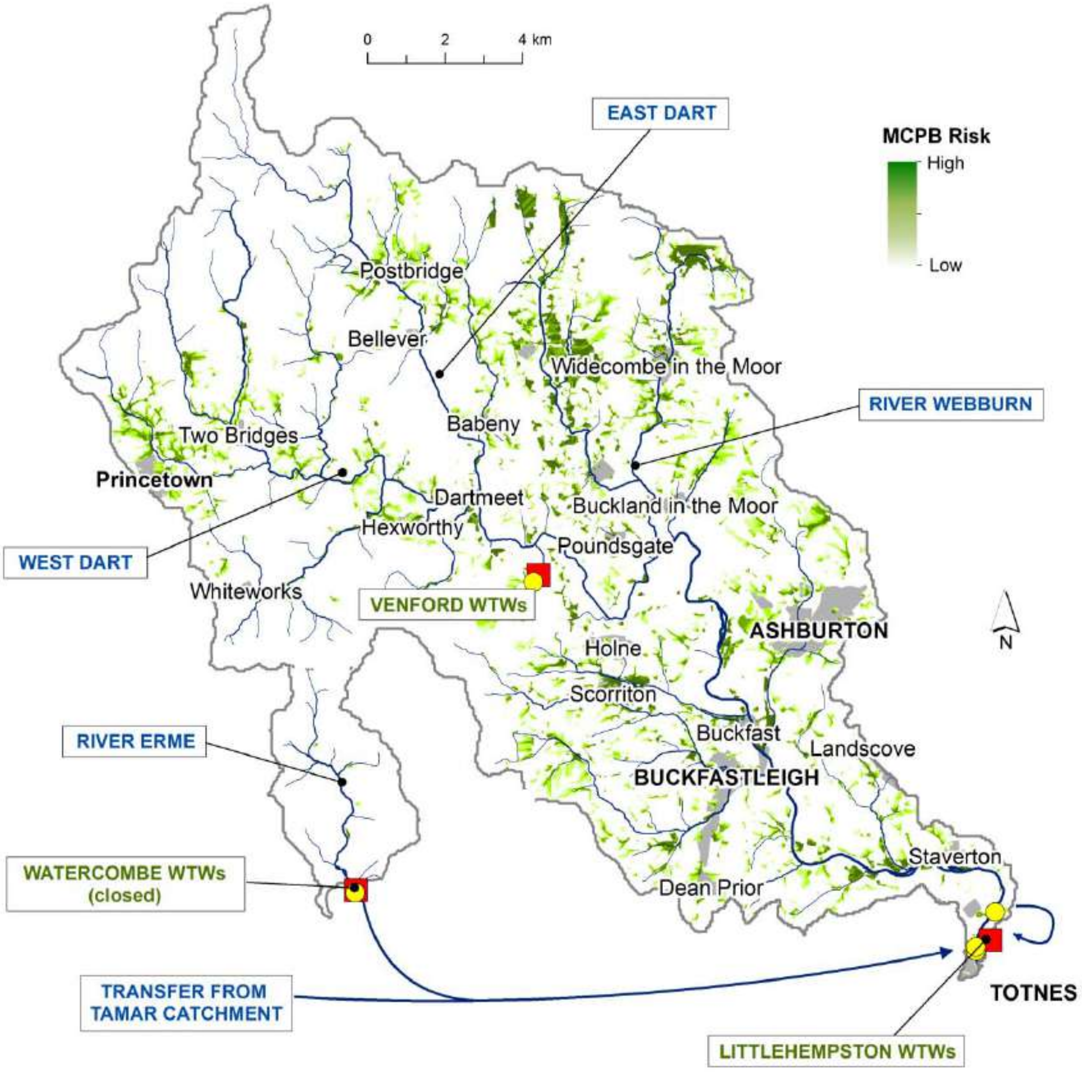


The acid herbicide ***MCPB*** (4-4-chloro-2-methylphenoxy-butanoic acid) is a selective, systemic herbicide for post-emergence control of annual and perennial broad-leaved weeds including thistles and docks. MCPB is often used in combination with other active ingredients including; Mecoprop and MCPA.

The i-Map Water system estimates that, in 2011, 294 kg of MCPB were applied to 160 Ha of temporary grassland (0.52 kg/Ha) in the Littlehempston catchment. It does not estimate that there was any application of MCPB to permanent pasture or arable land. We can use these application rates, in combination with the maps of landuse and hydrological connectivity for the catchment to identify areas where there is an elevated risk of MCPB being mobilised following its application.

The resulting risk map, shown in Figure 30, indicates that the greatest risk of MCPB pollution is spread quite widely across the catchment (in line with the far wider distribution of the temporary grassland on which it is exclusively used). There are particularly extensive areas of risk in the middle reaches of the Webburn valley, in the upper reaches of the West Dart around Princetown and around the Ashburn and Mardle tributaries in the south of the catchment.

Figure 30. Pesticide pollution risk model for the acid herbicide MCPB.



5.6. Water Resources

If water runs off the land and accumulates in rivers too rapidly during periods of low rainfall, and there is insufficient volume of water retained in the catchment, then the reliable supply of water to rivers can be jeopardised.

When these so-called 'base-flows' reach extremely low levels, for whatever reason, there is a risk that the ecological condition of the river will be degraded and that there will be insufficient flow further downstream, where it is relied upon for uses such as the supply of drinking water, dilution of discharged effluents or agricultural irrigation.

Fluctuations in the provision of water resources by the River Dart catchment can have significant implications for the quality of the raw water and treatment processes undertaken at the

Littlehempston WTWs. The management of water resources in the Dart catchment has recently been the subject of a detailed study by WWF UK (WWF UK, 2011), which concluded that careful water resources management would be required in the future to avoid significant additional treatment costs, water pumping costs and environmental damage being incurred.

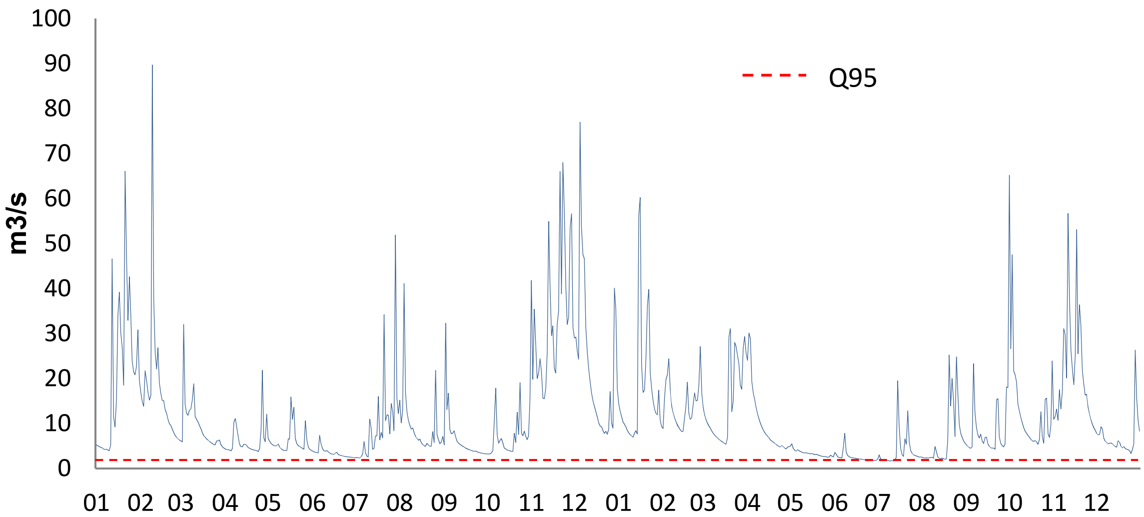
When the flow at Austin's Bridge on the River Dart is 0.789 cumecs (68 Ml/day) or less, not more than 9 Ml/day can be abstracted and alternative sources, such as water from the Tamar catchment, must be used. Changing the source of the raw water treated can result in lower quality water that requires a greater intensity of treatment being brought into the WTWs.

When the river flow at Austin's Bridge rises above 0.789 cumecs, for each unit increase in flow above this figure a like unit may be abstracted, up to a maximum of 27.28 Ml (around 60-70% of the average treated volume at the WTWs). The permitted abstraction constitutes as much as 30% of total flow in low flow spells (30% at the Q99, 20% at the Q95).

Hydrometric data from the Environment Agency gauging station at Austin's Bridge on the River Dart at Buckfastleigh (see Figure 31) indicate that, typically for a Dartmoor river with granite bedrock, the Dart has a very 'flashy' hydrograph.

It also shows that, since 2005, the flow has never fallen below the minimum of 0.789 cumecs mean daily flow where restrictions on abstraction come into force. However, there have been ~60 days when the flow fell below the Q95 level and the abstraction could have exceeded 20% of the total flow in the river.

Figure 31. Hydrometry data from Austin's bridge on the River Dart at Buckfastleigh for 2009-2010.



What is clear from these data is that there are occasions when the River Dart is unable to provide a reliable source of raw water for Littlehempston WTWs and alternative sources must be found.

At present these alternative sources represent a satisfactory solution to a water shortage in the Dart catchment and, in recent years, this system has not been put under significant pressure. If, however, water resources pressure is increased on these alternative sources, such as Burrator Reservoir and the River Tamar in the Roadford supply area, then the risk that there will be a water shortage at Littlehempston will be significantly increased.

6. Intervention strategy development

6.1. Current mitigation of risk & cost in the catchment

Before we can proceed with the development of a catchment management programme for the Littlehempston WTWs catchment we must first gather precise and detailed evidence of what plans are already in place and what interventions have already been delivered across the catchment.

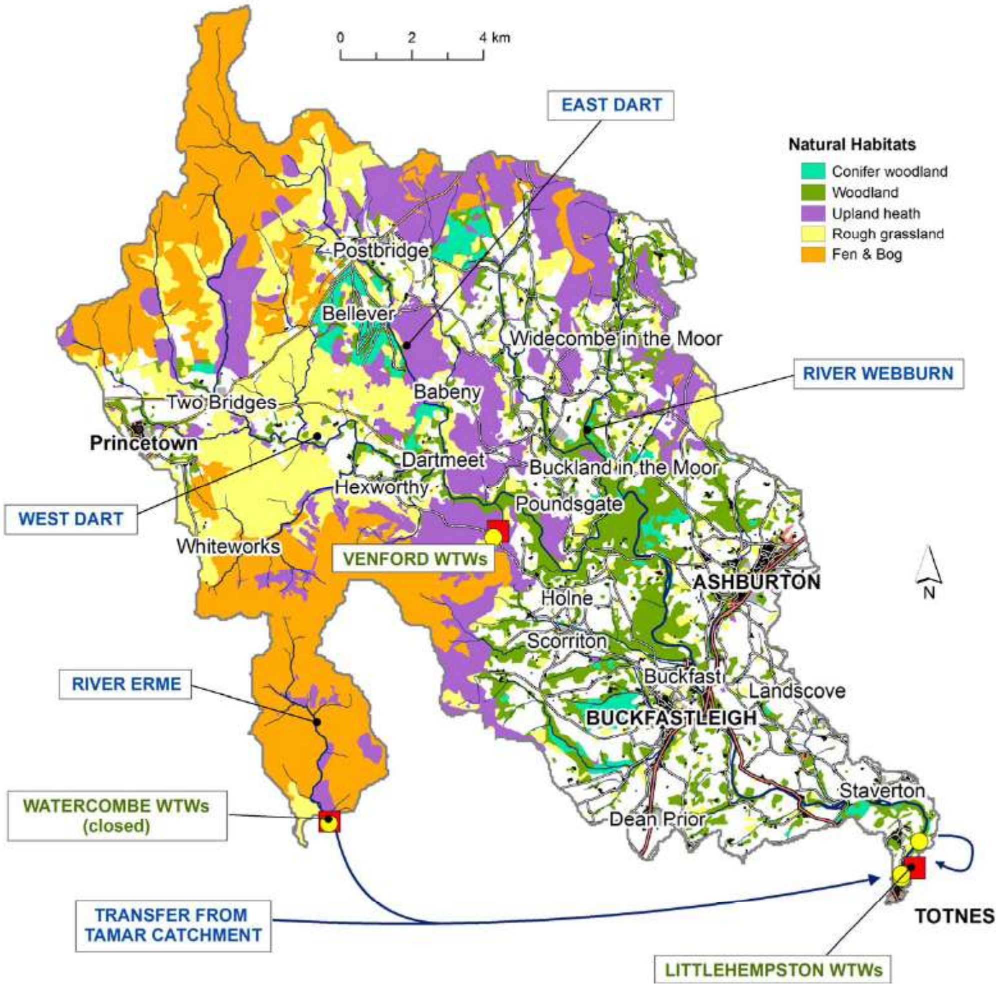
In the following section, we will give an overview of the regulatory, policy and practical interventions that have already been delivered to mitigate the impact of pollution on both the ecological health of rivers and on the risks and costs incurred at Littlehempston WTWs through having to treat low quality raw water.

6.1.1. Natural mitigation & designated sites

Natural habitats play a key structural and functional role in the ability of our natural ecosystems to provide the services on which we all depend; including the protection of clean, fresh water in our rivers and streams, the mitigation of flood risk and the prevention of erosion. Extending and increasing the connectivity of existing natural habitats across catchments, in addition to the creation of new riparian wetlands to disconnect hydrological pollution pathways, are some of the key methods used in catchment management and natural resource protection.

Figure 32 shows the distribution of natural habitats across the Littlehempston catchment. These data, obtained from the Natural England habitat inventory, indicate that there are ~3,500 Ha of heathland, ~7,350 Ha of fen and bog and ~7,000 Ha rough/moorland grazing habitat in catchment.

Figure 32. Distribution of important natural habitats in the Littlehempston WTWs and Watercombe catchments.



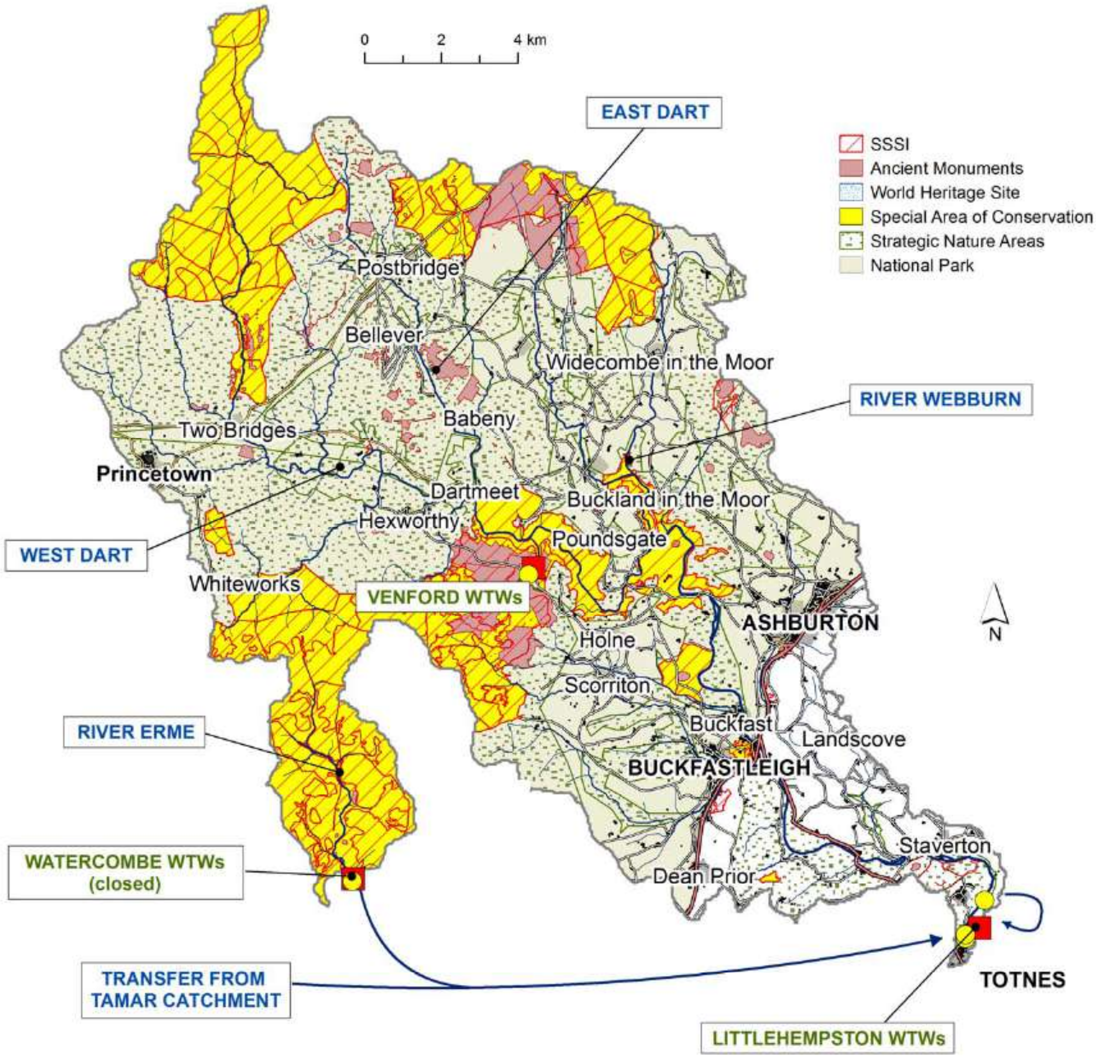
Under the Conservation (Natural Habitats) Regulations 1994, the UK is committed to the designation and protection of three types of internationally important conservation sites: Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar Sites. We also have a statutory framework for the designation and protection of nationally important Sites of Special Scientific Interest (SSSIs), and protected species – through the Wildlife and Countryside Act 1981.

The designation and protection of land that is important for nature conservation has historically been one of the key methods used to protect and conserve the natural environment in the UK.

In an attempt to increase the benefits obtained from the protection and expansion of the designated site network in the Westcountry, Biodiversity South West are adopting a more integrated landscape-scale approach to nature conservation. They have identified a series of Strategic Nature Areas that are being prioritised for conservation action through active partnership within and beyond the environmental sector. Their objective is to achieve the best environmental return for the optimum investment of resources.

Figure 33 shows the distribution of designated land across the Littlehempston WTWs catchment. The catchment area above the A38 is within Dartmoor National Park and almost the entire catchment area is designated as either a Dartmoor Blanket Bog or Woodland Strategic Nature Area. There are also several Sites of Special Scientific Interest (SSSIs) and Scheduled Ancient Monuments (SAMs) in the catchment. Several areas of Dartmoor and the whole of the Watercombe catchment on the River Erme are also designated as Special Areas of Conservation (SAC).

Figure 33. Distribution of important natural habitats in the Littlehempston WTWs and Watercombe catchments.



6.1.2. Previous on-farm interventions: Environmental Stewardship

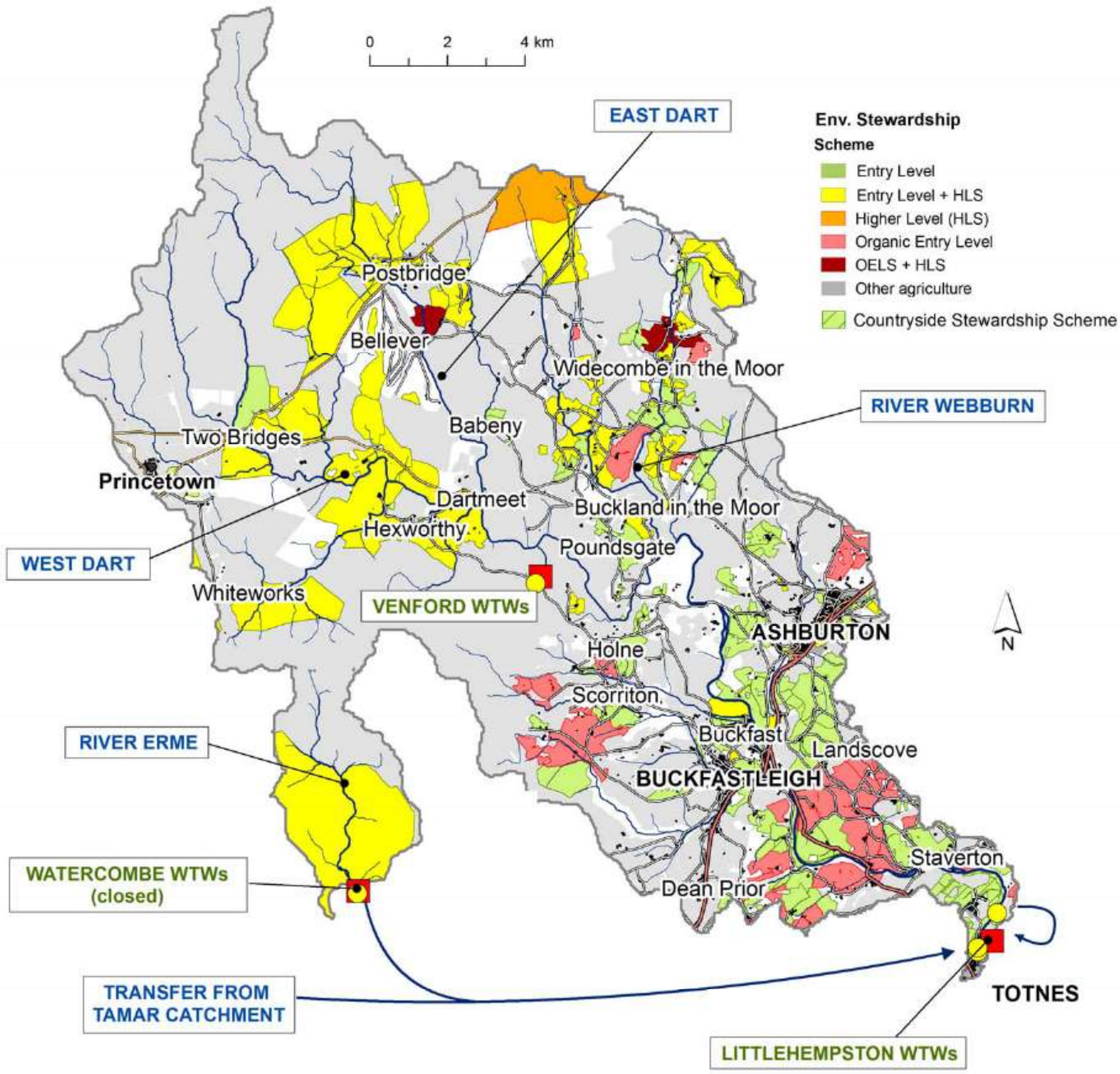
The Environmental Stewardship (ES) Scheme, incorporating the Entry Level Scheme (ELS), Organic Entry Level Scheme (OELS), the Uplands Entry Level Scheme (UELS) and Higher Level Scheme (HLS), provides payments to farmers to undertake specific management practices or capital works that protect and enhance the environment and wildlife.

The ESS is offered to farmers on a voluntary basis and is promoted as multi-objective scheme covering a range of biodiversity, heritage and natural resource protection objectives, including soil and water protection.

The ELS, OELS and UELS are non-competitive schemes and are open to all farmers whilst the HLS is a competitive scheme within which farmers must effectively bid for a share of a limited budget. According to Natural England personnel engaged with the project, HLS currently covers 10% of agricultural land across England and is increasingly focusing on SSSI sites and Habitats Directive designated areas.

Figure 34 shows the distribution of farm holdings currently engaged in an ES scheme across the Littlehempston catchment. These data indicate that there are 8 farms in the catchment that are in Organic Entry Level (6) or Organic Higher Level (2) Environmental Stewardship schemes, around 15 that are in Higher Level Stewardship and several others that are in Entry Level Schemes.

Figure 34. Distribution of Environmental Stewardship schemes taken up by farmer in the Littlehempston catchment.



6.1.3. Previous catchment interventions: The Dartmoor Mires Project

The principal land-based interventions that can delay the release of water from a catchment are: good management practices that maintain the healthy structure of soil, the cessation of land drainage in areas with a propensity to accumulate water (i.e. that are naturally wet), and the creation/restoration of upland and floodplain wetland habitats.

Wetland habitats, whether on upland peat-based soils or on the floodplain, have been shown by many studies to play a key role in the regulation of the hydrological cycle in river catchments and one of their principal actions is to act as water storage that releases water to rivers during periods of low rainfall and to therefore contribute to the maintenance of base-flows (e.g. Bradley, 2002 and Bullock and Acreman, 2003).

The Dartmoor and Exmoor Mires Projects represent a real opportunity to make a significant difference by implementing sustainable hydrological management in upland river catchments. Increased storage and retention times of surface waters should result in local modifications to the existing hydrology with small scale reductions in peak flows, elevated base-flows and reduced water velocities. The buffering capacity of restored wetlands may also contribute locally to the reduction of environmental damage and pollution associated with extremes in flow.

The Dartmoor Mires Project is a 5 year project which began in April 2010. It is a pilot project which aims to investigate the feasibility, practical implications and cost of restoring damaged areas of high value blanket bog. It will investigate the benefit this brings for biodiversity, water and carbon storage. Evidence gathering is a major driver for the project and this is reflected in the majority of areas of work.

The project benefits from funding of £1.1m from South West Water through the Upstream Thinking programme, and is a sister project to the Exmoor Mires on the Moors Project. It also benefits from substantial contributions from its other partners.

Work to restore an area of bog at Winney's Down, which began in autumn 2011, was completed during September 2012 (see Figure 35) and further work has also taken place on a second area around 0.5 miles north of the first.

Both areas contain high quality blanket bog which was threatened by encroaching erosion that had already reduced the quality of blanket bog in places across the site, particularly around the periphery.

Figure 35. Before (left) and after (right) photographs from Whinney's Down the first phase of restoration undertaken as part of the South West Water and Dartmoor National Park-funded Dartmoor Mires Project. *Images: Dartmoor Mires Project.*

6.1.4. Previous catchment interventions: Catchment Restoration Fund

Building on a long track record of river restoration and catchment management activity in the River Dart catchment, in June 2012 the Westcountry Rivers Trust was successful in their application for a three year Catchment Restoration Fund project on the Dart by the Environment Agency.

The Dart and Teign River Improvement Project (DTRIP) is primarily about delivering on-the-ground action to address the Water Framework Directive (WFD) failures and improve the overall ecological status of all failing water bodies within the Teign and Dart catchments by 2015.

In order to establish the true ecological condition of the rivers and inform effective management decisions a very carefully designed monitoring programme is to be conducted, including –

- ***Juvenile Electro-Fishing Surveys.*** A catchment wide annual juvenile electro-fishing survey programme will be conducted.
- ***Diatom Sampling.*** Diatom sampling has been conducted to assess pH and nutrient levels derived from soil movement and agriculture.
- ***Water Chemistry Data Loggers.*** Data loggers will be installed to assess the fluctuations in pH and chemicals derived from road run off.
- ***Fisheries Habitat Walkover Surveys.*** To assess in-channel and bankside habitat conditions
- ***pH Feasibility Study.*** The pH issues will be addressed with highest caution. University College London (UCL) is currently carrying out an Acid Feasibility Study to investigate the true causes and effects of low pH on Biodiversity. The results from this study will inform the next stages, where potential remediation methods maybe trialled.

To tackle issues in the Dart and Teign river catchments, the DTRIP project will manage delivery of the following activities:

- ***Weir & Culvert Easements.*** Direct physical action to improve the connectivity of the river for multiple migrating species (fish and/or eels), therefore removing the factor that is causing the waterbody to fail for fish;
- ***Gravel augmentation.*** Restoration of fish spawning habitat by means of gravel works will increase spawning rates and survival of the early stages of salmonid and other fish life cycles, thereby improving areas that are failing for fish;
- ***River Bank Management*** – This approach combines shade management through coppicing, selective planting and Coarse Woody Debris (CWD) addition or removal (depending on ecological benefit and flood risk assessment) with the aim of improving areas that are failing for fish;
- ***Fencing and Alternative Drinking Source Grants.*** Where agricultural input is a causative issue of failure under WFD, riparian fencing and associated drinking points has multiple benefits; it reduces poaching of banks caused by livestock, it allows patchwork mosaic of different riparian habitat growth (when done well), it avoids areas that are best left unfenced (such as some upland areas), it acts as a partial capture system to incept land and road run off and increases in-stream ecological diversity;
- ***Nutrient Management.*** Free soil tests and nutrient management advice will be made available to farmers within both catchments.

- ***Abstraction.*** Some tributaries are fed by reservoirs which alter natural flows and can result in periods when pH is very low. There are also a number of hydro-electric schemes on both rivers. These conditions negatively impact on biodiversity and will be addressed through working with local water companies such as South West Water;
- ***Improved Road Drainage Systems.*** Many of the River Teign's northern tributaries run adjacent to the main A30 road. This has been reported to cause chemical diffuse pollution to flow into connecting water bodies, which causes water quality to fail under WFD standards. Specifically designed monitoring methods will investigate and inform effective management strategies to address this water quality issue;
- ***In Channel Habitat Restoration Works.*** Gravel management work to improve spawning conditions and increase biodiversity e.g. Gravel weeding, cleaning etc.
- ***Partner Engagement.*** Working with partners across the catchment to monitor, identify and communicate what actions are required.

Success in the Teign and Dart catchments will include the direct delivery of the above WFD targeted actions, but will also include the development of a strong partnership that brings together local communities and encourages them to take pride and ownership of the issues affecting the catchment they live in.

By promoting this awareness and ensuring that the local community understands their dependence on these natural resources, the Westcountry Rivers Trust aim to ensure the project is not only successful in the short term but will be sustainable and continued into the future.

6.2. Proposed catchment management programme

Over the last 10 years the Westcountry Rivers Trust has developed farm management advice, which can help minimize loss of pollutants from farms whilst maximizing their on farm usage to increase yields and save costs. Some of the most common on-farm Best Farming Practices (BFPs) we recommend to farmers, and which we are now delivering on farms across the Westcountry as part of the Upstream Thinking and WATER Projects, are illustrated in Figure 36.

These BFPs have been assessed by a group of academics, funded by DEFRA, to produce a peer-reviewed and published manuscript, which describes the effectiveness of the BFP measures for the reduction of diffuse agricultural pollution (Cuttle et al 2007).

During the development of the measures there were a number of key design considerations which allow our farm advisors to correctly tailor and target their application:-

Mechanism of action. It is important to understand the mechanism via which the intervention will reduce pollution. Often this will require the presentation of evidence that it is the farming practice which is actually causing pollution before intervention is undertaken.

Applicability. Each measure must have the farming systems, regions, soils and crops to which it can be applied clearly defined. Farm advisors must recommend interventions that are suitable for the situation found on a farm.

Feasibility. The ease with which the measure can be implemented and any potential physical or social barriers to its uptake or effectiveness must be identified. Careful consideration must be given to measures that have impacts on other farming practices.

Costs and benefits. The cost of implementing, operating and maintaining the measure must be clearly understood. The potential practical and financial benefits to the farmer of implementing the measure must also be estimated as it is vital for encouraging uptake of the measures. In some circumstances, for example where the cost is high or the measure will result in a loss of income to the farmer; there will be a need for the farmer or farm advisor to find additional funding from incentive or capital grant schemes.

6.2.1 .Proposed Littlehempston catchment management programme

Our proposed catchment management project for the Littlehempston WTWs catchment will incorporate the delivery of a suite of intervention and mitigation measures, including:

Farm visits and advice

An integrated farm advice package will cover many aspects of a farmers practice and will indicate where the adoption of good/best practice may minimise the risk that an activity will have a negative impact on the environment and where it may enhance the provision of a particular ecosystem service.

In addition to broad advice on good practice, an advice package should produce a targeted and tailored programme of measures that could be undertaken and will include specific advice on pesticide, nutrient and soil management on the farm.

- ***Pesticide management plans.*** Standards for the use and management of pesticides in the UK are set out by *BASIS* and the *Health and Safety Executive* and, in 2001, the farming and crop protection industry established the *Voluntary Initiative* to promote best practice in the use and management of pesticides and to minimise their environmental impacts. The Voluntary Initiative programme was developed as an alternative to a pesticide tax which had, until that time, been under consideration by the Government. Advice and training in the use and management of pesticides, delivered to farmers and their contractors via a pesticide plan, can prevent accidental pollution from occurring either during preparation or following application.

Given the level and frequency of pesticide contamination experienced in the raw water at Littlehempston WTWs the delivery of pesticide advice and planning should be given extra priority in the catchment management plan delivered.

- ***Nutrient management plans.*** Nutrient management can help farmers to save money and reduce pollution, and they are an important record of practices undertaken on a farm. A nutrient management plan will ensure that farmers are aware of Cross Compliance Statutory Management Requirements (SMRs), such as Nitrate Vulnerable Zone regulations and the regulation relating to the appropriate use of fertilisers.

- ***Soil management plans.*** A soil management plan will set out how a farmer can manage their land to reduce the risk of soil erosion occurring. Farm advisors, supported by a number of guides produced by DEFRA, the Environment Agency and other organisations, can work with a farmer to document a field-by-field assessment of erosion risk and to identify the steps that can be taken during the year to minimise the risk of run-off and erosion.

Capital grants for on-farm infrastructure

Where our farm advisers believe it to be appropriate they will recommend in the farm plan that improvements or additions be made to the infrastructure on a farm. The uptake of these measures is entirely voluntary and the grant will be made as contribution to the total cost of the work.

Land covenants to change farming practice

Alongside the delivery of capital investment in farm infrastructure we are also able to attach covenants to farmers' contracts which restrict what practices they can undertake on certain section of their land.

Farming community engagement

We will continue working to raise awareness of the Upstream Thinking initiative among the local farming communities in each catchment and to establish/re-establish contact with new and existing contacts on the ground. To facilitate this work, our farm advisors will convene a series of farmer meetings in the various sub-catchments to explain the project and collect contact details.

Figure 36. Best Farming Practices (BFPs) that can minimize loss of pollutants to watercourses as a result of agricultural activity.

Soil management

- (A) Cultivate and drill across the slope
- (B) Avoid over-winter tramlines
- (C) Establish in-field grass buffer strips
- (D) Adopt minimal cultivation systems
- (E) Avoid high risk crops next to river

Livestock management

- (A) Reduce overall stocking rates on livestock farms
- (B) Reduce field stocking rates when soils are wet
- (C) Move feeders and water troughs at regular intervals
- (D) Construct troughs with a firm but permeable base
- Reduce dietary N and P intakes

Fertiliser management

- (A) Do not apply fertiliser to high-risk areas; Avoid spreading fertiliser to fields at high risk time
- (B) Use clover in place of grass

Farm infrastructure

- (A) Fence off rivers & streams from livestock
- (B) Construct bridges for livestock crossing streams
- (C) Re-site gateways away from high-risk areas
- (D) Farm track management
- (E) Establish new hedges
- (F) Establish Riparian buffer strips; Establish & maintain artificial wetlands

Manure management

- (A) Increase the capacity of farm manure (slurry) storage; Install covers on slurry stores
- (B) Site manure heaps away from watercourses; Site manure heaps on concrete and collect effluent
- (C) Minimise volume of dirty water and slurry produced

Mire and upland restoration

There is considerable evidence that re-wetting of peat-lands and mires that have been degraded by drainage, the over-exploitation of peat or intensive landuse practices (agriculture or forestry) can reduce the leaching of Dissolved Organic Carbon (DOC) compounds that cause colouration of raw water.

We believe that a programme of mire and wet-woodland restoration undertaken in the Littlehempston WTWs catchment may successfully mitigate the risk of high colour levels occurring in the raw water supplied to the works. This programme would require close partnership working between the National Park Authority, the Dartmoor farming community, the Forestry Commission and the Duchy of Cornwall to facilitate the delivery of these improvement/management interventions.

In addition to the water quality benefits associated with work of this type, it also possible that improved management or restoration of the wetland habitats in the catchment could mitigate costs and risks posed by the extreme low flows that are occasionally experienced in the catchment during dry periods and which require supplementary raw water to be pumped in from other sources which may themselves be under increasing pressure.

Septic Tank surveys and management advice

There are a number of additional potential point sources which could be making significant phosphorus and microbial contributions to the watercourses in the catchment and having some impact on their ecological health and, potentially, on the raw water quality abstracted for treatment.

Among these point sources are a number of properties which may have unconsented septic tank discharges and these need to be investigated and checked to ensure they are being operated optimally. We will undertake a survey of septic tank usage and give management help and support to mitigate any problems found.

Water quality monitoring programme

We are committed to continuing our water quality, invertebrate and pesticides monitoring programmes. This will allow us to gather further information on the raw water quality in the rivers and to demonstrate any improvements that are achieved as a result of our catchment management activities.

This monitoring programme will include the initial trialling of the passive sampling technology currently being developed in association with SWW and the University off Portsmouth.

6.3. Deliverables and costs for proposed plan

In light of all of the findings of this investigation we have developed a costed 5-year intervention strategy that includes all of the elements described above. The proposed core deliverables and their estimated costs for this plan have been set out in a similar way to the structure of the current Upstream Thinking catchment management projects and are summarised in Table 3. Additional elements can easily be added to this structure if required.

This plan does not include the costs for upland/peatland restoration interventions, but a habitat restoration and management project of this type could cost around £4-5 million.

Table 3. Approximate deliverables and costs for the proposed Littlehempston WTWs Upstream Thinking catchment management project to be delivered between 2014 and 2019. These are estimated numbers of deliverables based on the number of farms engaged, the uptake and average spend achieved in the current Upstream Thinking initiative. Costs are approximate and for guidance only.

Advice & testing	Output	Unit Cost (£000)	Total Cost (£000)
- Farm planning/advisory visits including full farm survey, farm advisory plan & capital grant offer / negotiations	100		
- Pesticide plans including full pesticide risk assessment and usage plan, documentation and follow-up	50		
- Septic tank management plans survey and advice programme for septic tank best practice and management	50		
- Nutrient management plans including full nutrient and fertiliser management plan, documentation and follow-up	50		
- Soil tests including full soil assessment on each farm according to EA standard, documentation and follow-up	50	0.5	**25**
- Water chemistry monitoring weekly or bi-weekly samples at 6 locations for 2 years (yrs. 1 & 5)	300	0.125	**37.5**
- Pesticides monitoring passive sampling in triplicate at 6 locations - 4 seasons for 2 years (yrs. 1 & 5)	144	0.2	**28.8**
- Invertebrate monitoring 2 season sampling at 6 locations in 2 years (yrs. 1 & 5)	24	0.4	**9.6**
Total			**100.9**

Investments	Output	Unit Cost (£000)	Total Cost (£000)
- Fencing riparian corridor fencing (kms)	10	5	**50**
- Farm infrastructure slurry storage, tracks and crossing points, major clean & dirty water separation, roofing etc.	40	20	**800**
- Minor infrastructure alternative drinking, troughs, pumps, clean and dirty water separation etc.	50	0.3	**15**
Total			**865**

*** HR, delivery costs and overheads are not included here.

7. Assessment of outcomes

The principal, over-arching aim of our work is to improve raw water quality in Westcountry lakes and rivers and to make a significant contribution to their attainment of good ecological status in accordance with the EU Water framework Directive.

It is therefore vital for us to collect sufficient evidence to provide an objective and scientifically robust assessment of the effectiveness of our interventions. Ultimately, we must be able to justify that the money we have spent and the interventions we have made across the landscape have either delivered significant improvements in raw water quality (and have therefore made significant contributions to the delivery of good ecological status of river catchments) and have generated significant secondary financial, ecological and social benefits.

In light of these over-arching aims, we have developed a range of approaches that will allow us to assess various outcomes delivered by our catchment management work. This approach is designed to achieve the following objectives;

Quantification of intervention delivery. We are gathering precise and detailed evidence of what we have delivered, where we have delivered it, what it has cost and, perhaps most importantly, what the intended outcome is for each.

Monitor and evaluate environmental outcomes. We will attempt to collect a comprehensive and robust set of data and evidence which demonstrates qualitatively and quantitatively that we have achieved genuine improvements in raw water quality. In order to demonstrate the effectiveness of our interventions, it is vital that we collect baseline data (of the type presented in this report) and, in addition to temporal (before intervention) controls we have also explored the potential for some catchments/sub-catchments to form spatial controls for our studies. This approach will include a comprehensive evaluation of the current scientific literature relating to the likely outcomes achieved through the delivery of on-farm measures and the use of the most advanced modelling techniques which can be used to estimate the improvements in water quality that have been achieved.

Monitor and evaluate secondary outcomes. In addition to the key requirement for the Upstream Thinking Project to demonstrate real improvements in raw water quality, the initiative is also expected to have an array of other outcomes that could make considerable contributions to the ecological status of waterbodies or towards other environmental or nature conservation targets. We are engaging in a number of monitoring and modelling approaches to assess how our catchment management programme has enhanced the provision of other ecosystem services across the catchment and to quantify the economic gains achieved by those engaged in the process.

Further information & contacts

Dr Dylan Bright, Trust Director

Trained as a limnologist and freshwater ecologist Dylan is Director of the Rivers Trust and Managing Director of Tamar Consulting. He is an experienced farm and land management advisor and has led Defra funded projects investigating Water Framework Directive Metrics and implementation of catchment management plans to inform good status.

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Dr Nick Paling, GIS Officer

Nick is an applied ecologist and conservation biologist with 8 years of experience using spatial techniques to inform conservation strategy development and catchment management. He provides data, mapping & modelling support for all Trust projects and coordinates and manages a number of large-scale monitoring programmes currently being undertaken by the Trust.

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Hazel Kendall, Upstream Thinking Project Officer, BSc (Hons) AIEEM

Working with Upstream Thinking partners to collate information and data collection for reporting, Hazel will combine this role with bio-monitoring undertaken as part of the proof of concept study supporting the physical works of the initiative, using a range of sampling techniques and Biotic Indices.

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