APPENDICIES

APPENDIX A: Detailed methods

Long listing process

The first step in this project (Figure 1) was to collate a long list of potential case studies that are addressing the pressures of interest (DOC and taste/odour). This was carried out using two linked approaches:

1) We identified case studies through known contacts and existing networks (including those of the steering group); either through a known point of contact or via an established network linked to the topic area (e.g. European Expert Drinking Water group). Some of these networks were international and had 100's of members. An email was sent to these contacts inviting them to participate in our study if they felt their case was relevant. As a result, we received numerous positive replies of which many cases fitted the long listing criteria. The advantages of using this approach were that it is more personal and easier to elicit in English. It also invites the contact to say whether they would be willing to participate in the project further. However, a disadvantage is that stakeholders are very busy, so may not respond to our request;

2) Secondly, we identified case studies through literature and web searches. Particular attention was paid to cases from a similar land use, climate or policy context to Scotland. Searches were conducted using: i) an internet search engine to identify potential cases and grey literature; and ii) utilising Google Scholar to identify academic case studies supported by peer-reviewed evidence. An advantage of this approach was that it was quick to identify quantitative knowledge i.e. data on a case study. However, a disadvantage was that it was difficult to find grey literature from water boards or regulators that was published in a language other than English. Scientific peer reviewed papers are mostly in English; therefore, we conducted a search using Google Scholar to identify academic studies which worked with regulators/water boards as part of that case study (the regulator/waterboard was usually either a co-author or mentioned in the case study description and acknowledgments). Table 1 highlights the full long list of identified case studies. At this stage, the available literature was used to populate the long list. If the case was deemed relevant for short listing, then the lead author of the paper was contacted and invited to further participate in the study (see next step).

The long listing of cases was captured in a database which contained information such as the project name, country, number of sites, work done, key finding, project website and contact organisation. This information formed the bases of an interim report which was presented to the steering group in March 2018.

Short listing process

We shared and discussed the interim report with the project steering group to shortlist cases for further investigation. The steering group were looking for cases which could bring new knowledge on delivery of a prevention-led approach (e.g. new management methods, evidence, governance structures) that would be relevant to the Scottish context. They scored the cases which were of most relevance to their organisation and pressures pulling out the top five cases of relevance. It was decided on the information presented that 4-6 shortlisted UK and EU cases (Table 1; step 2), would be explored in further detail and through a one-day workshop event (see Section 2.2.). Based on the cases presented and to keep the workshop event focused, only cases of relevance to DOC management were selected (however, most of the selected cases also explored nutrient management to address algal issues within their catchment).

Designing the detailed case template

The short-listed cases were explored in further detail, a key point of contact was confirmed (Table 1; step 2), asked for further information on their case study and invited to a workshop where the case would be discussed in detail. If a case study point of contact could attend the workshop, they were then asked to complete a detailed case study template (Table 1; Step 3).

A template (Table 2) was developed and distributed to the steering group to determine the questions of relevance to the project aims and objectives. This detailed case study template was developed to provide a consistent approach for extracting relevant information from the shortlisted selected cases. The steering group provided a general steer to finding new information on evidence of effectiveness and lessons learnt about prevention-led approaches, which were relevant to Scottish pressures. However, as DOC was the focus of the workshop, the template focussed on drawing out more in-depth knowledge on prevention-led techniques to manage DOC in catchments (whilst capturing wider knowledge on nutrient management). The key question areas the template explored were;

a) What new evidence is available?
b) What has and what hasn't worked?
c) What are the gaps in our knowledge?

However, the template set out detailed questions we wished to explore in each selected case example (Table 2; left column). We provided reasoning (Table 2; right column) as to why a particular question was selected, based on reasoning from the first steering group meeting. This template (Table 2) was then applied to selected case studies and was then sent to the relevant point of contact for review. After another iteration of the case template a final document was created and was used as the basis for a one-day workshop event.

One-day workshop

We designed a one-day participatory workshop (27th September 2018) focussed on advancing our knowledge of evidence for protecting drinking water supplies in Scotland from DOC. The steering group helped to co-design the workshop through two opportunities to comment on the draft workshop plan. The workshop aimed to include representatives from the international case-studies selected by the steering group, as well as the steering group members and the project team. The objective of the workshop was to present and discuss what new evidence was available; what hasn't worked (and why), and; what were the main gaps in knowledge.

Enticing colleagues to present and discuss their case studies was important and challenging. To increase the likelihood of their attendance we used the templates (Table 1) (and correspondence) to gain their involvement in the project: we made it clear at least three months before the workshop that we would like to invite them to attend, would cover their travel and accommodation, and we highlighted the practical nature of our project including the attendance of the steering group. In addition to an overview of the Scottish context, we invited five external colleagues representing four case studies. Four cases were presented at the workshop; a list of the workshop participants is provided in Appendix x. In total there were 15 participants, including an independent UK expert on DOC to help highlight relevance in a Scottish context and to provide reflections during the workshop. The workshop was structured around a series of activities (see Appendix C) that aimed to set out the Scottish context and the need for the project, followed by a presentation from each of the cases and a plenary discussion. This was followed by small group discussions where the participants rotated between each case and further discussion in pairs to summarise key evidence and gaps from a Scottish perspective. The workshop was planned and facilitated by an experienced facilitator, and notes were collected by five colleagues and summarised with agreement from the participants.

Appendix B - Workshop participants

- (KM) Kit Macleod, workshop facilitator
- (MW) Mark Wilkinson
- (DM) Don Monteith, CEH, long-term monitoring projects, noticed increased widespread DOC
- (AH) Amanda Hutcheson, Scottish Water, catchment management
- (CB) Claire Bullen, United Utilites, Catchment strategy management,
- (MS) Marc Stutter, soil and water biogeochemistry
- (SM) Shasta Marrero, CREW Project Management
- (PK) Pirkko Kortelainen, limnologist
- (IS) Ian Speirs, water environment team, diffuse pollution
- (MG) Miriam, catchment scientist/modeler
- (HP) Heikki Poutanen
- (DS) David Smith, peatland scientist background
- (SP) Sue Petch, DWQR for Scotland, SW strategic review of charges, rising organic is an issue that has been identified; only able to attend first couple hours in morning
- (MM) Moira Malcolm, catchment
- (PE) Petri Ekholm, water distribution

Appendix C - CREW Prevention led workshop 27th September 2018

Focus

A one-day participatory workshop focussed on advancing our knowledge of evidence for protecting drinking water supplies in Scotland from dissolved organic carbon (DOC). The workshop will include representatives from the international case-studies selected by the Steering Group, as well as the Steering Group members and the project team.

Objectives

To present and discuss: what new evidence is available, what hasn't worked (and why).

Location

Edinburgh Centre for Carbon Innovation (ECCI), High School Yards, Infirmary Street, Edinburgh EH1 1LZ. https://edinburghcentre.org/

Workshop activities and key times

9.15 Arrive and refreshments
9.30 Welcome to workshop and project
Brief introduction to the geographic setting of the cases
Scottish context
First two cases and discussion
Coffee
Second two cases and discussion Small group discussions of the cases Plenary feedback and discussion Summary / reflections on the morning Lunch (around 13.40)
Key evidence and gap analysis from a Scottish perspective
Final discussion
Summary / reflections on the day
Thanks, next steps and close
Finish by 15.30

Participant and organisation

Clare Bullen, United Utilities
Don Monteith, Centre for Ecology & Hydrology (CEH)
Pirkko Kortelainen, Finnish Environment Institute (SYKE)
Heikki Poutanen, Helsinki Region Environmental Services Authority
Petri Ekholm, Finnish Environment Institute (SYKE) David Smith, South West Water
Marc Wilkinson, The James Hutton Institute (JHI)
Miriam Glendell, The James Hutton Institute (JHI)
Moria Malcolm, Drinking Water Quality Regulator for Scotland (DWQR)
Sue Petch, Drinking Water Quality Regulator for Scotland (DWQR)
Marc Stutter, The James Hutton Institute (JHI)
Shasta Marrero, Scotland's Centre of Expertise for Waters (CREW)
Ian Speirs, Scottish Government
Jon Rathjen, Scottish Government
Amanda Hutcheson, Scottish Water

Appendix D1 - Case study Template

Code	Question/variable	Prompts for types of information we would like to collect
	Description	
1	UID	SC_4
2	Name of the case	**Sustainable Catchment Management Programme (SCaMP)**
3	Contact	Clare Bullen, United Utilities (UU)
4	Main organisations involved	United Utilities owns 56,385 ha of land in North West England, which is held to protect the quality of water entering the reservoirs. Through the delivery of the 'Sustainable Catchment Management Programme' (SCaMP) United Utilities is recognised within the UK water industry as being at the forefront of catchment management which aims at securing multiple benefits at a landscape scale. In 2005 UU was the first company to be allowed by the economic regulator Ofwat to invest customers' money on large-scale land management. United Utilities continue to deliver projects under this approach to improve the management of UU owned catchments for water and wildlife. Between 2005 and 2015 UU worked in partnership with the RSPB to support UU's farm tenants to apply for agri-environment payments which provide a sustainable income to the tenant, while UU invested in the farm infrastructure to facilitate access to higher level schemes. Beyond 2015 the approach has extended to catchment land beyond the boundaries of UU ownership and in the period 2015-2020 is delivering across 207,800 ha of catchment land, regardless of ownership by working in partnership with others. Partners include RSPB, Rivers Trusts, Wildlife Trusts and Moors for the Future. In 2013, to coincide with the launch of Defra's Catchment Based Approach (CaBA) United Utilities launched a scheme called Catchment Wise. This provided funding to the 16 CaBA groups across the United Utilities' region and a competitive interventions fund which could be applied to with projects to improve rivers and bathing waters. Building on the success of Catchment Wise, UU joined forces with the Environment Agency, Natural England, The Rivers Trust and Greater Manchester Combined Authority to successfully bid for EU LIFE funding. This 10-year project, which began in 2015 aims to build capacity to protect and improve the North West water environment, now and for the future. Since 2015 UU have applied the SCaMP approach to their wastewater business, looking at integrated asset and catchment solutions to improving wastewater discharges, sewer flooding and diffuse pollution.

5	Links to available information	*Websites, project reports, scientific papers etc* Main project website: https://www.unitedutilities.com/corporate/responsibility/environment/catchment-management/ - the website acts as an excellent resource for all who are interested in the project. Key reports and publications from the project: *[note: numbering refers to referencing in the document]* 1. Davey, A., et al., Quantifying the benefits of SCaMP in the Longdendale catchment: Final report, United Utilities, Editor. 2012. 2. United Utilities, Safegaurd Zones, United Utilities, Editor. 3. Ross, S. and G. Hammond, United Utilities SCaMP programme: Final report, United Utilities, Editor. 2015. 4. Ross, S. and G. Hammond, United Utilities SCaMP Annual Report 2018, United Utilities, Editor. 2018. 5. Higginson, M. and P. Austin, A Review of United Utilities Sustainable Catchment Management Programme and Cost Benefit Analysis, U. Utilities, Editor. 2014: Warrington.
6	Where has this been carried out?	*Would like examples from lots of geographical areas if possible* Between 2005 and 2010 SCaMP focused on 45 UU land holdings in the Trough of Bowland and the Peak District. Through the success of this early work, UU secured funding for the next 5 year period (2010-2015), which extended the programme into UU owned land in the Lake District and Central Lancashire areas [1]. Since 2015 SCaMP focuses on land regardless of ownership and aims to implement activities identified under the Environment Agency's Safeguard Zone Action Plans (under Article 7.3 of the WFD). These zones are located throughout the NW England in key pressure areas (mainly for issues such as colour, algae, pesticides and groundwater nitrates).
	What has been done?	
7	Status e.g. ongoing, when did it start?	*Need to consider the length (timescale) of the study* Ongoing since 2005. Initially focussed on improving the SSSI condition of land in UU's ownership and latterly focusing on safeguard zones. UU is committed to the long term and therefore SCaMP will continue with a focus on sustainable and resilient land and water resource management by restoring natural processes.

8	Pressures addressed?	*Multiple pressures may be addressed* Multiple pressures are being addressed. Between 2005 and 2010 of concern were Organics (colour and DOC) in drinking water from upland land holdings. Since 2015 the SCaMP approach has been used to address other concerns on land holdings regardless of ownership, in particular: • DOC/colour • Disinfection by products (THMs) • Turbidity • Algae (taste and odour issues) • Pesticides • Pathogens • Nitrate (in groundwater bodies in particular) • Phosphorus (in rivers) • Protected site (SSSI/SPA) condition • Natural flood management. However, UU are committed to addressing several other concerns such as flooding and greenhouse gas emissions. It is doing this in collaboration with its partners utilising an integrated approach, demonstrating how it can enhance natural capital in line with Defra's 25 year Environment Plan.
9	Type of prevention-led best practice e.g. catchment management, point sources	*The focus of the study is about prevention-led, therefore catchment management is just one of the measures. Project would also like to discuss point sources if applicable.* Prevention led management is being delivered through Integrated catchment management approaches (hence sustainable catchment management programme [SCaMP] project name). The aim is to address pollution at source to (i) reduce deterioration and (ii) prevent or delay the need for additional water treatment by restoring natural processes. A catchment management approach is being used to tackle a range of water quality issues from colour, pesticides and algae in surface water to nitrates and solvents in groundwater. Of significance to UU has been the restoration of peatlands to improve SSSI condition and to reduce DOC/colour issues in drinking water. SCaMP has put in place plans to restore a vast area of the landscape UU owns. Work included peatland restoration, afforestation and livestock reduction over 27,000 ha of land. During 2005 to 2015 the following measures were applied to ~13,000ha of blanket bog on the land it owns: • More than 320 km of grips blocked (either with peat or plastic dams) • 470 ha of eroded peat treated with new vegetation or heather brash. • Large gulley's were blocked with stones • A reduction in stocking densities and moorland burning. However, through SCaMP 3 the area of interest is increasing significantly. Since 2015, water safeguard zones have been created through a collaboration between UU and the EA as a basis for long term catchment management. 31 of these have been created across NW England. There are 22 surface water and 9 groundwater safeguard zones. 12 of the surface water safeguard zones address the risk of colour in drinking water. 5 safeguard zones address algae (taste and odour issues) [2]. UU state that the SCaMP programme is approximately 10 times as bigger in area than previous SCaMP initiatives, however, they envisage to spend 10 times as less by working in partnership with others to combining interests (Integrated catchment management approach). Some of these Safeguard zones will tackle point-based issues such as WwTW and local septic tanks (e.g. in the Petrill catchment, Cumbria).
10	What was driving these initiatives/measures? Including wider governance.	*What are other countries doing and what is driving these measures? Is it Article 7 or other social aspects? Information about measure success and on how they delivered this (individual or collective).* *Add governance to the template? e.g. has the case study team heard of Art 7? Is this something else to them?* Safeguard Zones are being driven by Article 7 of the Water Framework Directive. UU pay particular reference to this Article in their safeguard zone documentation [2] and have worked with the EA to deliver action plans (Article 7.3) which form part of the River Basin Management Plan. It is hoped this initiative will improve the key pressures. However, in the event there is no improvement in water quality then the EA may seek to designate these areas as Water Protection Zones and enforce mitigation measures. Some areas have been given *"watching briefs"* which means they potentially could become a safeguard zone if things do not improve or when more is understood about the deterioration and whether catchment management would be a viable solution. The Water Framework Directive "no deterioration" mantra, feeds through to Article 7 in relation to drinking water catchments. However, safeguard zones are not statutory; they rely on a voluntary approach. The Environment Agency are responsible for implementing the WFD but their resource is limited and the voluntary approach is not always the most effective when it comes to achieving standards. From a water company perspective, UU cannot rely on a voluntary approach to manage the risk to drinking water supplies, when the consequences of a failure is unpalatable.

		There is a gap between the WFD standards for water bodies in terms of what makes 'good ecological status' and the drinking water standards. Most catchment groups are working towards WFD whereas water companies must ask people to voluntarily go beyond those standards in safeguard zones. Because of this gap, the water company and hence customers end up paying the price of the additional work required to bring the rest of the catchment up to the higher standard. It should be noted that UU have been aware of raw water deterioration longer than WFD Article 7 has been in existence and the concept of Safeguard Zones came in as they have a primary aim to protect drinking water supplies. The Acts of Parliament in the Victorian times saw not only that a reservoir was built for supply but that the surrounding land was given to the Water Corporations to protect the supply from contamination. However, as previously noted, UU do not own all the land in the wider catchment area.
11	Is there information on how they delivered the measures? Including governance.	*Information on how they delivered this (individual or collective group of organisations).* Delivery of SCaMP is a regulatory obligation for UU because it is funded as part of their Business Plan agreed with the regulator Ofwat. Between 2005 and 2015 farm plans were developed in partnership with RSPB and Natural England. The plans were agreed between UU and the tenant farmer. Farmers (or contractors acting on their behalf) delivered the measures identified in the plans and received an agri-environment payment from Defra/Natural England, typically for a 10-year period. In SCaMP 1 and 2 the measures were delivered as a collective group of organisations. UU led the work as most of the measures were implemented on the land it owns. However, this was done in conjunction with the RSPB and Natural England. This partnership approach was needed to successfully deliver the measures (e.g. stewardship payments for reduced grazing numbers act as compensation packages for the tenant farmers which Natural England assisted with). In SCaMP 3 measures in safeguard zones are delivered through a wider set of partners. Key to this has been through working with local rivers and wildlife trusts.
12	Is there any cost information?	*If costs are available then it would be good to include but acknowledge this may be difficult.* Some examples on costs are given in the various literature sources. In the Longdendale valley, colour was a significant issue. An estimated cost of £30m was needed to upgrade the treatment works. Instead, UU took a catchment-based approach to mitigate the issue at source. The total cost of the peatland restoration in Longdendale has been £11.7m of which £4m was funded by UU. During phase 1 of SCaMP UU invested £10.8m in improving the condition of 13,000 ha in the Peak District and Bowland areas. During phase 2 of SCaMP, UU then invested £11.6m on the Haweswater and Thirlmere Estate (Cumbria), West Pennies and Peak District. Both phases generated £4m in grant income for tenant farmers to implement measures to protect drinking water quality and biodiversity. As part of SCaMP 3, UU are part of the Moors for the future partnership, which has delivered restoration across the Peak District since 2005. As a result, they have been successful in attaining EU LIFE funding bids to restore peatlands. The current project MoorLIFE 2020 aims to restore 2000 acres of Moorland with £152m investment (£1m match funded by UUEU) which covers three of UU's safeguard zones as well as land relating to Yorkshire Water and Severn Trent's safeguard zones.
	What has been learned?	
13	Is there information about the success of the measures? Including criteria for success. What level of evidence is there?	*What are others countries doing and what is working. Important questions include: what is driving these initiatives/measures (is it Article 7 or other social aspect) therefore information about measure success. Information on success of the measures; **keen on the success criteria** i.e. what are they using to measure success.* The success criteria for safeguard zones is agreed with the EA before any activity is supported. This is to (i) make sure that UU acts and delivers its regulatory commitments; (ii) there can be an evaluation at the end of the project. Long term (10 years+) monitoring shows that some degraded peatland sites are on a trajectory towards recovery which should in time reduce or stabilise the increase in DOC release to drinking water supplies. This is useful to inform long term investment plans for water company infrastructure. Long term monitoring shows the importance of the influence of climate variability and the need to review results from shorter term monitoring in the context of the prevailing weather. UU contracted Penny Anderson Associates to perform hydrological and vegetation monitoring of the grip blocking in three locations. This monitoring commenced in 2006 and is ongoing. It captures bare peat and the restoration period. The research suggest colour production and delivery to streamflow appears to be generally stable within the long-term dataset (with a couple of exception sites) [3]. However, year on year there is changes in the trend depending on local factors highlighted by the report (nevertheless, the trend is opposite to unrestored sites over the same period) [3]. Turbidity trend are driven by storm events. However, at two sites there is a reversal of trends with turbidity increasing after a few years of decline. The authors note this unusual activities to be a result of breaking up of some moss layer in selected areas resulting in re-exposed bare peat [3]. In Longdendale, the trend of increasing colour was rapidly increasing before restoration. After restoration this trend has slowed down, but colour is still an issue therefore some investment may still be needed at the treatment works. It could take several decades for this trend to reverse (i.e. to have a fully functioning restored peatland). Therefore, UU are committed to the long-term plan. In 2018 it was reported that the raw water

<table>
<tr><td></td><td></td><td>colour trajectories were stabilising in most catchment with only a few increasing trends remaining [4]. However, the lasting impact of the wildfires of 2018 is yet unknown.
An economic assessment of the costs and benefits was also conducted focusing on the Longdendale catchment to assess whether a catchment-based approach offers a more cost-beneficial solution compared to conventional treatment solutions. The impact was quantified for four ecosystem serves (water quality, non-use biodiversity, recreation and climate regulation). The total present value benefits of SCaMP over the 60 year assessment period range from £6.1M (pessimistic scenario) to £21.6M (optimistic scenario) with a central estimate of £12.8M [1]. The large range in the values is down to uncertainties regarding the extent and rate of peatland recovery following re-vegetation and stock exclusions [1]. The research suggest that peatland carbon sequestration is the single largest benefit accounting for 45% of the present value. However, the direct financial benefits to UU are in the region of £470 K (range: £0 to 2,169k) [1]. The research by WRc then took all costs and benefits into account and the net present value of SCaMP (over the 60-year assessment period) was estimated to be £2.4M (central estimate). This equates to cost benefit ratio between 0.55 and 2.24 [1]. There is a risk that SCaMP in Longdendale may not be cost beneficial to UU if the catchment responds slowly or does not restore adequately and/or the future farm costs are higher than expected [1]. Nevertheless, this is highly unlikely and a mid-estimate cost benefit ratio of 1.2 to 1 was deemed to be more adequate. However, WRc calculated the cost benefit ratio to be much higher if the external costs were omitted from the analysis to give the perspective of UU's customers. Finally, a more realistic central estimate is that the benefits will outweigh the costs by £9.8M, and that every £1 spent will benefit UU customers by £4.30 [1]. However, all this research was based on expert judgement and further refinement would reduce the uncertainties.
Further cost benefit analysis were conducted by UU across six catchments and treatment works [5]. The results presented below highlight the maximum length of payback time for the investment made (considering savings to future treatment costs including emissions from greenhouse gases). The results show that factors such as pesticides and algae have a quick payback time, however, Nitrate and Colour take much longer. This is due to Nitrate being present in groundwater systems which are slow to respond, and the long time required for a blanket peatbog to restore fully.</td></tr>
<tr><td></td><td></td><td>Pay back period for catchment interventions, source: United Utilities [5].
<table>
<tr><th>Parameter at risk of deterioration</th><th>Maximum length of time for pay back (years)</th></tr>
<tr><td>Pesticides</td><td>5</td></tr>
<tr><td>Algae</td><td>15</td></tr>
<tr><td>Nitrate</td><td>30</td></tr>
<tr><td>Colour</td><td>>60</td></tr>
</table></td></tr>
<tr><td>14</td><td>What has worked and what hasn't?</td><td>What we would like to know is what works and what doesn't; BUT also in what case does it work and in what case it does not.

Hard grazing exclusion (i.e. fencing) is crucial to enable plants and trees to flourish. Where woodland planting has been done without stock exclusion, there has been little growth. Where stock numbers have been reduced under agri-environment agreements, it is difficult to monitor compliance. Encroachment from neighbouring flocks has a damaging impact on vegetation re-growth. Fencing is a highly political issue in some places and needs full support of all stakeholders to be successful.
For a scheme to be successful, the budget must include a payment (one-off, on-going or a combination) to the farmer to incentivise them or compensate them for forgone income.
Advice-led approaches are more successful for reducing a source contaminant such as pesticides, and the advice is most effective when coupled with wider advice for the farm business, e.g. nutrient management planning. It is difficult to engage farmers about pesticides as a single issue. However, it only takes one accident or breach of compliance (e.g. pesticide applied to land during wet conditions) to cause a failure of the drinking water standard at the WTW and therefore a thorough risk assessment is needed to understand the risk and appropriate controls needed (e.g. alternative sources, temporary treatment) should the primary control at source fail. This follows the Drinking Water Safety Plan approach required by the Drinking Water Inspectorate in England and Wales.</td></tr>
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		Use of partnership working to deliver water company activities where they align to others' objectives is successful to a point. Success is dependent on the personality, skills, knowledge and experience of the individuals delivering the activity. Organisational priorities can be conflicting, which creates an issue when the water company is funding up to 100% of the activity delivered by a third party. Whilst it is often a more efficient way for water companies to deliver activities in the catchment, short-term project work creates a risk around staff retention. This is an issue, particularly where successful delivery relies on the engagement and relationship developed between the third party and the farmers, for example. Staff leaving for a permanent contract elsewhere leave behind some intangible benefits. Water company customer research shows that the bill payers support sustainable approaches to investment in water treatment, including land management activities and working with third parties. However, customers do not support paying more to third parties to deliver activities already seemingly paid for through other funding schemes e.g. single farm payment for cross-compliance. It could be argued that local scale increases in turbidity are a result of certain management practices not working as intending (e.g. revegetating did not work at all sites). However, this needs to be explored further. The moorland restoration has been a success in terms of the wider ecosystem services it provides. SCaMP 3 is ongoing and in the coming years the success of these Safeguard Zones will be evaluated.
15	How relevant is this to best practices in Scotland?	*Trying to learn how other EU countries are implementing A7, and how relevant these best practices are to Scotland.* • Current Scottish Water research on colour in drinking water and the treatability of organics • Land management schemes to demonstrate sustainable agri-environment systems post EU exit. • Enforcement and support from regulators is needed – is it different in Scotland and if so why? • Appetite for partnership working • Sharing analysis and comparing monitoring studies
16	Additional background information	First UK water company to take a catchment management approach to drinking water (in 2005). **Addressing the question "What are the gaps in our knowledge" (Page 1):** The social-science aspect is a gap in our knowledge in terms of what makes people change. How do we win the 'hearts and minds' of the farmers and land managers? The science doesn't always speak for itself – people don't want to believe it.
		Have we done enough? Perhaps there is more investment required to end and reverse water quality deterioration. Perhaps some systems are beyond recovery and therefore treatment is the best option. Perhaps we just need longer to see the results of our actions.

References

1. Davey, A., et al., *Quantifying the benefits of SCaMP in the Longdendale catchment: Final report*, United Utilities, Editor. 2012.
2. United Utilities, *Safegaurd Zones, United Utilities*, Editor.
3. Ross, S. and G. Hammond, *United Utilities SCaMP programme: Final report*, United Utilities, Editor. 2015.
4. Ross, S. and G. Hammond, *United Utilities SCaMP Annual Report 2018*, United Utilities, Editor. 2018.
5. Higginson, M. and P. Austin, *A Review of United Utilities Sustainable Catchment Management Programme and Cost Benefit Analysis*, U. Utilities, Editor. 2014: Warrington.

Appendix D2 - Case study Template

Code	Question/variable	Prompts for types of information we would like to collect
	Description	
1	UID	CS_3
2	Name of the case	**Upstream Thinking (UST)**
3	Contact	David Smith, South West Water
4	Main organisations involved	South West Water (SWW), Environment Agency for England and Wales (EA), Natural England (NE), Exmoor and Dartmoor National Park Authorities (ENPA, DNPA), Devon Wildlife Trust (DWT), Westcountry Rivers Trust (WRT), Cornwall Wildlife Trust (CWT)
5	Links to available information	*Websites, project reports, scientific papers etc* Main project website: http://www.upstreamthinking.org/ - the website acts as an excellent resource for all who are interested in the project. Key reports and publications from the project: *[note: numbering refers to referencing in the document]* 1. Upstream Thinking, Upstream Thinking 2 (2015-20): South West Waters Catchment Management Programme, South West Water, Editor. 2017. 2. Ecostarhub.com, Upstream Thinking: Case study under natural capital accounting. 2015: Online. 3. South West Water, Upstream Thinking: An award-winning catchment management programme from South West Water, South West Water, Editor. 2015: Exeter. 4. Upstream Thinking, Catchment Management Evidence Review: Water Quality, 2013: Callington, UK. 5. Angus, M., M.-R. Lane, and R. Brazier, Case Study 36. Exmoor Mires Partnership, in Working with Natural Processes Evidence Directory - Case studies, Environment Agency, Editor. 2017: Bristol, UK. 6. Grand-Clement, E., et al. Restoration of shallow peatlands on Exmoor (UK): initial effects on water quality. in EGU General Assembly Conference Abstracts. 2014. 7. Ritson, J.P., et al., Managing peatland vegetation for drinking water treatment. Scientific Reports, 2016. 8. Grand-Clement, E., et al., Evaluating ecosystem goods and services after restoration of marginal upland peatlands in South-West England. Journal of Applied Ecology, 2013. 50: p. 324-334.
		9. Grand-Clement, E., et al., New approaches to the restoration of shallow marginal peatlands. Journal of Environmental Management, 2015. 161: p. 417-430.
6	Where has this been carried out?	*Would like examples from lots of geographical areas if possible* In the South West of England. Upstream thinking is a comprehensive catchment management programme extending across 10 drinking water abstraction catchments and covering 75% of SWW's abstractions. The project is addressing several catchment pressures and delivering a range of ecosystem services (of which improving drinking water quality is one in both the uplands and lowlands). Between 2010 and 2015 (UST1) these were the main projects, delivery partners and locations (all in Devon and Cornwall, UK): • Lowland farm catchment management advice and investigations; delivered by WRT (e.g. Tamar and other lowland catchments) • Exmoor Mires Project; a partnership led by SWW (Exmoor National Park) • Dartmoor Mires Project; a partnership led by Dartmoor National Park Authority (Dartmoor National Park) • Working Wetlands; delivered by DWT (Tamar, Dart, Otter, Lower Exe, Fernworthry and Barnstaple Yeo Catchments) • Wild Penwith; delivered by CWT (Penwith, Cornwall) In 2015 Upstream thinking phase 2 (UST2) commenced with an extended programme and partners as follows;

		 **Diagram of catchment partnership working in UST2 [1]** Post 2020 UST plans include 5 additional new projects (or catchments) and the continuation of the work in the 10 ongoing catchments.
	What has been done?	
7	Status e.g. ongoing, when did it start?	*Need to consider the length (timescale) of the study* The concept began in 2006 with pilot work on the Exmoor Mires in partnership with ENPA, followed by a farm runoff reduction project on the Upper Tamar lakes in partnership with WRT in 2008. The project came into full force between 2010 to 2015 and became known as "Upstream Thinking". It was agreed in the PR14 SWW business plan to continue and extend this work in the 2015-20 period, this current period is called "Upstream Thinking 2". All phases since 2016, the pilots, and phase 1 and 2 come under the UST banner. The projects have included monitoring outcomes since inception which has been delivered by the partners, volunteers and in association with the University of Exeter (and other institutions). The project is lucky to have, in many cases, at least 5 years monitored restoration data and as time progresses the range of monitored outcomes and quality of the data and information is increasing. This includes academic papers as well as internal reports and grey literature available on its website. The project is set to continue in the 2020-25 period, pending approval of the SWW business plan by Ofwat the water regulator in England and Wales.
8	Pressures addressed?	*Multiple pressures may be addressed* The project is addressing a range of ecosystem services which are important to the delivery partners, water customers and the Regulators (DWI, Ofwat, EA, NE) from improving drinking water quality to enhancing bio-diversity. SWW's main pressures were from increased DOC concentrations (and colour issues), agricultural diffuse pollution and taste issues from algal blooms in reservoirs. The current programme has a focus on pesticides and the reduction of Metaldehyde and acid herbicides. The other agriculture derived issues of concern are nutrients (N and P), sediment, faecal coliforms and veterinary medicines.
9	Type of prevention-led best practice e.g. catchment management, point sources	*The focus of the study is about prevention-led, therefore catchment management is just one of the measures. Project would also like to discuss point sources if applicable.* Upstream Thinking aims to protect tap water quality at the source by working together with farmers and landowners to improve agriculture, restore wetlands and reduce pollution. The project has two areas of work; lowland farms and upland peatland [2]. The project is a collaborative partnership with a sustainable approach aimed at considering how we think about water in the landscape [3]. The project has a vast array of catchment improvements including in the uplands: • Exmoor Mires Project: blocking drainage channels using local materials to rewet the area. As of 2015, 5000 acres were restored with over 14,000 ditches blocked. • Dartmoor Mires Project: As of 2015, 60 ha of damaged peatland were restored. In the lowland programme across the 10 catchments the focus is on: • Drawing up management plans with farmers and land managers to protect waterways whilst helping to keep farms profitable [3]. This is delivered by the WRT, CWT and DWT who have teams of farm advisors who engage with the farmers and follow up with water and environment farm plans. UST then co–funds the investments recommended in the farm plans which include standard catchment

		management interventions such as buffer strips, wetlands, farm yard infrastructure improvements, river bank fencing, new drinking points, etc.
10	What was driving these initiatives/measures? Including wider governance.	*What are other countries doing and what is driving these measures? Is it Article 7 or other social aspects? Information about measure success and on how they delivered this (individual or collective). Add governance to the template? e.g. has the case study team heard of Art 7? Is this something else to them?* Upstream Thinking (the wider partners) are aware of Article 7 and it is a key driver to their work [4]. SWW believe that catchment-based approaches are more sustainable than investing in end of pipe solutions. Water treatment costs and taste issues were the main starting driver for taking a catchment-based approach. In 2008 SWW encountered eutrophication issues with some of its lakes/reservoirs [3]. They were experiencing nutrient-driven algal bloom. SWW started to work with local rivers trust to work with farmers to manage the land better e.g. to control Nitrates which were causing the blooms (Tamar catchment was a pilot). Case was put forward to Ofwat to roll out wider in 2009 (which lead to the creation of phase 1). The 'Upstream Thinking' initiative came about by some 'lateral thinking' through the project partners and challenges in getting the rural landscape to deliver both food and many other ecosystem services. Each partner has a specific interest, for SWW this is to improve the overall condition of drinking water using a catchment-based approach. Measures have been delivered through a collective partnership. Key to this has been using intermediary bodies (e.g. WRT) who have been able to work with the farmers to deliver measures which can help to improve drinking water quality.
11	Is there information on how they delivered the measures? Including governance.	*Information on how they delivered this (individual or collective group of organisations).* Upstream thinking is delivered through a collective partnership group. South West Water worked with, and contracts, local conservation groups to deliver a catchment-based approach. These intermediaries (e.g. WRT) use the funds supplied by SWW to employ farm advisors to engage with landowners. New novel funding mechanisms have been created. For example, SWW worked with the University of East Anglia to create a new funding mechanism for paying for the delivery of ecosystem services. This was done through holding 'reverse' auctions in the River Fowey catchment, where farmers bid for environmental funding. Competition for investment allows the project team to champion the best bids and stimulate the biggest changes in water management [3]. Another mechanism helped farms transition to more sustainable practices by making grants of up to 50% of related costs to areas where raw water quality improvements should result (e.g. through slurry stores) [3]. SWW have also developed a PES payment per ha for moorland landowners who engage with the Exmoor Mires restoration project.

12	Is there any cost information?	*If costs are available, then it would be good to include but acknowledge this may be difficult.* The project engaged the University of Exeter in 2015 in a programme of evaluation of the value of the UST farm engagement and grant funding work in terms of the direct savings and reduced risks to SWW at its water treatment works. This is a follow up project to the ongoing UoE engagement in the measurement of the impacts of the peatland restoration work on Water quality, flow and wider environmental benefits to biodiversity and improved carbon sequestration. The Water treatment works benefits investigation is first due to report in 2020. The mires restoration benefits work has led to many of the published papers referenced. Investment and restoration costs across the project phases are known. The total budget for UST 1 was £9m with £10.5m available for UST2. Some restoration costs are also given: • Capital grants for on-farm infrastructure (2008-2015) 1,700 visits to farms, and allocated 180 capital grants to farmers totalling €2.6m [2]. • The 'Working Wetlands' project initial funding of £1m increased to £8m as a result of input from third parties [3]. This suggest the partnership are very successful in leveraging extra funding through an even wider collaborative approach. • SWW has invested £3.2m into peatland restoration over the period of 2010-2015. Therefore a total £4.5 million (2010 to 2020) in envisaged to restore 3,000 ha of peatland, with 1,400 ha achieved by December 2016 [5]. • The average restoration cost of the Exmoor moorlands was around £306 ha^{-1}, this figure is below the median national value for the UK [4]. However, local site variations (e.g. a deeper and wider channel) can increase the costs of restoration locally. • Restoration costs for peatland restoration varied from just less than £1 per metre of ditch blocked (using peat dams and an excavator) to £16.50 per metre with wooden dams in phase 1. This roughly works out at a cost of £490 ha and represents a third of the median restoration costs of other sites across the [4]. This is probably owing to the shallow nature of the Exmoor peatlands (as deeper peatland sites have more expensive working costs). • Supported by the Environment Agency and Natural England, the project aims to undertake €20m of land improvements over the next project period 2015-2020 [2]. The project notes that the average farmer will be around £20,000 a year better off by engaging with Upstream Thinking [3]. This suggests that the project aims to work with the farmed environment rather than against it.

	What has been learned?	
13	Is there information about the success of the measures? Including criteria for success. What level of evidence is there?	*What are others countries doing and what is working. Important questions include: what is driving these initiatives/measures (is it Article 7 or other social aspect) therefore information about measure success. Information on success of the measures;* ***keen on the success criteria*** *i.e. what are they using to measure success.* SWW believe that catchment-based approaches are more sustainable than investing in end of pipe solutions. Therefore, if the cost and benefits (including the wider ecosystem services) are better than investing in end of pipe solutions then this will be a key success criterion. It is noted that the catchment management programme benefits the water going into 15 water treatment works (owned by South West Water) supplying 310 million litres/day, or 72% of the region's tap water[2]. However, all partners are aware that to gain valuable scientific knowledge on reductions of all pollutant DOC concentrations will take time. Benefits are measured through both delivery partner monitoring and quality of scientific information. The partnership includes local university groups who have been monitoring and analysing the restorations works. There have been around five PhD projects on the restoration work, one of which is specifically focused on DOC management. Key wider evidence findings so far include: • Exmoor Mires Project: A third less water now leaves the restored moorland during heavy rainfall compared to three years ago [3]. The same project has noted a decrease in concentration of DOC of up to 30% [3] at local sites. However, further work is needed with longer datasets and upscaling the values. • Grand-Clement et al. (2014) highlighted no significant change in DOC concentrations six months after restoration (using a restored and control stretch of drains). They suggest that the effects of restoration could be hidden by inter-annual variations in the total and mean rainfall over this short period [6]. This highlights that it is hard to draw conclusions on effectiveness from a short dataset. However, since this publication, ongoing monitoring has shown the following: • Water storage rates: A rise in the water table level of 2.65 cm on average across the areas monitored and up to 21 cm in some deeper peat locations [5]. • Water quality: In Exmoor, DOC, colour, humic to fulvic acid ratios and pH monitored at eight locations within the Spooners and Aclands catchments. Researchers have noted an overall reduction in the total carbon yield from the restored sites of up to 50% since restoration [5]. • Initial results from the Exmoor restoration also suggest that restoring Sphagnum moss cover may deliver improved drinking water quality [7]. Restoration has generally caused a decrease in overall DOC load downstream owing to the lower peak flows [7, 8].
		• It should however be noted that the peatlands of Exmoor are shallow and there is little evidence from management practices from these types of peatlands. • With respect to diffuse pollution management, by using controlled-release fertilisers, one farmer in the Otter Valley halved the amount of fertiliser applied to first-cut silage from 108 to 49kg/N/ha [3]. The monitoring of these restoration sites is ongoing, so it is predicted that further findings will arise from this project over time. The success criteria for the project are multiple and include outcomes and outputs; • 750 farm plans resulting in actively improved management and investment in the catchment (in the current UST2 period) – see https://www.southwestwater.co.uk/globalassets/document-repository/waterfuture-archive/south-west-water-business-plan.pdf. • 3212 acres of habitat created or in improved management /9in the current UST2 period) – see above link • Reduced treatment costs and greater resilience at water treatment works: SWW note that this is difficult to evaluate and cost, but there is the ongoing University of Exeter project due to report in 2020 plus a set of case studies developed by the partners to support the PR19 business plan that set out the benefits realised so far. • Natural capital stock improvements across the catchments: Also hard to evaluate but there is an ongoing body of work by the partners with case studies looking at the range of improvements made for species and habitats by the programme. • Achievement of the outcomes set out for the programmes Drinking Water Protected Areas (DWPA's) by the EA, with special regard to the pesticide reduction outcomes. Each DWPA had a measure specification form that sets out the expected outcomes, which include reduced levels of pesticide and species and habitat outcomes.
14	What has worked and what hasn't?	*What we would like to know is what works and what doesn't; BUT also in what case does it work and in what case it does not.* **Worked well** • Improved relationship between landowners, farmers, public and project partners. The project delivery partners have been key to this (e.g. WRT). Honest broker approach • Partnership match funding which has doubled the SWW funding. • Advisor 1 to 1 contact with farmers • Stakeholder and customer support

		• Initial research suggests the first compelling evidence that restoring peatlands through a catchment management approach offers benefits in relation to water treatment process with lower seasonal DOC peaks and improved treatability [6, 7], although the authors highlight the transferability and scaling up of these results need to be assessed. • Pesticide amnesties for farmers to dispose safely of old stocks **Not so well/weakness** • Advisor led approach is labour intensive, not practical to visit all farms and the potential for all the funds to be used on a small number of farmers. Balancing size of grant to catchment needs and priorities is key. • Reverse auction approach has also been tried, but found to be difficult to engage who catchment also, match and value different interventions offered, and the lack of advisor 1 to 1 contact is a problem • In Exmoor, the use of bales, commonly used elsewhere to block drainage channels was found to be problematic. Leaky dam or wood/peat combination dames were used instead and found to be better at diverting flow and last longer [9]. • Dartmoor peatland restoration very expensive due to remoteness of sites, need for UXO (unexploded ordnance) surveys and requirements for high spec diggers and intensive site management. Much work has gone on into simplifying and automating site survey and block location prioritisation with Uni of Exeter
15	How relevant is this to best practices in Scotland?	*Trying to learn how other EU countries are implementing A7, and how relevant these best practices are to Scotland.* This project is very much relevant to Scotland. The climatic conditions in the SW of England are common to parts of Scotland. Lessons learnt from installing some of the restoration techniques could easily be applied in the Scottish context. One important part of this project is the partnership working mechanisms between project partners and landowners. In parts of Scotland this approach is being utilised (e.g. delivery bodies of Tweed Forum and Dee Catchment Partnership). *[suggest this section is expanded further later on – e.g. as outcome from workshop]* - *Lessons learned from the restoration of shallow peatlands, marginal mires and valley mires are relevant to Scotland* - *UST approach in the 10 catchments has been directed at largely grassland farming landscape of the SW with diary, Maize, beef, etc as major challenges. Very similar to Scotland, in less arable and where it is its on risky locations on slopes, fragile sandy soils etc, lots of run-off problems.* - *Also, a salmon /sea trout fishing area, but massive declines esp in salmon.*
16	Additional background information	The project has won numerous awards: • Water Industry Achievement Awards 2009 (Sustainable Drainage and Flood Management Initiative the Year) • Golden Green Apple Award 2011 (Exmoor Mires Project) • Water Industry Achievement Awards 2012 (Partnership Initiative of the Year) • Finance for the Future 2012 (Large Business) • Utility Industry Achievement Awards 2012 (Environment Award) • Chartered Institution of Water and Environmental Management 2013 (Living Wetlands Award) Water Industry Achievement Awards 2015 (Data Project of the Year)

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1. Upstream Thinking, Upstream Thinking 2 (2015-20): *South West Waters Catchment Management Programme*, South West Water, Editor. 2017.
2. Ecostarhub.com, *Upstream Thinking: Case study under natural capital accounting*, ecostarhub, Editor. 2015: Online.
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9. Grand-Clement, E., et al., *New approaches to the restoration of shallow marginal peatlands. Journal of Environmental Management*, 2015. 161: p. 417-430.

Appendix D3 - Case study Template

Code	Question/variable	Prompts for types of information we would like to collect
	Description	
1	UID	
2	Name of the case	**SAVE – Saving the Archipelago Sea by applying gypsum to agricultural fields**
3	Contact	Petri Ekholm, petri.ekholm@environment.fi
4	Main organisations involved	University of Helsinki and the Finnish Environment Institute, Funding from: Ministry of Environment, Finland and EU Interreg Central Baltic (via the project NutriTrade)
5	Links to available information	*https://blogs.helsinki.fi/save-kipsihanke/project-save-in-english/?lang=en*
6	Where has this been carried out?	Savijoki river basin in Lieto, southwestern Finland. The pilot area covers an area of 82 km². The field percentage of the area is 43%, and 43% of the fields were amended with gypsum, that is, a total of 18% of the catchment was treated with gypsum.
	What has been done?	
7	Status e.g. ongoing, when did it start?	15.2.2016 – 31.12.2020
8	Pressures addressed?	Water quality – phosphorus pollution, eutrophication, turbidity
9	Type of prevention-led best practice e.g. catchment management, point sources	Application of gypsum to 1550 hectares of agricultural land as part of cultivation practices as a means for protecting waters. A hydrologically uniform area is treated with gypsum, and the effects on the water quality of river Savijoki and the nutrient state in the fields are monitored. Phosphorus loading and erosion are expected to reduce significantly, clearing the water in river Savijoki, thus making the river more attractive for recreational use.
10	What was driving these initiatives/measures? Including wider governance.	For example, the requirements of HELCOM's Baltic Sea Action Plan (country-allocated nutrient reduction targets), Water Framework Directive and Marine Strategy Directive
11	What has been done (how, when, where, how and why)? https://blogs.helsinki.fi/save-kipsihanke/files/2017/03/The-effect-of-gypsum-on-agricultural-phosphorus-losses.pdf http://nutritradebaltic.eu/two-policy-briefs-on-gypsum-amendment-released/	Gypsum has the potential to significantly lower the phosphorus loading originating from agriculture and ending up in the Baltic Sea. The method is easy for farmers to apply, and as a water protection measure it is quick and effective. Earlier studies suggest that gypsum can reduce the phosphorus load by half without requiring changes in farming practices or a decrease in cultivation area or yields. The gypsum can be spread using the same machinery as lime. Gypsum application to fields is more cost-efficient at reducing phosphorus loading than any other water protection method currently in use.
12	Is there information on how they delivered the measures? Including governance. https://blogs.helsinki.fi/save-kipsihanke/files/2017/03/Summary-of-experiences-from-the-gypsum-pilot-project.pdf	The recruitment of farmers to the gypsum experiment began in February 2016. The farmers living in the target area, a total of 107 people, were first contacted with a letter. Information about the project was disseminated at the same time through the municipal board of Lieto and local newspapers. After this, a round of telephone interviews was launched offering the farmers an opportunity to express their thoughts about the project and ask questions about the gypsum application. At the same time, the farmers were also asked whether they were interested in participating in the gypsum pilot project. In addition, in March, an event for farmers was organised in Lieto town hall, which offered a forum for common discussion. The viewpoints brought up by the farmers in the early stages of the gypsum pilot project helped the researchers clarify the preconditions for carrying out the study, identify the risks and prepare for problems. The most important issues included the limited liquidity of the farms, preparedness for adverse weather conditions and organisation of the large logistical process. These issues had to be solved before engaging any farmers in the experiment, as they needed to be taken into account in both the gypsum application agreement and the planning of the supply chain. The project paid part of the costs directly and the remaining costs were compensated for the farmers against an invoice. Regarding the autumn, preparations needed to be made for very rainy circumstances as well. Under wet conditions, the carrying capacity of the fields, on one hand, and the gypsum getting wet, on the other, would have had an effect on how gypsum deliveries, storage and application succeeded. Therefore, the project was also prepared for postponing the application until next spring and storing the gypsum under rainproof cover by the side of the field over the winter. On the other hand, farmers also had concerns over

		the capacity of private roads to carry delivery trucks. This was solved in such a manner that the farmers were advised both to take into account any challenging sites in the planning of gypsum application areas and to inform the delivery chain of any factors affecting the routes when they were placing the order. They were asked to place the gypsum orders 1.5 months prior to the proposed time of application, so that there would be enough time for making the overall logistical plan and other preparations. The engagement of farmers in the process continued through farm consultant's visits to the farms, during which the suitability of the sites selected for gypsum application was inspected from the viewpoints of fertility analysis data, location and cropping plants, and the sites to be treated with gypsum were recorded in the agreement. Gypsum treatment was regarded as suitable for fields tilled in autumn and fields sowed directly with spring cereals, whose Ca-Mg ratio allowed for the additional load of calcium coming with gypsum. The negotiations with the farms ended in May. In total, 55 farms agreed to join the project, covering 1,559 hectares of farmland to be treated with gypsum.
13	Is there any cost information?	The costs include the gypsum itself and its transport and spreading. They vary markedly depending on the availability of gypsum and the distance between the source and the target area.
	What has been learned?	
14	Is there information about the success of the measures? Including criteria for success. What level of evidence is there?	Gypsum ($CaSO_4 \cdot 2H_2O$) enables phosphorus to remain in the soil. It increases the ionic strength of soil solution, creating larger aggregates of soil particles and, thus the phosphorus release to run-off is decreased. Phosphorus remains available for plants, but erosion will lessen and the soil structure will improve. Gypsum reduces the run-off of both dissolved and particulate phosphorus, along with organic carbon run-off. The effects begin immediately after the dissolution of gypsum and last for several years.
15	What has worked and what hasn't?	So far, gypsum has only been tested in fine (clayey) soils. The performance of gypsum in other soil and environmental conditions should be tested.
16	How relevant is this to best practices in Scotland?	This case study was carried out on clay soil fields which are suitable for the gypsum treatment procedure. On the other hand, there are no lakes in the pilot area, which could suffer from the sulfate in gypsum, or acid sulfate soils, on which gypsum treatment is unlikely to work, and might increase the losses of exchangeable aluminium. The original interest in gypsum was related to abatement of eutrophication in the coastal waters of the Baltic Sea by reducing the losses of P from the catchment. Additional sulfate does not do any harm there, because the marine systems are inherently rich in sulfate. To be on the safe side, in our catchment analyses on areas suitable for gypsum amendment we have included only those fields parcels that do not discharge to lakes. Whether gypsum (= sulfate) causes problems in freshwater systems depends on the tradeoff between (1) the reduction of bioavailable phosphorus (possibly dissolved inorganic carbon) and (2) an increase in sulfate. Unfortunately, no quantification for this balance exists, at least for the moment. Assuming that Scottish lakes and reservoirs are oligotrophic, sulfate should not be harmful, but here again there is no threshold value for the degree of primary production (availability of C) that is sufficient to trigger sulfate reduction in sediments. In rapidly flowing rivers the probability for sulfate reduction should be quite low. The potential ecological effects of sulfate on riverine biota has been extensively tested in the SAVE project. The laboratory and *in situ* ecotoxicological studies, involving the effects on fish, mussels and mosses, showed no harmful impacts at the concentration level anticipated to occur after gypsum amendment of agricultural fields. **In addition to phosphorus, gypsum markedly reduces the losses of DOC from agricultural fields. The magnitude of the reduction is being estimated at the moment.** So, among the factors that should be accounted for when considering gypsum use are: - soil type - receiving water body (freshwater, marine/brackish, lotic, lentic) - the need for P abatement - the need for DOC abatement
17	Additional background information	Based on farmers' experiences and the research results, a plan is being compiled for a large-scale application of gypsum in southern Finland. The potential for gypsum treatment in other countries in the Baltic Sea region, e.g. Poland, will also be assessed. Another issue under examination is the possibility of incorporating gypsum treatment into the Finnish agri-environmental support scheme. The results of the pilot will also be utilised for developing a scheme to promote voluntary nutrient reductions and funding in the project NutriTrade.

Appendix D4 - Case study Template

Code	Question/variable	Prompts for types of information we would like to collect
	Description	
1	UID	
2	Name of the case	1. *Lakes, streams, rivers in Norway, Sweden and Finland* 2. *The Langtjern catchment in Norway* 3. *Lake Päijänne in southern Finland*
3	Contact	*Heleen de Wit (heleen.de.wit@niva.no)* *Pirkko Kortelainen (pirkko.kortelainen@ymparisto.fi)* *Heikki.Poutanen (Heikki.Poutanen@hsy.fi)*
4	Main organisations involved	*NIVA, SLU, Syke, HSY*
5	Links to available information	1. De Wit, H. A., S. Valinia, G. A. Weyhenmeyer, M. N. Futter, P. Kortelainen, K. Austnes, D. O. Hessen, A. Räike, H. Laudon and J. Vuorenmaa (2016). Current browning of surface waters will be further promoted by wetter climate. Environmental Science & Technology Letters **3**(12): 430-435. 2. De Wit, H. A., R. M. Couture, L. Jackson-Blake, M. N. Futter, S. Valinia, K. Austnes, J. L. Guerrero and Y. Lin (2018). Pipes or chimneys? For carbon cycling in small boreal lakes, precipitation matters most. Limnology and Oceanography Letters **3**: 275–284. 3. Forsius, M., A. Räike, I. Huttunen, H. Poutanen, T. Mattsson, S. Kankaanpää, P. Kortelainen and V.-P. Vuorilehto (2016). Observed and predicted future changes of total organic carbon in the lake Päijänne catchment (southern Finland): Implications for water treatment of the Helsinki metropolitan area. Boreal Environment Research **22**: 317-336.
6	Where has this been carried out?	1. *Lakes, streams and rivers in Norway, Sweden and Finland* 2. *Catchment in Norway* 3. *Lake Päijänne insouthern Finland – the second largest lake in Finland, max depth 95 m*
	What has been done?	
7	Status e.g. ongoing, when did it start?	1. *Trend analysis of 1990-2013* 2. *Analysis of lake inputs and outputs 1986-2015* 3. *Trend analysis of COD 2000-2014*
8	Pressures addressed?	1. *Acid deposition and climate* 2. *Acid deposition and climate* 3. *Climate, atmospheric deposition, land-use related factors and catchment characteristics*
9	Type of prevention-led best practice e.g. catchment management, point sources	1. *Most catchments are semi-natural with forest cover varying from 0-100%, variable peatland cover, and little agriculture – except for larger river catchments. Changing atmospheric deposition and variations in precipitation appear to drive most of the trends.* 2. *See above – a forested catchment with ca 20% peatland.* 3. *Drinking water source for > 1million people in Helsinki metropolitan area, important for fisheries and recreation*
10	What was driving these initiatives/measures? Including wider governance.	*not relevant?*
11	What has been done (how, when, where, how and why)?	*not relevant*
12	Is there information on how they delivered the measures? Including governance.	*not relevant*
13	Is there any cost information?	*not relevant*
	What has been learned?	
14	Is there information about the success of the measures? Including criteria for success. What level of evidence is there?	1. No measures were taken, however the % cover of lakes in catchment has been shown to be negatively related to C, N and P load export to Baltic Sea (Mattsson et al. 2005; Lepistö et al. 2006). Further, in numerous studies strong negative correlation between catchment lake % and TOC has been shown (e.g. Kortelainen and Mannio 1988). Mattsson, T., Kortelainen, P. & Räike, A. 2005. Export of DOM from boreal catchments: Impacts of land use cover and climate. Biogeochemistry 76: 373-394. Lepistö, A., Granlund, K., Kortelainen, P. & Räike, A. 2006. Nitrogen in river basins: Sources, retention in the surface waters and peatlands, and fluxes to estuaries in Finland. Science of the Total Environment 365: 238-259. Kortelainen, P. & Mannio, J. 1988. Natural and anthropogenic acidity sources for Finnish lakes. Water, Air, and Soil Pollution 42: 341-352. **2.** Lakes remove a higher % of incoming DOC, when lake water residence time (WRT) is higher. In this case this was not managed, the variation in WRT was an effect of climate variability. Not certain if the same applies to water residence times in catchment soils, but if so, it would be beneficial for DOC removal to increase water residence time in the landscape and thereby allow for more processing of DOC. **3.** Explaining variables are site-specific and observed changes are mainly due to a combination of climate and atmospheric deposition. No relationship between COD increases and land-use related factors or specific catchment characteristics was found.
15	What has worked and what hasn't?	A lot of the browning in Scandinavian catchments is usually explained by regional phenomena like sulphur deposition and rainfall, and those are hard to manage at the local level. This is likely to be the case for the UK as well.
16	How relevant is this to best practices in Scotland?	Scandinavian drinking water catchments are often protected – as in having as little management as possible, and hardly any settlements and agriculture. In some cases, this is not possible, especially in densely populated areas. Management in such catchments is not aimed at reducing DOC, but rather at reducing point sources of pollution to reduce the risk of parasites and other health hazards such as algal toxins.
17	Additional background information	TOC concentrations in Finnish freshwaters are generally high due to flat topography and high peatland proportion in catchment but there is no good method to decrease TOC transport from the catchment (Kortelainen, pers. comm). The organic carbon is in a dissolved form, coagulation is effective in a lab, but too expensive in the field. HSY uses iron sulphate to coagulate DOC from drinking water source. The Gypsum case study by Petri Ekholm demonstrates the possibility to decrease C load from fields.

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