Fine sediment, pollutants and microplastic impacts on the River Itchen SAC from the proposed Development Application B and C.

The impact of urbanisation is known to be almost wholly negative on water quality and receiving watercourses. Recognition of this prompted in the UK and elsewhere, the development of a series of research programmes to investigate measures to improve the environment of urban centres. Some of these have resulted in directly relevant outputs to this planning application, notably the poorer performance than expected of sediment mitigation structures in SUDs.

Excessive sedimentation in urban rivers lead to a number of adverse ecological and environmental consequences as the loading of suspended sediment from an urban environment is significantly higher than that in rural catchments (Sangaralingam et al., 2019; Arias et al., 2013; Poleto et al., 2009). This is because increased impermeable surfaces in the urban environment protect and trap sources of coarse material and disproportionally increase fine materials in stormwater runoff (Brodie and Dunn, 2009; Savage, 2005). Fine sediments harbour nutrients, pollutants, microplastics and coliform bacteria which are generated from the urban environment and transported by storm runoff (Sangaralingam et al., 2019; Jartun et al.,2008). This stresses the biological, chemical and physical integrity of the receiving water through eutrophication, toxification, limited permeability and reduced oxygen delivery. Further siltation reduces the flow capacity of the river channel and functional capacity of the stormwater systems (Butler and Karunaratne, 1995) that can increase downstream flood risk. Moreover, contaminants associated with suspended sediment particles and dissolved solutes in stormwater runoff are more difficult to manage than those associated with coarse (sand) particles (Sangaralingam et al., 2019; Birch et al., 2006). Allen et al (2018) and Sangaralingham et al (2019) state that despite the recognised multiple benefits, there are still concerns over the long-term performance of SUDs in urban catchments as the performance of the features varies considerably with rainfall, flow and site conditions, the latter changing with the construction and urbanisation process. Moreover, managing sediments on construction sites is challenging; silt control measures are not 100% effective, and silt fences are frequently damaged, overloaded and fail (**see Appendix 1.0 for a recent example from an ongoing construction in the Option C Pembers Hill area**).

The basis of my concerns as a professional of 28 years practice in research and application of sediment management and fine sediment impacts on chalk and other river ecosystems at local, national and international level, is the extent to which the risk of fine sediment release from construction and subsequent urban runoff with mitigation is in sufficient doubt relative to the sensitivity of the receiving SAC ecosystem, to warrant consideration of alternative options. Fundamentally, I first make the case based on robust scientific evidence, that the sensitivity of the receiving reaches are higher than most river types. Secondly, I demonstrate that the mitigation options will fail to trap highly damaging fine sediments and associated pollutants. I therefore conclude that there is sufficient doubt to justify rejection of this plan, and instead trigger consideration of alternative options including alternative areas and or modification of proposed plans to avoid the river catchment areas that drain into the river Itchen SAC.

Sensitivity of Chalk streams to fine sediments.

Chalk stream foodwebs are complex and highly connected (Jones et al., 2012, 2014). The important point is that they are impacted at all levels by fine sediments in three main ways; productivity of organisms (embryo life stage), sub-lethal and lethal impacts to juveniles, and direct impacts on adult life stages (Jones et al 2012; 2014; Kemp et al 2011; Collins et al., 2011). Reviews of recent evidence point to the importance of sediment quantity, grainsize, and quality, specifically organic matter. It is worth considering the conclusions of a recent review of sediment targets for river ecosystems (Collins et al 2011). In this the authors concluded that Aquatic biota can be adversely affected by **extremely low [sediment] concentrations.**

Because of their physical nature; chalk streams are highly sensitive to small increases in fine sediment loads – thus in comparison with other river types, the risks are much higher (Sear et al 2008; see Figure 1). Fine sediments impact ALL levels of the food chain, and all lifestages in the aquatic environment. Current research demonstrates that sediment quality and specifically sources derived from road and urban areas are far more damaging regardless of quantity than agricultural or river bank sources (Sear et al., 2017; Collins et al 2014). In the Itchen Sac, the receiving water from the proposed development drain directly into a key Atlantic salmon spawning reach. Monitoring of the site (Bateman et al 2012) shows lower fine sediment levels in spawning gravels over two seasons relative to other locations. Other data indicate that survival in the Itchen is highly dependent on fine sediment loads and that these are directly related to the concentration of dissolved oxygen in the salmon redd (nest). Figure 1, laboratory studies (Grieg et al 2005; Sear et al., 2017) and field studies (Acornley & Sear 1999; Sear et al 2008 etc) point to a higher sensitivity of chalk streams to small changes in sediment load – in effect a higher proportion of fine sediment passing over a gravel bed in a chalk stream will accumulate in the gravels compared to runoff dominated rivers. Figure 1 indicates that increases in fine sediment of <20% will result in reductions in salmon embryos survival of 40-50%. Given the critically low populations of Atlantic salmon in the river Itchen, and the increasing pressures on the species predicted over the next 30+ years as a result of warming ocean temperatures in the N Atlantic, such impacts on recruitment in the river bed will be damaging to the SAC. A similar deleterious impact is to be expected for other species on the basis of the evidence presented in a range of recent reviews. Whilst there is relatively little than can be done about ocean temperatures, it places increased emphasis on the need to protect and enhance those critical habitats supporting SAC species. It is in this context that the following sections explore the ability to protect the SAC from the proposed urban development.

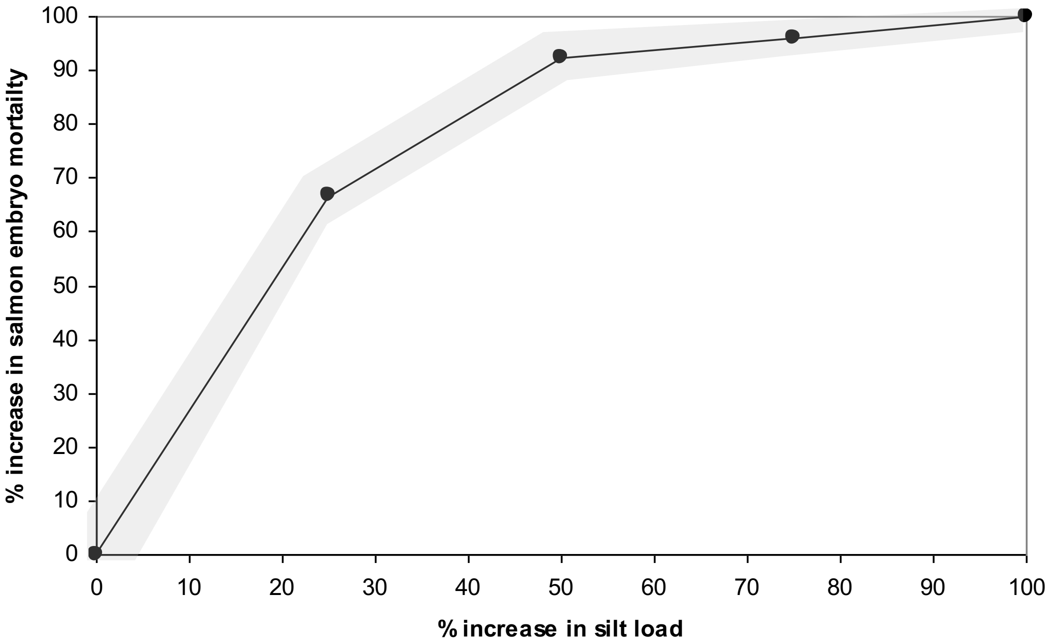

Figure 1: Modelled sensitivity of Atlantic salmon embryo survival to increases in silt load. Atlantic salmon show a high sensitivity to small increases in fine sediment. This is shown in numerical models, laboratory and field experiments. Modelled data here used the SIDO-UK model (Sear et al., 2014; Sear 2010) calibrated using field data from UK rivers. It is anticipated that this sensitivity would be even higher for chalk streams such as the river Itchen due to their inability to flush fines from their river beds. The effectiveness of mitigation options proposed for the clay/silt rich geology of the Option B/C sites is unlikely to amount to more than 50% based on measured performance of SUDs, resulting in net outputs of urban sediments into the receiving waters with clear potential for impacts on one SAC species (Atlantic salmon).

Headwater streams such as those impacted by the proposed development are **net sources of sediments, nutrients an organic matter** (e.g. Riley et al., 2018 review). The accompanying June 2019 report by Urban Edge (HRA 2019) shows a complete misunderstanding of how headwater streams function – stating in section 6.6.31 that headwater streams '*will store sediment*'. Winter rainfall in the Itchen catchment is when 80%+ of fine sediment is transported, which is also when the local headwater streams are flowing. The headwater streams in Options B and C rather than stores of fines are in fact sources, and provide connections from the landscape into the receiving waters of the SAC. Moreover, there is no explicit recognition of the importance of fine sediments or their mitigation in the HRA proposal. Instead, high level, generic statements and a focus on nutrients dominate the report. Fine sediments are a key issue for the SAC, but this report fails to address it both in terms of processes (it does not mention and fails to understand fine sediment accumulation in the watercourse and completely fails to use existing evidence widely available, on sediment impacts to the Itchen and chalk streams more generally), impacts and mitigation. The report is so high level as to be doubtful whether the statements are of any value other than cut and paste form policy level documentation. This current document is an effort to raise the awareness and evidence base for why this development will, without reasonable doubt, negatively impact on the SAC **regardless of mitigation**.

Efficacy of sediment management treatments

Sediment management in the UK is relatively new and is still in its infancy (HR Wallingford 2011; Collins et al., 2012). Indeed much sediment management is undertaken on the basis of assumed effectiveness in the absence of monitoring evidence (Darby & Sear 2008). Current best practice policy for urban areas and agricultural land relies on a range of mechanisms designed to trap sediments and pollutants in runoff. These policy measures are based on comparatively little data (The Industry standard CIRIA manual 2015;2017 does not refer to trap efficiency of sediment per se in its design specification referring instead to pollutants generically and focussing on sediment in terms of disposal and maintenance) and the basis of engineering designs for SUDs and sediments have specific design assumptions; notably the measures of sediment (and for that matter water and pollutants) trap efficiency are specifically for a single design rainfall-runoff event with an event mean concentration (Allen et al 2018) and for conditions assuming full trap functionality. The UK SuDS Manual suggests the following potential effectiveness for a range of mitigation options for a single event, mean suspended solids concentration Total Suspended Solid (TSS) improvement (Woods Ballard et al. 2015):

Swale: 50–60%
Linear wetland: 75–85%
Wetland: 80–82%
Pond: 75–80%

Two important points need making; **first the assumption of mean SS is an incorrect simplification**; for impermeable subcatchments such as the ones in this plan, over 80% of the sediment runoff occurs in the lower frequency high magnitude events when the SUDs manual itself recognises many of the features fail to trap anything like this quantity of sediment. Secondly, **there is no accounting for the different trap efficiencies of variable grainsizes or sediment type** (organic vs inorganic). Fine silts and clays, and particulate organic matter, the most damaging components to the SAC features and the dominant load produced by the soil types in the proposed application, are not retained by anything like these proportions. Indeed, trap efficiency of silts and clays are typically less than 50% and frequently less than 10% for mitigation measures of the type proposed (Verstraeten & Poesen, 2000). Sediment management manuals in Canada and the US where practice and design of sediment management are more advanced than in the UK (Allen et al (2018), conclude that *"Finer size particles (i.e., clay and fine silt) will require a long time to settle and therefore may not be deposited in the sediment containment facility during the time of retention. As such, targeting clay, fine silt particles and organic silts for sedimentation is not practical",*(Design Manual for sediment control Alberta Transportation Manual 2011). Let us be clear from the outset therefore, that when this application talks about mitigation of sediment it refers to coarse silts and sands only. **The more damaging finer silts and clays to which pollutants and nutrients are chemically bound, and particulate organic matter will NOT be effectively treated by the proposed mitigation options** simply because the mitigation measures are unable to generate the settling conditions necessary to deposit these finer sized particles.

In recent years, and in response to concerns about the sediment trap efficiency of best practice measures, research programmes have been undertaken by UK Research Councils, to update and test the performance of SUDs over a) multiple rainstorms and b) longer timescales – those that account for reduced efficiency as features mature. In all instances, these new research (e.g. Allen et al., 2017; 2018; Sangaralingam et al., 2019) demonstrate;

1) Much lower efficiency in sediment trapping and pollutant reduction than the single event assumptions made in best practice (34% ± 17%).
2) Highly variable effectiveness between different rainstorms including increases in sediment released from features (values range from -11% to 69%).
3) Progressive reduction (24%) in performance over time as the systems become less effective.

These results caused Sangaralingam et al., (2019) to conclude that "*it is difficult to set water quality standards for stormwater ponds due to randomness in the rainfall events*"; the same point made by other sediment management manuals. Recent analysis of multiple SUDs measures (Allen et al 2017) show that 17% of fine sands and coarse silt escape a multiple SUDs system under multiple rainfall events, and that this is likely to increase as the performance of the SUDs degrades as they must, over time. They conclude that "*The assumption that urban sediment pollution is captured and permanently retained by a SuDS asset during the initial event is therefore inaccurate*" (Allen et al., 2017; 2018).

Use of buffer strips can be highly effective in reducing coarser sediments (sands and coarse silts) and nutrient runoff into rivers; but they do not work when the sediment is already in the stream running through the buffers such as is the case in the current proposals. Moreover, the efficiency of buffers reduces with grainsize, with limited protection for silt and clay sediments (Figure 2; Meyer et al 1995; Lee et al., (2000); Yuan et al 2007). In a review of field experiments of sediment trapping, Yuan et al (2007) found on average a 71% ± 21% (1 standard deviation), but this dropped significantly with increasing overland flow rate and slope. Slopes greater than 5% saw reductions in the effectiveness of riparian buffers. Similar to SUDs ponds and swales, trap efficiency of buffers reduces over time, such that to maintain best practice levels of effectiveness they **have to be maintained and managed to attain the higher rates of trapping and nutrient processing quoted in the literature (Yuan et al., 2015)**. Furthermore, nutrient retention by buffers is highly dependant on groundwater conditions – working best (the assumption made in best practice) where groundwater tables fluctuate seasonally and where organic carbon levels in the soils are high. Neither is the case in the proposed catchment geology/soil types in the application, thus there is considerable doubt over their nutrient and sediment retention efficiency. As the Defra review on riparian buffers (Defra 2007) states, most research on buffers has been conducted in laboratory or manipulated field experimental conditions and few quantitative data exist on buffer performance under natural field conditions. This review also makes the point that fine sediments are not as effectively removed by buffers citing a single study in which over 70% of clay loads were not trapped in buffers.

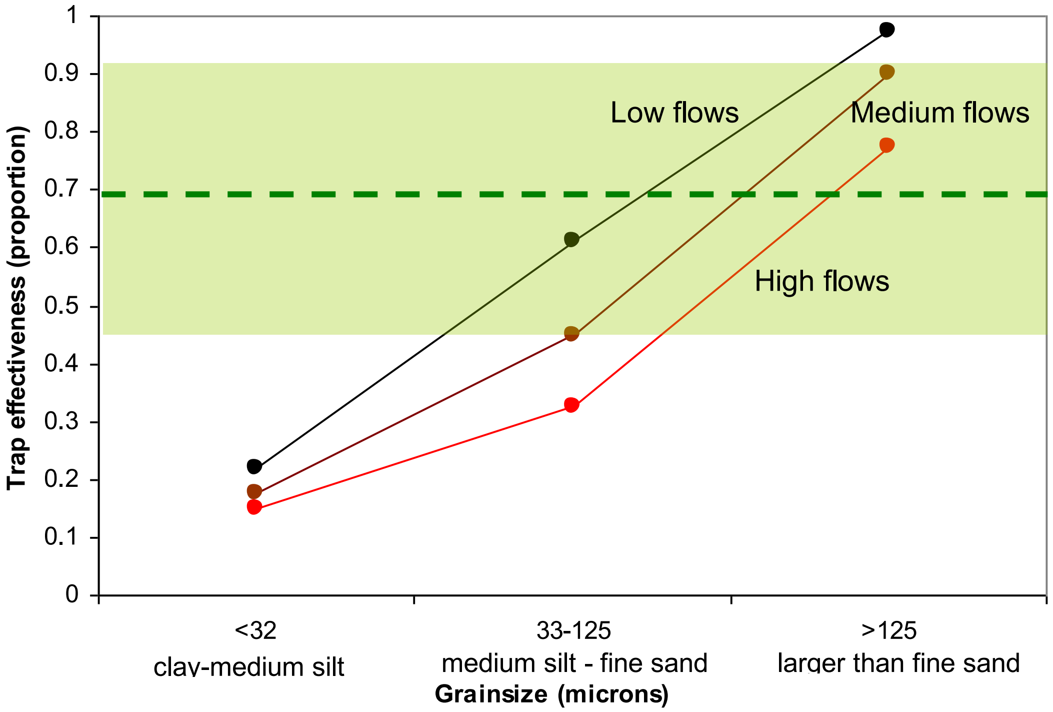

Figure 2: Variation in trap efficiency of riparian buffer features with grainsize and overland runoff rates (Yuan et al., 2007). Green dashed line is mean value of trap efficiency for field data from 99 studies; green zone is one standard deviation of this data (Yuan et al 2007). Note how for fine grainsizes (clays and silts), the trap efficiency is of buffers is less than 25% regardless of flow rates. Given overland flow on impermeable soils with high clay content such as Option B and C, will tend towards higher rates under current and much higher under climate change, there is a high level of certainty that the buffers proposed will not protect the SAC features form silts and clays.

River restoration or channel works on rivers can have multiple benefits if undertaken in concert with a full understanding of the natural systems being modified (Beechie et al., 2010). Stating that creating wetlands or restoration of river channels is a mitigation for fine sediment is however, too simple an assumption. In two of the only monitored examples in the UK, Sear et al., (1998) and Millington (2011) show how during and after construction of river restoration works, fine sediment loads rose by 152% and 140% of the inputs to the restored reach, generating suspended sediment concentrations that were 300 times higher than natural background loads despite mitigation measures (heather bales and sedimentation traps). Any construction works involving disturbance to a river channel will deliver pulses of fine sediments during rainfall events due to disturbance of the land surface and river channel bed and banks. In both examples cited above, fine sediment loads did not return to background after two years – thus the effects are prolonged. Note the geology of both sites are the same or similar to the proposed development site in Option B/C.

The current situation arises whereby best practice is proposed for mitigation and supported by statutory bodies on the basis of national rather than local policy (the case with EA and NE), but emerging evidence commissioned by Defra/EA who recognise the need for better evidence on SUDs performance, strongly points to a need to change the assumptions of best practice. The new evidence thus far, clearly points to lower effectiveness of proposed Best practice measures and moreover a highly variable performance over time and between different storms. For all proposed mitigation measures, the risk of the finer most damaging sediments (silts and clays) remains high, since these are highly mobile, reactive and chemically associated with pollutants and macronutrients. ALL the evidence points to much lower trap efficiencies than best practice bulk sediment experiments have shown. **The result is substantive and substantial doubt in the assumptions underpinning the mitigation plans based on best practice. This doubt raises the probability of failure to mitigate,**

and hence the risk of damage to the SAC features of interest above what a range of independent international experts recognise as unacceptable. In this instance Habitat Regulations (WFD, Habitats Directive) require consideration of alternative options which in this instance exist in the form of i) reducing the no. houses proposed back from 5500 to UK Government target levels 3300, therefore removing the need for the Option B site which most impacts the Itchen SAC, or (ii) reconsidering in equivalent detail, the alternative sites (Options D/E) whose impact on the Itchen SAC features would have lower risk owing to absence of spawning habitats and higher fine sediment tolerance in the lower river reaches of the SAC/SSSI.

Monitoring of proposed mitigation works

River restoration and sediment management projects are seldom monitored and when undertaken are frequently insufficient to address the (often unstated) targets – assumed in most cases to be reduced sediment output and no net degradation in habitat (Skinner et al., 2008). My own personal experience of river and sediment management including natural flod management schemes, comes to the same conclusion. Monitoring is not done effectively if it is done at all. I am therefore highly doubtful that it will be implemented effectively on this proposal. Evidence to the contrary would need to be compelling (specific, adequate resourcing, careful monitoring design against specific targets). Rather, monitoring tends to be seen as unnecessary or is undertaken without specific targets and using methodologies that are insufficiently robust to provide the evidence necessary to quantify to an acceptable level of confidence for the effectiveness of a given treatment. Project spend on monitoring is recommended as 10-20% of a total budget but in reality it is much lower. In reviews of monitoring (Skinner et al (2008); Roni et al (2010)), there are important considerations that are common; first to set clear and justified targets (e.g. mitigation measures will reduce sediment load to the SAC reach by 80%, or; there will be no reduction in Atlantic salmon embryo survival in Atlantic spawning redds in the receiving reach over a 20+ year period compared to control reaches with no impacts). Secondly, the need for robust before, after and control sampling so that natural variability can be quantified and against which the effectiveness of the treatments can be measured; and thirdly, sufficient replication to test the targets to robust levels of statistical confidence (e.g 95% confidence levels). Rutherford (2008) presents a helpful table in which levels of monitoring are afforded 'medals' according to their robustness and ability to deliver useful useable information. In most cases 'Plastic' medals are awarded – the information is flawed and unusable. In the case of this application, a globally significant (because the UK hosts all major global chalk streams) riverine ecosystem is under threat of degradation due to a development proposal. In this instance we are looking at Gold medal standards of monitoring, involving significant investment and careful design. For example, to correctly quantify the target performance of sediment mitigation measures there would need to be continuous sampling of sediment load, grainsize, organic matter and pollutants including microplastics because it is the high magnitude, relatively infrequent rainstorms that generate the sediment pulses (>90% of the sediment load can be transported in <10% of time (Walling and Webb, 1987). Daily, monthly or weekly sampling would be insufficient as these events typically occur over 2 hours, and at night when air temperature drop and rainstorms occur. Furthermore, sampling would need to be undertaken at multiple sites, upstream of treatments, downstream of treatments and upstream of the inflow to the SAC and downstream of the inflow to the SAC river in order to account for potential upstream changes. Samples would need to be processed in laboratories. This sampling and monitoring regime would need to be continued into the future as the scheme develops and evolves (10% urban uplift due to extensions, paving of drives etc; 40% uplift in runoff due to climate change), and as the mitigation treatments change over time; resulting in deployments into the 2040's. This is only the sediment and pollutant aspect, and only the data collection. The data would need regular interpretation and reporting, with triggers set at which point activity on site would need to be halted, and additional mitigation implemented including (and I do not know how this would be achieved) mitigating any impacts arising from deleterious releases of sediment and pollutants into the SAC. Monitoring of the ecology would be important across all levels of the food chain and at intervals and with controls and replicates that would enable Statutory bodies to determine level of impacts and potential requirements for remedial/mitigation activities (currently unspecified as to how these would be achieved).

A major body of research indicates that current sediment targets are incapable of affording the levels of protection required for SAC species – thus we have no relevant targets with which to set mitigation goals against which to monitor (Collins et al., 2011). Thus for future monitoring site specific ecological relevant targets will need to be locally defined before any monitoring can be undertaken. As it stands, assumption of no net increase in sediments and pollutants from the development are flawed because the SAC is currently in a degraded condition as a result of flow and sediment impacts. The assumption therefore must be for lower than current levels for fine sediment load, grainsize, organic matter, macronutrients, metals and microplastics in the SAC receiving waters downstream of the input from the urbanised catchment.

Conclusion
Recourse to best practice as a national policy at local planning scale fails to properly consider the risks associated with runoff from building works where site specificity is important as it is in this case. This is recognised by statutory bodies. It is widely recognised that SUDs and other mitigation measures to reduce sediment runoff from building works and new developments, have efficiencies that are highly variable and far lower for finer damaging sediments than those cited in existing manuals used to justify planning applications across the UK. At the same time, extensive evidence points to the uniquely sensitive nature of chalk stream ecology to small increases in fine sediment loads. Together, these present unacceptable levels of doubt in the ability of the planning, design and implementation of this development to adequately protect the SAC, SSSI features of interest in the river Itchen. On this basis my recommendation would be that alternative sites are considered that will enable EBC to deliver on its government targets for housing, and that these should avoid direct connectivity into the sediment sensitive SAC chalk stream reaches. Some of these alternative sites have already been identified.

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Appendix 1.0: Evidence for recent sediment pollution incident arising from construction works and moderate rainfall.

14th - 15th October 2019

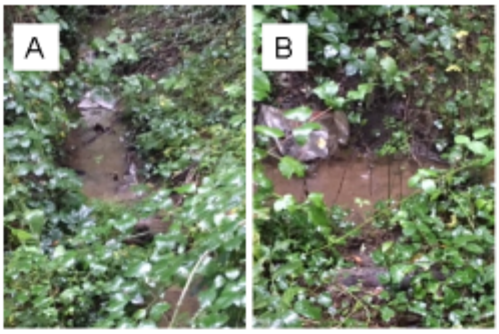
As part of a long term watching brief on the small stream draining Pembers Hill, I witnessed unusual and elevated sediment loads in the stream relative to background (Photo A,B). The concentrations continued to rise during rainfall, such that by 12:00. the suspended solids load and colour were clearly pointing to local increases in sediment supply given that the discharge of the stream was still relatively low (Photo C,D). The bed of the stream following the event (16th Oct) was saturated with fine sediments stored in the gravels and debris (Photo E,F).

Subsequently, on the morning of the 15th October, I was able to gain access to the watercourse immediately downstream of the construction site. This clearly revealed a) damage to the silt fencing caused by works adjacent to the channel including construction of a pipeline; breaching of the silt fencing by sediment runoff from disturbed land (Fig 2 Photos), c) elevated sediment loads that matched the colour of the suspended sediments seen the day before (Fig 2 Photos) and, d) evidence of no such sediment in the stream bed/wetland feature upstream of the sediment injection point (Fig 2 Photos). It was clear that this was the source of the sediment event seen in the river and that it derived from the construction site works.

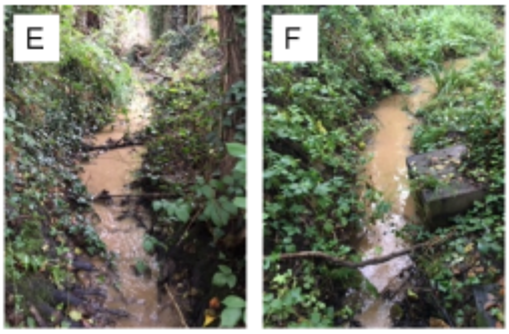
Given this site is part of the Option C development area, has been the subject of concerns regarding flood risk and sediment pollution, and yet was passed by EBC on the basis of mitigation, it casts reasonable doubt on the ability of developers to meet the conditions placed on their works. Moreover **it makes clear the point that best practice in operation is different to that assumed and used in planning applications, and highlights my point that risk is sufficiently high to cast doubt on the ability of mitigation measures to deliver on their stated efficacy.** No monitoring was evident that would have picked up this event, and yet the sediment loads would be sufficient to damage the ecology of the receiving waters. It should be noted that this is a minor building site in terms of area relatively to those proposed in the Option B and C plans.

Of additional concern were remarks by a local resident through whose garden abuts the site, that a pipe had been laid that intercepted flows and ran down to the river channel. The point of entry of the line of the pipe into the channel was covered by cut tree debris (Photo X), making it impossible to see the point where the alleged pipe entered the stream. This would seem to suggest a direct attempt to direct drainage off site into the stream against best practice.

Figure 1: Pembers stream immediately upstream of Mortimers lane culvert showing building site sediment runoff during a modest rainstorm.



14/10/19 am Susc Sediment conc.
Start of event



15/10/19 pm Bed sediment deposition after event

15/10/19 am Suspended sediment Conc. During event

Fine Sediment in Pembers Hill headwater stream during modest rainfall event.

Figure 2: Site Conditions leading to delivery of fine sediments into headwater stream and its transport into receiving watercourses.