Kingston Brook – Meadow Park, East Leake: Ecological and Physico-chemical Investigation - 2012

1. Introduction

This report details an ecological and habitat survey conducted on the Kingston Brook, Meadow Park, East Leake on 21 September 2012. The following features of the Kingston Brook were investigated at 4 sites as shown in Figure 1:

- aquatic macro-invertebrate community structure
- aquatic macrophyte and marginal plant assemblage
- physical habitat structure and water chemistry.

The surveys were initiated in response to the completion of river maintenance activities conducted by the local Internal Drainage Board (IBD) along the length of the Kingston Brook in March 2012, six months prior to the 2012 survey. Within Meadow Park these works included clearance of riparian trees, stream bed dredging, desilting and bank slope re-profiling works, that in the opinion of the author were undertaken with little regard to the ecology of the stream or the wider benefit of Meadow Park. Furthermore, the majority of the works observed along the stream appear to be in conflict with the Association of Drainage Boards own guidance on channel maintenance (Buisson *et al*. 2008). Photographic images taken soon after the works are presented in Appendix A.

The 2012 survey builds on an earlier investigation of the Kingston Brook undertaken by the author in 2002 (Morrissey, 2002) which in combination provides the opportunity to review and undertake the following:

1. Macro-invertebrate community change over a 10 year period.

2. Calculate new macro-invertebrate community metrics in the investigation of flow and physical habitat quality and infer reasons for current ecological condition.

3. Assess likely response of stream physical and chemical condition and ecology to the IDB works.

4. Provide a baseline for physical habitat condition against which future system adjustments can be measured.

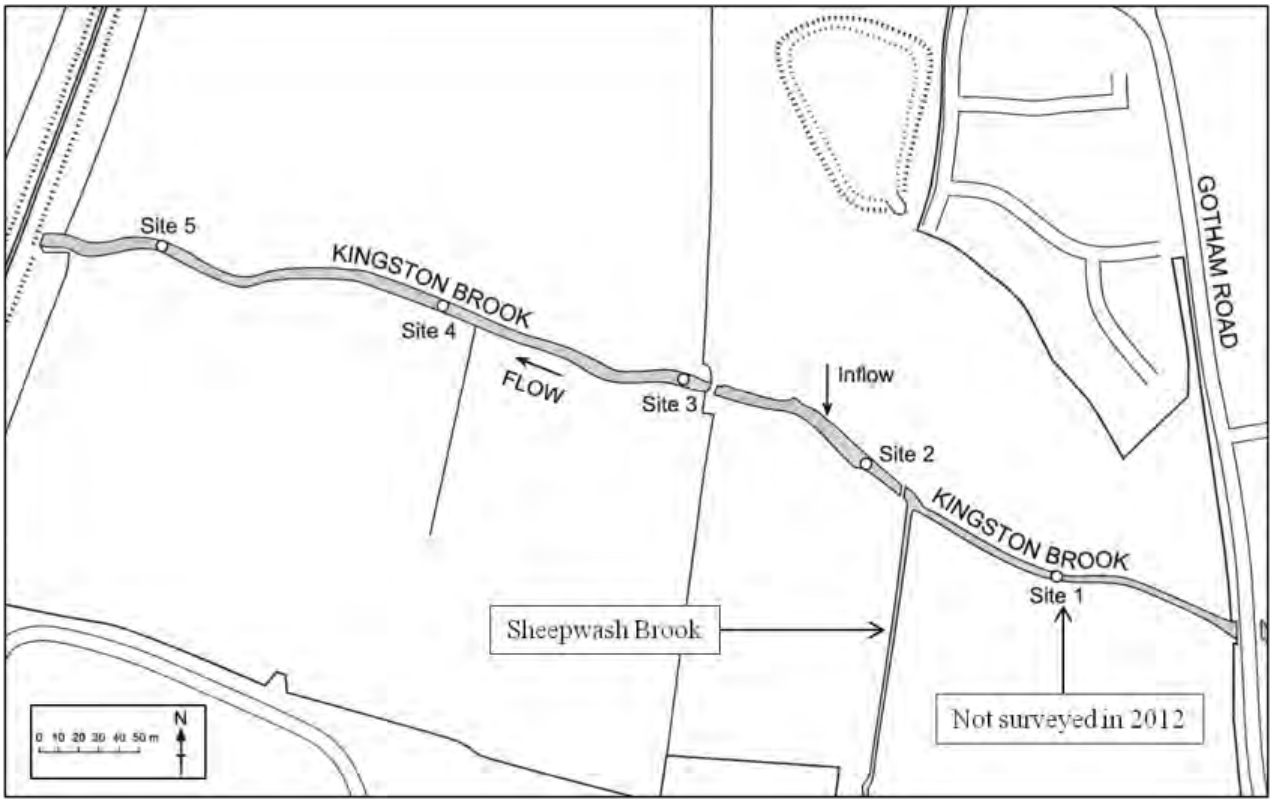

Figure 1. Location of survey sites on Kingston Brook, Meadow Park

2. Aquatic macro-invertebrate survey

2.1. Survey methods

Aquatic macro-invertebrates were collected to standard Environment Agency sampling protocols using a hand-held pond net (500µm mesh) at sites 2, 3, 4 and 5 (Figure 1). Depending on habitat type a 3-minute kick or sweep sample was collected and augmented with a 1 minute hand search. All taxa were identified on the bank side to the lowest possible taxonomic resolution and assigned to one of the following abundance classes:

- A = 1 - 9 individuals
- B = 10 - 99
- C = 100 - 999
- D = 1000 - 9999
- E = 10 000+.

This contrasts with the 2002 survey in which most taxa where recorded to species level under laboratory conditions.

2.2. 2012 survey data

Surveys conducted at sites 2 to 5 in 2012 indicate the presence of an impoverished aquatic macro-invertebrate community within the Kingston Brook, with only 23 taxa being recorded across the 4 sampling sites (Table 1). Over 50% of the taxa recorded occurred in at least three of the sampling sites indicating a high level of commonalty between the sites. No one site exhibited a notably distinct community in terms of the range of macro-invertebrate groups recorded; although Site 5 stands out due to the higher number of taxa supported compared to the other sites sampled (Total number of taxa = 18). All taxa recorded are commonly occurring

macro-invertebrates of lowland stream systems with the majority being associated slow flow/static water conditions.

Table 1. Macro-invertebrate survey results 2012 and comparison with 2002 data

Kingston Brook, Meadow Park aquatic macro-invertebrate survey results

Site	Kingston Brook - East Leake
Survey date	21/09/2012
Surveyor	Ian Morrissey

Group	Family	Genera/species	Site 1*	Site 2	Site 3	Site 4	Site 5
Gastropda/Bivalvia (Molluscs)	Valvatidae	Valvata piscinalis			A	A	A
	Lymnaeidea	Radix balthica		A	A	B	
	Hydrobiidae	Potamopyrgus antipodarum					A
	Sphariidae			A	A	A	B
Hirundinea (Leeches)	Glossiphonidae	Glossiphonia complantata		A		A	A
	Erpobdellidae	Erpobdella octoculata		A			
Malacostraca	Gammaridae	Gammarus pulex		B	B	A	D
	Asellidae	Asellus aquaticus		A		B	A
Ephemeroptera (Mayfly)	Baetidae	Baetis sp.				A	C
Hemiptera (True bugs)	Corixidae	Sigara sp.		A			
Coleoptera (Beetles)	Dytiscidae	Potamonectes depressus elegans		B	A	B	
		Larvae indet.			A	A	A
	Elmidae	Elmis/Limneus			A		A
	Haliplidae	Haliplus lineatocollis		A		A	A
Megaloptera (Alderfly)	Sialidae	Sialis lutaria		A	A	B	
Tricoptera (Caddisfly)	Limnephilidae						A
	Hydroptilidae	Hydrotia sp.					A
	Hydropsychidae				A		B
	Polycentropidae			A	A		
Diptera (True-fly larvae)	Chironomidae			C	B	B	B
	Muscidae						A
	Ceratopogonidae						A
Oligochaeta (Worms)					B	B	B
Hydracarina (Mites)					B	B	A

Notes:
* Site 1 not sampled in 2012
** Comparable biological meterics from 2002 survey

Biological metrics (2012)	Site 1*	Site 2	Site 3	Site 4	Site 5
Total number of taxa		12	13	14	18
BMWP		49	47	42	61
Number BMWP scoring families		12	11	12	15
ASPT		4.08	4.27	3.50	4.07
LIFE(F)		6.18	6.22	6.00	7.00
PSI		16	40	15	54

Biological metrics (2002)**	Site 1	Site 2	Site 3	Site 4	Site 5
BMWP	15	41	30	43	69
Number BMWP scoring families	4	10	8	10	16
ASPT	3.75	4.10	3.75	4.30	4.31

The following biotic indices were calculated for the four sites using the macro-invertebrate community data, in the assessment of biological water quality (BMWP, ASPT and NTAXA), flow character (LIFE) and sediment load (PSI). Summary details and references for each metric are provided:

- Biological Monitoring Working Party (BMWP), Average Score per Taxon (ASPT) and Number of BMWP Scoring Families (NoT) (Biological Monitoring Working Party, 1979):

  - BMWP, NoT and ASPT are the standard indices used by the Environment Agency in assessment of water quality, primarily as indicators of organic pollution. All families of common British freshwater macroinvertebrates have been allocated a score between 1 and 10 dependent on their sensitivity to organic pollution. Species that are very tolerant of poor water quality score 1 and species that are very intolerant of poor water quality score 10; other species are allocated scores between these two extremes depending on their tolerances. The standard indices are derived from these scores.

- BMWP is simply the sum of scores from all the scoring families found in a sample. NoT is derived from the number of family groups that contribute to the BMWP, and ASPT is the average score achieved by all the scoring families and is determined by dividing the BMWP score by the NoT. Generally speaking, ASPT is seen as a more reliable indicator of water quality than BMWP itself as it is more stable and less prone to seasonal fluctuations.

- Lotic-invertebrate Index for Flow Evaluation (LIFE) (Extence *et al*., 1999):

  - The LIFE metric is primarily based on recognised flow associations of different aquatic macro-invertebrate species and families. Commonly identified British freshwater species are allocated into one of six flow groups depending on their preference to flow with the community LIFE score obtained by using estimated abundance categories and the defined flow group associations. In summary, a community shaped by higher flows should exhibit a high LIFE score.

- Proportion of Sediment Intolerant macroinvertebrates (PSI) (Extence *et al*., 2013):

  - The PSI is based on the known ecological responses of different macroinvertebrate species or family groups to the accumulation of sediment on riverine substrata. Those taxa that are known to benefit from, or that are largely unaffected by, sedimentation, are given a high score, known as a 'Sediment Sensitivity Rating (SSR)'. Those taxa that are known to suffer from the accumulation of sediment are given a low SSR. The metric also depends on the relative abundance of different taxa and so is not just dependent on "presence-absence", but also on the numbers of different taxa recorded.

  - The PSI score describes the percentage of sediment-sensitive taxa present in a sample with high values indicating a greater proportion (percentage) of silt intolerant invertebrate species present within the macroinvertebrate community sampled. Scores obtained indicate a range of sediment conditions from unsedimented to heavily sedimented (unsedimented 81-100; slightly sedimented 61-81; moderated sedimented 41-60; sedimented 21-40 and heavily sedimented 0-20).

Biological indices of water quality, namely BMWP and ASPT, indicate the presence of a "stressed" community containing a high proportion of pollution tolerant taxa (ASPT scores all <5.0). In addition, the low abundance records for the individual taxon (majority recorded at abundance class A and B) indicate that poor habitat quality is also likely to be a factor constraining the current communities. Of the sites sampled in 2012, Site 5 supported the highest taxon richness (Total number of taxa = 18), with sites 2, 3 and 4 exhibiting very similar, but slighter lower species richness.

LIFE(F) scores recorded at sites 2, 3 and 4 indicate that the macro-invertebrate communities present have a low sensitivity to reduced flows (range 6.00 to 6.22). In other words, the communities are indicative of a predominately slow flowing environment. In contrast, the LIFE(F) score at Site 5 (7.00) indicates that the community is moderately sensitive to reduced flows i.e. it contains proportionally more taxa associated with high flow velocities. Site 5, is in fact, one of only a couple of small areas of the Kingston Brook within Meadow Park, that exhibits riffle type habitat character i.e. elevated bed level with coarse substrate over which higher flow velocities are maintained even during low water periods.

PSI scores calculated from the aquatic macro-invertebrate community data at each site provide a biological measure of the level of fine sedimentation within the Kingston Brook bed substrate matrix. PSI scores for sites 2 and 4 (16 and 15, respectively) reflect the heavily sedimented nature of these habitats, which are characteristic of the majority of the habitats within Meadow Park (see Section 3). Lower levels of sedimentation are evident at Site 3 (PSI = 40) and Site 5 (PSI = 54), which are assessed as sedimented and moderately sedimented respectively. The fact that Site 5 supported the highest total number of taxa (18) out of all the sites sampled in 2012 indicates that negative impact that fine sediment can have on macro-invertebrate community structure.

2.3. Comparisons between 2002 and 2012

BMWP, number of BMWP scoring families and ASPT values show a high level of similarity between the two survey periods, with data from both 2002 and 2012 both indicating poor water and habitat quality along the Kingston Brook through Meadow Park (see Morrissey, 2002).

There is no direct evidence within the aquatic macro-invertebrate community data of significant deterioration in quality at the sites sampled as a result of the IDB maintenance activities. However, the communities present prior to the maintenance works have been previously identified as degraded and therefore will have a high level tolerance to physical disturbance within the system. It should be noted that sites 3, 4 and 5 escaped significant channel works (such as those shown in Appendix A) and, therefore, the communities of these sites are unlikely to have been directly affected by physical habitat disturbance. As anticipated, the removal of fine sediment from the channel bed at Site 2, had not caused further deterioration, to what was already an impoverished assemblage.

3. Macrophyte and physical habitat assessment

3.1. Macrophyte, physical habitat and water chemistry survey methods

The method adopted for the assessment of macrophyte community structure and physical habitat monitoring at sites on the Kingston Brook was broadly based on Common Standards Monitoring techniques for streams and rivers such as those defined in:

Monitoring Ranunculion fluitantis and Callitricho-Batrachion Vegetation Communities (Life in UK Rivers, 2003).

The advantages of this method are:

- It is an easily repeatable survey method for which reaches and plots are easily defined and relocated for future surveys.
- The survey is relatively quick to undertake.
- The method includes recording of physical habitat structure, flow character and the wider river corridor.

An adaptation to this method was the provision of a more detailed substrate character record at the individual survey sites and the use of a multi-parameter water quality probe to take basic water chemistry readings.

3.2. 2012 survey findings

Macrophyte and physical habitat data collected in 2012 is provided in Appendix B and are discussed in turn below.

Macrophytes

Plot scale (10m sections) aquatic macrophyte surveys were conducted at sites 2, 3, 4 and 5. These yielded seven aquatic macrophytes in total, of which *Callitriche stagnalis* (common water star-wort) and *Cladophora* agg. (filamentous green algae) were the only truly submerged species. All other plants recorded were emergent species. All species recorded are commonly occurring plants in nutrient rich lowland stream systems.

Macrophyte species richness and percent cover at the sites surveyed was generally low, due to the naturally occurring shading checks caused by riparian tree cover along the stream. The exception was Site 5, where *Cladophora* agg. was recorded at 90% cover on the bed sediments. This relatively shade tolerant alga is indicative of enriched nutrient conditions in the stream and is considered to have been abundant at Site 5 due to favourable flow and the stable nature of the bed sediments.

Maintenance of a mosaic of open and shaded channel sections through, for example, sympathetic and selective tree clearance, can result in improvements in the distribution and resilience of aquatic macrophytes and improvements in flow character within lowland systems. However, in the case of the Kingston Brook tree works were done in an ad hoc manner with little/no thought given to the impacts on the stream, riparian corridor and the ecology of Meadow Park. The removal of native black poplars planted by the Friends of Meadow Park demonstrates the significant lack of care and knowledge of the team undertaking the works. In addition, the

grubbing out of trees (see Appendix A, Plate A-3) has locally reduced bank stability and will potentially lead to bank failure and fine sediment ingress, all of which are harmful to the ecology of the stream.

Physical habitat

The entire length of the Kingston Brook through Meadow Park has been extensively re-sectioned as a result of historical full channel realignment and maintenance activities which have aimed to improve land drainage, flow conveyance and reduce flood risk in the wider catchment. This has resulted in the creation of a relatively straight planform, with a much wider and deeper channel than would naturally occur for the gradient and flow of the stream. Recent aerial photographs identify the position of a relic channel in the floodplain which exhibits a much more meandering planform than the present day alignment (Figure 2). Dating the realignment is problematic due to the availability of historical mapping for the area. However, the Kingston Brook is shown in its current position through Meadow Park in the 1798 Enclosure Map. The relic channel shown in Figure 2 was therefore bypassed over 200 years ago through the creation of the current channel. This was probably done for land drainage purposes which might have been implemented as early as the 1600s.

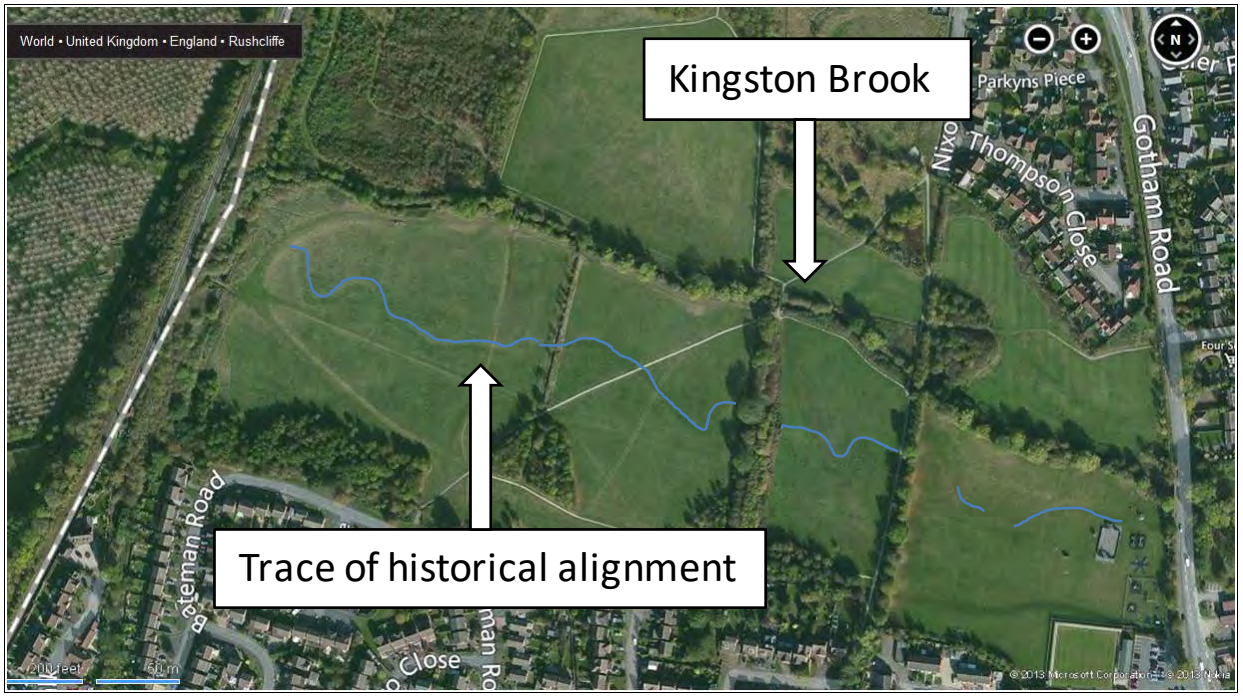

Figure 2. Aerial photograph showing current and historical alignment of the Kingston Brook through Meadow park

As a result of the historical realignment and more recent maintenance activities, the present day channel form is over-wide throughout (e.g. wetted with at Site 2 = 11.50m), often trapezoidal in form and shows very limited variability through Meadow Park, with slowing flowing, silt dominated conditions predominating; a factor identified as constraining current ecological condition. Sites 2, 3 and 4 were all indentified as being depositing habitats which is evidence by the high levels of fine sediment observed on the stream bed at survey.

Works undertaken by the IDB in March 2012 have acted to maintain, and in some instances increase, channel capacity (re-sectioning) and freeboard (bed lowering). The effect on the Kingston Brook is a reduction in habitat diversity and localised stream gradient, which in turn reduces flow velocity and facilitates fine sediment deposition (see Appendix A, Plate A-1). Streams are dynamic features in the landscape and in response to such intervention will attempt to re-adjust their sediment transport processes to provide a more stable state. This is clearly evidenced by the high levels of fine sediment deposition in the channel, development of low level berms/bars (as seen at Site 3 and Site 5) and encroachment of emergent vegetation into the channel. All of these are natural processes that restore appropriate hydro-morphological condition (flow and channel form) and are what in fact the IDB works act to undo.

The dredging and removal of coarse substrates from riffle habitats in the Kingston Brook (see Appendix A, Plate A-2) is perhaps the best example of inappropriate maintenance working by the IDB. Identified as providing a valuable habitat for aquatic macro-invertebrates (and also utilised by fish for spawning) riffle removal is significantly damaging within the context of the current condition of the Kingston Brook. Due to the scarcity of coarse substrates within the system this will be a permanent habitat loss unless replaced as a component of a restoration scheme. It should be noted that the removal of coarse substrate goes against the IDB's own maintenance guidance (Buisson *et al.*, 2008).

Targeted maintenance works which act to modify stream cross-sectional area are justified where flood risk to people and property is a serious and realistic concern. However, it is the author's opinion that the IDB works throughout the Kingston Brook, and in particular Meadow Park, had little to do with the alleviation of flood risk in the area. Perversely, the outcome may be the direct opposite as a result of an increase in flood water conveyance through the catchment i.e. by getting more water to the same place quicker. The flooding in East Leake of November 2012 (see Appendix A, Plate A-5) would undoubtedly occurred had the IDB works not been undertaken, as nearly 500mm of rain fell on the catchment between June 2012 and end of November 2012 (data from Sutton Bonnington rain gauge, Met Office, 2013). However, the significance of the event certainly brings in to question the validity of the works in Meadow Park from a flood risk perspective. The author has recently completed a number of river restoration schemes for the Environment Agency and Norfolk Rivers IDB which have included works to increase channel roughness and selectively encourage water onto the floodplain to reduce flood risk to people and property. This has been achieved by locally raising river bed levels and narrowing the river channel to encourage water on to the floodplain in a controlled way.....after all floodplains like Meadow Park are meant to flood.

Water quality

Collection of water quality data in 2012 was limited to measures of dissolved oxygen concentration, specific conductivity and pH. Of particular note are the very high readings for specific conductivity which ranged from 1,839 to 1,943 μScm^{-1}. Such levels are likely to indicate input of phosphates and nitrates to the system from the predominantly agricultural land-use in the catchment. pH values are within the range expected for the stream typology.

Dissolved oxygen concentrations were well above critical levels (all >65% saturation) that could cause harm to the ecology of Kingston Brook. However, water temperatures were low on the day of survey (average = 9.35^{o}C) which reduces oxygen demand. During summer periods when water temperatures are higher it is likely that oxygen levels will fall significantly in the stream, particular in the unshaded shallow, slow flowing sections. Here, elevated water temperatures combined with seasonally low water levels and high fine sediment loads will result in increase respiratory levels from bacteria and other organisms within the sediment, placing a significant demand on available oxygen in the water. High nutrient levels and other organic pollutants will exacerbate this issue and could ultimately lead to deleterious effects on the aquatic macro-invertebrate and fish populations of the stream. The ecological communities of the stream have in effect been made more vulnerable to low flow periods as a result of increases to the channel capacity and the localised reduction in flow velocity.

4. Conclusions

- Comparative assessment of the 2002 and 2012 ecological data shows that no broad scales changes have occurred in quality as inferred from the aquatic macro-invertebrate assemblages over a ten year period.
- There was no direct evidence, six months after the IDB maintenance works, of deterioration in ecological quality at the sites sampled. However, the macro-invertebrate communities present prior to the works were already significantly degraded. Therefore the communities will have had a high level of resistance to physical disturbance and as such a low sensitivity to the maintenance works.
- Macrophyte species richness and percent cover at the sites surveyed was generally low, due to the naturally occurring shading checks caused by riparian tree cover along the stream.
- IDB works have acted to maintain, and in some instances increase, channel capacity (re-sectioning) and freeboard (bed lowering) through Meadow Park. This has facilitated fine sediment deposition which in the long-term will be deleterious to the stream ecology and habitat quality.

- The ecological communities of the stream have been made more vulnerable to low flows as a result of increases to the channel capacity and the localised reduction in flow velocity. Deleterious effects are most likely to occur during summer low flow periods as a result of increases in biological oxygen demand.
- Due to the high levels of historical disturbance along Kingston Brook it is very unlikely that natural geomorphological processes will be able to fully restore appropriate form and function along the Kingston Brook through Meadow Park. For example, the stream will not be able to naturally recover the coarse sediment removed from riffle habitats which was dumped on the banks.
- To achieve improvements in ecological and habitat quality significant levels of intervention at both a site and catchment scale will be required. Restoration measures required to improve flow and sediment character, such as localised bed raising, low level berm creation and addition of large woody debris, will potentially conflict with the remit of the IDB and may therefore struggle to get the required consents.
- However, the author is happy to advise and remains optimistic that open dialogue between the Friends of Meadow Park and the new IDB will ensure that any future maintenance works are undertaken in line with best practice and the ecological and habitat requirements of Kingston Brook.

5. References

Biological Monitoring Working Party (1978). *Final report: assessment and presentation of the quality of rivers in Great Britain*. Unpublished report, Department of the Environment, Water Data Unit.

Buisson, R. S. K., Wade, P. M., Cathcart, R. L., Hemmings, S. M., Manning, C. J. & Mayer, L. (2008). The *Drainage Channel Biodiversity Manual: Integrating Wildlife and Flood Risk Management*. Association of Drainage Authorities and Natural England, Peterborough.

Extence, C.A., Balbi, D.M. and Chadd, R.P. (1999). River flow indexing using British benthic macroinvertebrates: A framework for setting hydroecological objectives. *Regulated Rivers: Research and Management* **15**, 543-574.

Extence, C.A., Chadd, R.P., England, J., Dunbar, M.J., Wood, P.J. and Taylor, E.D. (2013). The assessment of fine sediment accumulation in rivers using macro-invertebrate community response*. River Research and Applications* **29**, 17-55.

Met Office (2013). Historic rainfall, Sutton Bonnington. Accessed October 2013 at: http://www.metoffice.gov.uk/climate/uk/stationdata/suttonboningtondata.txt.

Morrissey, I. P. (2002). A biological and chemical assessment of the Kingston Brook flowing through Meadow Park, East Leake. Technical report supplied to FMPC and ELPC.

Appendix A – Photographs of Maintenance Works in 2012

Plate A-1: Further over-widening of channel between sites 2 and 3, combined with bed lowering has resulted in almost no flow velocity (March 2012)

Plate A-2: Clear evidence of bed dredging downstream of Site 5. Removal of gravel and cobble reduces in-channel habitat diversity and limits ecological potential (March 2012)

Plate A-3: Tree clearance and dredging deposits in Meadow Park (March 2012)

Plate A-4: Spoil deposits upstream of Meadow Park indicate levels of fine sediment accumulation in Kingston Brook. Rank vegetation often develops and can obscure views of the stream (March 2012)

Plate A-5: Flooding in Meadow Park (November 2012) (photograph by Vicenta Rose, reproduced with kind permission)

Appendix B – Macrophyte, Physical Habitat and Chemical Data (2012 survey)

Survey information and aquatic macrophyte data

River	Kingston Brook
Site	Meadow Park
Surveyor	IPM
Survey date	21/09/2013

	Site 2	Site 3	Site 4	Site 5
NGR (mid point)	SK 55293 26612	SK 55234 26648	SK 55104 26676	SK 54970 26713
Extent (m)	10	10	10	10
Macrophyte assessment	Yes	Yes	Yes	Yes
Structural assessment	Yes	Yes	Yes	Yes
Chemical assessment	Yes	Yes	Yes	Yes
Macroinvertebrate survey	Yes	Yes	Yes	Yes
Macrophytes: % cover				
Apium nodiflorum				5
Callitriche stagnalis			<1	<1
Cladophora agg.	<1	<1	10	90
Rorippa nasturtium-aquaticum	<1			
Sparganium erectum	10		5	
Veronica anagallis-aquatica/catenata	<1			
Veronica beccabunga				<1
Total No. species	4	1	3	4

Physical habitat and chemical data

River	Kingston Brook
Site	Meadow Park
Surveyor	IPM
Survey date	21/09/2013

	Left bank				Right bank			
Site code	Site 2	Site 3	Site 4	Site 5	Site 2	Site 3	Site 4	Site 5
Bank height (m)	1.75	1.5	1.5	1.5	2	0.5	2	1.5
Shading % total	0	40	50	30	10	0	20	30
Bank-top vegetation: B = Bare; U = Uniform; S = Simple C = Complex	S	C	C	S	C	C	C	C
Bank-face vegetation: B = Bare; U = Uniform; S = Simple C = Complex	S	C	C	C	C	C	C	C
Bank modifications								
Land use/buffer (reach): B = Bare; U = Uniform; S = Simple C = Complex	S	S	S	S	S	S	S	C
Bank stability: S = Stable; U = Unstable	S	S	S	S	S	S	S	U

Site code	Site 2	Site 3	Site 4	Site 5
Substrate %:				
Not visible				
Bedrock				
Boulder				1
Cobble		5	5	15
Pebble		40	30	50
Gravel		5	15	20
Sand		10	10	9
Silt	100	40	40	5
Clay				
Peat				
Earth				
Artificial				
Channel stability: (S) stable, (U) unstable (D) depositing	D	D	D	S
Other notes		Bed coated in fine sediment	Bed coated in fine sediment	
Flow: (I) = present E = extensive (>33%)				
Rapid				
Riffle		I		E
Run/Glide				I
Pool				
Slack	E	E	E	
Bars: Present (P), Vegetated (V)		I		I
Channel modifications: (I) = present E = extensive (>33%)				
Re-sectioned	E	E	E	E
Re-inforced				
Channel dimensions (m):				
Bankfull width (m)	11.50	9.00	9.00	8.50
Wetted width (m)	7.00	6.00	5.10	4.20
Depth (water)	0.40	0.15	0.35	0.10
Water chemistry:				
Time taken (BST)	12:30	11:30	10:40	09:40
Water temperature (^{0}C)	9.50	9.90	9.00	9.00
Dissolved oxygen (% saturation)	87.9	84.2	65.5	76.6
Specific conductivity (uScm^{-1})	1914	1839	1856	1943
pH	7.85	7.87	7.47	7.57


Friends of Meadow Park