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Suspended sediment and particulate phosphorus in surface waters of the upper Thames Basin, UK

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Water Framework Directive

Summary Suspended sediment (SS) and particulate phosphorus (PP) concentrations in surface waters of the upper Thames Basin are reported for the main stem of the River Thames, several of its tributaries, the Cherwell, Dun, Lambourn, Pang and Thame, the Kennet and Avon Canal (that drains to the Dun and Kennet) and an artificial supply reservoir (Wilton Water). For the rivers which are mainly supplied from Chalk aquifer sources, SS and PP concentrations are poorly correlated with flow and there are issues of both biological and inorganic production of SS and PP during the spring and summer months. SS and PP are better correlated with flow when the antecedent conditions are taken into account. Thus, if flows had increased the previous day, then SS and PP concentrations are augmented. Wilton Water and the Kennet and Avon Canal have, on average, higher SS and PP concentrations than the nearby Chalk fed rivers and this probably reflects increased effects of biological activity and calcite ($CaCO_3$) precipitation under more stagnant conditions. For the rivers draining less permeable (clay dominated) catchments, then there is clearer linkage between flow and SS and PP concentrations. This feature reflects the more responsive influence of runoff from the land surface without the confounding issues of seasonally-varying groundwater discharges, intersection of groundwater levels with the ground surface and overland flow that may well characterise the permeable Chalk catchments. SS and PP are linearly correlated across the catchments. For the Chalk catchments and the associated Wilton Water and Kennet and Avon Canal, the PP:SS ratios are similar, ranging typically between 2 and 4 μg/mg. For the clay dominated catchments, the ratios are typically higher at 3–7 μg/mg. The results are considered in the light of process understanding, farming, climate change/climate-variability and the Water Framework Directive.

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Introduction

A critical concern for the ecological vitality of riverine systems in agricultural areas of the UK is the influence of suspended sediment (SS) and associated particulate phosphorus (PP). This concern is an urgent one given the remit and timeframe of the Water Framework Directive with the requirement of maintaining or improving the ecological health of European water bodies over the next decade (WFD: CEC, 2000; Dwyer et al., 2002; RPA, 2003; Defra, 2004). Within the UK, there is a strong background of studies of sediment transport to surface waters from agricultural land and within-river attenuation (Foster et al., 1995; Gurnell and Petts, 1995; Walling and Leeks, 2001; Walling et al., 2002; Walling and Leeks, 2001). In the case of phosphorus (P), the dissolved and particulate fluxes have been extensively studied (Haygarth and Jarvis, 1996; Haygarth et al., 1998; Heathwaite and Dils, 2000; Heathwaite et al., 2005; Johnes and Heathwaite, 1997; Withers et al., 2001; Wood et al., 2005). While much work has been undertaken on sediment fluxes from the land to the river, there is a clear move to examine within-river processing within the context of sediment and particulate phosphorus sources from the land and sewage effluent. There is especially need to examine the linkages between dissolved and particulate P and the influence of abiotic and biotic processes (House and Warwick, 1999; House, 2003; Jarvie et al., 2005). There are important issues of water–sediment interactions for P (Jarvie et al., 2002, 2005; Neal and Jarvie, 2005). This is because the dissolved P, particularly the inorganic form (commonly referred to as phosphate, orthophosphate and soluble reactive P) is highly bioavailable. It is important to the WFD in relation to the issue of eutrophication and inorganic P sources to the water column.

In this paper, riverine SS and PP concentrations are examined for one of the key UK lowland river basins, the Thames: a region where issues of agricultural versus urban pollution is of particular importance in terms of population pressures and population intrusion into areas of 'green belt' and the ramifications of the Water Framework Directive with regards to eutrophication (Neal and Jarvie, 2005; Neal et al., 2006a,b). The Centre for Ecology and Hydrology (Wallingford) has undertaken extensive hydrochemical surveys of the main stem of the Thames and several of its tributaries of varying permeability. This paper provides the first integrated findings on SS and PP concentrations and variations for the Pang and Lambourn. Background material for a range of rivers in the Upper Thames Basin that drain both the Chalk and less permeable catchments are also presented. The study allows a comparison of information on agricultural systems with underlying high permeability (Chalk) and low permeability (clay) strata and a base for integrating new research within the contexts of a new lowland permeable catchment research programme, LOCAR (http://www.nerc.ac.uk/funding/thematics/locar/) and the environmental management of agricultural systems in a strategically important river basin of southern England.

Study area

The rivers studied here comprise the main stem of the Thames, four of its tributaries (the Cherwell, Kennet, Pang and Thame) and inputs to two of these tributaries, the Dun and Lambourn which join the Kennet, and the Ray which joins the Cherwell (Fig. 1). The rivers subdivide primarily into those associated with drainage from:

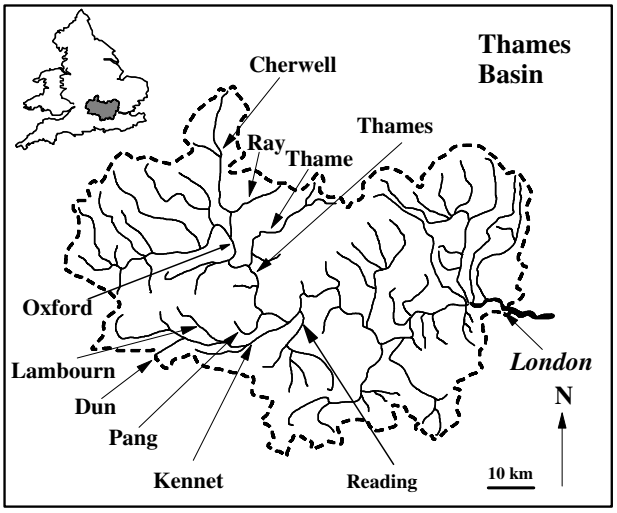

Figure 1 The study area. Detailed locations of the monitoring sites for each of the rivers studied are provided elsewhere: Dun, Cherwell, Kennet, Pang/Lambourn, Thame, Thames, Neal et al., 2005, 2006a, 2000a, 2004b, 2006b, 2000b, respectively.

1. Catchments with a predominance of high permeability (Cretaceous Chalk) aquifers (Baseflow index typically greater than 0.85; the Dun, Kennet, Pang and Lambourn).
2. Catchments with a predominance of low permeability sedimentary rocks, mainly of Jurassic age (Baseflow index less than 0.55; Cherwell, Ray and Thame).
3. A mix of high and low permeability strata (the main stem of the Thames–Baseflow index 0.64).

In addition to this, data are provided for Wilton Water, an artificial spring-fed lake used to supply water to the Kennet and Avon Canal, and the canal itself. The reservoir and canal waters provide important supplies and interchanges to the Dun and may well influence the Kennet as well. The salient features and key references are:

The permeable catchments: Pang and Kennet

The *Pang* drains to the Thames at Pangbourne (catchment area ~171 km^2). Six sites have been sampled at various times since 1997 together with a spring discharge, the Blue Pool, that provides significant flow during baseflow to the lower Pang (Neal et al., 2004a,b). The *Kennet*drains to the Thames at Reading (catchment area ~1200 km^2). The upper half of the Kennet has been sampled at 10 sites since 1997 (Neal et al., 2000a). Two tributaries to the Kennet have also been studied. Firstly, there is the *Dun* which drains to the Kennet near Hungerford (catchment area ~110 km^2). Here, one reservoir (Wilton Water), six Kennet and Avon Canal and six river sites (including two small streams-Froxfield and the Shalbourne) have been sampled since 2000 (Neal et al.,