Institution: University of Leeds

Unit of Assessment: C-17

Title of case study: Case 1 - Peatland catchment research on water colour yields economic benefits for the water industry.

1. Summary of the impact (indicative maximum 100 words)

The water industry sources significant drinking waters from peatland catchments and faces major water discolouration problems due to dissolved organic carbon (DOC) caused by peat degradation. DOC has to be removed to meet strictly regulated drinking water standards and to eliminate disinfection by-products. One proven, but expensive industry solution uses Magnetic Ion Exchange (MIEX) at treatment works. Research at the School of Geography (SoG) investigated catchment management as a potentially longer term, more sustainable treatment solution that addresses the problem at source. Yorkshire Water (YW) has subsequently adopted recommended practices, and has invested [text removed for publication] in catchment solutions yielding wider environmental benefits.

2. Underpinning research (indicative maximum 500 words)

Significant contributions to the work have been made by a number of SoG staff, including lead academics Prof Adrian **McDonald** (at Leeds 1972-present, Professor since 1992), Prof Joseph **Holden** (at Leeds since 2000, NERC fellow 2002-5, currently Professor), Dr Paul **Kay** (Research Fellow 2005-10, currently Associate Professor), Dr Pippa **Chapman** (Leeds academic 1999-present, currently Reader), Dr Sheila **Palmer** (SoG Lecturer, 2005-present), and postdoctoral researchers Dr Richard **Grayson** (2007-present), Dr Antony **Blundell** (2008-present), Dr Alona **Armstrong** (2006-7, now at Lancaster University) and Dr Zoe **Wallage** (2003-2007; 2011-2013).

The research focused on the development, evaluation and implementation of peatland management strategies to reduce or stabilise (in light of a 40-year upward trend in DOC) the significant deterioration of raw water quality. Research comprised a range of studies including large scale field experiments, plot studies and modelling. This has included funded projects including a NERC postdoctoral Fellowship held by **Holden** (Hydrological, fine sediment and water colour response of managed upland wetlands, 2002-05, £110,000); a NERC EMBER project involving **Brown**, **Holden** and **Palmer** (EMBER: Effects of Moorland Burning on the Ecohydrology of Rivers, 2009-12, £643,000) and two NERC CASE studentships (Aspray and Ramchunder, supervised by **Holden** and **Brown**), as well as novel research proposals that were developed in conjunction between SoG staff and YW and then funded as collaborative research. As a result of the work the SoG had undertaken, YW established a formal partnership with the SoG in 2005 to streamline research and development activity. This contract originally ran until 2010 but was subsequently renewed until 2015.

Work from **Holden's** NERC Fellowship **[i.e. 1-2]** showed that peatland drains were responsible for increased colour production and sediment release in peatlands and that blocking drains could significantly reduce DOC and sediment production. Subsequent large scale field trials showed that investment in this activity would provide net financial benefits in terms of reduced costs to water companies at larger scales and developed best practice for drain blocking techniques **[4]**. The team also used empirical data and process understanding formed from the research to develop a colour risk model **[3]** which provides spatial maps showing which areas of land have the potential to deliver the worst colour and where improvements could be best achieved via land management interventions.

The research demonstrated wider detrimental effects of peatland drainage on hydrological function and aquatic ecosystems (and the recovery of aquatic ecosystems that could be expected after drain blocking **[e.g. 5]**). The research also found negative impacts of moorland burning on DOC and on stream aquatic ecosystems and has shown that the negative impacts of prescribed burning on the peat system are very strongly evident in the peat archaeological record at key YW sites over

the past 100 years. The research also provided the first indication that peatland vegetation cover may influence colour production **[e.g. 4]**. Research continues to investigate drainage, burning and vegetation cover manipulation on major catchment-scale trials to refine best practice for peatland management for multiple benefits. Results indicate that peatland restoration measure will provide benefits that continue to accumulate over several decades as hydrological restoration permits the peat forming vegetation to recover.

3. References to the research (indicative maximum of five references)
The results of this research have been published in a range of internationally recognised peer-reviewed journals. The research was supported by grants including a NERC fellowship and a NERC grant. Outputs 1 and 2 were included in the School of Geography's return for RAE 2008 (95% of which was classified as at least 2* quality).

Selected research papers:

1. First demonstration that natural peatland pipes might be influenced by land drainage leading to subsurface erosion:
HOLDEN, J. (2006) Sediment and particulate carbon removal by pipe erosion increase over time in blanket peatlands as a consequence of land drainage. Journal of Geophysical Research, 111, F02010, doi:10.1029/2005JF000386

2. Demonstration that drain blocking as a management strategy could reduce water discolouration:
WALLAGE, Z.E., HOLDEN, J. and **MCDONALD, A.T.** (2006) Drain blocking is an effective treatment for reducing dissolved organic carbon loss and water colour in peatlands. The Science of the Total Environment 367, 811-821, doi: 10.1016/j.scitotenv.2006.02.010

3. Modelling to link land management to water quality and assist with planning and land management change strategies and priorities for water companies:
GRAYSON, R., KAY, P. & FOULGER, M. (2008). The use of GIS and multi-criteria evaluation (MCE) to identify agricultural land management practices which cause surface water pollution in drinking water supply catchments. Water Science and Technology, 58.9, 1797-1802, doi: 10.2166/wst.2008.569

4. Evidence that drain blocking benefits water quality in peat systems in a paper co-authored with Yorkshire Water staff.
ARMSTRONG, A., **HOLDEN, J., KAY, P.,** FRANCIS, B., FOULGER, M., GLEDHILL, S., **MCDONALD, A.** & WALKER, A. (2010). The impact of peatland drain-blocking on dissolved organic carbon loss and discolouration of water: results from a national survey. Journal of Hydrology, 381, 112-120, doi: 10.1016/j.jhydrol.2009.11.031

5. Demonstrates the impacts of upland peat restoration on stream ecosystems:
RAMCHUNDER, S.J., **BROWN, L.E.** & **HOLDEN, J.** (2012) Catchment-scale peatland restoration benefits stream ecosystem biodiversity. Journal of Applied Ecology. 49: 182-91, doi: 10.1111/j.1365-2664.2011.02075.x

<u>Selected grants:</u>
NERC Fellowship, Hydrological, fine sediment and water colour response of managed upland wetlands, 2002-05, £110,000 (**HOLDEN**)

NERC Grant, EMBER: Effects of Moorland Burning on the Ecohydrology of Rivers, 2009-12, £643,000, **BROWN** (PI), **HOLDEN, PALMER** (Co-Is)

4. Details of the impact (indicative maximum 750 words)
Research in SoG has had a major impact on YW's asset management strategy because, following the research-based recommendations made by SoG, the company is now pursuing catchment

management change as its primary long-term means to stabilise water colour and DOC rather than sole use of capitally intensive "end-of-pipe" treatment technologies. The latter are still used where risk to water quality is more immediate as part of a 'twin track' approach to achieve compliance in both the short term by engineering solutions, in parallel with the longer term catchment management solutions and is aligned with guidance on catchment management solutions. Such a strategy is aligned with guidance on catchment management solutions for water companies issued by the Drinking Water Inspectorate (DWI) in January 2013.

Other companies are now also following their lead including South West Water, United Utilities and Northumbrian Water. This approach is very different from the traditional means for dealing with DOC, which is based on capitally and operationally expensive and energy/chemical consuming and waste producing processes at water treatment works. Indeed, continued peat degradation often results in an operational response to exclude some catchments as water supply sources at certain times of the year because treatment costs are too high. Selection and timing of exclusions to deliver the required reductions in DOC were informed by modelling at the SoG during the 1990s. SoG's more recent research on catchment management solutions has therefore increased water security by enabling more catchments to act as water sources for longer periods of the year.

Catchment management intervention includes drain blocking, gully blocking, bare peat revegetation, vegetation change through heather removal and raised water tables (to encourage *Sphagnum* and sedges), and discussions with tenants and those who hold shooting rights to review prescribed moorland burning on both YW land and on non-company owned land which drains to YW supply systems.

SoG research provided the scientific basis for the implementation of land management measures to reduce water colour at the catchment scale. The quality of the research and the case put together for the merits of catchment management to control water colour is evidenced by the fact that the water industry regulators (OFWAT) approved all YW's proposed catchment management projects (which had been derived in close collaboration with SoG) for the 2010-15 regulatory period, representing [text removed for publication] of investment **[A]**. Since 2010 the investment in catchment management meant that expensive ([text removed for publication]) MIEX advanced treatment works in five catchments were not constructed and operated (also saving significant running costs of [text removed for publication]). SoG's research enabled YW to adopt a corporate strategy to produce excellent catchments, rivers and coasts. This strategy secures future water resources and simultaneously saves many tens of millions of pounds by avoiding or delaying expenditure (as part of the twin-track approach in line with DWI guidance) on MIEX advanced treatment works in some catchments **[A]**.

These savings benefit YW by enabling efficiency which is also passed on to the 1.8 million households and 13,000 businesses supplied by YW in keeping water bills as low as possible while securing the highest quality and safest drinking water possible. Moreover, YW also received an unprecedented [text removed for publication] to spend on further research and development over 2010-2015, more than any other water utility in the UK, as a result of the quality and impact of R&D being delivered by SoG along with that of three other research framework partners (Cranfield, Sheffield and Imperial) between 2005-2010 **[A]**. Our colour risk modelling [3] was also applied and used to inform catchment management proposals for the 2015-2020 expenditure period that have been submitted by YW to the regulator.

There are also environmental impacts of the implemented catchment management measures that are significant in their own right, and that also provide YW with important corporate social responsibility esteem benefits. The investment has resulted in significant landscape-scale change to upland environments in catchments delivering water to treatment works. The peatland management strategies being adopted help to promote enhanced biodiversity in the uplands, delivery of obligations under the EU Habitats Directive, and have supported the recovery of the trophic status of Sites of Special Scientific Interest (SSSI). Yorkshire Water own 11,500 ha of SSSI land and in 2003 had just 9% in target condition (favourable or recovering as determined by Natural England, the legal authority). By 2011 there was 99.9% in favourable or recovering

condition **[A]**. Furthermore, peatlands are the UK's most important terrestrial carbon store and degraded peats act as net sources of carbon to the atmosphere. However, by pursuing the catchment solutions recommended by SoG researchers, YW are not only reducing carbon losses from the landscape (both from the peat to air and water and from reduced energy consumption at water treatment plants) but they are also contributing to climate change mitigation by helping the peat to recover to a state in which it becomes a strong net sink for carbon from the atmosphere (our research suggests net gains of 10,000 tonnes of CO_2 equivalents per year through our landscape solutions compared to baseline). The whole systems catchment management approach has now become embedded in company policy which has been highly publicised by Kelda **[B]** (Kelda are the owners of Yorkshire Water).

The research has also provided wider economic benefits in the supply chain because peatland restoration companies, such as the SME Dinsdale Moorland Services (DMS) are able to grow their operations to provide land management solutions **[C]**. As such SoG led a NERC and TSB funded KTP (knowledge transfer partnership) with DMS to support supply chain innovation in best practice for catchment management solutions (which has delivered [text removed for publication] of economic benefit to the company to date) which are being applied on YW sites as well as other peatland restoration and management sites across the UK (e.g. Malham Tarn National Trust site). We have held workshops specifically for water companies to help them understand peatland management and water quality issues (e.g. May 2012, supported by the NERC Valuing Nature Network and a NERC KE Fellowship held in SoG) to drive impact across the water industry. As a result several water companies are now sharing some data and strategies around land management to promote best practice, including United Utilities, Northumbrian Water and South West Water where SoG leads a funded NERC internship in collaboration with Birmingham City University.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Yorkshire Water's submission to OFWAT for the Periodic Review 2009 demonstrates SoG's research has impacted the business: http://www.yorkshirewater.com/pr09 (for example document B1 points 76-130). [Available on request]

The following contacts can support the impact narrative provided here:

A. CEO, Yorkshire Water.
This letter corroborates all aspects of the case relating directly to Yorkshire Water, who have read the case study and corroborate the text. [Available on request]

B. Kelda Group (2011) Taking responsibility for the water environment for good. Available at: http://www.keldawater.co.uk/about-us/our-vision.aspx [Available on request].

C. Director, Dinsdale Moorland services, Company Number: 05316278.
This letter corroborates the impacts related to Dinsdale Moorland services, as a key example of the impact on peatland restoration services. [Available on request].