CLAD | CARBON LANDSCAPES AND DRAINAGE

"Mapping DOC research relevant to sustainable catchment management"

A Carbon Landscape and Drainage Knowledge Exchange Network report for Scottish Water

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1 Executive Summary

This report, the information herein and accompanying data files were compiled by the KE network Carbon Landscapes and Drainage (CLAD, hosted by the University of Glasgow) to aid Scottish Water in ascertaining whether/where there are knowledge gaps in their Strategic Research Plan for dissolved organic matter, particularly carbon, in drinking water catchments (SRP-DOM). To determine the extent to which the SRP-DOM priority areas are supported by existing research activity, an analysis has been undertaken on how much relevant research and data exist in the following four key areas Scottish Water consider are most crucial for sustainable catchment management:

- How will DOC change in the future? (Q1)
- How will climate change alter current trends? (Q2)
- How does land management impact DOC release? (Q3)
- Can we identify new sources with low potential DBP formation? (Q4)

Broadly these questions require understanding of the magnitude, controls, processing, composition and treatment of DOC in surface waters, particularly drinking water catchments. This analysis identified relevant resources from key words of relevance to Q1-4, but did not review the literature identified to generate an overview understanding of the content of these resources.

The analysis required searching electronic resources to identify published literature, PhD research, databases and projects (completed or ongoing) and mapping these to the key research areas in SRP-DOM listed above, noting a given resource may contribute to more than one key areas. The resources are summarised in submitted excel files if large (Published_DOC.xlsx, PhD Research_DOC.xlsx), or in the body of this report if small (databases and projects), and in EndNote libraries. However, the Endnote libraries generally will contain the abstract of the research if it was provided in the search engine and so offer further detail. As the project was only for two months, electronic searches were restricted to research with a field location(s) in the UK and Republic of Ireland, geographic regions where research in these field locations was considered likely most relevant to Scottish Water's SRP-DOM.

This analysis identified 419 published articles, 94 PhD projects, 25 published databases, and 10 research projects that have or will produce relevant research outputs. These span the years 1990 to March 2017. Their details are stored in the file outputs. The relevance of published articles and PhDs has been mapped to the four 'Key Questions' of Scottish Water's SRP-DOM listed above (the data bases contain a coding to identify to which research questions the output is relevant). To understand if there are trends in the research direction, the availability of resources pre-2010 (20 years) has been compared to post-2010 (7 years) as similar levels of activity for the latter shorter time period constitute greater focus on this area in recent research. Additionally, to help understand quickly the key trends within the databases, word clouds have been used to visualise key

researchers, institutes, research terms and locations of the research. These proved valuable, for example in identifying that some institutes may hold a large body of unpublished research in PhD thesis (e.g. Universities of Glasgow and Manchester), and these are not the same institutes that have produced most publications (e.g. Universities of Durham and CEH institutes).

To consider how the research activity identified supports the SRP-DOM, it is best to consider the published research and completed PhD projects as these represent tangible outputs; current PhDs and on-going projects represent understanding likely to develop. Overall, research relating to DOC trends/controls (Q1) is the most prevalent. Within this understanding 'how fractions will change in the future' is gaining more research interest (publications: 39 pre-2010; 20 since-2010), but lacks the significant number of publications that understanding how DOC quantities will change has generated. Research relating to new sources that minimise treatment/by-products (Q4) is least-well supported by published research or PhD research, both historically and in recent focus. Consideration of how land management impacts DOC release (Q3) seems important to PhD research and although is an area of growing interest since 2010, this has not yet been supported by a publication base as strong as some of the other categories. Climatic influence on DOC (Q2) has been considered equally with land management (Q3) for PhD research, but has generated more publications than land management. Thus questions 3 and 4 seem areas of less secure understanding (fewer outputs) and so it may be worth investing in developing these two areas, first by confirming with the scientific community whether fewer research outputs represents reduced knowledge or whether less research is needed as there is a very secure understanding here.

Additionally, there are three large research / knowledge exchange projects currently active, NERC-funded and managed by the academics at Institutes, whose identity and location emerges in word cloud analysis as having made a significant contribution research supportive of SRP-DOM. Over the next 3-5 years these projects will generate insight also of relevance to SRP-DOM. These are LOCATE, DOMAINE and iCASP. It would be beneficial for Scottish Water to discuss further with the lead researchers of these programmes what aspects of the SRP-DOM will be supported by these projects and the likely timescale of secure outputs.

If the outputs these projects will generate are not sufficiently aligned with the SRP-DOM, or the timescale for outputs is too long, such that Scottish Water consider their research needs are not being met, and reach the conclusion that they still need to invest in research, then it would be advantageous to proceed with investing in research in conjunction with a partner(s). Such a partnership could be co-funding research in conjunction with a research council, or across research councils, and indeed with other water companies - where there is not commercial sensitivity, this could be valuable as it would avoid duplication, demonstrate to other funders a wider significant need than one organisation, and potentially increase the budget to levy matched funding.

There are several mechanisms that Scottish Water could use to commission research, either with or without other water industry or cognate partners, which would engage a wide academic community and ensure the research is subject to external peer review. These are:

1. Bid for a joint research investment with RCUK support. Given the catchment and field science focus of SRP-DOM then the Natural Environmental Research Council (NERC) would be the most appropriate partner. An example of an opportunity here would be a a 'Joint Strategic Response' initiative where NERC would co-match (or greater) partner funding. The turnaround decision is quick (3 months) and this would roll out a research programme that would be subject to peer-review, so should ensure the highest quality research with reviewers also identifying in proposed research unnecessary repeat of research activity.
2. Review the NERC innovation funding to assess or request a call that suits your needs funding. Currently there are bids that Scottish Water are engaged with such as the NERC Environmental Risk to Infrastructure Programme, but calls seem frequent and other opportunities may likely emerge, especially if driven by a recognised stakeholder (Scottish Water need)
3. Request joint support to co-fund PhD students. Partnering with NERC on a Scottish Water specific call would likely have a long lead-in time, so research needs could be realised more rapidly by co-funding PhD students in established Doctoral Training Partnerships. Outwith NERC, the Scottish Funding Council and Scottish Government may be receptive to a Scottish company driven need for investment.

There are two core approaches to deploy co-funded research, both of which have different advantages. The first is to commission a research team. The advantage of this is that it generates a group who are experienced and have a track record of completion of research. Thus the questions asked and research techniques can be more sophisticated, and outputs would be expected during and after the duration of the funded project. However, this is the more expensive option, with a 3 year post-doctoral research project, associated investigator time and project running costs typically costing £500,000.

The second is to fund post-graduate researchers to develop their research skills within a research framework of relevance to SRP-DOM. A strong PhD student can make considerable progress, and here funding for 3.5 years with some analytical budget will be circa £80,000 (more if analysis and fieldwork have high costs). This is considerably cheaper than the PDRA-led research. However, a PhD is a training process, and thus progress is not always linear, and a very small numbers of PhD students will not complete their training. Thus this approach may not be appropriate for time-bound, crucially important research needs. An optimal solution may be a combination of PDRA and PhD research focussed in a few geographical regions and thus offering overlap.

In summary this analysis has identified for Scottish Water research activity and outputs cognate to the SRP-DOM. It has not reviewed literature nor considered resources outside the UK, so it may also be beneficial in deciding how to develop the SRP-DOM to consult with researchers from other temperate regions as they may offer valuable further insight in the areas of land management and low DBP sources. In addition to this report, a meeting has been organised for mid-May 2017 to present the results to members of the community identified in this research as being key academics and to discuss the key research priorities and identify how to proceed. Particularly important will be their feedback on whether fewer research outputs represents reduced knowledge or whether less research is needed as there is a very secure understanding here. In closing this loop Scottish Water will be better positioned to decide how to proceed with the SRP-DOM.

2 Introduction

Increases in dissolved organic carbon (DOC) have been observed in many surface waters across the UK and Europe over recent decades, and particularly those with peat-dominated catchments (Monteith, 2000; Evans, 2001; Freeman, 2001; Monteith, 2007; Monteith, 2014). Some debate remains over the primary driver and projected magnitude of this increase, but suggested mechanisms include: (i) recovery of surface waters from acidification in response to declining atmospheric deposition (e.g. Evans, 2001; Monteith, 2007), (ii) increased decomposition of catchment organic matter in climate change-induced warmer drier summers/droughts (e.g. Worrall, 2006; Sowerby, 2010), (iii) increased leaching of soils in climate change-induced wetter, stormier winters (e.g. Tipping, 1999), (iv) changes/increases in landuse and land management practices (e.g. moorland grazing, burning, cutting, draining and construction) (e.g. Yallop, 2009; Clutterbuck, 2010; Davies, 2016), and (vi) a combination of these. DOC is removed from drinking water due to the aesthetic, chemical and biological impacts on potable water (Gough, 2014).

During the water treatment process, DOC reacts to form disinfection by-products (DBPs) such as trihalomethanes (THMs) which have been reported to be detrimental to human health (e.g. Gough, 2014; Brooks, 2015). Thus rising concentrations of DOC in surface waters are problematic as it is becoming increasingly difficult for drinking water companies to maintain THM concentrations below maximum regulatory requirements (e.g. Goslan, 2004). It is therefore vital to increase/consolidate knowledge of current DOC trends, predicted trends, and water treatment processes to enable water companies to manage increasing DOC in raw waters to continue to supply safe drinking water.

This report, the information herein and accompanying data files (Published_DOC.xlsx, PhD Research_DOC.xlsx) were compiled by the Carbon Landscapes and Drainage KE network, University of Glasgow, to aid Scottish Water in ascertaining whether/where there are knowledge gaps in their Strategic Research Plan for Drinking Water Catchments (SRP-DOM). An in-depth literature review would require substantial time to produce and therefore resource, thus the aim of this two-month commission was to gather and analyse information on the breadth of relevant DOC-related research and resources available. Information has been gathered on existing/planned research relating to the magnitude, controls, processing, composition and treatment of DOC in surface waters. The research outputs and projects identified have been categorised according to the key questions of Scottish Water's SRP-DOM (Figure 1), to determine which of the SRP-DOM priority areas are already supported by existing research activity, and highlight any gaps. Preliminary analysis of the data collected has been undertaken.

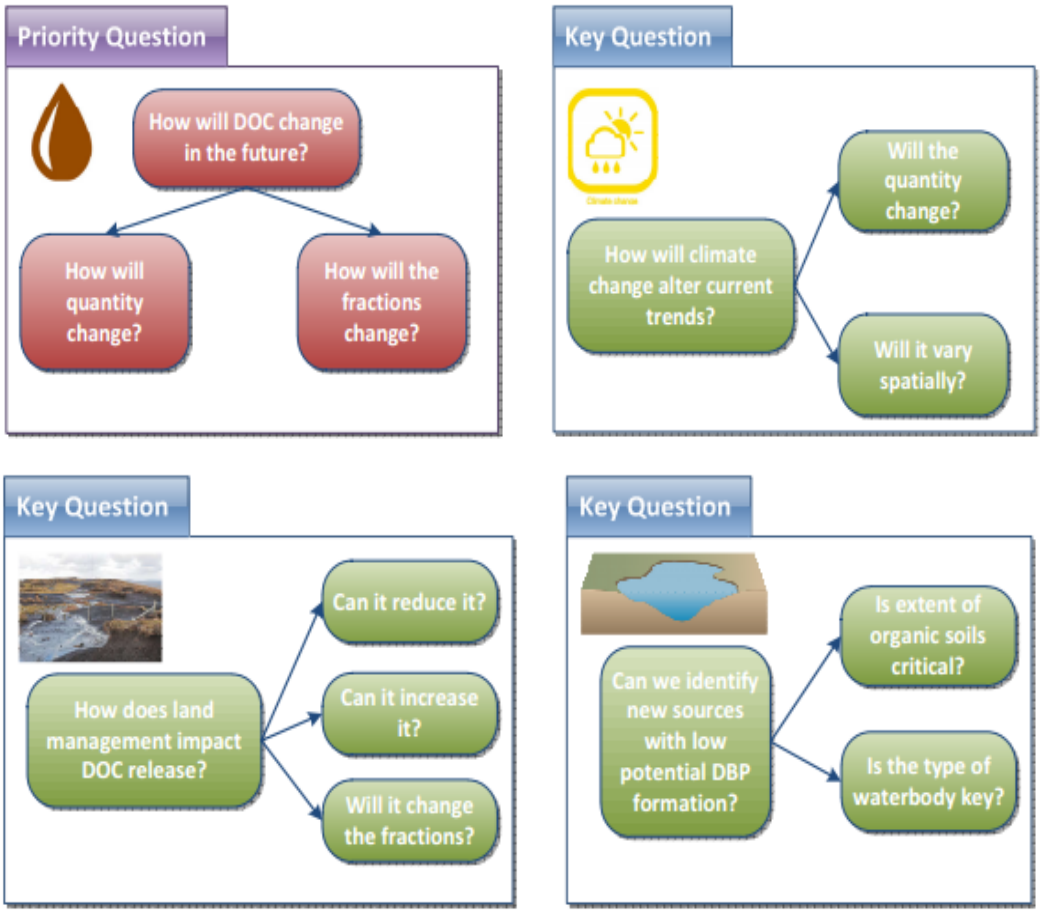

Figure 1: Key Questions from the "What do we need to know?" section of Scottish Water's Strategic Research Plan for DOC in Drinking Water Catchments.

3 Methods

DOC research and resources were located/identified using internet searches. Searches were limited to research with field sites in the UK and Republic of Ireland, as these are expected to be most useful/relevant to Scottish Water. Where possible searches were carried out using a structured tiered approach to avoid repetition and thus maximise findings in the time available. The types of resources targeted were published articles, PhD research, databases and large-scale projects relating to DOC. An excel workbook has been created for the findings of each of the first three; the projects are described in this report. Appendix 1 summarises the structure of the Excel workbooks.

Each published article and PhD project was categorised according to the key questions from Scottish Water's SRP-DOM (Figure 2). This has not been undertaken with databases or projects as less-time was available. Research/resources were not designed/written with Scottish Water's key questions in mind, thus it was not possible to always use the categories prescriptively. As such, broader topics were assigned to each key question (blue text on Figure 2) and the single number (1, 2, 3, and 4) categories used to reflect those. Category 5 was added for use when the focus of a resource was not DOC, but if DOC data and/or information was contained within (e.g. line 396 of

Published_DOC.xlsx (worksheet 'Linked – search approach & results') where the research focus is the relationship between macroinvertebrates and trace metals, but DOM is considered and data provided). Clearly category 5 also describes all databases. When it was clear a sub-question was addressed more closely by a resource, the lettered-number categories were used (1a, 1b, 2a, 2b, 3a, 3b, 3c, 4a and 4b; annotated on Figure 2 by the authors).

Categories or sub categories were assigned to a resource based on assessment of the content of the abstract/research summary and an academic decision regarding the relevance of that resource to each category, i.e. attribution of a resource to the SRP-DOM key areas goes beyond relying on key words in Table 1. For example: resources that indicated forestry / drain-blocking / grazing practices / peat-burning / land cover / land management were identified as relevant to land use/management, category 3 (e.g. lines 22 and 38 of Published_DOC.xlsx, worksheet 'core –search approach and results'); resources that indicated the water treatment process / by-products / reservoirs / water treatment works were assigned a category 4 (e.g. lines 67 and 130 of Published_DOC.xlsx, worksheet 'core – search approach and results'). Thus for the core papers considered, their relevance to each key area should have been correctly identified. Each resource was assigned as many categories as were deemed relevant, with many resources offering information relevant to multiple categories.

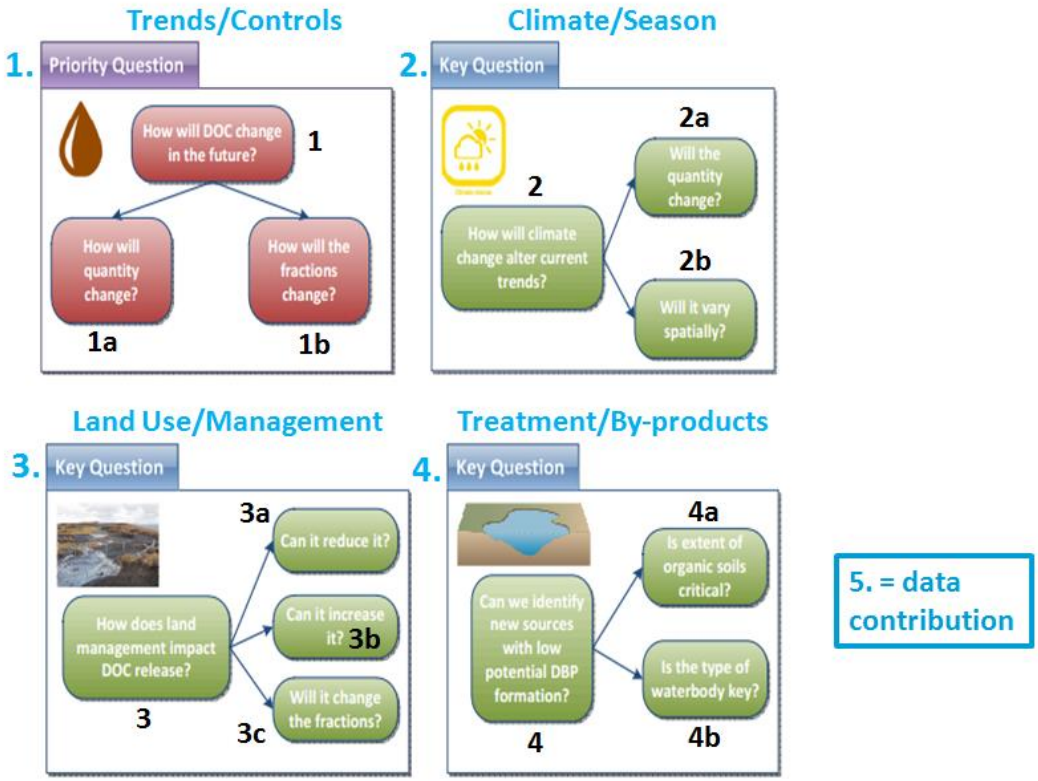

Figure 2: Category system for the key questions from Scottish Water's Strategic Research Plan for DOC in Drinking Water Catchments. Blue text gives the broad topic for the key question.

When a resource was less closely-related to the key questions, brackets were used around the categories in the data bases. For example, below are the most commonly bracketed questions and a reason for their bracketing:

(1b) or '+1b+' when an article/resource relates to DOC fractions, but not necessarily future trends (e.g. method development, laboratory simulation);

(2) when an article/resource relates to event flows, extreme weather events, seasonal variations etc., but not climate change directly;

(2b) when an article/resource relates to spatial variation in DOC, but not in relation to climate change;

(3) when an article/resource relates to non-anthropogenic variations in catchment characteristics;

(4) when an article/resource relates broadly to water treatment or by-products but not the category 4 key questions directly;

(4a) when an article/resource relates to soils, but not in relation to water treatment;

(4b) when an article/resource relates to contrasting water bodies, but not in relation to water treatment.

3.1 Published Articles

Web of Science™ was used as the primary search tool for locating/identifying published articles relating to DOC. Web of Science™ (WoS) gives access primarily to published journal articles, but additionally to some books, book chapters, conference papers and reports. Searches were highly-structured using a tiered approach. The search terms used are listed in Table 1 (overleaf) and each first search term was refined by all second search terms, which in turn were refined by all third search terms. Thus effectively all search terms were cross-referenced.

Searches were tracked and saved using the WoS "Marked List" tool for efficiency. This meant any article checked in previous searches, whether relevant or not, was identified in subsequent searches and thus not re-checked.

Relevant findings were exported directly from WoS to EndNote™, a reference manager database. Additional useful/desired information (where available) was added manually to each record in EndNote™:

- **Research Summary** – a reduced version of the abstract, containing only relevant information. NB, much of this is a direct copy of excerpts from the publication so if used verbatim in an academic output should be cited appropriately.
- **Broad Topic** – a one line summary of the research for quick/easy reference
- **Category** – as explained in Section 3, Methods
- **Research Field Location** – location of the field site or water treatment works, at least to the regional location but usually the surface water system studied is named.
- **Funder(s)** – the body/organisation(s) that financially supported the research

Table 1: Search terms used in Web of Science™ published research searches*

SEARCH TERMS		
First	**Second**	**Third**
DOC	Catchment	UK
dissolved organic carbon	River	Scotland
dissolved organic matter	Lake	England
natural organic matter	Stream	Wales
	Loch	*Ireland*
	Lough	
	Reservoir	
	drinking water	
	freshwater	
	treatment	
	DBP	
	disinfection byproducts	
	THM	
	trihalomethane	
	hydrophilic	
	transphilic	
	hydrophobic	
	water colour	
	humic	
	fulvic	
	hazen	
	peat	
	drought	
	water quality	

*DOM and NOM were not used due to time constraints and assumption (based on DOC vs. dissolved organic carbon searches) that there will be very few articles that use the acronym without defining it. Search terms in *italics* were dropped in later searches as they had returned few new results in earlier searches.

Each search (date, location and search terms) and number of hits were recorded in an Excel spreadsheet along with information about each relevant find, which was exported directly from EndNote™ to Excel. Information from the following EndNote™ fields were exported into the Excel file: research type, journal, publication date, title, broad topic, category, research field location, authors, authors' addresses, funding, key words, summary, DOI. The data is stored in the Excel file (Published_DOC.xlsx), in which format it will be passed to Scottish Water.

Published articles have been separated into 'core articles' for those highly/directly relevant to DOC/water treatment and 'linked articles' for those with a focus other than DOC/water treatment, but which contain DOC information and/or data. Core and Linked articles are stored in separate sheets of the Excel file.

3.2 PhD Research

In order to capture past unpublished research, ongoing research and planned research, completed, current and advertised PhDs were searched for.

Locations searched include:

- **Findaphd.com** (https://www.findaphd.com/)
- **NERC Doctoral Training Partnership websites**: 'DTPs' (http://www.nerc.ac.uk/funding/available/postgrad/responsive/dtp/)
- **Individual institutions** – particularly those that featured regularly in the published articles
- **Ethos** – British Library e-thesis online service (http://ethos.bl.uk/Home.do)

PhD searches varied in structured/tiered approaches due to highly variable website design/mode of displaying information. Some websites had a search tool, some could be searched using 'Ctrl+F' function, while others had to be scrolled through manually. It was most difficult to extract information from the latter, and current PhDs were difficult to categorise due to often lacking information on student profiles (although this was very variable).

Identical search terms to those used in published article searches (

Table **1**) were used to identify/locate relevant PhD research. However due to the aforementioned difficulties with website structure, search terms were generally used individually rather than as a tiered approach.

Each search (search date, search location, search terms, number of hits) and relevant finding were recorded directly into an Excel spreadsheet (PhD research_DOC.xlsx), in which format the data will be passed to Scottish water. The following information was recorded from relevant finds: research type, whether advertised/current/completed, year of completion, whether available online, title, overview/aims/abstract, category, research field location, institution, PI(s), funder(s), student name, keywords.

3.3 Databases

Database searches were primarily carried out using the data section of the CEH website, to access resources such as the Environmental Information Data Centre (EIDC), the National River Flow Archive (NRFA) and the Environmental Change Network (ECN). The Agricultural and Environmental Data Archive was used to assess if data sets arising from the Demonstration Test Catchments (detailed in section 5) existed, but this was not searched independently due to time limitations and

these outputs were considered of likely lesser relevance as the DTC was a project related to diffuse agricultural pollution.

Databases were difficult to search due to a lack of possibility for tiered searching and sometimes unusual search outputs, and as a result, careful manual scanning through search hit lists was required. As a result, searching was more time-consuming and thus less accessible than information generated about articles and PhDs, and so less ground was likely covered here in the time available.

Each search (search date, search location, search terms, number of hits) and relevant findings were recorded directly into an Excel spreadsheet (Databases_DOC.xlsx), in which format the data will be given to Scottish water. The following information was stored of relevant finds: research type, title, research field location, publication date, authors, DOI.

3.4 Data Analysis

Numerical statistics: total and percentage of articles and PhDs relating to each category were calculated using Microsoft Excel.

Word Clouds: were created for articles and PhDs using wordle.net. Categories, keywords, authors, first-author institutions, publication journal and field site (where given) were used to create word clouds for articles, and word clouds of categories, titles and institutions were created for PhDs. How to best display the following was considered: core and linked articles, bracketed and non-bracketed categories, hyphenated keyword/title phrases vs. using all keywords/title words individually, and all vs. first authors. For example, when a resource was less closely-related to the key questions, brackets were used around the categories in the data bases. However, wordle did not accept brackets and so bracketed results were annotated instead using + to replace brackets i.e. '+ *category* +' was used. How wordle was structured to accommodate these considerations is specified in the relevant results section. Appendix 2 also offers alternative layouts for some wordle outputs, should it be preferred to use these.

4 Results

4.1 Summary of Findings

Of 950 published articles checked, 419 were recorded as relevant (266 core, 153 linked) and added to the data bases (Table 2). 94 PhDs were identified as being relevant. PhDs completed or current are a more secure resource to consider as the currently-advertised PhDs may not be filled and relevant research findings will not emerge until after October 2018 (assuming an October 2017 start) by which time Scottish Water may have commissioned research. 25 data files were found that may be of relevance.

Table 2: Number and percentage of core articles in each key question category

Published Articles:	**PhDs:**	**Databases:**
950 articles checked 266 core articles recorded 153 linked articles recorded 419 articles recorded in total	21 advertised PhDs recorded 10 current PhDs recorded 63 completed PhDs recorded 94 PhDs recorded in total	25 data files recorded, mainly through the EIDC
Projects	10, with some less relevant	

Each of these areas in table 2 is considered in more detail below, categorising first the breakdown of resources in each area accompanied by a visual representation of which categories recent research effort is relevant to. This is followed by visual analysis of the data using word clouds to depict the major and minor trends. At the end of each sub-section there is a summary analysis of trends.

4.2 Published Articles

4.2.1 Numerical Statistics

There are 266 core articles (Table 3) with 149 published in the 20-year period spanning 1990-2009, and 117 in the 7 years thereafter from 2010-2017 present day.

Table 3: Number and percentage of core articles in each key question category. The total number of publications across all categories (and so the % of all articles) is greater than the total number of publications as some publications are relevant to more than one category.

Category	Key Question	Core Articles Only					
		Number All Articles	**% All Articles**	**Number 1990-2009**	**% 1990-2009**	**Number 2010-present**	**% 2010-Present**
1	**How will DOC Change in the future?**	171	64	101	68	70	60
1a	How will quantity change?	136	51	81	54	55	47
1b	How will fractions change?	68	26	39	26	29	25
2	**How will climate change alter current trends?**	128	48	71	48	57	49
2a	Will the quantity change?	69	26	42	28	27	23
2b	Will it vary spatially?	40	15	24	16	16	14
3	**How does land management impact DOC release?**	102	38	46	31	56	48
3a	Can it reduce?	24	9	9	6	15	13
3b	Can it increase?	38	14	20	13	18	15
3c	Will it change the fractions?	14	5	6	4	8	7
4	**Can we identify new sources with low DBP formation?**	28	11	17	11	11	9
4a	Is extent of organic soils critical?	28	11	13	9	15	13
4b	Is the type of waterbody key?	6	2	5	3	1	1
5	**Not core, but source of DOC data**	-	-	-	-	-	-
	TOTAL NUMBER:	**266**		**149**		**117**	

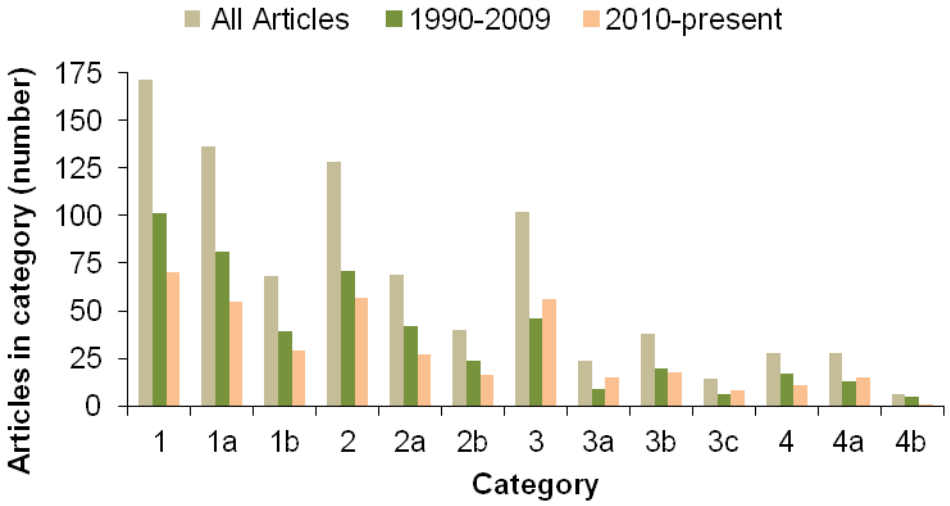

Figure 3: Number of core articles in each key question category, for all core articles, core articles published 1990-2009 and core articles published 2010-present.

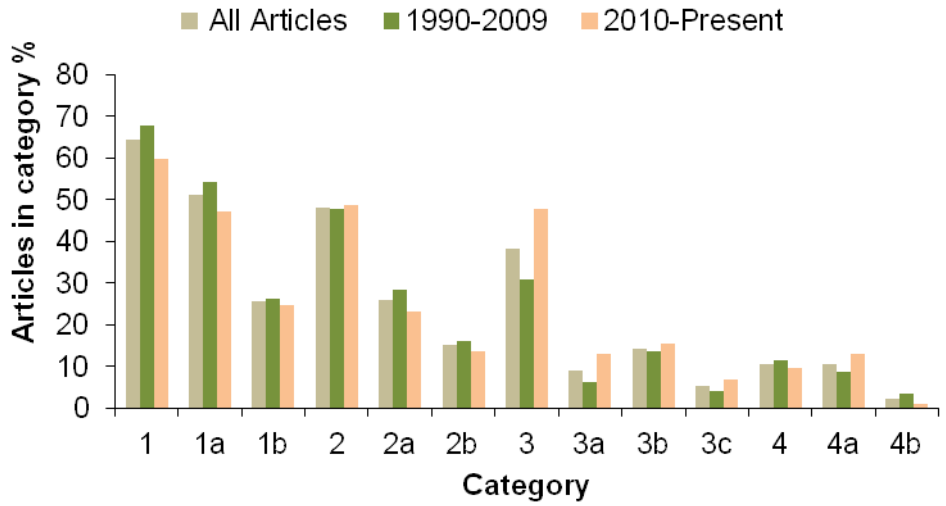

Figure 4: Percentage of core articles in each key question category, for all core articles, core articles published 1990-2009 and core articles published 2010-present. This figure is shown additionally to the absolute number of publications as it shows how relative trends are changing as a function of a cohort under consideration.

4.2.2 Article Word Clouds

4.2.2.1 Article Categories:

NB: Category word clouds were created using only the core articles and do not include the linked articles. A range of word clouds was created using only non-bracketed categories and both bracketed and non-bracketed categories, as well as for pre- and post-2010.

Figure 5: Categories of all core articles, including the bracketed (less closely-related) categories. Bracketed categories are represented by +n+.

Figure 6: Categories of all core articles, with bracketed categories excluded.

Figure 7: Categories of articles published 1990-2009, including bracketed categories. Bracketed categories are represented by +n+.

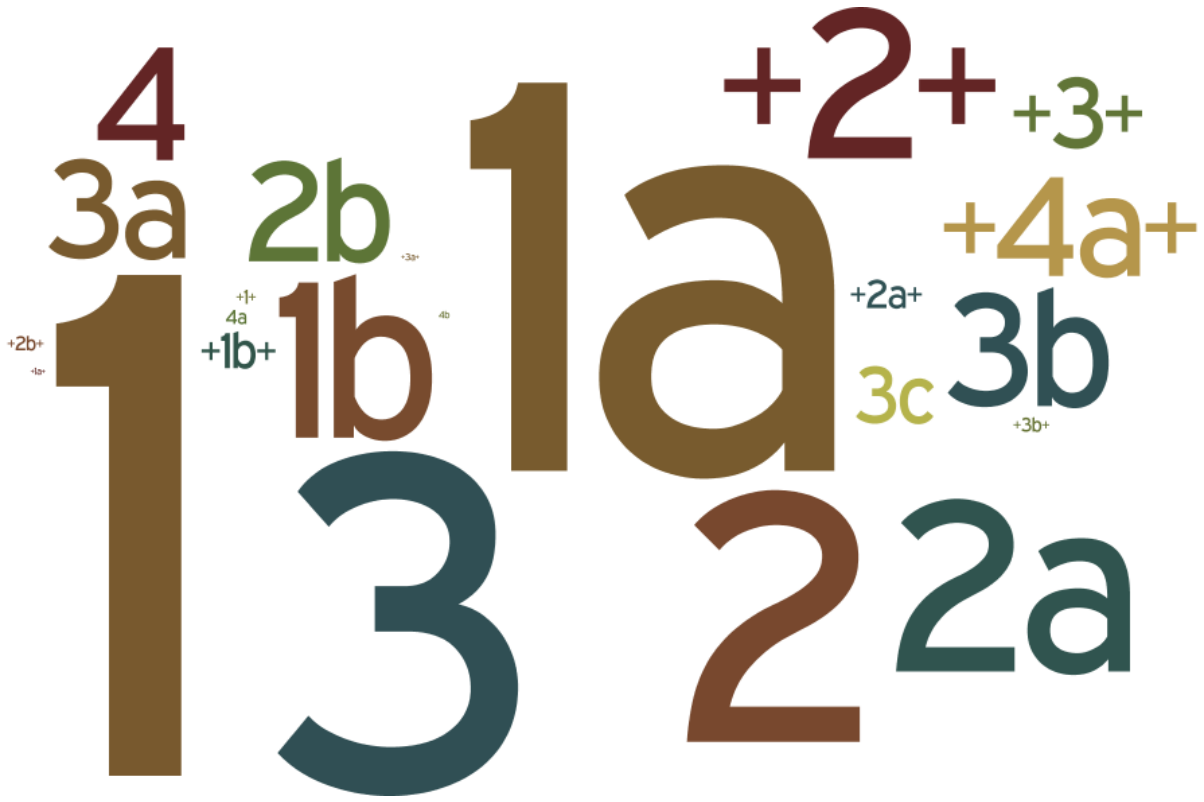

Figure 8: Categories of articles published 2010-present, including both bracketed categories. Bracketed categories are represented by +n+.

4.2.2.2 Keywords:

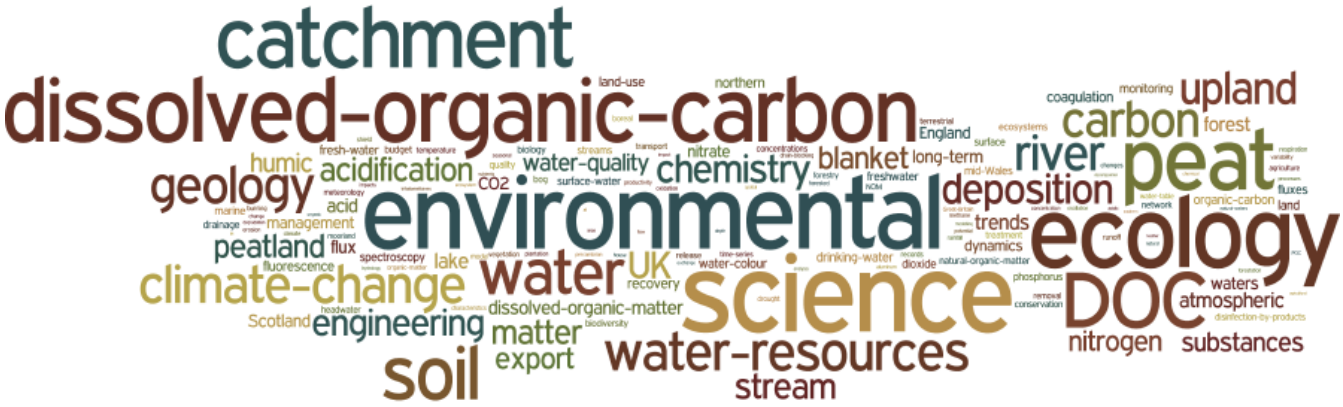

Figure 9: Word cloud of all articles' keywords, with key phrases hyphenated to normalise the phrase to one input.

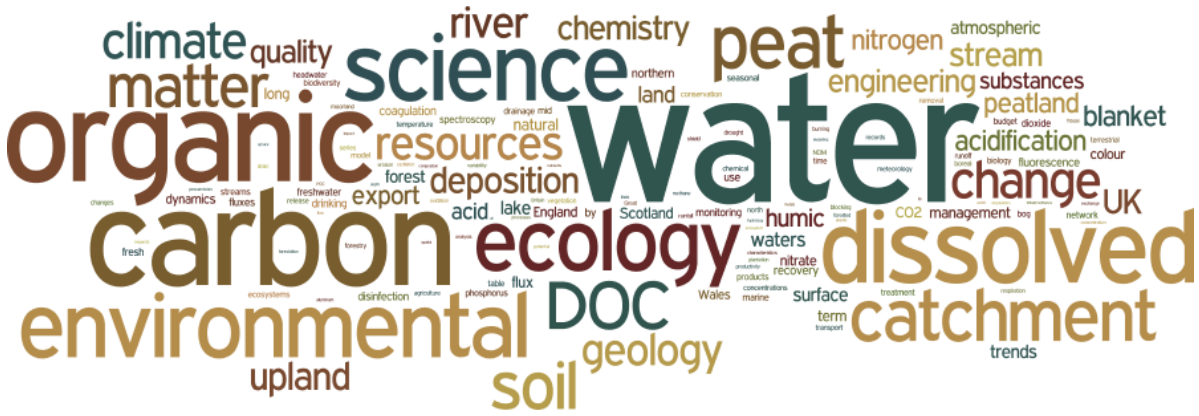

Figure 10: Word cloud of all articles' keywords, with no hyphenation of key phrases thus keywords appear and have been weighted individually.

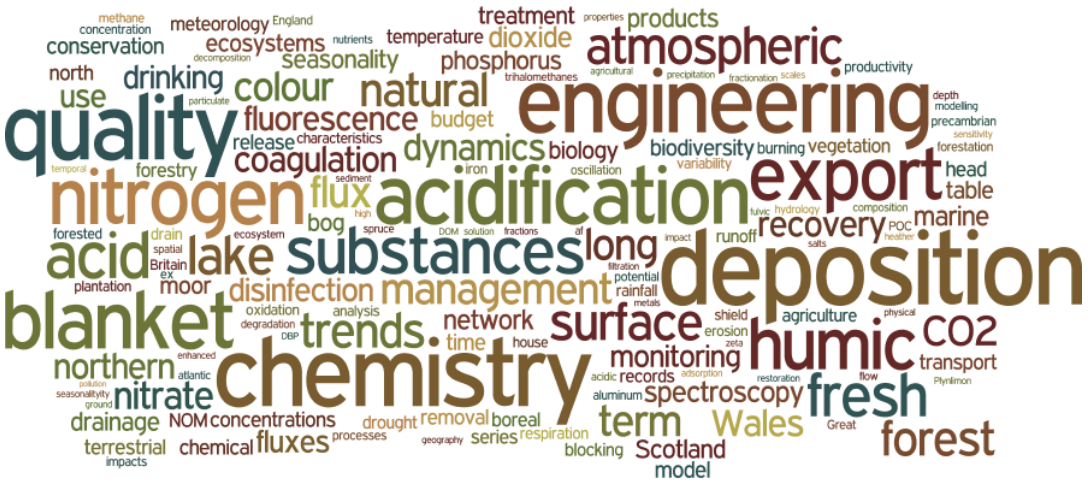

Figure 11: Word cloud of all article keywords, with no hyphenation of key phrases, and dominant keywords (from Fig. 9 and 10) removed to reveal weighting of less dominant keywords. Removed words: dissolved, organic, carbon, matter, environmental, DOC, catchment, ecology, soil, peat, change, climate, geology, science, land, UK, river, stream, resources.

4.2.2.3 Authors:

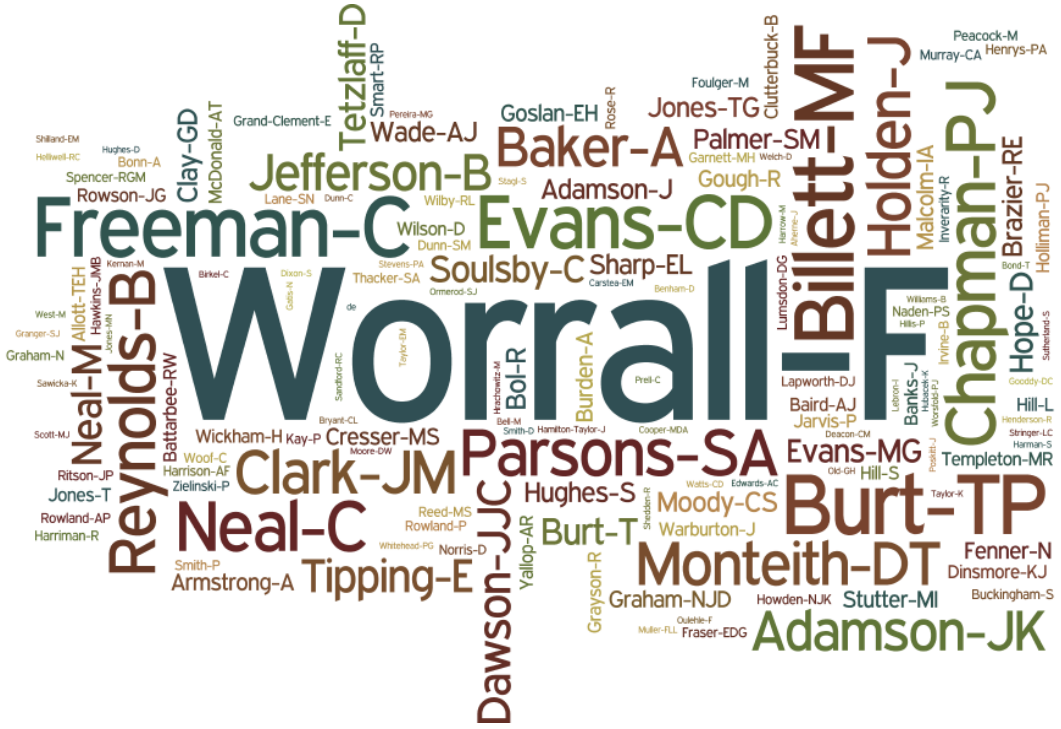

Figure 12: Word cloud of <u>all authors</u> with mixed-direction layout. In Appendix 2, Fig. 12a offers the horizontal direction lay-out.

4.2.2.4 First Author Institution:

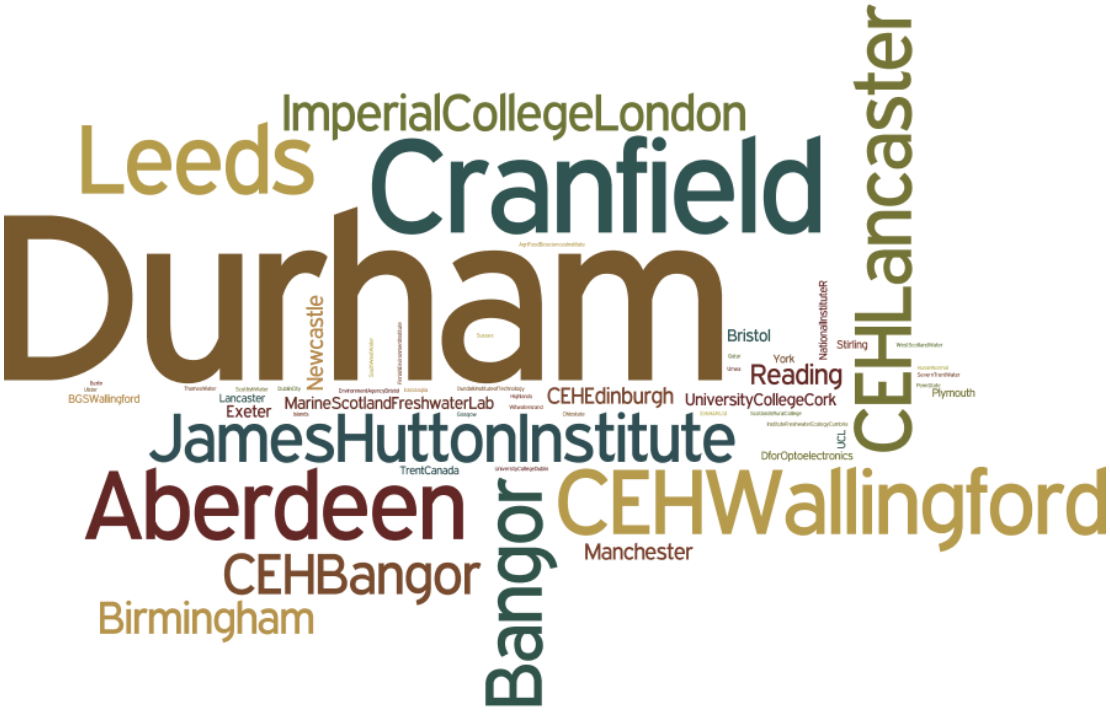

Figure 13: Word cloud of first author institutions with mixed-direction layout. In Appendix 2, Fig. 13a offers the horizontal direction lay-out. <u>NB:</u> Co-authors institutes are not included in

the institutional analysis as the lead author institution is considered to represent the home of the research.

Figure 14: Word cloud of the journals in which core articles were published, with horizontal direction layout. In descending order the most popular journals were Science of the Total Environment, Journal of Hydrology, Hydrological Processes, Hydrology and Earth System Sciences, and Biogeochemistry. These have been removed from this word cloud to allow the other journals to be read. In Appendix 2, Fig. 14a offers the mixed direction lay-out and Fig. 14b shows the word cloud generated with the dominant journals retained.

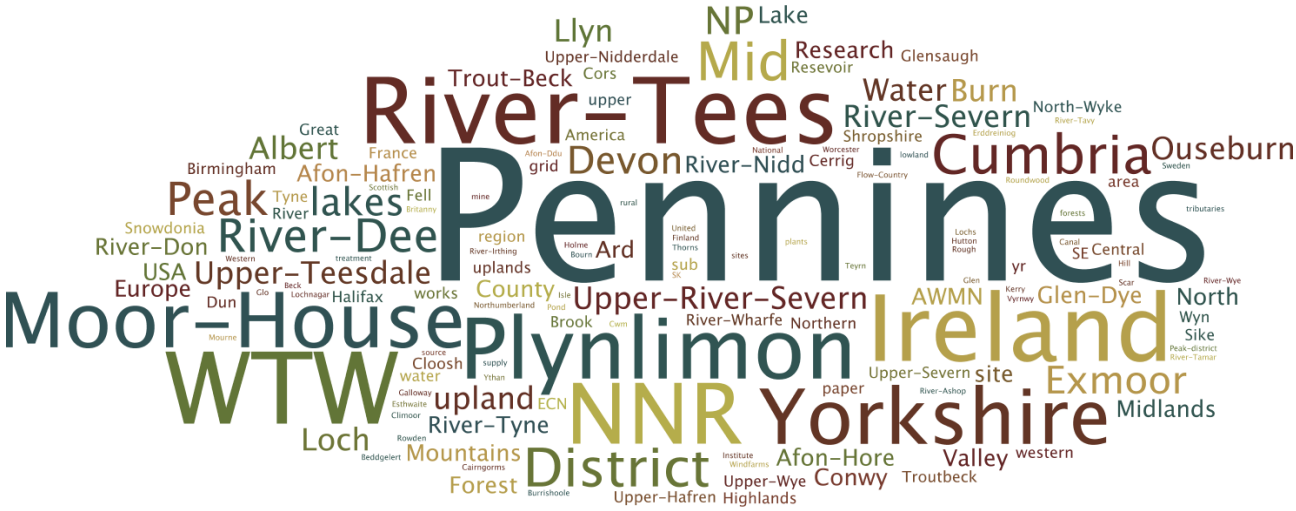

Figure 15: Word cloud of field site location of resources in core articles. UK, Scotland, Wales, England and compass directions, such as NE, were removed from this word cloud to allow key locations to stand out.

4.2.3 Published Articles: summary analysis of trends:

4.2.3.1 Overall most dominant research area:

Categories: category 1 (DOC trends/controls) is the SRP-DOM research area dominating published articles, particularly 1 and 1a. This is followed by category 2 (climate/season) particularly 2 and 2a. These trends are seen in both the numerical results (Table 3) and in the word clouds (Figures 3 – 4 and Figures 5 – 8 respectively).

Keywords: dominant individual key words were: dissolved, organic, carbon, matter, environmental, DOC, catchment, ecology, soil, peat, change, climate, geology, science, land, UK, river, stream and resources. Dominant keyword phrases were dissolved-organic carbon, climate-change, water-resources, water-quality, dissolved-organic matter, long-term and to a lesser extent drinking-water and water-colour. These are quite general relating to DOC in the environment and climate change and as would be expected (see Figures 9 and 10).

4.2.3.2 Overall least dominant research area:

Categories: category 4 (treatment/by-products) is the SRP-DOM research area that is least dominant, particularly 4b (relating to the type of waterbody). Categories 3a and 3c (reducing and increasing DOC trends with landuse) also lack research. These trends are seen in both the numerical results (Figures 3 and 4) and in the word clouds (Figures 5 – 8).

Keywords: when dominant individual keywords were removed (Figure 11), words relating to composition (quality, fluorescence, characteristics, humic, spectroscopy, substances, degradation), land management (management, vegetation, bog, drainage, blanket, burning, conservation, forest, recovery, forestation, fractions, use) and water treatment (coagulation, engineering, drinking, disinfection, NOM, products, treatment, substances, trihalomethanes) emerged showing the detail behind the general DOC- and climate-related research areas and a broader diversity of topics. This reflects patterns seen in the category results (Figures 2 – 8 and Table 3).

4.2.3.3 Research areas increased in interest in last 7 years:

Categories: the largest increase in research since 2010 is observed in category 3 (landuse/management), with increases across sub categories 3a and 3c. There is some increase in research within category 4 (treatment/by-products), specifically sub-category 4a. However it should be taken into consideration that category 4a was also used to represent research generally relating to soils. There have been increases in category 1 (DOC trends/controls) as well as category 1b (DOC fraction/composition). These trends are seen in both the numerical results and in the word clouds (Figures 3 – 4 and Figures 5 – 8 respectively).

4.2.3.4 Research areas decreased in interest in last 7 years:

Categories: The most noticeable decreases in research since 2010 are seen in categories 1a (change in DOC quantity) and 2a (change in DOC quantity relating to climate change). This is perhaps because there has been much research done on these areas in the past, and so these questions are beginning to be answered and thus now require less additional research. Interestingly, category 1 (DOC trends/controls) and 2 (climate/season) have increased and remained constant, respectively, indicating the focus has shifted from determining the pattern/magnitude of DOC in surface waters, to other aspects of trends and climate (e.g. DOC composition, spatial variation or climate effects on land-use). These trends are seen in both the numerical results and in the word clouds (Figures 3 – 4 and Figures 5 – 8 respectively).

4.2.3.5 Linked articles:

Many of the linked articles recorded have a focus in other water quality issues, mostly nitrates and heavy metals and so are not considered in detail here, instead the databases should be consulted

4.2.3.6 Authors

Dominant authors of published articles: Worrall, M.F. Billett, T.P. Burt, C.D. Evans ,C Freeman., B. Reynolds, P.J. Chapman, D.T. Monteith, S.A. Parsons, J.M. Clark, C. Neal, A. Baker, J.K. Adamson, B. Jefferson, J. Holden, E. Tipping and J.J.C. Dawson.

4.2.3.7 Institutions

Dominant institutions are: University of Durham, Cranfield University, University of Leeds, CEH Wallingford, CEH Lancaster, University of Aberdeen, Bangor University, CEH Bangor, University of Birmingham and Imperial College London.

4.2.3.8 Journals Published

The dominant journals are Science of the Total Environment, Journal of Hydrology, Hydrological Processes, Hydrology and Earth System Sciences, and Biogeochemistry. Excluding these from the word cloud (Fig. 14) showed that relevant resources had also been identified in the more technology- and policy-facing journals, such as Environmental Pollution, Water Science and Technology, Water Resources Research, and Land Use Policy.

4.2.3.9 Location of the research

After removing country-specific location identifiers, dominant research locations were most apparent in Northern England and Wales e.g., The Pennines, Plynlimnon, Moor House (Fig. 15). In

Scotland, the River Dee, Glen Dye, Glensaugh, and the Flow Country are apparent within the word cloud. These field sites are located close to the lead author's institution, indicating that relatively easy field site accessibility may be important in generally a significant body of work and thus remoter areas will be understudied. If an overseas location is identified in the word cloud (e.g. USA Fig.15) it is because there has been comparative analysis in the core article.

4.3 PhDs

There are 94 relevant PhDs (Table 4) of which 63 are completed and 31 are in progress or being advertised (Table 4). Where the funder is known this has been noted in the database.

4.3.1 Numerical Statistics

Table 4: Number and percentage of PhDs in each key question category. The total number of PhDs across all categories (and so the % of all PhDs) is greater than the total number of PhDs as some PhDs are relevant to more than one category.

Category	Key Question	PhD Type					
		Number All	% All	Number Completed	% Completed	Number Current/ Advertised	% Current/ Advertised
1	**How will DOC Change in the future?**	42	45	27	43	15	48
1a	How will quantity change?	35	37	24	38	11	35
1b	How will fractions change?	33	35	21	33	12	39
2	**How will climate change alter current trends?**	37	39	24	38	13	42
2a	Will the quantity change?	26	28	18	29	8	26
2b	Will it vary spatially?	29	31	22	35	7	23
3	**How does land management impact DOC release?**	39	41	29	46	10	32
3a	Can it reduce?	19	20	17	27	2	6
3b	Can it increase?	17	18	15	24	2	6
3c	Will it change the fractions?	6	6	5	8	1	3
4	**Can we identify new sources with low DBP formation?**	14	15	10	16	4	13
4a	Is extent of organic soils critical?	12	13	12	19	0	0
4b	Is the type of waterbody key?	6	6	5	8	1	3
5	**Not core, but source of DOC data**	16	17	6	10	10	32
	Total number	**94**		**63**		**31**	

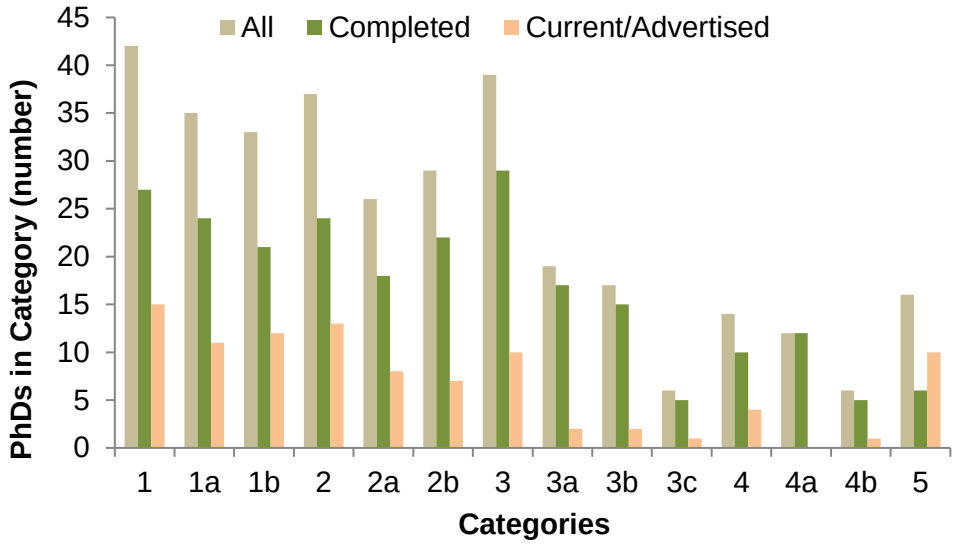

Figure 16: Number of PhDs in each key question category, for all PhDs, completed PhDs and current/advertised PhDs.

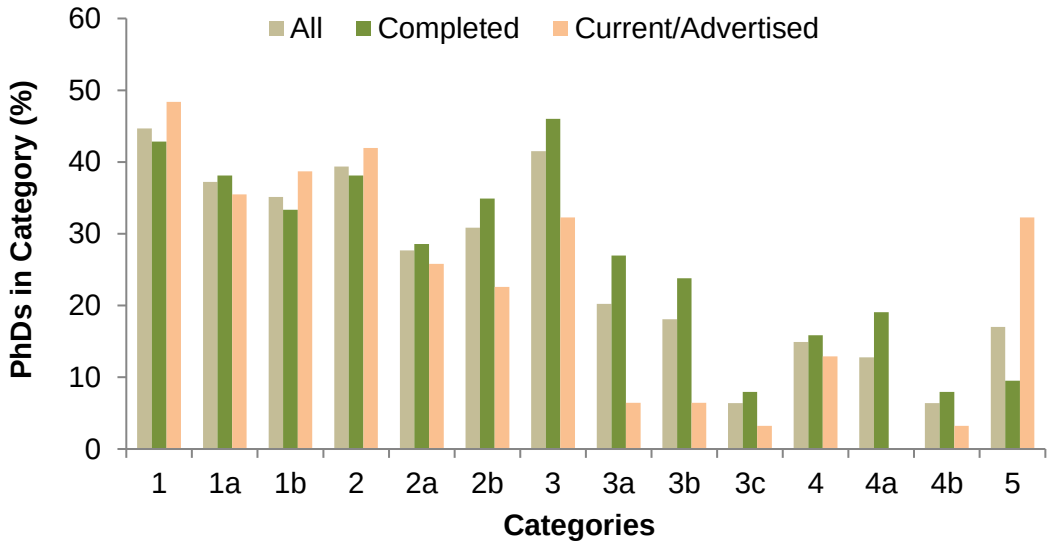

Figure 17: Percentage of PhDs in each key question category, for all PhDs, completed PhDs and current/advertised PhDs. This figure is shown additionally to the absolute number of PhDs as it shows how relative trends are changing as a function of a cohort under consideration.

4.3.2 PhD Word Clouds

4.3.2.1 PhD Categories:

NB: Bracketed and non-bracketed categories have been combined for all the following PhD word clouds.

Figure 18: Word cloud of all PhD categories

Figure 19: Word cloud of completed PhD categories

Figure 20: Word cloud of Current and advertised PhD categories

4.3.2.2 PhD Titles:

NB: key phrases in titles were not hyphenated – all title words appear and have been weighted individually.

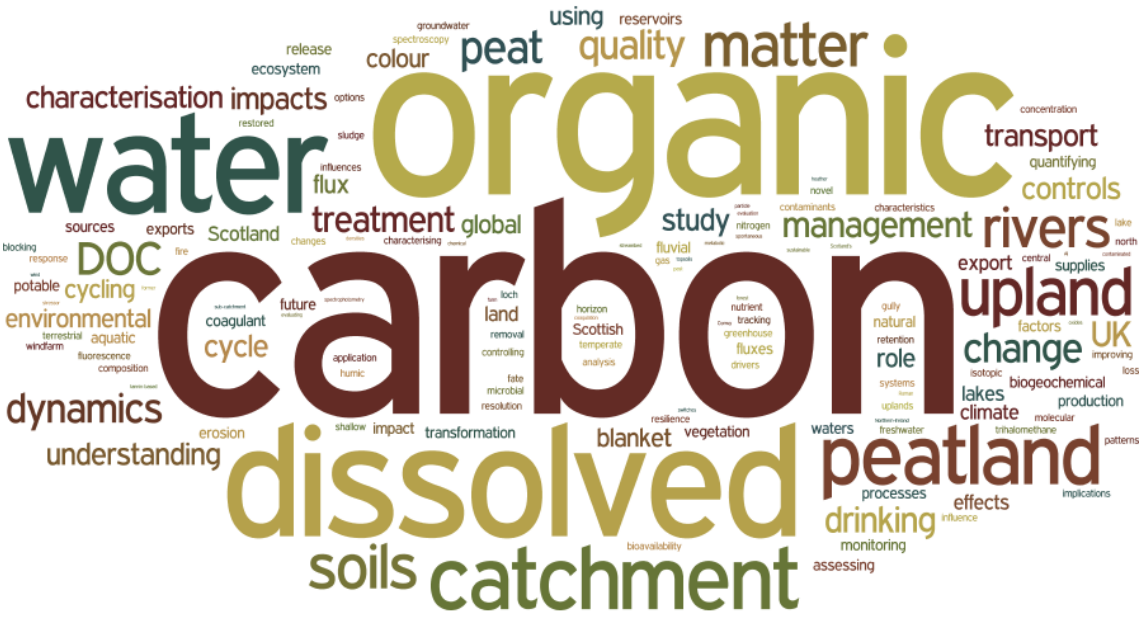

Figure 21: Word cloud of all PhD titles

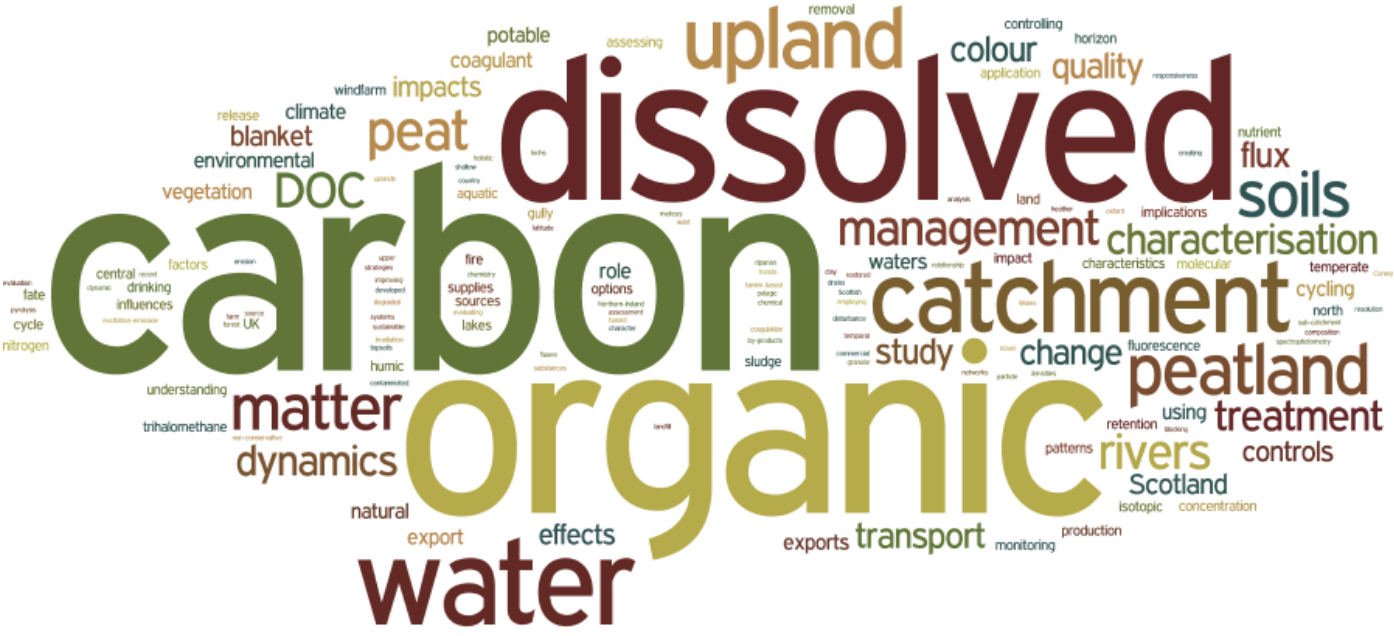

Figure 22: Word cloud of completed PhD titles

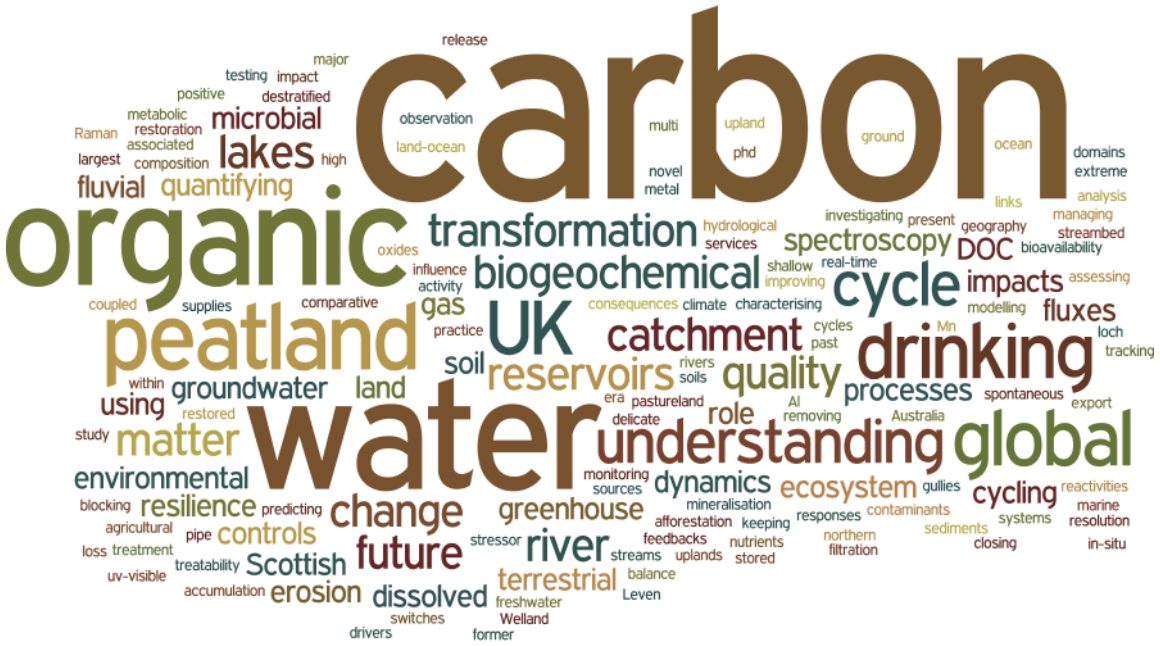

Figure 23: Word cloud of current and advertised PhD titles (Jan-Feb. 2017)

4.3.2.3 PhD Institutions

Figure 24: Word cloud of all PhD Institutions

4.3.3 PhD: summary of trends

PhDs were less easy to categorise than published articles, as the amounts of information on the aims/outcomes varied considerably and therefore our interpretation of fit to the SRP-DOM is less secure.

4.3.3.1 Overall most dominant research area:

Categories: category 1 (DOC trends/controls) is the most dominant research area, closely followed by categories 2 (climate/season) and 3 (landuse/management) which show variation in the dominance of their sub categories (Figures 17).

Titles: dominant words from all PhD titles were: carbon, organic, dissolved, water, catchment, peatland, matter, soils, peat, quality, DOC, upland, rivers, drinking, treatment, management, characterisation, colour, transport, controls (Figure 21).

4.3.3.2 Overall least dominant research area:

Categories: Category 4 (treatment/by-products) was the least dominant category, reflected in both numerical statistics (Table 4, Figure 16,17) and the word cloud (Figure 18).

4.3.3.3 Research areas increased in current and advertised PhDs:

Categories: categories 1 (DOC trends/controls), 1b (DOC fraction/composition) and 2 (climate/season) are more proportionally dominant in current and advertised PhDs than in completed PhDs (Figures 16,17). These trends are also reflected in the category word clouds (Figure 18 – 20)

Titles: dominant words in the titles of completed PhDs appear to be similar to those of current and advertised PhDs (Figures 22 and 23 respectively). Some words relating to treatment (e.g. treatment, reservoirs, quality, removal) that appear in completed PhD title word clouds do not seem to increase in dominance in current and advertised PhD title word clouds (Figures 22 and 23 respectively), as might have been expected. However the terms drinking and transformation do stand out more.

4.3.3.4 Research areas decreased in current and advertised PhDs:

Categories: most noticeably, there is a large decrease in category 3 research (landuse/management) in current and advertised PhDs compared to completed PhDs (Figure 16 and 17), suggesting less current and planned research relates to land management. Although an increase was seen in category 2 (climate/season), decreases are seen in categories 2a (DOC quantity relating to climate

change) and 2b (spatial variation in DOC) (Figure 16 and 17). The increase in climate/season research must be due to a shift away from quantity and spatial variation in climate-related DOC research towards other types of climate influence on DOC. Category 4 has slightly fewer PhD students currently engaged on research in this area, or advertised to undertake research in this area and no project identifies consideration of the extent of organic soils as a key research area (Figures 16 and 17). This was not expected and may relate to the general lack of information available on current and advertised PhDs but this would be worth exploring with the community.

4.3.4 Institutions

Overall the dominant institutions are: University of Durham, University of Glasgow, University of Manchester, Bangor University, University of Leeds, University of Stirling, University of Edinburgh, Cranfield University, Newcastle University, University of Aberdeen and University of Exeter. The James Hutton Institute, CEH Edinburgh and the National Oceanography Centre have become more dominant in current and advertised PhDs (Figure 24a, Appendix 2).

This is a different pattern of key research providers to published articles and indicates that there may be a considerable body of unpublished research in some institutes (Figure 24b, Appendix 2 identifies institutions holding completed relevant PhD thesis), which may not make publication soon as this was not possible during the PhD. However, most University libraries make e-thesis available on-line and so this understanding should become accessible, if not immediately, within a few years as the thesis may be subject to a temporary embargo to support publication.

5 Databases and Projects

In addition to the published articles and PhDs, 25 databases (Table 5) and 10 research projects (Table 6) were identified as outputs that may contain information relevant to SRP-DOM. Databases and projects were identified by considering known on-line data holdings, for example the NERC Informatics Data Centre hosted by CEH, or by use of internet searches. This analysis was completed after the analysis of the published articles and PhDs, and so is less detailed and more of a ‘snapshot’ of easily-found information undertaken during the remaining time. However, within a promising finding, keyword searches were carried out (similarly to Table 1). The detail of the hierarchy of search terms is given in the data bases.

These findings are detailed below and a brief discussion follows after the tables.

Table 5: List of databases containing data that may be relevant to the SRP-DOM

Database title	Year	Lead author
Chemistry of iron in freshwaters of Northwest England	2009	Lofts, S.
UK lowland river chemistry	2010	Neal, C.
Water quality survey of streams across Wales: runoff from forested and felled catchments draining a range of soil types	2010	Neal, C.
Conwy catchment - spatial water chemistry dataset	2013	Cooper, D.
Five year record of aquatic carbon and greenhouse gas concentrations from Auchencorth Moss	2013	Dinsmore, K. J.
Major ion and nutrient data from rivers [LOIS]	2013	Leach, D.
Dissolved polycyclic aromatic hydrocarbons (PAHs) & dissolved organic carbon (DOC) in the River Wyre (NW England)	2013	Moeckel, C.
Plynlimon research catchment high-frequency hydrochemistry data	2013	Neal, C.
Plynlimon research catchment hydrochemistry (2011-2016)	2013	Neal, C.
Vyrnwy research catchment hydrochemistry	2013	Reynolds, B.
Water quality data from the Ribble and Wyre catchments 2008-2010	2013	Scholefield, P.
Rain chemistry and volume data from Climoor fieldsite in Clocaenog Forest	2014	Sowerby, A.
Soil water chemistry data from Climoor fieldsite in Clocaenog Forest	2014	Sowerby, A.
Field measurements of peatland carbon cycling at a wind farm hosting peatland in Scotland, UK	2015	Armstrong, A.
UK Environmental Change Network (ECN) stream water chemistry data: 1992-2012	2015	Rennie, S.
UK Environmental Change Network (ECN) soil solution chemistry data: 1992-2012	2015	Rennie, S.
UK Environmental Change Network (ECN) precipitation chemistry data: 1992-2012	2015	Rennie, S.
UK Environmental Change Network (ECN) precipitation chemistry data: 1992-2012	2015	Rennie, S.
UK Environmental Change Network (ECN) stream water chemistry data: 1992-2012	2015	Rennie, S.
UK Environmental Change Network (ECN) soil solution chemistry data: 1992-2012	2015	Rennie, S.
Aquatic carbon and greenhouse gas concentrations in the Auchencorth Moss catchment following drain blocking	2016	Dinsmore, K.J.
Soil nutrient data from Winklebury Hill, UK, in 2014	2017	Fry, E.L.
Soil physical, chemical and biological measurements in the Conwy Catchment (North Wales) 2013 and 2014	2017	Glanville, H.C.
Plynlimon research catchment hydrochemistry	2017	Norris, D.A.
Defra's Demonstration Test Catchment data sets (Eden, Cumbria; Wensum, Norfolk; Avon, Hampshire; Tamar, Devon/Cornwall). – accessible from the FBA Agricultural & Environmental Data Archive using 'Demonstration Test Catchments' as a title and refined by 'organic C' http://www.environmentdata.org/dtc-archive-project/dtc-archive-project.	Variable	Multiple authors

Table 6: Active and completed research projects in the UK of relevance to SRP-DOM (as of Feb. 2017)

Project title, funder, investment, duration, lead PI and home institute, project description
Active projects
Land Ocean Carbon Transfer (LOCATE) NERC National Capability, £4,057,600, Apr.16- Mar.21 PI: Richard Sanders, NERC National Oceanography Centre Relevant Abstract (abbreviated from http://gtr.rcuk.ac.uk/projects?ref=NE%2FN018087%2F1): Soils across the globe contain about 4 times as much carbon as the fossil fuel carbon which to date has entered the atmosphere via combustion, with this pool being largest at high latitudes such as northern Scotland. The British pool of soil carbon is a large element of our 'natural capital' - the value that the ecosystem represents to us. It is so large that restoring some damaged elements of it, such as upland peat bogs, would probably save us £570M over the next 40 years in carbon values alone. Each year some of this leaches into rivers and streams, with the concentration of carbon in rivers gradually increasing in Britain and Europe. As this material gets into estuaries and coastal waters some of it gets returned to the atmosphere when bacteria use it to grow or when it's destroyed by sunlight, some is buried and some enters the open ocean. We don't understand what controls these various processes, so aren't currently in a position to say how they will change into the future. For these reasons we plan to undertake a programme called LOCATE, which will establish the current status of our peatland stocks is (how much soil carbon is getting into our rivers and estuaries), and then determine what happens to this material in our estuaries (including measuring the key processes). Based on this we will do some accurate up to date carbon accounts for the GB landmass and also produce some simple mathematical equations describing what happens to soil organic matter in our rivers and estuaries. These equations will then be embedded into a much larger model of the Earth System so that we can begin to answer questions about the long term fate of the soil organic carbon pool over the next 50 or 100 years. Other comments: No outcome so far on RCUK website, No other info online Future outputs likely to be relevant
Dissolved Organic Matter In Freshwater Ecosystems (DOMAINE) http://www.nerc-domaine.uk/ NERC Large Grant funding, £1,996,726, Apr.14- Mar.19 PI: Penny Johnes, University of Bristol Characterising the nature, origins and ecological significance of dissolved organic matter in freshwater ecosystems Abstract (from http://gtr.rcuk.ac.uk/projects?ref=NE%2FK010689%2F1): The origins, nature and metabolic pathways controlling the impact of dissolved organic matter (DOM) on aquatic ecosystem and human health are poorly understood, undermining our ability to develop appropriate policy and planning to bring adverse effects under control. The DOMAINE project, funded by the Natural Environment Research Council (NERC) aims to assess the origins and rates of Dissolved Organic Carbon (DOC), Dissolved Organic Nitrogen (DON) and Dissolved Organic Phosphorus (DOP) flux to aquatic ecosystems from the surrounding landscape. Furthermore the DOMAINE project will investigate the dominant enzymatic pathways controlling nutrient processing and the rate of dissolved organic nutrient fraction uptake in support of algal, plant and microbial production in waters of differing character and asses the availability of DON and DOP to riverine phytoplankton, epilithon and macrophytes. This will be achieved through a series of field and lab based experimental studies. For further details please refer to the tabs above. Broadly the project objectives are to: (i) Define the character of DOC, DON and DOP pools instream as they vary in relation to source character, (ii) Isolate the pathways by which DOC, DON and DOP move from terrestrial to aquatic systems, (iii) Gain an insight into the

ecosystem functional role of the individual nutrient fractions delivered from a range of catchment sources.
Data collection: Continuous monitoring of the in-stream conditions; Real-time hydrochemistry data currently available as expandable summary boxes on maps, but does not offer C determinants
On completion of the project data will be archived at the EIDC, so will be available by 2021.

Yorkshire Integrated Catchment Solutions Programme - Yorkshire iCASP
(**https://www.environment.leeds.ac.uk/research/yorkshire-icasp/**)
NERC Environmental Science Impact Programme, Feb. 17 - Jan. 22, £4,811,200
PI: Joe Holden, University of Leeds
This uses the Yorkshire Ouse basin, which contains large urban areas, lowland agriculture and sparsely-populated uplands including National Parks and Areas of Outstanding Natural Beauty, to instigate a programme of work which uses existing NERC-funded science to identify, develop, test and improve integrated solutions on a range of environmental impacts. This encompasses mitigation of drought and flood risk through improved connectivity between weather forecasting, land management and water resource management; improvements in water quality for both human water supply and rivers/other water bodies; and better management of soils for improved regional food security and carbon storage (in woodlands and peatland). Yorkshire iCASP will capitalise on existing NERC-funded science to develop tools, strategies, plans and policies to promote hazard resilience, mitigation of extreme events (floods and droughts), develop flood forecasting capability, improve water quality, enhance soils and farm practice and develop a joined-up approach for land and water management. iCASP has been co-created by partners drawn from local authorities, government agencies, major infrastructure/utility owners, private sector service providers, academic institutions, and third sector organisations who will work together to produce and deliver a work programme that seeks to enhance the economic and societal status of the region. Outcomes from the collaboration will deliver tools and techniques with applicability outside the region, creating services and products which can be used around the world to further benefit the region and the UK economy more generally. Projects that have been discussed in the work programme include raw water management approaches that reduce the cost of water treatment and Pippa Chapman is the academic lead for the Water Quality project.

Additionally to this it is worth noting the following projects that have been undertaken by Dr. Richard Grayson from the University of Leeds, who works with Joe Holden who leads the iCASP programme, so they may be feeding into iCASP:
https://www.geog.leeds.ac.uk/people/person/work-in-progress/?shortname=r.grayson

- **Water quality response to upland land management** , Yorkshire Water, December 2011 – ongoing
- **Monitoring at Stean Moor restoration site,** Environment Agency, Yorkshire Water, Natural England, Nov. 2009 – ongoing
- ***The role of in-situ UV-VIS spectrophotometers to continually measure and characterise DOC** June 2009 – ongoing
- **Colour risk mapping of the Esk and Leighton/Roundhill catchments.** Yorkshire Water, July 2013
- **Baseline erosion survey of an actively eroding upland peat using terrestrial laser scanning,** Peatscapes, North Pennines AONB, October 2010 - April 2011
- **Colour risk mapping of the Nidderdale Catchment.** Nidderdale AONB, October 2009
- **Monitoring hydrological recovery at Winscar**, Yorkshire Water, Mar. 2006 – Dec. 2010
- **Catchment management for reduction of dissolved organic carbon in water supplies**, Yorkshire Water, Dec. 2007 – Aug. 2010

Some of these projects have informed published papers e.g. the UV-VIS measurement project highlighted with an asterisk informed a 2012 publication, which is in the database. But some may be within stakeholder reports.

Completed projects in chronological order.
Land-Ocean Interaction Study (LOIS) NERC funded, 1992-2000, PI & amount unknown. The Land-Ocean Interaction Study (LOIS) was a NERC research programme designed to study processes in the coastal zone. The Rivers, Atmosphere and Coasts Study (RACS) was a major component of LOIS that looked at land-sea interactions in the coastal zone and the major exchanges (physical, chemical and biological) between rivers and estuaries and the atmosphere. A sub-component was studying the rivers that drain into the North Sea (RACS (R)) but the study focused on the east coast of the UK from the Wash to the Tweed and, so did not cover much of Scotland. Some of this data is lodged in the CEH dataset and may be of relevance, for example Leach et al (2013) major nutrient data from rivers contains DOC ~ weekly DOC concentration data from 1994 to 1997. This dataset has been picked up in the dataset analysis and thus it is likely that relevant LOIS outputs have been captured. There does not appear to be an active link to LOIS other than https://www.bodc.ac.uk/projects/data_management/uk/lois/
Lowland Catchments Research Programme (LOCAR): NERC Programme grant, £10,000,000, Multiple PIs, 2000-2006 LOCAR funded twelve research projects which each focused on a part of the hydrogeology or ecology of one or more of the three LOCAR study catchments on porous rock (Chalk and sandstone) and all in England. The research projects seem not very relevant to SRP-DOM, but would produce a good understanding of lowland river catchments and functioning. There is an end of project report entitled 'Go With The Flow: Science to help manage our lowland rivers now and in the future, but this overview is quite simplistic (available at http://catchments.nerc.ac.uk/docs/go_with_the_flow.pdf), and the more technical report would need to be accessed from NERC: 'An Integrated View of the LOCAR Programme Research Outcomes'. The programme web page documents more than 150 publications from this project – only one has the word C in the title and this was a conference abstract. Relevant outputs from here should have been captured in the publication analysis.
The Water and Global Change (WATCH) programme (WATCH) EU 6th Framework Programme February 2007 to July 2011 WATCH brought together the hydrological, water resources and climate research communities at an international level to analyse, quantify and predicty the components of the global water cycle and the related water resources – for the present and for the future. They also evaluated the associated uncertainties, and clarified the vulnerability of global water resources within key societal and economic sectors. It seems to have a focus on hydrological modelling for rivers worldwide and with some key links dead it is difficult to find more information about what was measured, but the outreach report does not mention carbon so it is likely it was not a focus. http://nora.nerc.ac.uk/19254/1/WATCH_Outreach_Report_-_low_resolution.pdf
Assessment of the contribution of aquatic C fluxes from to carbon losses from UK peatlands https://www.sniffer.org.uk/er18-project-summary-electronic-pdf, SNIFFER 2011 This project sought to: i) review current literature to report on knowledge of losses of C from organic soils by the aquatic pathway, considering balance across C species and controls on their overall balance; ii) survey UK organisations and researchers to create a meta-database for aquatic C forms; ii) undertake analyses of key datasets to assess the effect of climate change, recovery

from acidification and land management regimes on aquatic fluxes of C from peat and organo-mineral upland soils. There is much valuable information in this report that could be of relevance to development of the SRP-DOM, for example a key finding being that land management was unable to be incorporated into the data analysis due to the lack of spatial datasets.

NERC Macronutrient Cycles Programme.
http://www.nerc.ac.uk/research/funded/programmes/macronutrient/
NERC, £9,550,000, 2011-2015
Mutliple PIs, listed below. The academic contact for this programme was Paul Whitehouse, Oxford University: paul.whitehead@ouce.ox.ac.uk
The overall goal of the Macronutrient Cycles programme was to quantify the scales (magnitude and spatial/temporal variation) of N and P fluxes and nature of transformations through the catchment under a changing climate and perturbed C cycle. Five consortia grants and two proof-of-concept grants were funded. The consortia grants most relevant and listed below, with the principal investigator identified.
LTLS: Analysis and simulation of the Long-Term / Large-Scale interactions of C, N and P in UK land, freshwater and atmosphere (Ed Tipping, Lancaster PI) http://www.ltls.org.uk/ This contains an up-to-date publication list.
The Multi-Scale Response of Water Quality, Biodiversity and C Sequestration to Coupled Macronutrient Cycling from Source to Sea, commonly known as 'Surf2Turf' (Andrew Wade, Reading PI) https://sites.google.com/site/turf2surfproject/
The role of lateral exchange in modulating the seaward flux of C, N, P (Mark Trimmer, Queen Mary, University of London PI)Quantifying annual cycles of macronutrient fluxes and net effect of transformations in an estuary: their responses to stochastic storm-driven events (Duncan Purdle, Southampton, PI)

Diversity of Upland Rivers for Ecosystem Service Sustainability (DURESS) http://nerc-duress.org/
NERC funded, £3,000,000, June 2012- Dec. 2015
Isabel Durrance, Cardiff University
The DURESS project (http://gtr.rcuk.ac.uk/projects?ref=NE%2FJ014818%2F1) — this project focussed on four examples of river ecosystem services chosen to be explicitly biodiversity-mediated: the regulation of water quality; the regulation of decomposition; fisheries and recreational fishing; and river birds as culturally valued biodiversity. Each is at risk from climate/land use change, illustrating their sensitivity to disturbance thresholds over different time scales. These services vary in attributable market values, and all require an integrated physical, biogeochemical, ecological and socio-economic science perspective that none of the project partners could deliver alone. Theme 4 is likely the most relevant, led by Nick Chappell of Lancaster University (http://www.lancaster.ac.uk/lec/sites/duress/out.htm) which focussed on ' How do changes in catchment land use/ management and climate affect river biota?' and thus underpinning this was collected of hydrochemistry data that would be connected to catchment land use, including the use of high resolution sensors to capture DOC dynamics (Jones TD et al, 2014). This publication has been picked up in the publications data set and thus it is likely that relevant DURESS outputs have been captured. However, funding for this project only ceased 16 months ago and it is likely that outputs will continue to emerge.
The water companies are listed as beneficiaries: In deepening our understanding of the relationship between landuse/management and climate changes and river ecosystem processes, this project will help the water industry implement a whole catchment approach to water quality management. In particular it will help to identify options to reduce and manage impacts on water quality, notably in areas that add large costs to water treatment such as elevated nitrate and

Dissolved Organic Carbon content, colour, and waterborne pathogens that are not controlled using standard water disinfection such as Cryptosporidium.
National Demonstration Test Catchments (DTC) £2,462,231, Initial funding 2009-14, Lead Institute: University of Lancaster. A UK government-funded project designed to provide robust evidence regarding how diffuse pollution from agriculture can be cost-effectively controlled to improve and maintain water quality in rural river catchment areas. It focussed on four study catchments across England, which were considered representative of 80% of UK soil/ rainfall combinations and the major farm types in England and Wales. This investment generated data and research outputs. A link to the accessing data is given in table 5. A final report on phase 1 is available from the http://sciencesearch.defra.gov.uk website. The final report (DTC, year unknown) does not have a focus on NOM or DOC. Dissolved material is considered but the focus was more on nutrient concentrations, although 'Dissolved organic matter fingerprinting (Hampshire Avon)' is mentioned and it is noted that the NERC Domaine project, which focuses on dissolved organic matter transfromation used DTC facilities and knowledge.

5.1 The databases

Compared to publication, a relatively small number of databases have been found and so these can be listed in this document (Table 5). The databases are often a product of the same lead author (14 lead authors for 24 databases) and most have been created by authors employed by, or with a strong connection to the NERC research centres (a condition of NERC funding implemented over the past few years is to make data freely available after the project is completed).

Other data holdings may exist of relevance but these have not been published to be freely available, for example such listings can be found within ER18 (Assessment of the contribution of aquatic C fluxes from to carbon losses from UK peatlands, Stutter et al, 2011), a report commissioned by SNIFFER. In the summer of 2010, Stutter et al contacted approximately seventy individuals form organisations likely to have data holdings e.g., Universities, institutions, government bodies, companies.

Sixteen responses were received and some of these provided data which sits within a meta-database (hosted by CLAD at http://www.clad.ac.uk/resources/aquatic-carbon-meta-database/) and associated GIS file, accessible by contacting the lead author. Importantly the ER18 report identifies a large amount of TOC data that has been collected by SEPA and Marine Scotland Freshwater Laboratory (ER 18, Appendix 3) and the location of these studies and the timescale collected. This data should be freely available upon request, although SEPA are still reprocessing data and creating software outputs, using Tibco Spotfire, to analyse and visualise data (Cundill et al., 2017). It is understood this tool will be available to external parties.

Of relevance also may be data generated through Defra's Demonstration Test Catchments. Defra's Demonstration Test Catchment (DTC) project investigated solutions to the long-standing problem of diffuse pollution and its impact on water quality in agricultural landscapes. It concentrated research in four river systems with intensive monitoring of the environment and testing of different mitigation measures. These are described as demonstration test catchments because the ideas that are being tested will provide valuable information which can then be applied to other sites around the country. Within the data sets, dissolved organic C concentration data can be found, but this parameter was not a core focus.

5.2 The projects

Fewer projects in the UK than databases were identified as relevant to the SRP-DOM, and as such and given their importance to SRP-DOM planning, the projects to have been summarised here (Table 6). Their relevance to the SRP-DOM has been ascertained from an abstract. Those that have been completed should have resulted in publications and if publicly funded data-set submission, but linking publications and data-sets to these projects has not been explored explicitly as it was considered this was a lesser priority. Effective publication and data-set searching should have ensured project outputs were not missed and information in Table 6 evidences that outputs have been captured.

The underpinning relevance of current projects to SRP-DOM would have to be confirmed by discussion with the relevant researchers as they understand more the project aims and findings to date than can be ascertained from the on-line overview. Two large projects (+£1M NERC investment) currently active will have aims relevant to some of the under-represented areas in SRP-DOM. LoCATE identifies spatial and temporal variation in freshwater C loading from multiple sites around the UK, including Scotland, and DOMAINE is investing effort into the characterisation of DOM and how this affects its in-system processing. DOMAINE also intend to develop a number of novel technologies, including the testing of novel sensor technologies to capture high resolution information on CDOM flux at catchment scale, and so this seems very relevant, indeed Scottish Water are listed as a project partner

Of the completed projects DURESS and the NERC Macronutrient Cycles Programme are likely more relevant to SRP-DOM than LOCAR and the Demonstration Test Catchments (DTC). DURESS focuses on upland catchments in Wales so will have more similar catchments and land use than the LOCAR lowland permeable catchments with considerable groundwater resource abstraction in southern England, or the DTC farmed catchments. C was a key determinant with the NERC Macronutrient Cycles Programme and so data outputs from this will be relevant. LOIS and WATCH appear to have little relevance other than a few data sets. The ER18 SNIFFER report (2011) could

contain some very relevant understanding, and identify areas for which data lacking several years ago limited understanding. If this data is still lacking, this could be part of a research need.

In addition, currently NERC are scoping a strategic research programme entitled 'Enhancing the resilience of UK peatlands'. It is not yet known if this will be fully-developed to the funding stage, but if it is, as the call considers that degraded peatlands are linked to significant changes in water quality, this may represent a new set of projects commencing in mid-late 2018 with a component undertaking research relevant to the SRP-DOM, particularly on land management.

6 Summary of Trends in Results and suggested areas for research development.

The publication analysis shows that:

- category 1 (DOC trends/controls) is the SRP-DOM research area that has dominated published articles, particularly 1 and 1a (change in DOC quantity), closely followed by category 2 (climate/season).
- category 1b (DOC fraction/composition) has almost as many publications from 2010-2017 as before, so although there has been a decrease in publications since 2010 this is driven by 1a. Category 2a (change in DOC quantity relating to climate change) also shows a reduced number of publications from 2010-2017 than before this period. The differences in 1a and 2a before and after 2010 are small, and as a shorter time period is being considered here (2010-2017), although there are fewer publications, this is still an area of significant output.
- the largest increase in research since 2010 is observed in category 3 (landuse/management) with more publications over this shorter time period, than prior to 2010. Increases are observed across sub-categories 3a, and 3c. It may be the community feel these questions are more important than categories 1 or 2 as there have been many publications providing insight into trends (Q1) and climate change influence (Q2).
- category 4 (treatment/by-products) is the SRP-DOM research area that is least dominant, particularly 4b (relating to the type of waterbody). Additionally, although the community has been publishing more in category 3 since 2010, this is still an area of reduced publications, specifically 3a (reducing DOC trends with landuse) and 3c (the influence of landuse on DOC fractions).

The PhD analysis shows that:

- category 1 (DOC trends/controls) is the most dominant research area, closely followed by categories 2 (climate/season) and 3 (landuse/management), and categories 1 (DOC trends/controls), 2 (climate/season), 1b (DOC fraction/composition) dominate current and advertised PhDs.

- Category 4 (treatment/by-products) was the least dominant category in completed PhDs and has not increased in dominance in current and advertised PhDs either (Figures 19 and 20). Further, no project identifies consideration of the extent of organic soils as a key research area in current PhDs or that it will be important in currently-advertised projects. This may be as there have been several publications that demonstrate this outwith the UK e.g. Kortelainen et al 2006, and so the community has accepted this is a control and are not designing research around this.
- there is a large decrease in category 3 research (landuse/management) in current and advertised PhDs compared to completed PhDs, and instead of this being the most popular category for current or advertised research how DOC will change in the future (category 1) and climatic responses (category 2) are more popular.

The databases and projects have not been tied to the research areas – largely as detail is lacking in available information on where they will be most relevant too, but also as the most relevant current projects have published little yet to allow this analysis to be made.

So, with a greater security of understanding from the published research and PhD projects of what research exists relative to SRP-DOM, it appears that: question 4 is least-well supported by published research or PhD research; that 1b is gaining more research interest, but lacks the significant number of publications that 1a has produced; category 3 seems important to PhD research but this has not yet been supported by a publication base as strong as some of the other categories. These therefore seem areas that may be worth developing.

7 Funding options.

Before embarking on any research investment, in order to avoid commissioning research that is being undertaken but unknown, it would be prudent to ask the large projects NERC funded that are relevant to Scottish Water e.g., LOCATE, DOMAINE, i-CASP for an update on their activity and the timescale of any outcomes that are relevant to SRP-DOM. It may also be worthwhile contacting DURESS to ask for similar information as they likely have publications still to come, and also discussing with NERC the direction of the scoped 'Enhancing peatland resilience' programme. Both the research community and NERC would welcome interest from stakeholders such as Scottish Water and would share the information they can.

If after this, there are still research needs that Scottish Water have (the SRP-DOM does seem to ask other questions to the research programmes current), or that cannot be met on a timescale relevant to Scottish Water from these programmes, then having consulted with RCUK a stronger case could be made for investment. Multiple options exist through NERC, which is the research council this is most relevant to given the catchment management component of the SRP-DOM key questions.

These are outlined below, after contextual information of the level or activity research investment would support.

There are several approaches Scottish Water could consider that would assist in leveraging increased funding should they wish to commission research to support the SRP-DOM. The options below are based on an estimated investment from Scottish Water of £500,000 and the assumptions that a three-year post-doctoral researcher, with academic investigator contribution and research expenses is ~ £500,000 and a 3.5 year PhD student with some analytical budget will be £80,000. The PDRA-led research is likely more secure as will have at its core a trained researcher with a track record of project completion and it will be more time-bound. However, research students are supervised and one PDRA-led project could fund an equivalent of 5 PhD students.

1. NERC offer a 'Joint Strategic Response' initiative where they would co-match (or greater) partner funding. The turnaround decision is quick (3 months) and this would roll out a research programme. The combined funding could leverage 2-3 PDRA-led projects of approximately 3 years. It will not fund studentships. There is more detail to discuss with NERC, for example can the size of any bid be capped to increase the number of projects. Academics have a tendency to automatically design a three-year research project than consider if the research question may feasibly be answered in a shorter period. Further information can be found at http://www.nerc.ac.uk/research/portfolio/strategic/joint/

2. Specific research groups could be targeted to submit a grant application to the NERC Discovery Science funding scheme (two calls per year), with Scottish Water as a project partner. However, such funding is awarded to outstanding or excellent research and this generally involves a new understanding of a globally significant Earth system process. A UK-based question on catchment scale processes may not be perceived as sufficiently ambitious. Further many organisations are now subject to ‘demand management’ (the number of applications they can submit will be capped) and so there will be internal competition for the institute submission, thus an application with Scottish Water as a partner would be tensioned against others and may not be chosen. This route is not likely to return the body of research required by Scottish Water.

3. Funding coming through the NERC Innovation Route may offer some potential: http://www.nerc.ac.uk/innovation/together/toolkit/ Here there appears to be two opportunities, Strategic partnerships and Innovation Programmes:

A Strategic Partnership is a long-term, mutually beneficial arrangement between NERC and a partner organisation from the business, policy or third sector in which the various parties work together to: share and understand more deeply, and at an early stage, specific strategic interests and needs in environmental science; identify opportunities to accelerate and deliver impact by

translating existing environmental science into real world applications, tools and solutions; contribute to the identification of priorities for new strategic research; and strongly advocate sustained investment in environmental science and training for the benefit of the UK economy and society.

Innovation Programmes are designed to enable businesses, policymakers and civil society to work collaboratively in specific topic areas where there is a strong shared need for environmental research, which can be met by existing NERC science. An example of a currently active Innovation Programme is the Environmental Risks to Infrastructure, which Scottish Water are participating in. In addition, the call for 'Regional Impact from Science of the Environment (RISE)' bids has just opened. The purpose of this is to bringing research organisations together with businesses, policy bodies and other actors contributing to economic development specific to their location, to deliver significant regional impact from NERC environmental science. It was such a call that funded the iCASP programme and a Scottish Water specific focus could be in scope. This call is expected to occur annually. http://www.nerc.ac.uk/funding/available/schemes/ao-esip/

Thus prior to commissioning research in support of the SRP-DOM it would be sensible to discuss the research need with the NERC Innovation Team.

4. The funding could be used to target PhD student training on research projects relevant to the SRP-DOM. A £500,000 investment would fund ~ 5-6 students, but most University partners would be able to leverage internal funding such that this number would likely increase by 30-50% so could be up to eight students. This could allow two students per key research question or a different distribution depending on what areas are identified as a focus of the research. If this investment was also aligned with one, or several NERC Doctoral Training Partnerships (DTP), then it is likely co-funding would be possible and up to 12 students could be funded at 50 / 50 % Scottish Water / RCUK. The latter would provide immediate access to studentships and would have little lead-in time as the studentships are designed and advertised annually. An advantage of this approach is that all students could work in the same geographical area so generating significant momentum to produce an integrated understanding. A caveat may be that the studentships are normally awarded to the best student than strategically and so there is no guarantee of Scottish Water co-funded students being offered DTP funding. Thus a Scottish Water created DTP may be a more secure route.

If the student cohort funding approach was considered attractive, this could be explored further with NERC or the Scottish Funding Council, for example to augment the HydroNation Scheme (http://www.hydronationscholars.scot/index.html)

8 Future expansion of this overview analysis

This overview represents the activity that was possible within a two-month period and from a position of no accumulated information. As such the undertaking was limited to the UK and to land surface water bodies. Further, collating the most secure sources of information was prioritised e.g. peer-review research outputs, lists of completed PhD projects, published data sets. If this exercise was to be extended then the following may be valuable, but particularly the first suggestion as similar environments (climate, soil types and catchment management) can be found outside the UK:

- Extend searches to include research/resources from other temperate regions and water treatment works
- Extend numerical statistics to all results e.g. keywords, authors, institutions
- Extend the pre- and post- 2010 breakdown of categories (and keywords, authors, institutions) to yearly/5-yearly increments
- Further investigation into content of current and advertised PhDs – e.g. emailing students/supervisors to request information
- Expand research areas of interest to include heavy metal and nitrate, if these are also of concern to Scottish Water, as levels of these pollutants seem highly linked to DOC.

Additionally, this database now provides a resource that could be used to inform a review of the literature and from this identify a risk-security matrix i.e. where is knowledge 'secure' (i.e. where all researchers have reached a similar conclusion of a process understanding and decision can be made with more confidence), or where is there considerable uncertainty and the knowledge 'insecure' such that a resultant management decision may not result in the desired outcome. Reviewing the literature would support the creation of a hierarchy of risk e.g. understanding of a particular response may be very secure, however the knowledge synthesis has identified that this is not an important driver to DOC loading and so the consequences of acting with less knowledge are less serious.

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10 Appendices.

Appendix 1: This appendix provides information on how to read the following excel files: Published_DOC.xlsx; PhD research_DOC.xlsx

Interpreting the files:

The Excel files are comprised of several worksheets. The first worksheet is the database of core and linked articles or PhD projects (these worksheet titles contain the term 'databases'). The following worksheets detail the key search terms used, the results generated and a timescale over which this was undertaken (these worksheet titles contain the term 'search approach & results').

For published articles, PhDs and databases (Published_DOC.xlsx, PhD research_DOC.xlsx), search date, search location, search terms and number of hits were recorded for each search carried out. These columns are on the RHS of the spreadsheets (A-F for articles (see Figure A1) and PhDs; A-E for databases). The remaining columns (G/F onwards) record specific information about any relevant articles/resources found in the search (see Figure A1).

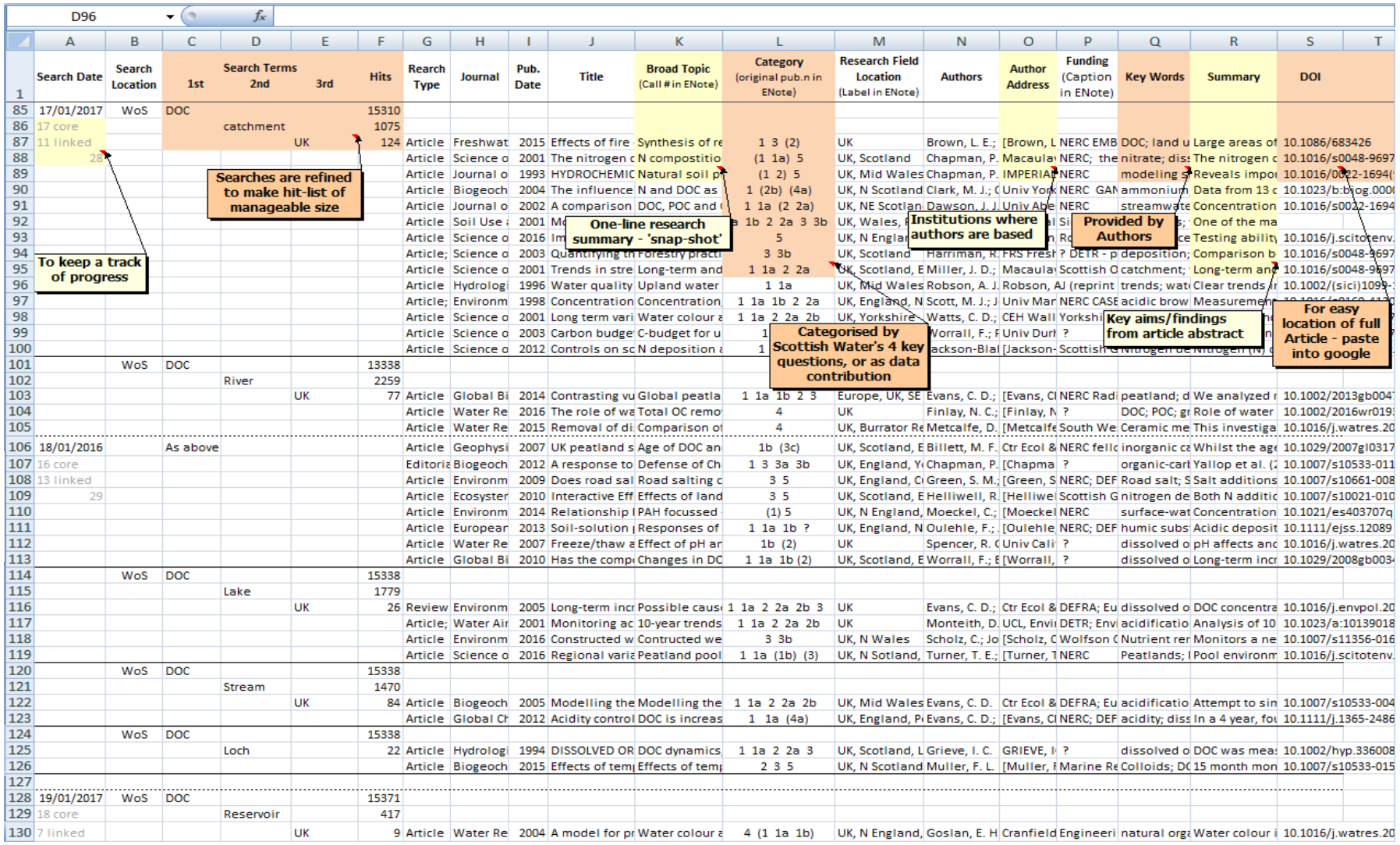
When the number of hits for a particular search was >100, the search was generally refined with further search terms before beginning to read abstracts/summaries and record article/resource information; this created blank rows in the spreadsheet. Blank rows were also created when a search returned no hits. When a search output contained an article/resource that had been found in a previous search, and/or recorded elsewhere, or that was not relevant, a note was made in the column adjacent to the hits (column G) and the left of the row left blank.

A solid line under an entry represents the end of a particular search (Published_DOC.xlsx), or the end of a broad search location (PhD research_DOC.xlsx). A dotted line under an entry represents the end of a given day (Published_DOC.xlsx and PhD research_DOC.xlsx). Where a thick solid line and dotted line appear together (Published_DOC.xlsx and PhD research_DOC.xlsx), this represents the completion of a particular search coinciding with the end of a day.

Occasional entries with non-UK field sites are entered in red text (Published_DOC.xlsx and PhD research_DOC.xlsx) – these were entered in error but left in place in case they could be useful at a later stage of the project.

"PhD research_DOC.xlsx" has additional colour coding the purpose of which is explained in a key in cells A8:A12. Also, where "Year of Completion" (column J) was not relevant (i.e. advertised PhDs or PhDs in progress) a zero was entered to allow an easy count of the total PhDs recorded.

There is a further worksheet entitled 'Categories' in both files and this is where the category coding for each resource has been pasted under the relevant category number to allow calculation of how many resources are relevant to each SRP-DOM question (Figure 2) and from this Tables 3 and 4 and associated figures were generated. These are not linked to the reference resource, but have been left for completeness in transparency of estimation.



	Search Date	Search Location	Search Terms 1st	Search Terms 2nd	Search Terms 3rd	Hits	Rearch Type	Journal	Pub. Date	Title	Broad Topic (Call # in ENote)	Category (original pub.n in ENote)	Research Field Location (Label in ENote)	Authors	Author Address	Funding (Caption in ENote)	Key Words	Summary	DOI
85	17/01/2017	WoS	DOC			15310													
86	17 core			catchment		1075													
87	11 linked				UK	124	Article	Freshwat	2015	Effects of fire	Synthesis of re	1 3 (2)	UK	Brown, L. E.;	[Brown, L	NERC EMB	DOC; land u	Large areas of	10.1086/683426
88	28						Article	Science o	2001	The nitrogen c	N compositio	(1 1a) 5	UK, Scotland	Chapman, P.	Macaula	NERC; the	nitrate; diss	The nitrogen c	10.1016/s0048-9697
89							Article	Journal o	1993	HYDROCHEMIC	Natural soil p	(1 2) 5	UK, Mid Wales	Chapman, P.	IMPERIA	NERC	modeling s	Reveals impo	10.1016/0022-1694(
90							Article	Biogeoch	2004	The influence	N and DOC as	1 (2b) (4a)	UK, N Scotland	Clark, M. J.;	Univ York	NERC GAN	ammonium	Data from 13 c	10.1023/b:biog.000
91							Article	Journal o	2002	A comparison	DOC, POC and	1 1a (2 2a)	UK, NE Scotlan	Dawson, J. J.	Univ Abe	NERC	streamwate	Concentration	10.1016/s0022-1694
92							Article	Soil Use a	2001	Mo		1b 2 2a 3 3b	UK, Wales,					One of the ma	
93							Article	Science o	2016	Im		5	UK, N Englar					Testing ability	10.1016/j.scitotenv.
94							Article;	Science o	2003	Quantifying th	Forestry practi	3 3b	UK, Scotland	Harriman, R.	FRS Fresh	? DETR - p	deposition;	Comparison b	10.1016/s0048-9697
95							Article	Science o	2001	Trends in stre	Long-term and	1 1a 2 2a	UK, Scotland, E	Miller, J. D.;	Macaula	Scottish O	catchment;	Long-term and	10.1016/s0048-9697
96							Article	Hydrologi	1996	Water quality	Upland water	1 1a	UK, Mid Wales	Robson, A. J.	Robson, AJ	(reprint	trends; wat	Clear trends i	10.1002/(sici)1099-
97							Article;	Environm	1998	Concentration	Concentration	1 1a 1b 2 2a	UK, England, N	Scott, M. J.; J	Univ Mar	NERC CASE	acidic brow	Measuremen	
98							Article	Science o	2001	Long term vari	Water colour a	1 1a 2 2a 2b	UK, Yorkshire	Watts, C. D.;	CEH Wall	Yorkshi			
99							Article	Science o	2003	Carbon budge	C-budget for u	1		Worrall, F.; F	Univ Durh	?			
100							Article	Science o	2012	Controls on sc	N deposition a	1		Jackson-Blal	Jackson-	Scottish G	Nitrogen de	Nitrogen (N)	
101		WoS	DOC			13338													
102				River		2259													
103					UK	77	Article	Global Bi	2014	Contrasting vu	Global peatla	1 1a 1b 2 3	Europe, UK, SE	Evans, C. D.;	[Evans, C	NERC Rad	peatland; d	We analyzed r	10.1002/2013gb004
104							Article	Water Re	2016	The role of wa	Total OC remo	4	UK	Finlay, N. C.;	[Finlay, N	?	DOC; POC; gr	Role of water	10.1002/2016wr019
105							Article	Water Re	2015	Removal of di	Comparison of	4	UK, Burrator Re	Metcalfe, D.	[Metcalfe	South We	Ceramic me	This investiga	10.1016/j.watres.20
106	18/01/2016		As above				Article	Geophysi	2007	UK peatland s	Age of DOC an	1b (3c)	UK, Scotland, E	Billett, M. F.	Ctr Ecol &	NERC fellc	inorganic ca	Whilst the age	10.1029/2007gl0317
107	16 core						Editoria	Biogeoch	2012	A response to	Defense of Ch	1 3 3a 3b	UK, England, Y	Chapman, P.	[Chapma	?	organic-carl	Yallop et al. (2	10.1007/s10533-011
108	13 linked						Article	Environm	2009	Does road sal	Road salting c	3 5	UK, England, C	Green, S. M.;	[Green, S	NERC; DEF	Road salt; S	Salt additions	10.1007/s10661-008
109	29						Article	Ecosyster	2010	Interactive Eff	Effects of land	3 5	UK, Scotland, E	Helliwell, R.	[Helliwe	Scottish G	nitrogen de	Both N additic	10.1007/s10021-010
110							Article	Environm	2014	Relationship I	PAH focussed	(1) 5	UK, N England,	Moeckel, C.;	[Moeckel	NERC	surface-wat	Concentration	10.1021/es403707q
111							Article	Europear	2013	Soil-solution	Responses of	1 1a 1b ?	UK, England, N	Oulehle, F.;	[Oulehle	NERC; DEF	humic subs	Acidic deposit	10.1111/ejss.12089
112							Article	Water Re	2007	Freeze/thaw a	Effect of pH ar	1b (2)	UK	Spencer, R. C	Univ Cali	?	dissolved o	pH affects anc	10.1016/j.watres.20
113							Article	Global Bi	2010	Has the compa	Changes in DC	1 1a 1b (2)	UK, Scotland, E	Worrall, F.; E	[Worrall,	?	dissolved o	Long-term incr	10.1029/2008gb003
114		WoS	DOC			15338													
115				Lake		1779													
116					UK	26	Review	Environm	2005	Long-term incr	Possible caus	1 1a 2 2a 2b 3	UK	Evans, C. D.;	Ctr Ecol &	DEFRA; Eu	dissolved o	DOC concentra	10.1016/j.envpol.20
117							Article;	Water Air	2001	Monitoring ac	10-year trends	1 1a 2 2a 2b	UK	Monteith, D.	UCL, Envi	DETR; Env	acidificatio	Analysis of 10	10.1023/a:10139018
118							Article	Environm	2016	Constructed w	Contructed we	3 3b	UK, N Wales	Scholz, C.; Jo	[Scholz, C	Wolfson C	Nutrient rer	Monitors a ne	10.1007/s11356-016
119							Article	Science o	2016	Regional varia	Peatland pool	1 1a (1b) (3)	UK, N Sotland,	Turner, T. E.;	[Turner, T	NERC	Peatlands; I	Pool environm	10.1016/j.scitotenv.
120		WoS	DOC			15338													
121				Stream		1470													
122					UK	84	Article	Biogeoch	2005	Modelling the	Modelling the	1 1a 2 2a 2b	UK, Mid Wales	Evans, C. D.	Ctr Ecol &	DEFRA; Eu	acidificatio	Attempt to sin	10.1007/s10533-004
123							Article	Global Ch	2012	Acidity control	DOC is increas	1 1a (4a)	UK, England, P	Evans, C. D.;	[Evans, C	NERC; DEF	acidity; diss	In a 4 year, fou	10.1111/j.1365-2486
124		WoS	DOC			15338													
125				Loch		22	Article	Hydrologi	1994	DISSOLVED OR	DOC dynamics	1 1a 2 2a 3	UK, Scotland, L	Grieve, I. C.	GRIEVE, I	?	dissolved o	DOC was meas	10.1002/hyp.336008
126							Article	Biogeoch	2015	Effects of tem	Effects of tem	2 3 5	UK, N Scotland	Muller, F. L.	[Muller, F	Marine Re	Colloids; DC	15 month mon	10.1007/s10533-015
127																			
128	19/01/2017	WoS	DOC			15371													
129	18 core			Reservoir		417													
130	7 linked				UK	9	Article	Water Re	2004	A model for pr	Water colour a	4 (1 1a 1b)	UK, N England,	Goslan, E. H	Cranfield	Engineeri	natural orga	Water colour i	10.1016/j.watres.20

Figure A1: Interpreting published article spreadsheet entries. Annotations are provided for the less self explanatory columns. PhD and database spreadsheets structures are similar.

Appendix 2. Additional layout for word cloud diagrams used in Figures 12 and 13. The figures have the same figure number the main text to which they are relevant, but have been sub-coded with a.

Fig. 14b Word cloud with horizontal layout for ease of reading, generated with the dominant journals retained

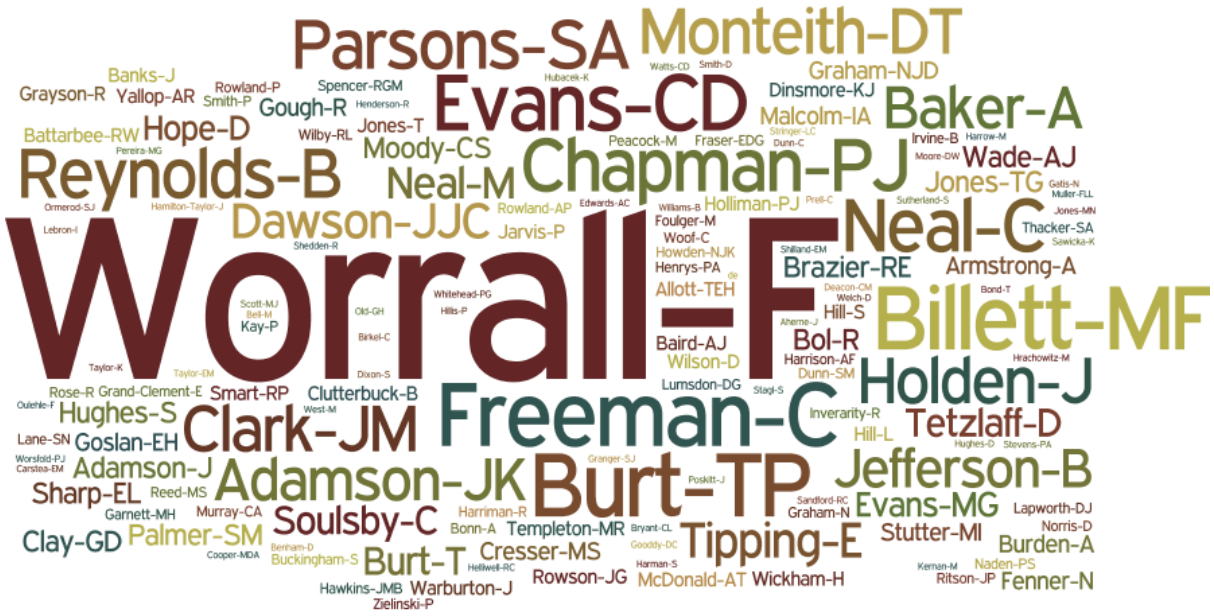


Figure 16a: Word cloud of all authors with horizontal layout for ease of reading.

Figure 17: Word cloud of first author institutions with horizontal layout for ease of reading.

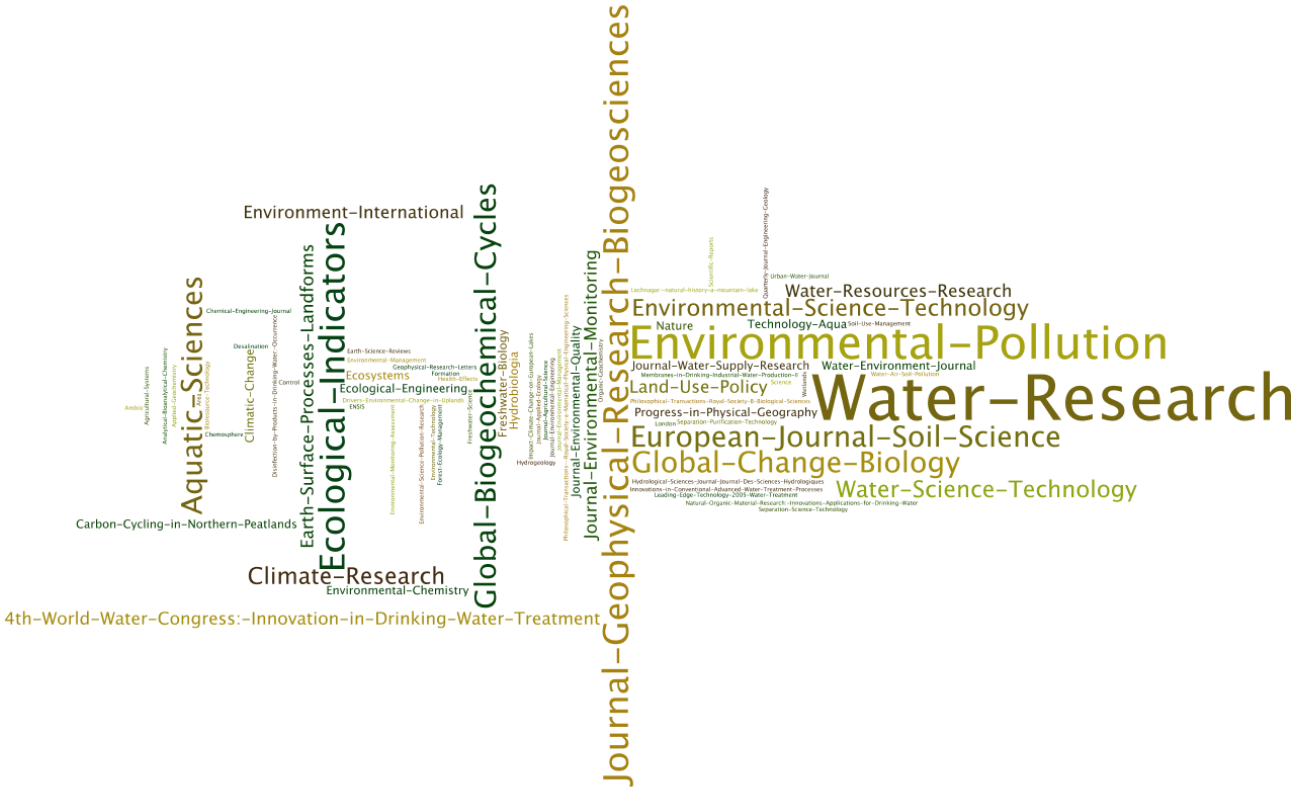


Figure 18: Word cloud with mixed layout for the journals in which core articles were published, and most popular journal titles removed.

Figure 24a: Word cloud of current and advertised PhD Institutions (Jan. – Feb., 2017)

Figure 24b: Word cloud of completed PhD institutions