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Storm-event suspended sediment and turbidity dynamics in the most urbanized

basin in the UK: the River Tame headwater catchment, West Midlands

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In urban environments, we are beginning to realize that significant mobilization or introduction of contaminants in river channels during storm events presents severe ecological and public health risks. Turbidity is one such important water quality variable, through its relation to light suppression, BOD impact, sediment-associated contaminant transport, and direct suspended sediment effects on organisms and habitats. However, few published field investigations of wet-weather turbidity dynamics, through several individual and sequenced rainstorms in extremely urbanized headwater basins, have emerged. This paper aims to address this gap, therefore, through a turbidity analysis of multiple storm events in 2001 in an urban headwater basin (57 - 400 km^2) of the River Tame, Birmingham, central England, the most urbanized basin for its size in the UK. Data at 15-minute resolution were collected intensively at automated monitoring stations for rainfall, streamflow and six water quality variables (turbidity, EC, temperature, DO, pH, ammonia). Disturbance experiments also allowed estimates of bed sediment storage to be obtained. These datasets allowed urban water quality models to be evaluated.

Six important and unusual features of the urban storm event turbidity response were identified: (1) Sluggish early turbidity responses, followed by a turbidity 'rush'; (2) Quasi-coincident flow and turbidity peaks; (3) Anti-clockwise hysteresis in the

discharge-turbidity relationship on all but one event, resulting from Falling-LImb Turbidity Extensions (FLITEs); (4) Increases in peak turbidity levels through storm sequences; (5) Initial micro-pulses (IMP) in turbidity; and (6) Secondary turbidity peaks (STP) or ‘turbidity shoulders’ (TS). Many of these features are newly-identified and provide little support for models of ‘first-flush’ effect, thought to be almost universal. Instead, substantial suspended solids transport continued right through the flow recessions, and little storm-event sediment exhaustion was evident. A simple, dimensionless hysteresis index, HI_{mid}, is developed and used to quantify the magnitude and direction of hysteresis in a clear, direct and intuitive manner. This index allowed the degree of departure from the classic ‘first-flush’, clockwise hysteresis models to be quantified, and is widely applicable to other determinands and contexts.

Of the initial 15 turbidity storm events considered, 10 coincided with ammonia spikes of up to 6.25 mg l^{-1}at Water Orton (the downstream station): this suggests that spills from Combined Sewer Overflows (CSO) or waste water treatment works (WwTWs) are significant in the throughput of turbid waters here. Substantial ammonia peaks related most strongly to total storm rainfall receipt, of the four rainfall variables considered, and significant ammonia peaks were generated even from low-magnitude ($<$4mm) storms, indicating that spills are a frequent occurrence. Sampling suggests that local bed sediment stores appear to be limited, suggesting that other distal sediment sources, such as road networks and old mine workings are probably more important. Strong hydraulic connections between road surfaces and river channels are demonstrated through abnormal EC excursions following dressing of road networks with anti-freeze agents in winter. Biofilms may possibly play a part in delaying sediment release till late in the hydrograph, and in suppressing late spring turbidity levels. These effects are expressed in the conceptual BASS model (Biofilm Adhesion of Sediment Supplies). Existing first-flush models appear to be an oversimplification. Such urban headwater basin responses can provide useful insights into the generation of contaminant waves, and offer the potential of vital early-warning systems for pollution events propagating downstream in the interests of risk reduction.