Natural Capital Assessment Tool for South West Water: Ecosystem Service Valuation Framework - Methodology document

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As part of the South West Partnership for Environmental and Economic Prosperity (SWEEP) project, the team at the University of Exeter (Gemma Delafield, Dr. Michela Faccioli and Prof. Brett Day) carried out a simplified natural capital accounting exercise for South West Water. Natural capital accounting is about: 1) identifying changes in natural capital (stock of natural assets) and in the flow of ecosystem services and goods that these natural assets supply; and 2) measure the benefits or costs to society linked to such changes in ecosystem services flows. While it is acknowledged that the environment plays an important role in providing different benefits to people, these benefits are not easily identified. The value of the environment to people is, in most of cases, not reflected in market prices and can therefore be easily omitted from decision-making. To address this shortcoming, economic valuation techniques have been developed over time to quantify, in monetary terms, the increase (or decrease) in wellbeing that people experience following an increase (or decrease) in environmental quality. The aim of this document is to outline the different valuation approaches adopted in the development of the natural capital accounting exercise for South West Water. [1]

In short, the goal of the natural capital accounting exercise designed for South West Water was to summarize the monetized value of the expected environmental and social impacts that are anticipated to result from the interventions planned between 2020 and 2025 in the different business cases participating in the South West Water Upstream Thinking programme. This exercise will be used to guide South West Water business planning and, in particular, to better inform decisions about budget allocation that will be taken as part of the PR19 price review process.

The first steps in the development of the natural capital accounting exercise required the collection of information from the different organizations involved in the Upstream Thinking programme (i.e. Devon Wildlife Trust, Westcountry Rivers Trust, Cornwall Wildlife Trust, Exmoor National Park). Each project manager was asked to provide information about: i) the interventions planned in each of the business cases between 2020 and 2025; and ii) the environmental impacts that are expected to result from the interventions from 2020 to 2045. To collect the relevant information, the team at the University of Exeter designed an Excel spreadsheet tool to be filled in by the different organizations responsible for each of the business cases. In section A of the Excel spreadsheet, partner organizations were requested

[1] For more information on the natural capital accounting framework, we refer the interested reader to: ONS (2017). Principles of Natural Capital Accounting A background paper for those wanting to understand the concepts and methodology underlying the UK Natural Capital accounts being developed by ONS and Defra.
For more details on economic valuation principles and techniques, we refer the interested reader to the following publication: Champ, P.A., Boyle, K.J., Brown, T.C. (2003). A primer on Nonmarket Valuation. Kluwer Academic Publishers, Dordrecht, the Netherlands

to provide information on the planned interventions, including woodland creation/management, grassland management, peatland restoration or other soil management activities, as well as interventions requiring changes in agricultural practices. In section B, project managers were asked to report information about the anticipated downstream impacts on the environment and people that might result from the planned interventions, including improved water quality, increased recreation, as well as reduced flood risk or changes in biodiversity.

Partner organizations were instructed regarding how to fill in the spreadsheet and particular stress was placed upon the importance of providing realistic and justifiable (as quantitative as possible) information regarding future interventions and impacts. If quantitative and accurate assessment could not be provided, the team requested project organizations to supply any qualitative assessment available (based on best guesses). Project managers were also encouraged to report their degree of confidence around the provided estimates to point out any uncertainty. After collecting the information on each business case, some iterations with project managers took place to clarify any unclear point and/or missing data.

Once information was collected from project managers regarding the interventions planned on the environment and the expected impacts, for example, on water quality, biodiversity, flood risks, etc. the team at the University of Exeter attempted to quantify the value (in monetary terms, where possible) of the expected changes in the flow of ecosystem services. To identify how much the different changes in ecosystem goods and services are worth to society, existing valuation evidence was considered. The present document aims to explain the methodology adopted to translate the information gathered on the change in environmental goods and services resulting from planned interventions into monetized values.

The information collected on planned interventions and expected environmental and social impacts, as well as the associated monetary values, were subsequently summarized into natural capital accounting templates. One reporting template was produced for each business case and one overall summary table was additionally produced to synthetize the interventions, impacts and values planned across all catchments.

SECTION A: DIRECT IMPACTS OF EACH INTERVENTION

Project managers were requested to answer questions about the interventions planned in each business case to determine anticipated intervention-specific changes in the flow of ecosystem goods and services.

1.1 Woodland

1.1.1 Woodland Creation

Carbon implications

Users identified how many hectares of woodland will be planted between 2020 and 2025, what tree species will be planted, the current land use and the woodland establishment method.

The carbon sequestration rates for tree biomass from the Woodland Carbon Code[2] were used to calculate the amount of carbon emissions avoided thanks to the intervention of woodland creation.

Table 1: Carbon sequestration rates for tree biomass

Tree species	Tree C sequestration (tCO2e/ha/yr)	Tree C sequestration range ($tCO_2e/ha/yr$)
Beech	1.352	1.352-16.352
Oak	1.675	1.675-17.928
Sycamore/ash/birch	9.649	9.649-24.466
Corsican pine	2.536	2.536-19.204
Douglas fir	8.732	8.732-26.224
European larch	2.804	2.804-16.056
Grand fir	8.528	8.528-23.22
Hybrid larch	6.124	6.124-17.5
Japanese larch	6.3	6.3-18.24
Leyland cypress	6.496	6.496-23.016
Lodgepole pine	0.648	0.648-16.656
Noble fir	2.873	2.872-18.008
Norway spruce	1.164	1.164-15.766
Western red cedar	5.964	5.964-20.806
Scots pine	0.194	0.194-15.668
Sitka spruce	1.268	1.268-21.95
Western hemlock	7.568	7.568-23.754

Information on the carbon emissions linked to different land cover types was obtained using the Cool Farm Tool[3] (i.e. output from TIM averaged for South West England using QGIS).

[2] https://www.forestry.gov.uk/carboncode
[3] https://coolfarmtool.org/

Table 2: Carbon emissions from different land cover types

Land Use	Carbon emissions (tCO2e/ha/yr)
Bulbs*	1.048905437
Cereals	2.361228725
Culm grassland*	0.054288713
Maize*	1.048905437
Oilseed rape	2.603636148
Other	1.048905437
Permanent grassland	1.483642211
Root crops	1.606843524
Rough grazing	0.054288713
Temporary grassland	1.718637873

* Land uses that are not defined by the Cool Farm Tool. The assumption has been made that bulbs and maize are similar to 'other' and culm grassland is similar to 'rough grazing'.

The amount of carbon sequestered was calculated by determining the difference in carbon emissions between the current land use and the future land use (i.e. woodland).

Carbon sequestered (tCO2e/yr) = (Carbon emission from current land use (tCO2e/ha/yr) – Carbon emissions from woodland (tCO2e/ha/yr)) * Hectares of woodland to be created (ha)

The carbon implications linked to the use of different woodland establishment methods were also accounted for by considering the soil disturbance carbon emission values from the Woodland Carbon Code.

Table 3: Carbon emissions from planting new woodland

Establishment method	Carbon emitted from soil (tCO2e/ha)		
	Previous land use: semi-natural	Previous land use: pasture	Previous land use: arable
Hand Screefing	0	0	0
Hand turfing and mounding	22	14.7	12.8
Forestry ploughing (Shallow turfing) and scarifying	44	29.3	25. 7
Forestry ploughing (Deep turfing and tine)	88	58.7	51.3
Agricultural Ploughing	176	117.3	102.7

The monetized value of carbon savings linked to new woodland created were calculated using the social cost of carbon for each year (BEIS, 2016).

Value of carbon saving (£/yr) = Carbon savings (tCO2e/yr) [- soil disturbance carbon emissions in 1st year (tCO2e)]* Social cost of carbon (£/tCO2e)

The net present value (NPV) was determined by calculating the carbon saving for each year, assuming that benefits accrue from whenever the intervention occurs (i.e. between 2020 and 2025, we take the mid-point for this period, 2023) to 2045. To calculate the net present value, the flow of benefits was discounted using the Treasury's discount rate (3.5%).

Assumptions:

- The Woodland Carbon Code lookup table provides a range of C sequestration values for different tree species depending on forest management practices (spacing, yield length etc.) and length of time benefits accrue for. A conservative carbon sequestration value was used in the tool (i.e. the minimum values from the lookup tables).
- The Woodland Carbon Code calculator considers the carbon in tree biomass (above and below ground) and the soil carbon loss due to the disturbance caused by establishing a new woodland. But it **does not** include soil carbon accumulation rates due to woodland planting (this is expected to be added to the Woodland Carbon Code in the future).
- The Woodland Carbon Code assumes that the carbon sequestration rate does not fluctuate over time.
- That woodlands are managed without clear felling.
- If current land use is not known (which is likely as specific locations for the interventions haven't been chosen yet) then an average SW land use emissions value was used.

Implications for recreation

Given the importance of woodlands for recreation, we additionally valued the recreational benefits associated with the creation of new forested areas. To do that, we collected data on the increase in the number of visits expected as a result of interventions of new woodland creation. Then, we multiplied this amount by the value of each recreational trip to forests (which is obtained from OrVal[4], based on the average value of recreational visits to a forest in the South West, which was rounded to £3).

Recreational value linked to woodland creation (£/yr) = Average recreational value of a visit to a woodland (£/visit) * Expected change in the number of visitors per year

To obtain the net present value (NPV) recreational values were discounted by considering the Treasury's discount rate (3.5%).

1.1.2 Woodland Management

Users were also required to report any information about the expected changes in woodland management (i.e. felling, increased public access, etc.), how many hectares of woodland will be subject to change in management, and the carbon and recreation implications of these changes.

Carbon implications

The implications for the carbon balance of changes in woodland management were assessed qualitatively by asking users in each business case to report information about the expected impact (positive or negative and low-medium-high) of the intervention on carbon sequestration.

[4] http://leep.exeter.ac.uk/orval/

Implications for recreation

To calculate the change in recreational value associated with changes in woodland management, we collected data on the increase in the number of visits expected as a result of the intervention. Then, we multiplied this amount by the average value of a recreational visit to a forest in the South West, which was calculated from OrVal and rounded to £3).

Recreational value linked to changes in woodland management (£/yr) = Average recreational value of a visit to a woodland (£/visit) * Change in the number of visitors per year

To obtain the net present value (NPV) recreational values were discounted by considering the Treasury's discount rate (3.5%). We additionally assumed that the increase in recreational visits as a result of the intervention of woodland management will take place starting from 2023 to 2045.

1.2 Peatland restoration

Carbon implications

To value the carbon savings from peatland restoration, users were asked to identify how many hectares of peatland will be restored between 2020 and 2025, the year when the restoration will be completed and the current (and future) state of the peatland if the planned intervention does not take place (takes place).

The emission factors from the Peatland Carbon Code[5] were used to calculate the avoided carbon emissions resulting from the intervention of peatland restoration.

Table 4: Carbon emissions factors associated with different peatland states

State of peatland	Emission factor (tCO2e/ha/yr)
Near natural	1.08
Modified	2.54
Drained	4.54
Actively eroding	23.84

The avoided carbon emissions were valued using the social cost of carbon for each year (BEIS, 2016).

Value of carbon saving linked to peatland restoration (£/yr) = Hectares of peatland to be restored (ha) * Emissions factor (tCO2e/ha/yr) * Social cost of carbon (£/tCO2e)

The net present value (NPV) was determined by calculating the carbon saving achieved in each year, assuming that benefits accrue from the year when restoration is completed to 2045. The flow of benefits was then discounted by using the Treasury's discount rate (3.5%).

[5] http://www.iucn-uk-peatlandprogramme.org/node/325

Assumptions:

- The Peatland Carbon Code emission factors include net GHG emissions (CH_4, CO_2, N_2O, DOC and POC).
- The Peatland Carbon Code calculator assumes that restoration activities will result in a single condition category change upon completion (i.e. modified to drained).
- The Peatland Carbon Code calculator assumes that peatlands cannot achieve a fully restored state in the short term.
- The Peatland Carbon Code calculator assumes that there is not a temporal change in carbon emissions from peatlands of a given state. This assumption is made due to lack of long term monitoring data.
- The Peatland Carbon Code assumes that a near natural peatland will still have net GHG emissions. The code uses conservative numbers as there is a lack of long term monitoring data.

Recreation

Peatland restoration could have implications also on recreational visits. To infer information about the total recreational value associated with activities of peatland restoration, we collected information from users on the expected change in the number of visits to a restored peatland area. We considered £4.31 as the average value of a recreational visit to a peatland (taken from the OrVal tool).

Recreational value of a visit to a restored peatland (£/yr) = Average recreational value of a visit to a peatland (£/visit) * Change in visitor numbers per year resulting from restoration (no./yr)

To obtain the net present value (NPV), we assumed that benefits will accrue every year from the year when restoration is completed to 2045 and we discounted the resulting flow of benefits by considering the Treasury's discount rate (3.5%).

Implications for cultural heritage

We additionally asked users to provide information on possible impacts of peatland restoration in terms of cultural/ archaeological heritage. The purpose of this was to try to place a value on the preservation of cultural heritage on or close to peatland areas.

We acknowledge the difficulty of valuing the impacts of peatland restoration on cultural heritage and, where applicable, we only provided a qualitative assessment of the impacts. Nevertheless, we present below examples of secondary valuation literature focusing on the value of preserving cultural heritage.

Table 5: Examples of willingness to pay for cultural heritage

Definition of the good valued	Value (£)	Literature/Source
WTP per year (for the next 10 years) to maintain this site and keep it open to the public - Aberlemno Cross (Early Medieval standing stones). Population surveyed: general public	£3.22/person/year	Kuhfuss and Hanley (2016)[6]
WTP per year (for the next 10 years) to maintain this site and keep it open	£2.54/person/year	Kuhfuss and Hanley (2016)

[6] Laure Kuhfuss, Nick Hanley Russell Whyte (2016). Should historic sites protection be targeted at the most famous? Evidence from a contingent valuation in Scotland.

to the public – Calanais (standing stones). Population surveyed: general public		
WTP per year (for the next 10 years) to maintain this site and keep it open to the public – Mousa Broch (Iron Age round stones). Population surveyed: General public	£2.32/person/year	Kuhfuss and Hanley (2016)
WTP for new artifacts	£7.52/visitor	Willis et al. (2009)[7]

1.3. *Culm grassland*

Carbon implications

Users were also asked to provide information on any planned wet grassland/ Culm grassland management intervention. They were requested to identify how many hectares of wet grassland/Culm grassland will be restored 2020 and 2025, as well as to provide information on the current land use.

To calculate the change in carbon emissions associated with moving from a given land cover to Culm grassland, the carbon emissions linked to different land uses were calculated based on the Cool Farm Tool (i.e. output from TIM averaged for South West England using QGIS). Given that Culm grassland is not explicitly considered in the Cool Farm Tool, it was assumed that culm grassland has similar carbon emission levels as 'rough grazing'.

Table 6: Carbon emissions from different land types

Land Use	Carbon emissions (tCO2e/ha/yr)
Bulbs*	1.048905437
Cereals	2.361228725
Culm grassland*	0.054288713
Maize*	1.048905437
Oilseed rape	2.603636148
Other	1.048905437
Permanent grassland	1.483642211
Root crops	1.606843524
Rough grazing	0.054288713
Temporary grassland	1.718637873

* Land uses that are not defined by the Cool Farm Tool. The assumption has been made that bulbs and maize are similar to 'other'.

The carbon sequestered as a result of Culm grassland interventions, was calculated by determining the difference in carbon emissions between the current land use and land use with Culm grassland.

Carbon sequestered (tCO2e/yr) = (Carbon emission from current land use (tCO2e/ha/yr) – Carbon emissions from land use with Culm grassland (tCO2e/ha/yr)) * Hectares of land converted to Culm grassland (ha)

[7] Kenneth G. Willis (2009). Assessing Visitor Preferences in the Management of Archaeological and Heritage Attractions: a Case Study of Hadrian's Roman Wall. Int. J. Tourism Res. 11, 487–505

The value of reduced carbon emissions was calculated by using the social cost of carbon for each year (BEIS, 2016).

Value of carbon saving (£/yr) = Carbon savings (tCO_2e/yr) * Social cost of carbon (£/tCO_2e)

The net present value (NPV) was determined by calculating the carbon saving for each year, assuming that benefits accrue from whenever the intervention occurs (i.e. between 2020 and 2025, we take the mid-point, 2023) to 2045. Then, the flow of benefits was discounted using the Treasury's discount rate (3.5%).

Assumptions:
- Land use types that were not explicitly stated in the Cool Farm Tool were given carbon emission estimations based on similar land use types. Bulbs and maize were assumed to be similar to 'other' and Culm grassland was assumed to be similar to 'rough grazing'.
- If current land use was not known (which is likely as specific locations for the interventions haven't been chosen yet) then an average SW land use emissions value was used.

1.4. *Agricultural land use change*

We valued several impacts associated with interventions oriented towards the change in agricultural land cover. These include both public benefits that might arise from changes in land cover type and stocking densities (including impacts on carbon emissions or changes in cultural heritage), as well as private benefits that might arise for farmers (change in gross margins and private savings).

1.4.1. Changing agricultural land cover type

Carbon implications

To identify the change in carbon emissions associated with different agricultural land uses, we considered the carbon emission factors obtained from the Cool Farm Tool (i.e. output from TIM averaged for South West England using QGIS).

Table 7: Carbon emissions from different land cover types

Land Use	Carbon emissions (tCO_2e/ha/yr)
Bulbs*	1.048905437
Cereals	2.361228725
Culm grassland*	0.054288713
Maize*	1.048905437
Oilseed rape	2.603636148
Other	1.048905437
Permanent grassland	1.483642211
Root crops	1.606843524
Rough grazing	0.054288713
Temporary grassland	1.718637873

* Land uses that are not defined by the Cool Farm Tool. The assumption was made that bulbs and maize are similar to 'other'.

The carbon saving from the land use change was calculated by determining the difference in carbon emissions between the current land use and the future land use.

Carbon sequestered (tCO_2e/yr) = (Carbon emission from current land use (tCO_2e/ha/yr) – Carbon emissions from future land use (tCO_2e/ha/yr)) * Hectares of land use change (ha)

The value of reduced carbon emissions achieved through land use changes was calculated by using the social cost of carbon for each year (BEIS, 2016).

Value of carbon saving (£/yr) = Carbon savings (tCO_2e/yr) * Social cost of carbon (£/tCO_2e)

The net present value (NPV) was determined by calculating the carbon saving for each year, assuming that benefits accrue from whenever the intervention occurs (i.e. between 2020 and 2025, we take the mid-point, 2023) to 2045. The flow of benefits was then discounted using the Treasury's discount rate (3.5%).

Assumptions:
- Land use types that are not explicitly stated in the Cool Farm Tool were given carbon emission estimations based on similar land use types. Bulbs and maize were assumed to be similar to 'other'.
- If current land use was not known (which is likely as specific locations for the interventions haven't been chosen yet) then an average SW land use emissions value was used.

Implications for farmers' gross margins

We also calculated the change in farmers' gross margins related to changes in agricultural land cover. To do that we relied on the gross margin's figures published in the John Nix Pocketbook for Farm Management (2018)[8].

Table 8: farmers' gross margins from different land cover types *

land cover/change	farmers' gross margins related to land cover types (£/ha)
Bulbs	601.38
Cereals	601.38
Culm grassland	0
Maize	822
Oilseed rape	524
Other	601.38
Permanent grassland	403.15
Root crops	2070.33
Rough grazing	403.15
Temporary grassland	551.50
Not sure	601.38

* 'Bulbs', 'Other' and 'Not sure' were assumed to have the same profitability as 'cereals'. We assumed that gross margins related to 'rough grazing', 'temporary grassland' and 'permanent grassland' are all

[8] Graham Redman (2018). The John Nix Pocketbook for farm management. 48th ed. Melton Mowbray: Agro Business Consultants.

based on 'ryegrass' (used for pasture and forage). Based on https://beefandlamb.ahdb.org.uk/wp-content/uploads/2016/07/BRP-Improving-soils-for-better-returns-manual-3.pdf we assumed that 'permanent grassland' and 'rough grazing' have lower margins per ha (by a factor of 0.731) with respect to temporary grassland.

After calculating the gross margins associated with the current and future land cover type, we then calculated the difference to obtain information on the change in gross margins per ha. By multiplying this amount by the number of ha subject to the land cover change, we could get an estimate of the total change in gross margins resulting from the intervention.

Total change (-) in gross margins = (Gross margins per ha associated with current land use – Gross margins per ha associated with future land use) * Hectares of land use change (ha)

The net present value (NPV) was determined by calculating the change in gross margins from when the intervention occurs (i.e. between 2020 and 2025, we take the mid-point, 2023) to 2045 and by applying the Treasury's discount rate (3.5%).

1.4.2._Changing stocking density

Users were additional asked to indicate whether the planned interventions will aim to change stocking densities (number of livestock per type by ha) and the hectares of land over which the change will take place.

Carbon implications of changes in stocking density

We calculated the carbon emissions associated with current and future stocking densities for given types of livestock by using the carbon emission factors based on the Cool Farm Tool (i.e. output from TIM averaged for South West England using QGIS).

Table 9: Carbon emissions from different livestock types

Livestock types	Livestock emissions (tCO2e/ha/yr)
Dairy	5.33523
Beef	2.17569
Sheep	0.30452

After calculating the difference in the carbon emissions linked to current and future expected stocking densities for given livestock types, the resulting amount was multiplied by the number of hectares over which the change in livestock rates will take place.

Carbon savings (tCO2e/yr) = (Carbon emission associated with current stocking density for given livestock type (tCO2e/ha/yr) – Carbon emission associated with future stocking density for given livestock type (tCO2e/ha/yr)) * Hectares of land where the change in stocking density will occur (ha)

The value of increases of decreases in carbon emission linked to different stocking densities was calculated by using the social cost of carbon for each year (BEIS, 2016).

The net present value (NPV) was determined by calculating the carbon saving for each year, assuming that benefits will accrue from whenever the intervention occurs (i.e. between 2020 and 2025, we take the mid-point, 2023) to 2045. The flow of benefits was then discounted using the Treasury's discount rate (3.5%).

Implications for farmers' gross margins of changes in stocking density

Based on the information collected on the changes in the stocking density (number of animals/ha) before and after the intervention, as well as the number of hectares where the change should take place and the farm gross margins related to different livestock types (John Nix Pocketbook for Farm Management (2018), see figures reported below), we calculated the loss or gains in gross margins that farmers would experience as a result of the decrease or increase in stocking density.

Change in farm margins linked to a change in stocking density (£/yr) = (Stocking density associated with current land use (no/ha) – Stocking density associated with future land use (no/ha)) * Hectares of land where the change in livestock will occur (ha) * farm gross margins associated with a specific livestock type (£/ha)

For the farm gross margins, we considered the figures publishes in the John Nix Pocketbook for Farm Management (2018).

Table 10: farmers' gross margins from different livestock types

Livestock types	farms' gross margins related to livestock (£/head)
Dairy	811.17
Beef	163.67
Sheep	27.75

The net present value (NPV) was determined by assuming that the change in farm's gross margin would accrue each year from whenever the intervention occurs (i.e. between 2020 and 2025, we take the mid-point, 2023) to 2045. The Treasury's discount rate (3.5%) was then applied.

1.4.3. Changes in soil management

Users were also asked to provide information on interventions aiming to improve the management of soils and the resulting benefits in terms of increased carbon sequestration as well as private savings for farmers in terms, for example, of reduced use of inputs (nutrients) or avoided yield loss.

Carbon implications

Information on the carbon benefits of better soil management was qualitatively assessed by asking users to provide information (where available) or expert judgment regarding whether carbon emissions would increase or decrease as a result of the intervention and by how much (small, medium or high change).

Private savings

Users were asked to provide information on the benefits that planned interventions of better soil management would generate for farmers in terms of private savings. In particular, two categories of private savings for farmers were anticipated as a result of planned interventions: i) those linked to reduced fertilizers and nutrients use; and ii) those linked to reduced soil erosion. We asked users to provide data (where available) or alternatively to use their expert judgment to estimate the amount of private savings that farmers would incur per ha of agricultural land, as a result of planned interventions. Given the heterogeneity in the figures provided, the research team decided, jointly with Upstream Thinking manager Dr. David Smith, to consider the most conservative figures across all business cases. Two figures were then taken into account:

- £ 100/ha/year reflecting the private savings that farmers would incur in terms of reduced fertilizers' costs resulting from better soil management and higher income linked to greater grass yield. It was expected that better soil management could improve nitrogen's uptake (decrease nitrogen's runoff) and increase grass growth, which generates both reduced costs and higher gross margins for farmers.
- £ 33/ha/year reflecting the private savings for farmers resulting from reduced soil erosion and including both avoided yield loss and avoided operational costs.

For each of the above-mentioned categories of private savings, we asked project managers in each business case to provide an estimate of the expected number of hectares of land where private savings might take place as a result of improved soil management interventions.

For each of the above-mentioned categories of private savings, the benefits for farmers in terms of reduced costs and increased income resulting from better soil management on agricultural land, could be calculated based on the following formula:

Value of on-farm private savings (£/yr) = Soil management savings per ha (£/ha) * No. of hectares of land subject to better soil management (ha)

As a next step, we calculated the net present value (NPV) of the flow of private savings. Based on project managers' recommendations, it was assumed that savings on nutrients would accrue each year from when the intervention takes place (2020-25, we took the mid-point, 2023) to 2045. Similarly, for the benefits resulting from reduced soil erosion, project managers advised to assume that savings would happen each year for 10 years starting from when the intervention is first put in place. To calculate the net present value of the flow of private savings, we employed the Treasury's discount rate (3.5%).

1.4.4. On-farm management (cultural heritage)

We also collected information on potential impacts of on-farm management for cultural heritage.

We acknowledge that it is difficult to value the effect of changes in agricultural land on cultural heritage and therefore opted for a qualitative assessment of those impacts. In any case, we report below some examples of published studies focusing on the value of preserving cultural heritage.

Table 11: Willingness to pay studies on the value of improving cultural heritage

Definition of the good valued	Value (£)	Literature/Source
WTP per year (for the next 10 years) to maintain this site and keep it open to the public - Aberlemno Cross (Early Medieval standing stones). Population surveyed: general public	£3.22/person/year	Kuhfuss and Hanley (2016)
WTP per year (for the next 10 years) to maintain this site and keep it open to the public – Calanais (standing stones). Population surveyed: general public	£2.54/person/year	Kuhfuss and Hanley (2016)
WTP per year (for the next 10 years) to maintain this site and keep it open to the public – Mousa Broch (Iron Age round stones). Population surveyed: General public	£2.32/person/year	Kuhfuss and Hanley (2016)
WTP for new artifacts	£7.52/visitor	Willis et al. (2009)

1.4.5. On-farm measures (biodiversity)

Qualitative information was also collected from users on the expected changes in biodiversity resulting from interventions planned on agricultural land. In particular, we collected information on possible benefits in terms of pollinators, as well as planned interventions to reduce the presence of invasive species. Biodiversity is a complex and highly context-specific concept and we did not attempt to provide a monetary value for it. Therefore, we only presented a qualitative assessment.

1.4.6. New farm buildings

Carbon implications

Users were also asked to provide information on whether new farm buildings are expected to be constructed as a result of planned on-farm measures and how many tonnes of concrete are likely to be used. This information was then linked with the figure provided by Hammond and Jones (2008) regarding the levels of embodied energy and carbon in construction materials per tonnes of concrete (0.128 tCO2eq/tonne of concrete).

Carbon emissions of concrete used in construction (tCO2e) = Embedded CO2e emissions from concrete (tCO2eq/tonne of concrete) * Tonnes of concrete used (tonne)

To calculate the value of the associated change in carbon emissions, we then linked the above figure with the social cost of carbon (BEIS, 2016). Assuming that the impact on carbon are one-off, we then discounted the resulting value using the Treasury's discount rate (3.5%).

1.4.7. Volunteering (health benefits)

Where volunteers are involved in interventions to better manage the environment, health benefits were also expected to take place. In fact, it is known that outdoor activities contribute to reduce the risks of heart attacks and other morbidities, as well as to increase mental wellbeing. This is particularly true in the case of frequent engagement in volunteering outdoor activities.

Even though it is difficult to place a monetary value on the health and mental benefits of volunteering, some calculations can be attempted (while acknowledging all the necessary limitations). To do that, we considered the concept of quality-adjusted life years (QALY), which is a measure of the state of health of a person. One QALY is equal to 1 year of life in perfect health.

In each business case, project managers were asked to provide information on the expected number of volunteer days related to the planned interventions. Information was collected on both the total number of volunteers expected to be engaged every year in each given catchment, as well as on the number of *frequent* volunteers expected to be involved in the implementation of planned interventions weekly or at least once a month. Monetized information could be obtained only for this latter.

This is because monetary figures on the health benefits of volunteering were only available for frequent volunteers, based on the study by Fujiwara et al (2013)[9]. This study follows the wellbeing valuation approach to estimate the value of an increase in a person's well-being resulting from frequent voluntary activity (weekly or at least once a month) using data on life satisfaction from the British Household Panel Survey (BHPS) for people aged over 16 years old. Based on Fujiwara et al (2013), the health benefits associated to frequent volunteering was estimated to be £3,249 per person per year, on average.

Health benefits of frequent volunteering (£/year) = Average health benefits associated with frequent volunteering activities (£/frequent volunteer/year) * Number of frequent volunteers expected to be engaged every year

The net present value (NPV) is determined by assuming that volunteering benefits would accrue every year until 2045, starting from the year when the intervention is implemented (i.e. between 2020 and 2025, we take the mid-point, 2023). To calculate the net present value of this flow of benefits, the Treasury's discount rate (3.5%) was employed.

1.4.8. Change in other habitats

Carbon implications

We additionally asked users to provide any information about expected changes in other land uses not already included in the categories presented before. In particular, we asked project managers to provide an estimate or qualitative assessment of possible changes in carbon emissions as a result of the change in land use.

[9] Daniel Fujiwara, Paul Oroyemi and Ewen McKinnon (2013). Wellbeing and civil society: estimating the value of volunteering using subjective wellbeing data. Department for Work and Pensions Working paper No 112

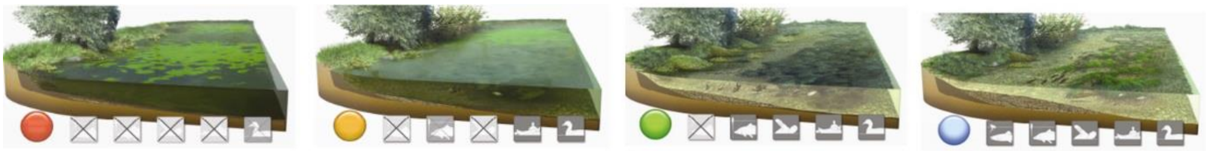
SECTION B: DOWNSTREAM IMPACTS OF INTERVENTIONS

In this section, we collected information about the possible environmental impacts that are expected as a results of the interventions planned for each business case. The main impacts considered included: water quality and related recreational impacts, as well as implications for water quantity.

2.1. Water quality (ecological condition)

We asked project managers in each business case to provide information about the cumulative (overall) impacts that are anticipated on water quality (ecological condition) as a result of the planned interventions. Water quality was classified by considering the Water Framework Directive categories, which give indications of the ecological health of a river. In this classification system, various parameters are considered, including the presence and type of aquatic plants, the extent and type of vegetation cover on bank sides, the number and types of fish species, as well as the presence of other animals like birds and possible recreational activities that can be undertaken (i.e. swimming and boating). Based on these parameters, the classification distinguishes between four main water quality categories: blue, green, yellow and red, with blue being the best water quality condition and red being the worst. To collect information about the water quality category, we considered a water quality 'slider' (shown below), based on the pictograms and categories developed by Hime et al. (2009)[10]. We additionally provided a description of the different water quality classes (reported in the Annex to this document).

Fig. 1. Pictograms used to describe the water quality categories, based on the Water Framework Directive classification



Given the heterogeneity in the responses provided by project managers in terms of the expected changes in water quality in the different business cases, the research team decided, jointly with the Upstream Thinking manager, Dr. David Smith, to adopt a uniform approach. Based on this, the most conservative estimation of water quality change was applied across all business cases. Taking all expected water quality changes reported by project managers, the most conservative estimate emerged to be a 0.6 step change (considering that a one full step change corresponds, for instance, to a change from poor to medium or from medium to good).

Recreational impacts

Changes in water quality are likely to generate substantial improvements in recreational benefits for the region.

Information on the recreational benefits associated with water quality improvements was obtained from the Outdoor Recreation Valuation Tool (ORVal). The ORVal tool is based on a sophisticated model of recreational demand for outdoor greenspace, estimated from data collected in the annual Monitor

[10] Stephanie Hime, Ian J. Bateman, Paulette Posen and Michael Hutchins (2009). A transferable water quality ladder for conveying use and ecological information within public surveys. CSERGE Working Paper EDM 09-01

of Engagement with the Natural Environment (MENE) survey (Natural England 2017) [11]. The model can be used to estimate the levels of visitation to existing or newly created greenspaces when a change in environmental quality takes place and to derive monetary measures of the value households attach to the recreational opportunities provided by those sites. This tool was developed by Day and Smith (2018)[12] at the Land, Environment, Economics and Policy (LEEP) Institute at the University of Exeter with funding support provided by DEFRA and is available at: http://leep.exeter.ac.uk/orval.

For the purposes of our research, the research team at the University of Exeter used OrVal to obtain information about the change in the number of visitors to a river (per km per year) that would occur as a result of water quality improvements. In addition, OrVal was used to obtain information on the average value per year of an additional recreational visit to a river experiencing a given water quality improvement. See Appendix 2 for a step-by-step description of how this information was calculated from the OrVal model.

To calculate the recreational value of expected changes in water quality, information was also collected from project managers. This includes: i) the expected change in water ecological condition (based on the 4-steps Water Framework Directive classification ladder) and ii) the km of river that will experience the improvement in water quality. One comment is worth regarding this latter point. To calculate the kilometers of river where water quality improvements are expected to take place in the future, we compared information provided by project managers with actual (GIS based) measurements. The actual (GIS-based) measurement was based on different datasets (OS main rivers and length of WFD rivers)[13] and it relied on the calculation of the maximum number of km of water courses within each catchment that could potentially be improved. Both actual measurement and estimations provided by project managers for each business case are reported in Appendix 3. For the purposes of our exercise, we opted for a conservative approach and, for each business case, we considered the lowest figure between the actual and estimated river length.

To calculate the aggregate recreational value of an improvement in water quality in a given business case per year, we multiplied together the following elements: i) the South-West average recreational value for a visit to a site with better water quality (£2.90/visit/year/one step-change in the water quality classification; ii) the South-West average increase in the number of visitors, resulting from the environmental improvement, (1,329 visitors/km/year for a one step-change in the water quality classification); iii) the number of km of river length where the water quality will be improved; and iv) the expected step change in the Water Framework Directive classification of water's ecological condition (taken to be the minimum reported figure of water quality change across all business cases, namely 0.6).

Recreational value of improved water quality (£/yr) = Length of river experiencing the water quality change (km) * Average number of extra recreational visits to an improved river in South West England

[11] Natural England (2017) Monitor of Engagement with the Natural Environment: Technical Report to the 2009-2016 surveys.

[12] Day, B. and Smith, G. (2018) The ORVal Recreation Demand Model: Extension Project, Land Environment, Economics and Policy Institute (LEEP), University of Exeter

[13] Datasets considered to calculate river length, include: OS main rivers GIS data. WFD river data available from the Environment Agency's 'WFD - River, Canal and Surface Water Transfer Water bodies Cycle 2' dataset (https://data.gov.uk/dataset/c5a3e877-12c3-4e81-8603-d2d205d52d7a/wfd-river-canal-and-surface-water-transfer-waterbodies-cycle-2)

per km per year (Visits/km/year/one step-change in the water quality classification) * Average recreational value of a river visit in South West England for a given water quality change (£/visit/year) * number of step changes in the water quality scale

The net present value (NPV) was determined by using the Treasury's discount rate (3.5%) and assuming that benefits accrue from whenever the water quality improvement is expected to occur (i.e. between 2020 and 2025) to 2045.

Assumptions:
- ORVal only values day trips not overnight visits.

2.1.2. Impacts on fishing recreation

Information was collected on the expected impacts of the planned interventions on fishing activities. We requested information on current levels of fishing activity, future expected levels without intervention as well as with the intervention. Users could provide information on the impact on fishing for two broad categories of fishes: coarse fishes and game fishes (salmons and trout). We asked project managers to indicate the nature of their available data on fishing activities (i.e. number of catches, visits or licenses).

To quantify in monetary terms the recreational (fishing) benefits associated with the planned water quality interventions, we considered published valuation studies (Johnston et al. 2006), providing estimates of the willingness to pay per fishing trips or catch, for different fish types.

Table 12: Willingness to pay studies on marginal value of a fish from Johnston et al (2006)[14]

Definition of the good valued	Value (£)	Literature/Source
Marginal value of a trout	$ 2.435 (mean)	Boyle, Roach, Waddington (1998)
Marginal value of a trout/salmon	$ 31.55 (mean)	Breffle et al. (1999)
Marginal value of a salmon	$ 11.29 (mean)	Cameron and Huppert (1989)
Marginal value of a salmon	$ 2.51 (mean)	Cameron and James (1987)
Marginal value of a salmon	$ 19.78 (mean)	Cameron and James (1987)
Marginal value of a trout	$ 39.77 (mean)	Cameron, Haneman and Steinberg (1990)
Marginal value of a trout	$ 1.74 (mean)	Johnson et al. (1995)
Marginal value of a brown and rainbow trout Marginal value of a rainbow trout	$1.24 (mean $ 2.58 (mean)	Johnson et al. (1989)
Marginal value of a gamefish	$ 40.99 (mean)	Kirkley et al. (1999)
Marginal value of a trout	$ 2.48 (mean)	Lee (1996)
	Average: $ 14.21	
Mean WTP for catching an additional fish (average over different types of fishes) was $14.33		

* values are in 2003 dollars. Dollar-pound conversion rate in 2003 was: 1 dollar=0.6 pounds. This means that the average mean value of an extra fish would be £ 5.6 (2003 pounds). In current values this would equal to £ 9.38 (in 2018 pounds).

To calculate the benefits associated with each additional fishing catch, we considered the average value of an additional game fish based on the literature reviewed above, namely £ 9.38 (in 2018 pound terms).

[14] Johnston, R., Ranson, M.H., Besedin, E.Y., Helm, E. (2006). What Determines Willingness to Pay per Fish? A Meta-Analysis of Recreational Fishing Values. Marine Resource Economics, Volume 21, pp. 1–32

Recreational fishing value (£/yr) = [Future no. of catches per year – No. of catches per year without the intervention] * Average recreational value of an additional fish (£)

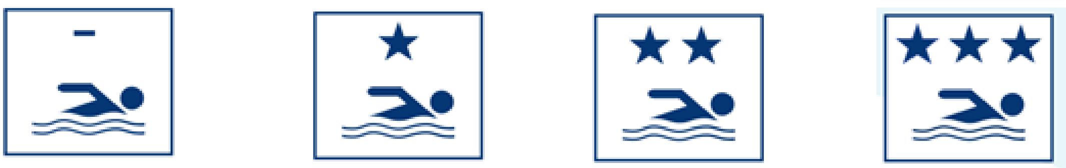
The net present value (NPV) was determined by using the Treasury's discount rate (3.5%) and assuming that benefits would accrue from whenever the intervention is undertaken (i.e. between 2020 and 2025, we take the mid-point 2023) to 2045.

2.1.3. Recreation: Bathing Water

If interventions generated some impacts in terms of bathing water quality, it could be possible to obtain information on the expected change in recreational values associated, by using the Outdoor Recreation Valuation Tool (ORVal). Based on OrVal, the recreational value of a stepwise increase in bathing water quality is worth £5.25.

We asked users to indicate the existing and expected bathing water quality in the different locations in the business cases. To do that, we presented some 'sliders' (as displayed below) with four main bathing water quality categories: excellent, good, sufficient and poor. These categories relied on the Bathing Water Directive (BWD) classifications, which summarizes information on the hygienic quality of the bathing water by measuring the level of faecal bacteria in the water. Bathing waters with high concentrations of these bacteria are at risk of also having pathogens present. These can cause diseases involving fever, sickness and diarrhoea, which can be bad for the health of bathers.

Figure 2. Pictograms for the bathing waters quality classification, based on the Bathing Water Directive



To value the expected recreational impacts of changes in bathing water quality, information was collected from project managers also to estimate the increase or decrease in the number of visitors as a result of planned interventions.

2.1.4 Flood risk reduction

Valuing flood risks will be a difficult task. Both in terms of forecasting expected flood risk reductions resulting from interventions and in terms of putting a monetary value on the risk reduction that could be achieved. For this reason, we recorded only qualitative information on the impacts of interventions on flood risk. Nonetheless we provide some examples of useful value estimates that could be used to attempt to calculate the monetary benefits of flood risk reductions based on the literature:

Table 13: willingness to pay studies on value of flood risk reduction

Definition of the good valued	Value (£)	Literature/Source
WTP per household per year to reduce the risk of internal flooding event	£127, 798	SWW
WTP per household per year to reduce the risk of external garden flooding event	£6,691	SWW
WTP for: - Reducing the flood probability by 1% - insuring against the risks associated with an increase in inundation depth by 10 cm - having an insurance covering not only home content but also the building - having an insurance covering not only home content but also evacuation - having an insurance covering not only home content but life insurance	€54.357/household/month €0.33/household/month €14.961/household/month €14.677/household/month €0 extra/household/month	Brouwer and Schaafsma (2013)[15]

Given that most of the information provided by project managers on flood risk was qualitative, no valuation exercise was attempted and in the natural capital accounts we included only a description of expected qualitative impact in terms of flood risk.

2.1.5. Low flows management (visual amenity value)

Reducing low flow problems in some river stretches could be beneficial for recreational angling, for the ecology of rivers and, overall, for the scenic (amenity) value of the site. However, it is a difficult aspect to value.

We did not attempt to calculate the monetary value of reducing low flow problems. Nonetheless we provide some useful references from the literature on existing studies dealing with the value of low flow reduction:

Table 15: willingness to pay studies on value of water low base management

Definition of the good valued	Value (£)	Literature/Source
WTP to improve flow conditions in South West rivers (Allen, Upper Avon, Meavy, Otter, Piddle, Tavy, Wyle)	£0·076/user/mile of river £0·0435/non-user/mile of river	Willis and Garrod (1999)[16]
WTP to maintain current flow levels WTP to improve current flow levels	£7.16/household/year £4.85/household/year	Garrod (1996)

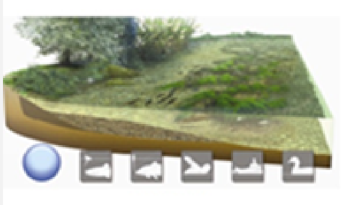
Given that most of the information provided by project managers on base flow management was qualitative, no valuation exercise was attempted and in the natural capital accounts we only included a description of expected qualitative impact in terms of flood risk.

[15] Roy Brouwer & Marije Schaafsma (2013). Modelling risk adaptation and mitigation behaviour under different climate change scenarios

[16] Willis and Garrod (1999). Angling and recreation values of low-flow alleviation in rivers. Journal of Environmental Management. 57(2). 71-83.

Annex 1. Description of the water quality categories, based on the Water Framework Directive classification

Key



Excellent

Aquatic plants: no algae; presence of water plants; good clarity

Bank-side vegetation: Phragmites australis (Reed). Where Found: form beds on river banks. Rorippa nasturtium (Water cress). Where Found: shallow flowing water, halfimmersed. Gyceria sp. (Sweet-grass). Where Found: By shallow water. Salix sp. (Willow). Where found: on land. Turf. Where found: on land.

Fish species: Mostly game fish with some coarse fish

Common birds present

Recreational activities possible: swimming and boating.

Good

Aquatic plants: Greater amount of aquatic plants taking up more of the open space; Slight increase in water turbidity

Bank-side vegetation: Phragmites australis (Reed). Rorippa nasturtium (Water cress). Gyceria sp. (Sweet-grass). Salix sp. (Willow). Turf

Fish species: Virtually no game fish more coarse fish

Common birds present

Recreational activities possible: swimming and boating.

Medium

Aquatic plants: Less aquatic plants with increases in algae; further increase in turbidity and green due to the water, Small number of algal mats.

Bank-side vegetation: Phragmites australis (Reed) Salix sp. (Willow) Turf (increase in prominence)

Fish species: Virtually no game fish, less coarse fish

Common birds present

Recreational activities possible: boating, but not swimming.

Poor

Aquatic plants: Large degree of siltation; Turbid water with a brown hue; Algal mat covering the substrate

Bank-side vegetation: Salix sp. (Willow) Turf (increase in prominence)

Fish species: No fish

Common birds' number reduced

Recreational activities possible: no swimming, no boating

Annex 2. Detailed descriptions of the steps taken to calculate information about the additional recreational visits (per km/unit of water quality increase/year) and value for each additional recreational visit to an improved river (per unit of water quality increase/year).

We started by taking the 'main' rivers in Devon & Cornwall as identified by the Ordnance Survey. Then, we created a 1km grid over the same area and selected out cells through which those rivers flowed. The resulting river cell network had 1201 cells.

By means of ORVal greenspace maps, we identified recreation parks and paths that provided access to those same rivers. There were 642 of those, concentrated in just 365 of the 1201 1km river cells. Clearly not all 1km sections of river in the region provide access for recreation.

Using the ORVal model, for each of those sites, we calculated the impact of improving river quality at that site from its current quality to good/excellent quality (note that 98 of the 642 recreation sites were already at the high water quality level so experienced no change). The outcome of those individual site improvements aggregated across all sites was an increase in annual visits of 3.193 million and an increase in welfare of £9.256 million (4,947 extra visits and £14,418 extra value per year per site).

To move from those site-based figures to per km numbers, we first divided the aggregate figures by 365, that is to say, by the number of 1km squares containing recreation sites. Accordingly, the average 1km river recreation square would receive 8,748 extra visits and generate £25,359 extra value from improving water quality to good/excellent status.

However, given the improvements in the SWW business plan could impact on any stretch of river, it would be wrong to assume that each 1km cell improved would yield those benefits. Rather we assume that a 1km improved could be any of the 1,201 river cells giving a likelihood of improving a location with recreation access as 365/1201. Scaling the visits and welfare values by that factor we end up with a best guess of 2,659 extra visits and £7,707 extra value from improving a randomly chosen 1km stretch of river.

Rather than low versus high quality, the data we received from the partners is based on a 4 point scale. If we make the assumption that the low versus high information used in the ORVal model is (on average) a 2 point movement up that scale, then we need to make one more adjustment to our figures to get numbers per unit of the quality scale. Accordingly, dividing through by 2 gives our final result:

- Additional recreation visits per km or river improved: 1,329 per year per unit of quality increase;
- Additional welfare value per km or river improved: £3,854 per year per unit of quality increase
- Equivalently; welfare value per additional visit: £2.90 per year per unit of quality increase

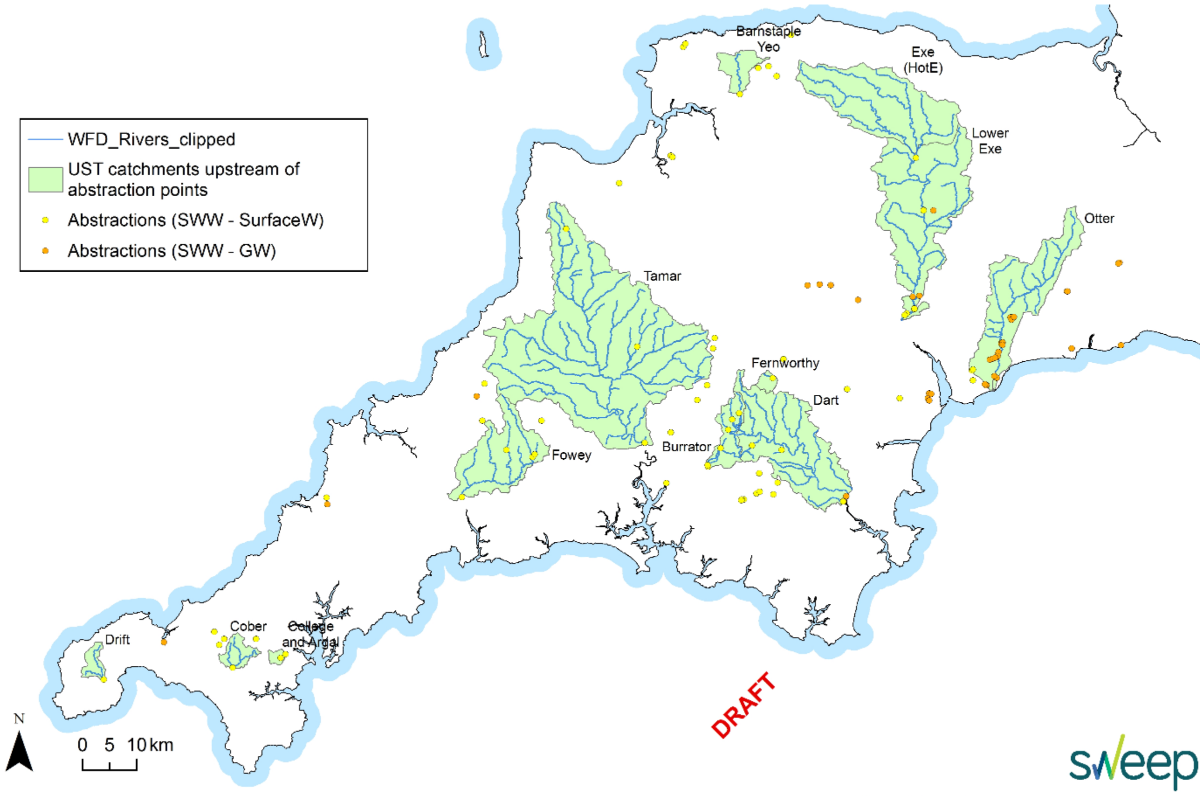
Annex 3. Information on actual and estimated (by project managers) km of river length in each catchment that could be subject to water quality improvements.

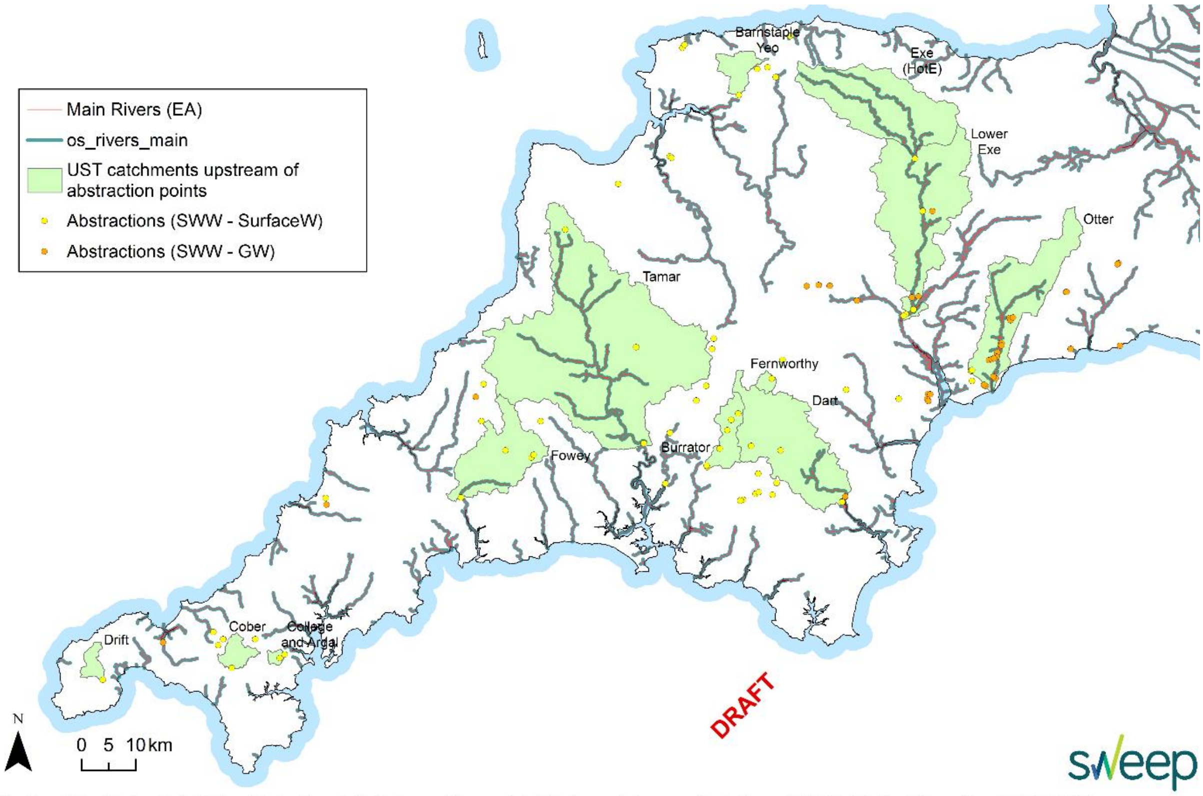
Acknowledgements: For the calculation (and mapping) of the km of river length subject to water quality improvements, we acknowledge the work of Dr. Donna Carlesss and Dr. Amanda Robinson, SWEEP Impact Fellows at the Department of Geography, University of Exeter.

Name of the business case	OS main river	WFD river	Project managers' estimations
Argal & College	0.00	0.00	not provided
Barnstaple	0.00	11.05	20
Burrator	0.00	56.06	not provided
Cober	0.00	18.61	not provided
Dart	29.17	206.95	45
			30
Drift	0.00	12.54	not provided
Exe	78.24	165.13	45
			40
Fernworthy	0.00	2.89	2
Fowey	12.06	80.68	40
Headwaters of Exe	77.88	132.68	not provided
Otter	64.43	111.65	20
			5
Tamar	200.30	496.93	70
			40

Note: in the biggest catchments (Tamar, Dart, Exe, Otter) multiple project managers are involved, even though they operate in different locations within the catchment. What project managers have reported is the expected length of water courses subject to water quality improvements in the portion of the catchment where they are involved.

Below we also report the maps showing the length of river subject to improvement in each catchment, based on the WFD river data and the OS main rivers' data.


WFD_Rivers_clipped
UST catchments upstream of abstraction points
Abstractions (SWW - SurfaceW)
Abstractions (SWW - GW)
Barnstaple Yeo
Exe (HotE)
Lower Exe
Otter
Tamar
Fernworthy
Dart
Burrator
Fowey
Drift
Cober
College and Argal
N
0 5 10 km
DRAFT
sweep


Main Rivers (EA)
os_rivers_main
UST catchments upstream of abstraction points
Abstractions (SWW - SurfaceW)
Abstractions (SWW - GW)
Barnstaple Yeo
Exe (HotE)
Lower Exe
Otter
Tamar
Fernworthy
Dart
Burrator
Fowey
Drift
Cober
College and Argal
N
0 5 10 km
DRAFT
sweep