Natural England Commissioned Report NECR143

Latchmore Brook Restoration Options Appraisal

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

The damage caused by historical drainage activities and contemporary engineering/ management of the mire systems and modification of rivers and streams is frequently cited as a reason for unfavourable condition of the New Forest SSSIs. Natural England aims to restore these SSSIs to favourable condition and to do this needs to understand the physical habitat and ecohydrogical processes and forms of the mire/wetland floodplain habitats.

Latchmore Brook (New Forest SSSI unit 48) is presently in unfavourable recovering condition having been adversely impacted by artificial drainage and engineering. The channel has been artificially deepened and straightened resulting in increased erosion of the river bed and reduced channel habitat diversity.

This report uses flow analysis and the findings from the following reports and their annexes to consider the restoration options for Latchmore Brook:

- New Forest SSSI Geomorphological Survey Overview (NECR140);
- New Forest SSSI Ecohydrological Survey Overview (NECR141); and
- Geomorphic and Ecohydrological Monitoring and Prioritisation Report (NECR142).

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Further information
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Latchmore Brook Restoration Options Appraisal

Executive Summary

Latchmore Brook (New Forest SSSI unit 48) is presently in unfavourable recovering condition having been adversely impacted by artificial drainage and engineering. The channel has been artificially deepened and straightened resulting in increased erosion of the river bed and reduced channel habitat diversity. Channel incision has also limited seasonal inundation of the surrounding floodplain grassland and woodland habitats. Response to straightening has not been limited to the main watercourse with knick point erosion progressing along some of the natural and artificial drainage lines linked to the watercourse and this is causing increased erosion within the mire systems, wet heath and grassland habitats. The Forestry Commission restoration plan for Latchmore Brook (New Forest SSSI unit 48) involves restoring a sinuous palaeo-channel course to the river and infilling the straightened channel as well as measures to control instability in the feeder streams and drains. More recently a hydromorphic audit of the SSSI[1] noted similar hydromorphic issues on Latchmore Brook to the Forestry Commission. This report suggested encouraging wider development of anastomosing channels.

Latchmore Brook and the associated mire SSSI sites are characterised by:

- A weakly anastomosing lower course characterised by a wooded local floodplain and multi-channel flow network.
- A single thread mildly incised channel running through floodplain woodland with disconnected palaeo-channel features including a well defined sinuous single thread channel on the left bank.
- A stabilised wandering reach characterised by an inset floodplain and numerous vegetated gravel bars dissected by a shallow dominant channel and several sub-channels all with abundant mobile gravels accumulating as shoals and more permanent riffle zones.
- A second incised single thread reach again with abundant mobile gravels accumulating as mid channel bars and riffles. Floodplain palaeo-channels are prominent in places.
- A short 'infilled' plane bed single thread reach characterised by a shallow, generally uniform, mobile gravel bed and strong floodplain connectivity.
- A third incised single thread reach with some mobile gravels and areas of exposed boulder clays, accumulating as mid channel bars and riffles. Floodplain palaeo-channels are prominent in places. This channel type extends into the plantation woodland where the channel has also been straightened historically and a prominent left bank palaeo-channel can be traced.
- A number of unstable feeder watercourses entering from the north.

The historical modifications to Latchmore Brook and associated drainage impacts have resulted in damage to adjacent habitats. In particular, the mire and wet heath habitats, found mostly to the north of the watercourse, towards the western end of the unit, are degraded with a lack of *Sphagnum* species, and it is likely that these habitats were once more extensive. As a result of drainage, extensive areas of wet grassland/lawns are now present adjacent to the watercourse along with small areas of wet woodland.

It is likely that the entire watercourse was anastomosed at one time before partial tree clearance and later channel straightening, with the multi-thread network of interlinked functional channels now rationalised into a single (often over-deep) dominant channel. The tree cover present in the past would have allowed the development of numerous debris-dams which would have led to the diversion of the main channel around these obstacles. In addition, Alder and Grey Willow trees would have gained a foothold and stabilised the bank, again encouraging the stream(s) to wander naturally around these obstacles. Tree removal and water table lowering through channel rationalisation has reduced the floodplain to a patchwork of grazed lawns and remnant

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[1] Latchmore Shade Restoration Plan - SSSI Unit 48. Report to Natural England. JBA Consulting March 2013.

wet woodland. The removal of the trees from the middle section of the survey reach has also lowered the resistance of the banks to fluvial erosion leading to historic channel wandering across the floodplain.

Ditching of the upper catchment will have impacted on the flood flow regime of the watercourse creating a more responsive system where flood peaks are concentrated and increased and water enters the main channel more efficiently. This effectively creates a higher energy system more capable of erosion and sediment transport.

Straightening of the watercourse has occurred along a number of reaches and this has had a profound effect on the nature and functioning of the river. The length of watercourse will have been shortened leading to a steepening of the system and the associated dredging will have over-deepened the channel. This in combination with artificially increased flows will have increased flood shear stress levels promoting erosion. The initial impact of straightening would have been incision along significant lengths of the wooded watercourse and wandering behaviour across the cleared zone. This initial incision episode is likely to have caused the knick point development moving through the tributary / drain systems.

To an extent the river can also be said to be recovering in the sense that it has now created a diverse hydromorphology consisting of multiple distributary channels and locally sinuous channels through what were straightened single thread reaches with an associated mix of pool, riffle, plane bed, point bar, mid-channel bar, lateral bar, transverse bar, gravel morphology and significant woody debris induced features. The nature and distribution of these features is however likely to alter significantly over the next decades as the large scale erosion, transport and deposition patterns change. This dynamism is not necessarily detrimental to the functioning of the system but it should be recognised that it has been instigated by multiple system intervention and inappropriate channel and floodplain management.

Similarly the impacted tributary / drain systems are responding to a series of knick points along their courses displaying multiple cut and fill sequences. Alterations to the Latchmore Brook will not impact on the current knick points and these will need to be addressed using separate restoration strategies.

A JFLOW 2D hydraulic simulation of the original channel and potential restoration options has been conducted using 0.5m aerial LIDAR for the reach. The model hydraulic outputs are used to map inundation levels and to calculate the shear stress from the DuBoys equation. The resultant predictions offer a detailed spatial picture of the pattern of shear stress, however, care must be exercised in interpreting the magnitude of shear due to the relatively simplistic nature of the estimation process and the inherent vertical inaccuracies in the LIDAR data. Modelling of the two year return period flow shows that the present system is energetic enough to mobilise gravels and to initiate bank erosion at a number of points along the present channel. This is in line with observations during the field survey where bank erosion and loose gravels were noted along the SSSI reach. It is also to be expected in an energetic system. The variably incised nature of the straightened channel is, however, concentrating high flows, restricting floodplain inundation and heightening the potential for erosion.

Re-meandering the channel coupled with channel infilling creates a dramatically different flow pattern during the two year return period discharge. In-channel velocity and shear stress predictions remain quite high and sediment mobilisation is predicted for long lengths of the restored channel. This will maintain sediment continuity with the downstream reach. Cohesive banks and those protected by live woody vegetation should remain generally resistant to erosion, other areas will display bank and bed erosion. Naturalising the channel using selective channel blocking at likely avulsion sites generates a more varied pattern of flow for the two year return period discharge with increased floodplain inundation and palaeo-channel activation and slightly reduced overall velocity and shear stress predictions. These lowered values are reflected in a more stable overall channel pattern although there are several zones of gravel transport predicted. This will maintain sediment continuity with the downstream reach.

The opportunities and constraints associated to the re-meandering and channel blocking approaches are provided in the table below.

Restoration approach	Opportunities	Constraints
Re-meandering	Sediment mobilisation will continue - maintaining continuity with downstream reach. Cohesive and wooded banks will remain generally resistant to erosion. Floodplain inundation will be increased. Increased sinuosity will generate greater in-channel hydraulic variation.	Construction costs will be higher due to machinery requirements and the degree of channel infilling. Short term damage to surrounding habitats will he higher using this approach due to the degree of works required. Less impact on diversity of the flow regime compared to the channel blocking method. Velocities and shear stresses remain higher than the channel blocking approach, providing less stable channel conditions. Channel infilling will destroy extant habitats.
Channel blocking	More varied flow patterns and dynamics. Increased floodplain inundation and palaeo channel activation. Lower velocities and shear stresses compared to re-meandering approach, although some section will still transport gravel to downstream reaches. Lower constructions costs and less channel infilling and machinery required. Lower risk of damage to surrounding habitats. Retains some backwater habitat where existing main channel areas remain unfilled.	Erosion can still be expected with this approach. Limited isolated backwater areas may trap fish after floods. Risk of reactivation of straightened reaches if incorrectly designed

Control of knick points along the incised lower reaches where the channel flows through mineral deposits is problematic and requires alternative techniques to staked heather bales used previously. Complete or substantive channel infilling with an organic porous base and mineral top layer could be attempted in the most severely eroding reaches. This would be a radical approach and requires detailed design which is outside of the scope of this report.

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1.1 Status of Latchmore Brook

Latchmore Brook (New Forest SSSI unit 48) is presently in unfavourable recovering condition having been adversely impacted by artificial drainage and engineering. The channel has been artificially deepened and straightened resulting in increased erosion of the river bed and reduced channel habitat diversity. Channel incision has also limited seasonal inundation of the surrounding floodplain grassland and woodland habitats. As a result these adjacent habitats are negatively affected. Response to straightening has not been limited to the main watercourse with knick point erosion progressing along some of the natural and artificial drainage lines linked to the watercourse and this is causing increased erosion within the mire systems, wet heath and grassland habitats.

1.2 Proposed Restoration Options

The Forestry Commission restoration plan for Latchmore Brook (New Forest SSSI unit 48) involves restoring a sinuous palaeo-channel course to the river and infilling the straightened channel as well as measures to control instability in the feeder streams and drains.

A recent hydromorphic audit of the SSSI[2] noted similar hydromorphic issues on Latchmore Brook to the Forestry Commission. This report suggested encouraging wider development of anastomosing channels.

1.3 Report Aims

This report summarises the current hydromorphic condition and functional linkages between Latchmore Brook (New Forest SSSI unit 48) and the associated mire catchments of Thompson's Castle, Latchmore Mire and Watergreen Bottom. It presents the results of a 2D hydraulic modelling exercise to simulate the implementation of the Forestry Commission re-meandering restoration plan and the anastomosing naturalisation option proposed following the recent New Forest Rivers and Mires restoration plan audit.

[2] Latchmore Shade Restoration Plan - SSSI Unit 48. Report to Natural England. JBA Consulting March 2013.

2 Latchmore Brook Character

2.1 Physical setting

The Latchmore Brook arises in Howen Bottom and Claypits Bottom to the north east, flowing through Island Thorns, Amberwood and Alderhill Inclosures before emerging again onto the Open Forest at Latchmore. The site as a whole includes the mire catchments of Thompson's Castle, Latchmore Mire and Watergreen Bottom, whilst the Latchmore Shade SSSI unit (along the watercourse itself) includes wet heath and lawn habitats. The Latchmore Brook flows in a straightened deepened drain channel for approximately two thirds of its length across Latchmore Bottom, before leaving the western edge of the Open Forest at Ogdens.

Unit 48 is supplied with gravels from the upstream and from local bank erosion and remobilisation of instream gravel deposits. The combination of a steep watercourse, strong gravel supply, historic channel straightening, riparian tree clearance and local grazing pressures creates a dynamic and responsive watercourse sensitive to perturbation.

Figure 2-1: Latchmore Brook restoration site location (flow direction is east to west)

2.2 Current hydromorphic conditions and issues along Latchmore Brook

Latchmore Brook within SSSI Unit 48 varies between:

- A weakly anastomosing lower course characterised by a wooded local floodplain and multi-channel flow network (Figure 2-2).
- A single thread mildly incised channel running through floodplain woodland with disconnected palaeo-channel features including a well defined sinuous single thread channel on the left bank (Figure 2-3).
- A stabilised wandering reach characterised by an inset floodplain and numerous vegetated gravel bars dissected by a shallow dominant channel and several sub-channels all with abundant mobile gravels accumulating as shoals and more permanent riffle zones (Figure 2-4).
- A second incised single thread reach again with abundant mobile gravels accumulating as mid channel bars and riffles. Floodplain palaeo-channels are prominent in places (Figure 2-5).
- A short 'infilled' plane bed single thread reach characterised by a shallow, generally uniform, mobile gravel bed and strong floodplain connectivity (Figure 2-6).
- A third incised single thread reach with some mobile gravels and areas of exposed boulder clays, accumulating as mid channel bars and riffles. Floodplain palaeo-channels

are prominent in places. This channel type extends into the plantation woodland where the channel has also been straightened historically and a prominent left bank palaeo-channel can be traced (Figure 2-7).

The pattern of issues is summarised in Figure 2-8.

Figure 2-2: Weakly anastomosed lower course of Latchmore Brook SSSI Unit 48

Figure 2-3: Mildly incised single thread reach of Latchmore Brook SSSI Unit 48

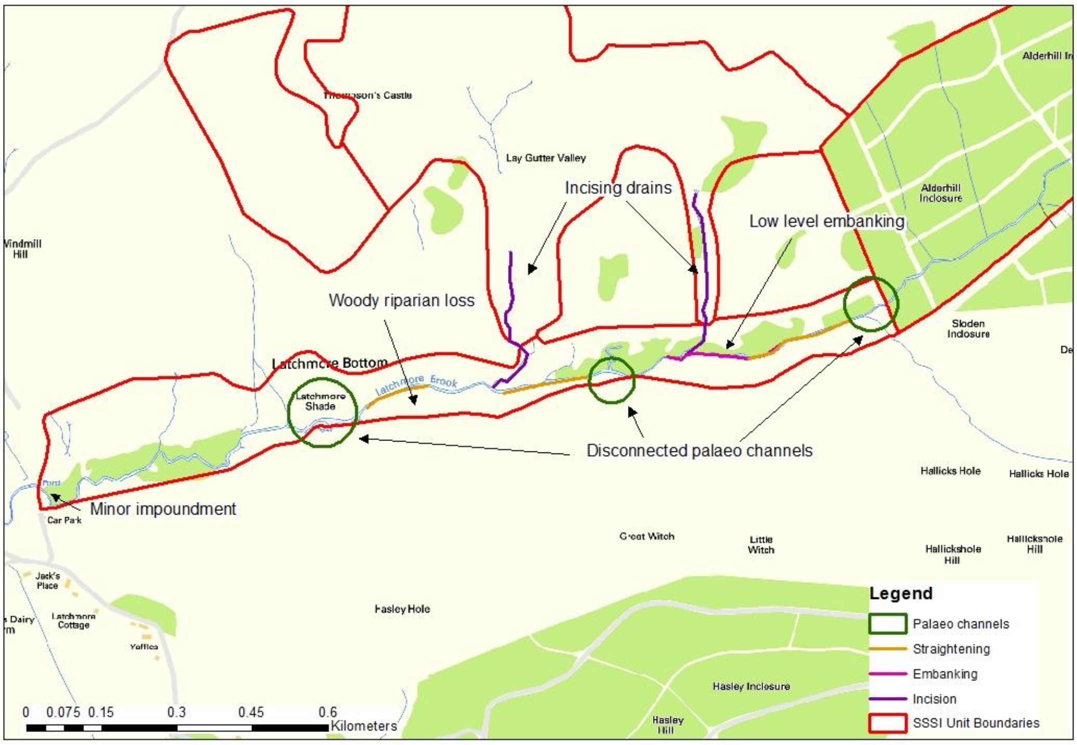
Figure 2-4: Stabilised wandering reach of Latchmore Brook SSSI Unit 48

Figure 2-5: Prominent palaeo-channel associated with Latchmore Brook SSSI Unit 48

Figure 2-6: Plane bed single thread reach of Latchmore Brook SSSI Unit 48

Figure 2-7: Forested single thread reach of Latchmore Brook SSSI Unit 48

Figure 2-8: Current hydromorphic conditions and pressures



The natural anastomosed channel network has been extensively modified through the SSSI unit with historic channel straightening along considerable lengths of the watercourse. The channel has reacted to this straightening by initially cutting down into the bed, creating an incised single channel. This will have increased flood shear stress levels promoting local erosion, particularly where flows are concentrated around in-channel bars (Figure 2-9). Subsequent resupply of gravels from upstream has resulted in a general over-filling of the channel in the middle reaches to create a shallow plane bed system, leading to frequent floodplain inundation. This channel state is not stable and will be subject to a renewed period of scour and disconnection as part of the general damped erosion/deposition cyclic response to the straightening.

Figure 2-9: Local flow concentration and bank erosion linked to gravel bars on Latchmore Brook

The historic incision of the channel floodplain has altered flood frequency and groundwater levels and much of the natural vegetation has been lost. This community change has been exacerbated by historic (and more recent) tree clearance and regeneration is being prevented by current management practices including grazing. The overall pattern of flooding frequency is significantly disrupted with reaches where the occurrence of overbank flow has been reduced due to incision and other areas where inundation rates are increased above normal due to gravel infilling. In addition flood connectivity is locally reduced where arisings from channel dredging are deposited on the bank.

The impact of incision, infilling and spoil dumping on groundwater levels has resulted in the drying of the immediate floodplain resulting in hummocky lawns across former *Molinia* mire in incised reaches and wetter where gravels have infilled the main channel. Floodplain swamp and pond areas have developed.

The gradient is low, compared to upstream, along the Latchmore Brook through SSSI unit 48 where the channel exhibiting a characteristically anastomosed network through a narrow wooded riparian margin. The change in gradient and associated tree clearance has created a long-term sediment storage and reworking zone which has previously been laterally active. The result is a stabilised wandering section which is inset into the wider floodplain and is characterised by a number of low vegetated and unvegetated bar features.

Floodplain connectivity improves through anastomosed reaches within the wooded lower section of the SSSI unit, although several channels remain disconnected from the main channel. The anastomosed network is assisted by debris dams which have provided local improved floodplain connectivity (Figure 2-210).

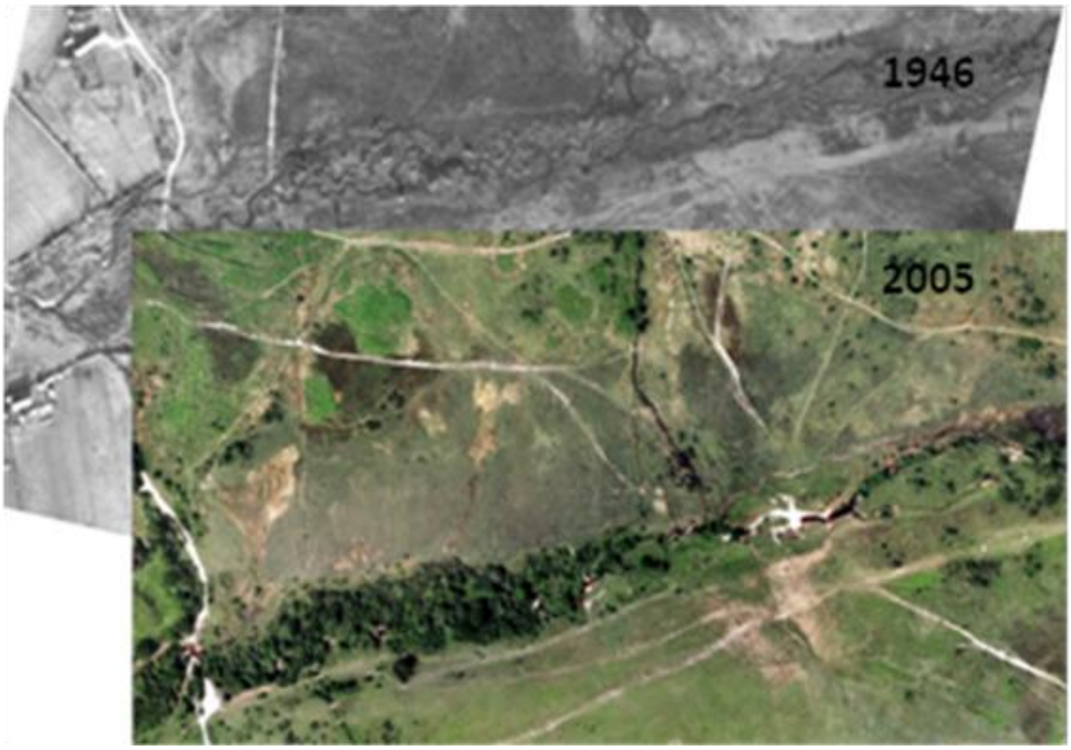
Figure 2-10: Woody Debris on Latchmore Brook

2.3 Historic channel behaviour

Historic Ordnance Survey mapping of the Latchmore Brook (Figure 2-11) indicates that the channel has been subject to natural movement (although the level of local change shown in the mapping is within the error on the cartography) and realignment with major straightening between the 1910 and 1963 map. Aerial mapping from 1946 (Figure 2-12) suggests that the straightening occurred after this date. The image is also interesting as it highlights the development of anastomosed wet woodland at the western end of the reach close to Ogdens Bridge.

Figure 2-11: Historic channel position of Latchmore Brook based on Ordnance Survey mapping

Figure 2-12: Comparison aerial photographs of Latchmore Brook 1946 and 2005



2.4 Current hydromorphic conditions and issues along incoming streams and drains

A number of watercourses (both artificial and natural) drain the mire systems to the north of Latchmore Brook (labelled 1-5 on Figure 2-13). These are in a variable state with instability noted during the walkover survey on watercourses 1 - 3. This instability can be linked to the incision episode on the main river linked to channel straightening. Multiple knick point development is now evident (Figure 2-14). The condition of the drainage lines is summarised in Figures 2-15 to 2-19.

Figure 2-13: Drainage into Latchmore Brook from the mire systems to the north

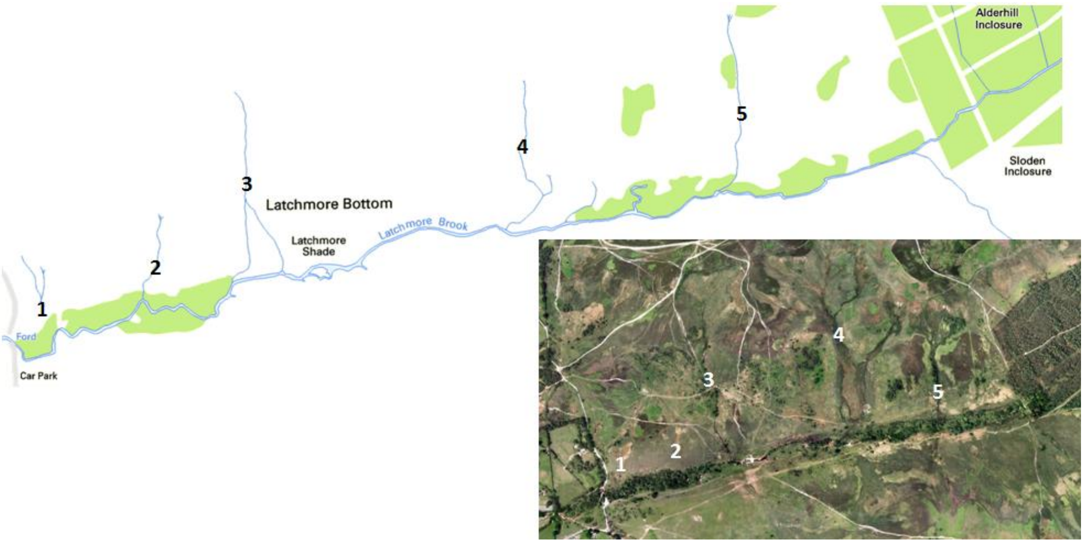


Figure 2-14: Knick point erosion on the tributary channels of Latchmore Brook

2.4.1 Drainage line 1

This area is unstable and is currently delivering large volumes of mixed sediment to Latchmore Brook (Figure 2-15).

Figure 2-15: Condition of drainage line 1, Latchmore Brook

2.4.2 Drainage line 2

This area is unstable and is currently delivering large volumes of mixed sediment to Latchmore Brook (Figure 2-16). It would appear that the instability has spread through multiple headward erosion upstream of an artificial straight drain that is now a distinct incised, single thread channel. Low elevation knick points are present along the incised reach although there appears to have been infilling and reduced activity recently.

Restoration should be concentrated in the upper reaches.

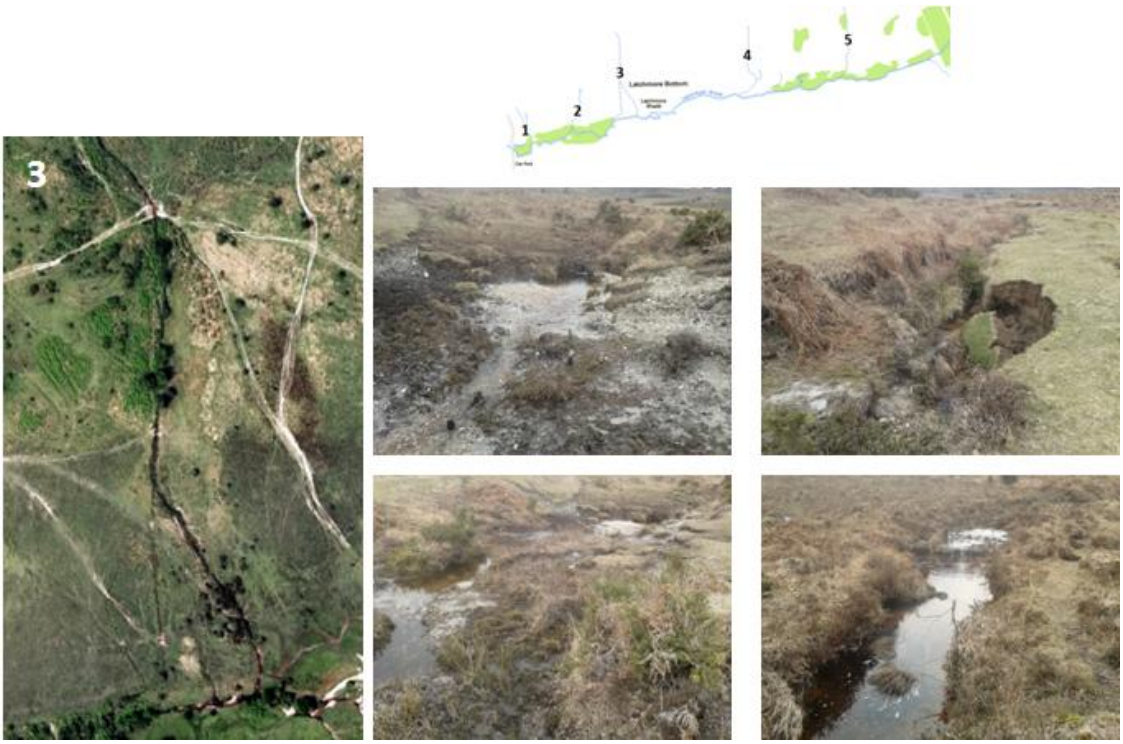
Figure 2-16: Condition of drainage line 2, Latchmore Brook

2.4.3 Drainage line 3

This channel is unstable along much of its length extending into the mire systems (Figure 2-17). It was probably a cut channel and breached the fluvio-glacial sediments forming a natural dam to the upper valley and seepage mires. Local restoration attempts aimed at controlling knick point erosion using staked heather bales have failed due principally to outflanking. Excess drainage of the seepage mires is occurring and will continue if not controlled.

Several major knick points are present along the incised reach with significant active vertical incision and more minor lateral erosion observed on site.

Figure 2-17: Condition of drainage line 3, Latchmore Brook



2.4.4 Drainage line 4

This and several smaller local drainage lines are presently stable and are characterised by poorly defined channels, diffuse surface flow and an aggrading fan distributary network entering the Latchmore Brook.

Figure 2-18: Condition of drainage line 4, Latchmore Brook

2.4.5 Drainage line 5

This and several smaller local drainage lines are presently stable and are characterised by poorly defined channels, diffuse surface flow and an aggrading fan distributary network entering the Latchmore Brook.

Figure 2-19: Condition of drainage line 5, Latchmore Brook

2.5 Current Ecological Condition

The historical modifications to Latchmore Brook and associated drainage impacts have resulted in damage to adjacent habitats. In particular, the mire and wet heath habitats, found mostly to the north of the watercourse, towards the western end of the unit, are degraded with a lack of *Sphagnum* species, and it is likely that these habitats were once more extensive.

As a result of drainage, extensive areas of wet grassland/lawns are now present adjacent to the watercourse. The lawns are used as feeding areas by wintering birds, in particular they seem to be favoured by Fieldfares *Turdus pilaris* as foraging sites with the nearby trees offering shelter when these birds sense danger. These areas are quite heavily grazed and contain frequent Purple Moor-grass *Molinia caerulea* with rush *Juncus* species in wetter areas. Scrub, Gorse *Ulex europaeus* and Bracken *Pteridium aquilinum* are also quite frequent within the wet grassland, particularly Bracken, which becomes particularly extensive towards the eastern end of the unit where it is colonising the ground more generally. Elsewhere it is present only on dry, former *Molinia*, hummocks within the lawn areas and scattered amongst the heathland plants as you leave the valley floor.

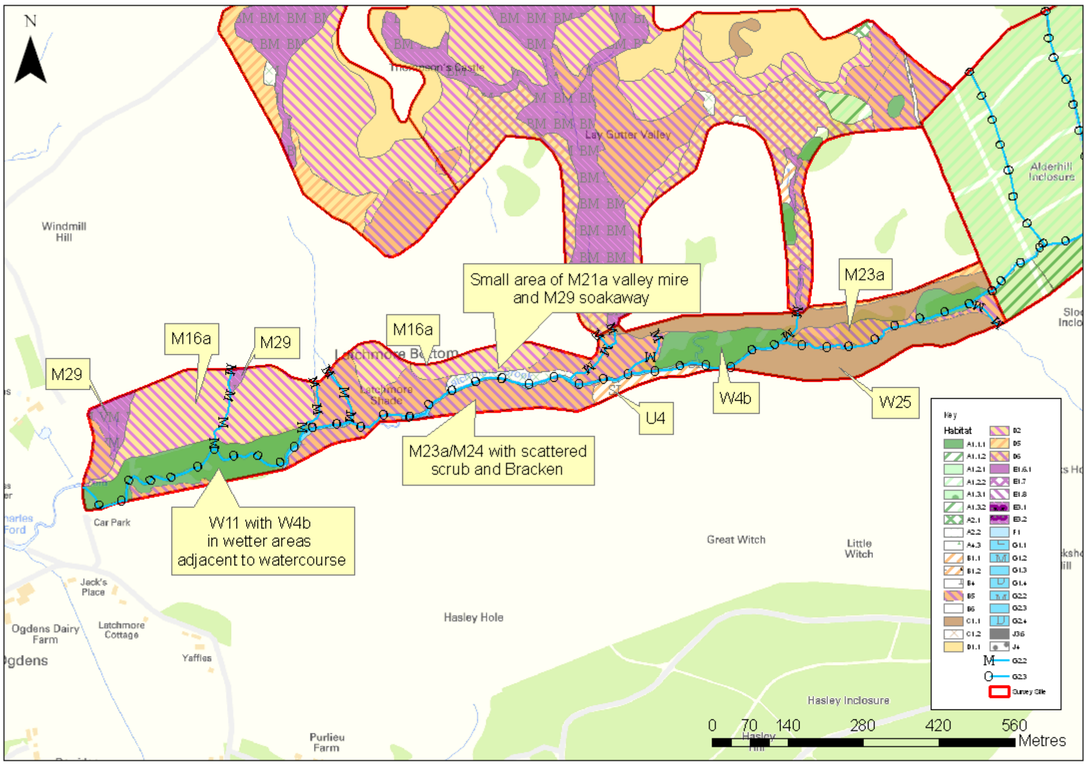
Along the watercourse there are small areas of woodland with Oak *Quercus* sp, Downy Birch *Betula pubescens* and Grey Willow *Salix cinerea* frequent and these are used as wildlife corridors and as foraging areas by flocks of tits, especially during the winter months. Some tree clearance, mostly Alder *Alnus glutinosa* has been undertaken upstream of Latchmore Shade and this has removed a valuable resource within the local ecosystem, especially since many of these Alders were in excess of 100 years of age. Most of these trees are now sprouting again from the remaining rootstocks and, over time, this section of the stream should recover. Nevertheless, the result is, within these areas, and elsewhere along the watercourse, just scattered scrub and occasional trees remaining. Bracken is also quite frequent along the bank tops of the watercourse with Hard Fern *Blechnum spicant* common just below the bank top, out of the reach of hungry mouths.

Within the watercourse there is very little vegetation, as it has a gravel bed, although here and there, there are small patches of Creeping St John's Wort *Hypericum elodes*, Bog Pondweed *Potamogeton polygonifolius* and Round-leaved Water Crowfoot *Ranunculus omiophyllus. Floating Club-rush Eleogiton fluitans is found occasionally in damp paleao-channels.*

Two small patches of Rhododendron *Rhododendron ponticum* were recorded within the eastern end of the unit. These should be removed.

Figure 2-20 shows the Phase I Habitat Map for the area around Latchmore Brook.

Figure 2-20: Phase I Habitat Map linked to Latchmore Brook



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2.6 Summary of likely historic channel development

It is likely that the entire watercourse was anastomosed at one time before partial tree clearance and later channel straightening, with the multi-thread network of interlinked functional channels now rationalised into a single (often over-deep) dominant channel. The tree cover present in the past would have allowed the development of numerous debris-dams which would have led to the diversion of the main channel around these obstacles. In addition, Alder and Grey Willow trees would have gained a foothold and stabilised the bank, again encouraging the stream(s) to wander naturally around these obstacles. Tree removal and water table lowering through channel rationalisation has reduced the floodplain to a patchwork of grazed lawns and remnant wet woodland. The removal of the trees from the middle section of the survey reach has also lowered the resistance of the banks to fluvial erosion leading to historic channel wandering across the floodplain.

Ditching of the upper catchment will have impacted on the flood flow regime of the watercourse creating a more responsive system where flood peaks are concentrated and increased and water enters the main channel more efficiently. This effectively creates a higher energy system more capable of erosion and sediment transport.

Straightening of the watercourse has occurred along a number of reaches and this has had a profound effect on the nature and functioning of the river. The length of watercourse will have been shortened leading to a steepening of the system and the associated dredging will have over-deepened the channel. This in combination with artificially increased flows will have increased flood shear stress levels promoting erosion. Where the channel banks are stronger (due to the presence of more resistant boulder clays rather than fluvio-glacial gravels and/or where riparian woody vegetation is dense enough to provide a coherent resistant root mat or along short sections where the channel banks may have been revetted) erosive energy will have been concentrated into vertical incision into the bed leading to an over-deep channel. Where the banks are less resistant (due to tree clearance, presence of gravels etc.) lateral erosion will also have occurred. This is evident in the wandering section of the Brook. Often in rivers with moderate to high energy, lateral erosion and widening is also associated with bar deposition concentrating flows around gravel shoals and promoting further lateral activity.

The initial impact of straightening would have been incision along significant lengths of the wooded watercourse and wandering behaviour across the cleared zone. This initial incision episode is likely to have caused the knick point development moving through the tributary / drain systems.

More locally the incision will be followed by in-channel deposition as gravels are dropped in lower energy zones during flood recession. Significant shoals will then influence channel hydraulics upstream, reducing the water slope and promoting more deposition. This ‘cut and fill’ activity is evident along the Brook with fill zones characterised by plane bed, shallow gravel reaches and more local gravel shoals and bars causing local lateral erosion. This pattern is often repeated over time as gravels are re-eroded and re-deposited along the system and this will in turn have generated successive knick-points along the tributary / drains.

The process of adjustment to the channel straightening, dredging, flow regime alteration and floodplain vegetation disruption is continuing despite the historic nature of many of the changes. As such the river remains highly responsive in nature and will not stabilise as a result of re-routing the watercourse back through a palaeo-course that was occupied possibly a century ago when channel and catchment processes and pressures would have been very different from today.

To an extent the river can also be said to be slowly recovering in the sense that it has now created a diverse hydromorphology consisting of multiple distributary channels and locally sinuous channels through what were straightened single thread reaches with an associated mix of pool, riffle, plane bed, point bar, mid-channel bar, lateral bar, transverse bar, gravel morphology and significant woody debris induced features. The nature and distribution of these features is however likely to alter significantly over the next decades as the large scale erosion, transport and deposition patterns change. This dynamism is not necessarily detrimental to the functioning of the system but it should be recognise that it has been instigated by multiple system intervention and inappropriate channel and floodplain management.

Similarly the impacted tributary / drain systems are responding to a series of knick points along their courses and themselves display multiple cut and fill sequences. Alterations to the Latchmore Brook will not impact on the current knick points and these will need to be addressed using separate restoration strategies. It should be noted, however, that restoration of the Latchmore Brook will minimise the risk of future knick-points propagating upstream through the tributaries and drains as a result of incision within the Brook.

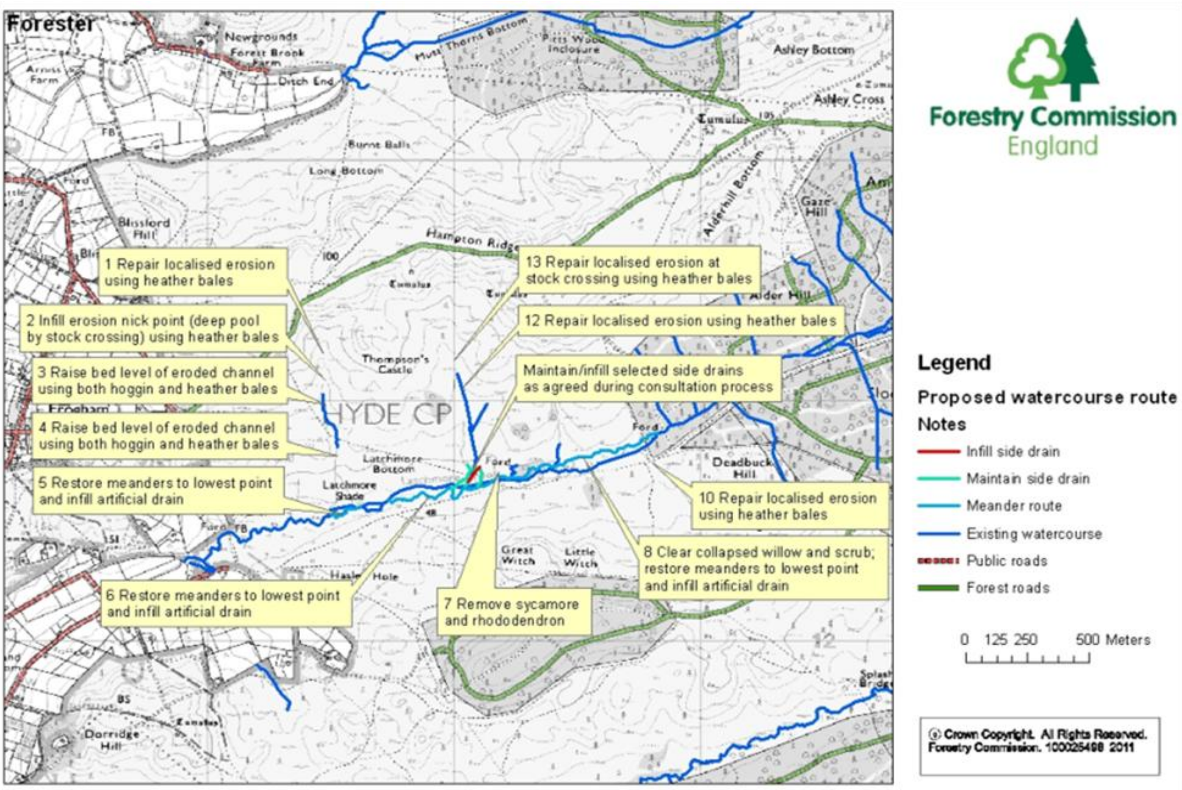
3 Restoration plan proposals

The Forestry Commission restoration plan for Latchmore Brook (New Forest SSSI unit 48) involves restoring a sinuous palaeo-channel course to the river and infilling the straightened channel as well as measures to control instability in the feeder streams and drains (Table 3-1 and Figure 3-1). This is similar to the suggested restoration measures proposed in the recent SSSI unit assessment[3]

Table 3-1: Forestry Commission restoration actions for Latchmore Brook (New Forest SSSI unit 48)

Action	Detail
Meander restoration	The original meander course occupies the lowest point in the floodplain, to the north of the existing drain channel, for the entirety of this upstream section of the Latchmore site. It then switches to the southern floodplain through to Latchmore Shade. The redundant drain channel will be infilled.
Incised channel infill	Partial infilling of a short stretch of localised erosion within the Watergreen Bottom SSSI unit using hoggin and heather bales to create a shallower vegetated channel, to support the mire.
Tributary / drain instability control	Installation of hoggin and / or heather bales to control knick point erosion.
Ford relocation	The existing gravel ford running parallel to the Inclosure fenceline will be relocated to the line of the restored meander course, and the approach to the junction with the driftway

Figure 3-1: Forestry Commission restoration actions for Latchmore Brook (New Forest SSSI unit 48)



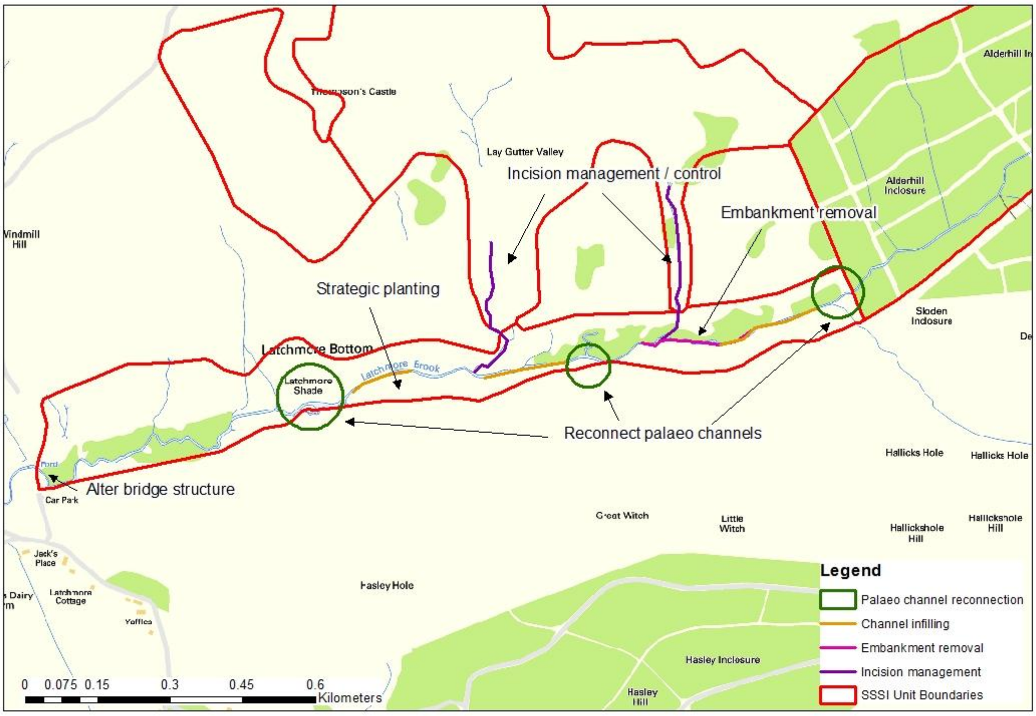
A summary of the current pressures, unmitigated impacts and suggested restoration measures proposed in the recent SSSI unit assessment[3] is given in Table 3-2 and shown in Figure 3-2.

[3] Latchmore Shade Restoration Plan - SSSI Unit 48. Report to Natural England. JBA Consulting March 2013.

Table 3-2: SSSI Unit 48 proposed restoration measures

Pressure	Restoration proposal	Hydromorphic improvement
Straightening	Palaeo channel reconnection. Infill. Restore in-channel morphology. Restore connectivity. Treat knick points.	Reinstate some channel length lost through straightening - helping to reduce incision. Encourages anastomosing channel development. Reduces fine sediment inputs. Slows gravel movement. Stabilises in-channel features.
Historic dredging	Incision management - debris dams, morphological restoration, floodplain works. Infill. Restore connectivity. Treat knick points.	Reconnecting the floodplain will improve in-channel hydromorphic condition and will reduce incision. Debris dams naturally occur along the reach. Reproduce using local materials. Morphological enhancement to raise bed and water levels will help improve floodplain connectivity. Local floodplain works may be necessary to give sufficient connectivity. Encourages anastomosing channel development. Reduces fine sediment inputs. Slows gravel movement. Stabilises in-channel features.
Embanking (low level)	Embankment removal - main channel and drains	Reconnect the floodplain, reducing incision rates and improving in-channel hydromorphic conditions. Slows gravel movement. Stabilises in-channel features.
Riparian vegetation removal	Reduced tree clearance at bank edge. Replant or allow regrowth to prosper through reducing grazing pressure.	Will help to stabilise banks in the wandering sections and alongside bed restoration to minimise incision, could improve floodplain connectivity Creates riparian hydromorphic diversity. Acts as fine sediment trap. Allows woody debris accumulation.
Over-grazing	Alter land management.	Stabilisation of stream margins. Reduction in fine sediment and faecal input to watercourse.

Figure 3-2: Proposed restoration measures for SSSI Unit 48



4 Modelling Results

4.1 Description of the JFlow 2D hydraulic model

The flow of water through the river channel was modelled using JFLOW. JFLOW is a 2D model which solves depth averaged fluid flow equations to model the movement of water over the ground. It has been used to predict critical flow paths and local hydraulics associated with the channel, with and without potential restoration structures. Simulations have been used to calculate in-channel and floodplain hydraulic parameters important for ecological functioning (flow shear stresses, flow depths, etc.) and sediment transport (unit stream power, shear stresses, peak velocities, etc.). The revitalised FSR/FEH rainfall runoff method was used to estimate the 2 year return period flow (widely reported as the approximate channel forming flow in temperate alluvial rivers). The model predicted a discharge of 5.1 m^3/s (Figure 4-1).

The Digital Elevation Model (DEM) used for the Latchmore study area is a 2D representation of the earth's surface taken from aerial LIDAR survey with heights given at a spatial resolution of 1 m to a vertical accuracy of 5cm to 10cm. The bed of the Latchmore Brook is picked up across exposed gravels and riffles and from the base of bank profiles. The DEM, therefore, delineates the exposed floodplain and the river channel including all morphologic features very accurately (Figure 4-2).

Figure 4-1: Two year flow hydrograph based on the revitalised FSR/FEH rainfall runoff method

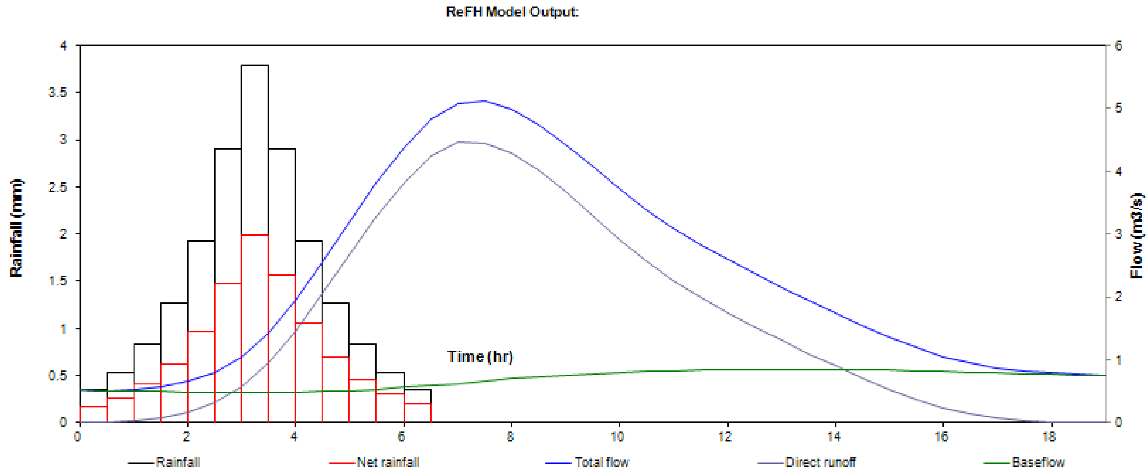
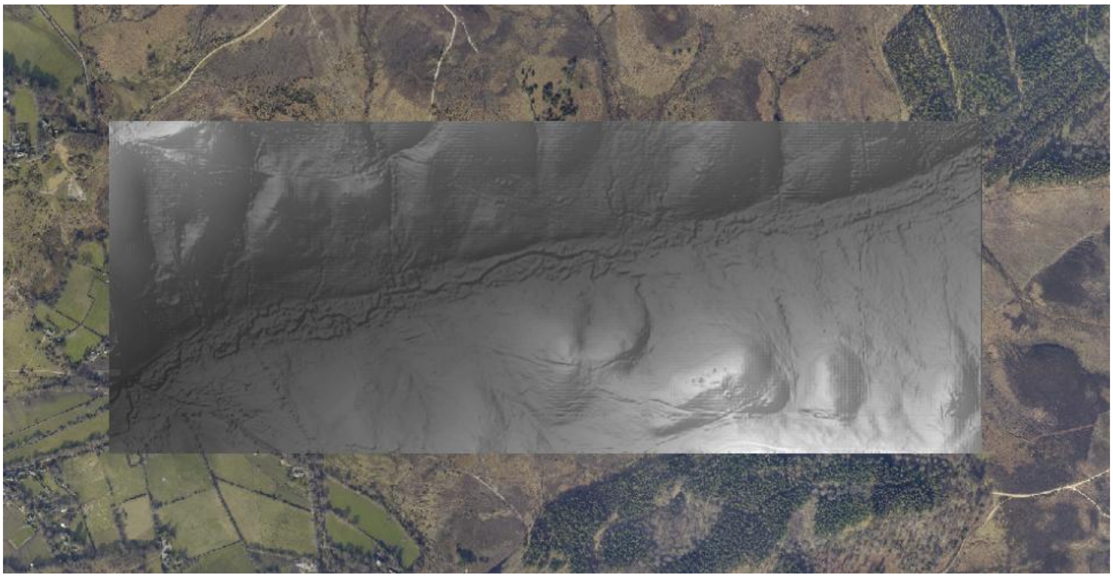


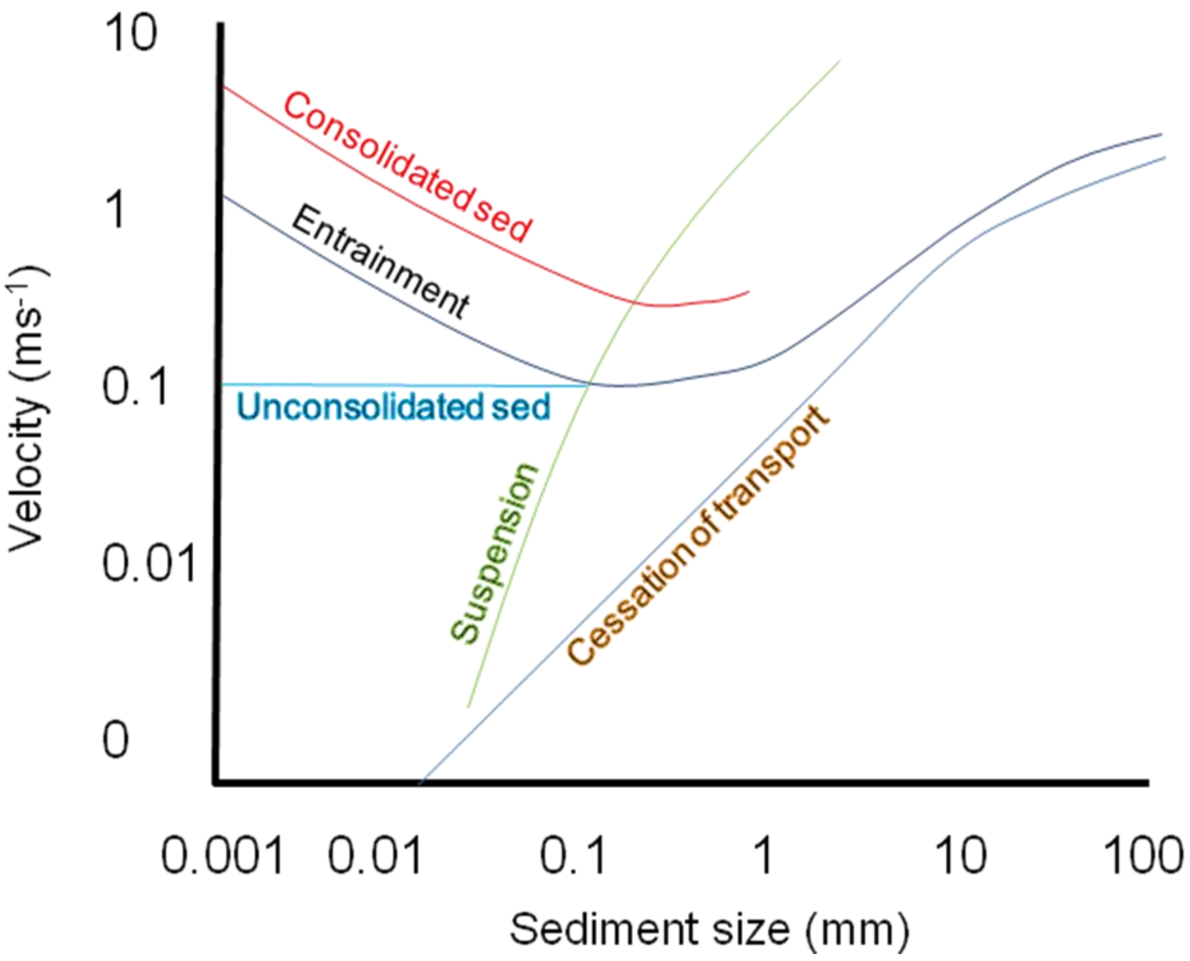
Figure 4-2: Digital Elevation Model of the Latchmore Brook SSSI unit 48 study reach



4.2 Hydraulic model output and interpretation

The hydraulic data were also used to estimate probability of lateral channel movement investigated based on a velocity threshold for clay dominated cohesive sediment erosion of 1.3m/s determined from the Hjulström curve (Figure 4-3).

Figure 4-3. The Hjulström curve showing approximate threshold velocity conditions for sediment erosion (a value of 1.3m/s was determined at the consolidated silt clay boundary)



With respect to unconsolidated sediments the critical threshold for movement (τ_{cr}) may be calculated from the Shields entrainment function:

$$T_{cr} = 0.045\,(\rho_s - \rho_w)\,\rho_w\,g\,D_g \qquad (1)$$

where ρ_s = density of sediment (2.65 t/m^3), ρ_w = density of sediment (1.00 t/m^3), g = gravitational acceleration (9.81m/s^2) and D_g = sediment size measured in mm. Given these values $\tau_{cr} \approx 0.73\,D_g$. Inverting this relationship reveals that the mobile grain size (mm) for a given shear stress is approximately 1.4 τ_{cr}.

With regard to the medium gravel sediments seen in the Latchmore Brook shear stress thresholds between 35-56 N/m^2 are used to define the onset of erosion, gravel transport and channel change.

4.3 Hydraulic character of the current channel

The JFlow model was run using the 2 year return period flow simulated hydrograph (Figure 4-1) using the unmodified DEM of Latchmore Brook. Hydraulic outputs of flow depth and velocity were recorded and these data were converted to shear stress using the duBoys equation:

$$T = \rho_w \, g \, R \, S \qquad (2)$$

where ρ_w = density of sediment (1.00 t/m^3), g = gravitational acceleration (9.81m/s^2), R = hydraulic radius (assumed equivalent to the flow depth) and S = water surface slope.

Plots of velocity, critical velocity highlighting areas susceptible to bank erosion, shear stress and critical shear stress for gravel movement are illustrated below in figures 4-4 to 4-7.

Figure 4-4 Plot of velocity distribution for the 2 year return period flow along the current Latchmore Brook

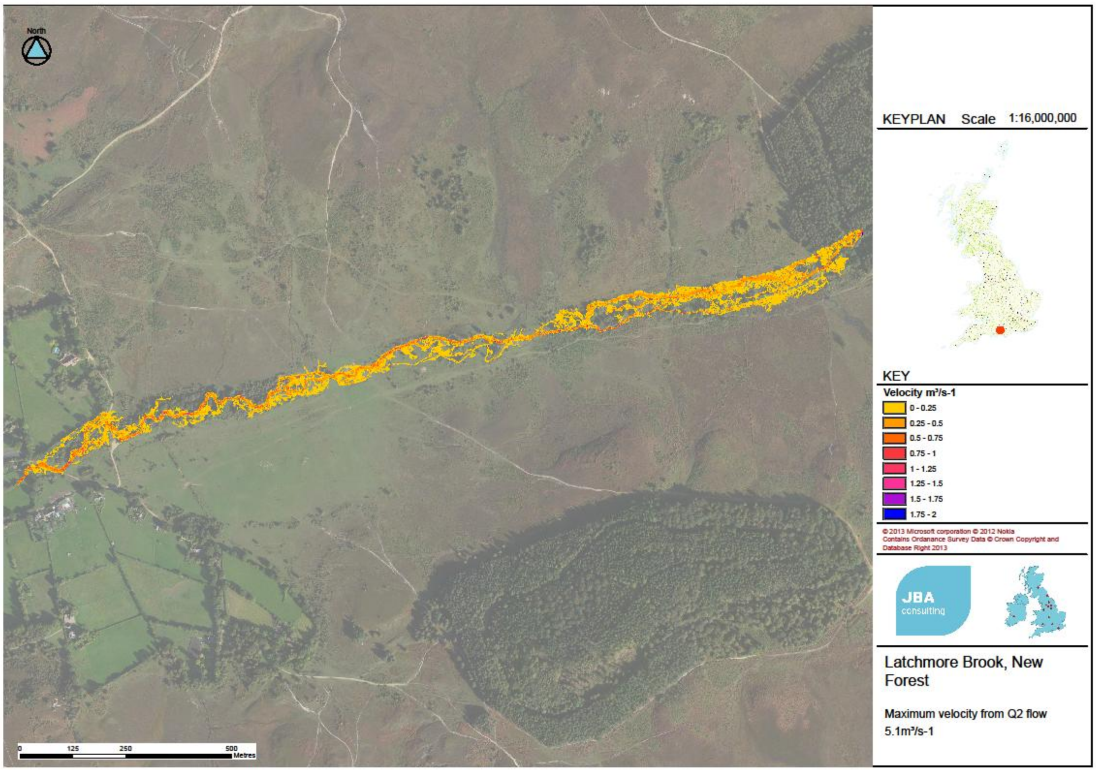


Figure 4-5a: Plot of critical velocity sites for the 2 year return period flow along the current Latchmore Brook

Figure 4-5b: Plot of critical velocity sites for the 2 year return period flow along the current Latchmore Brook

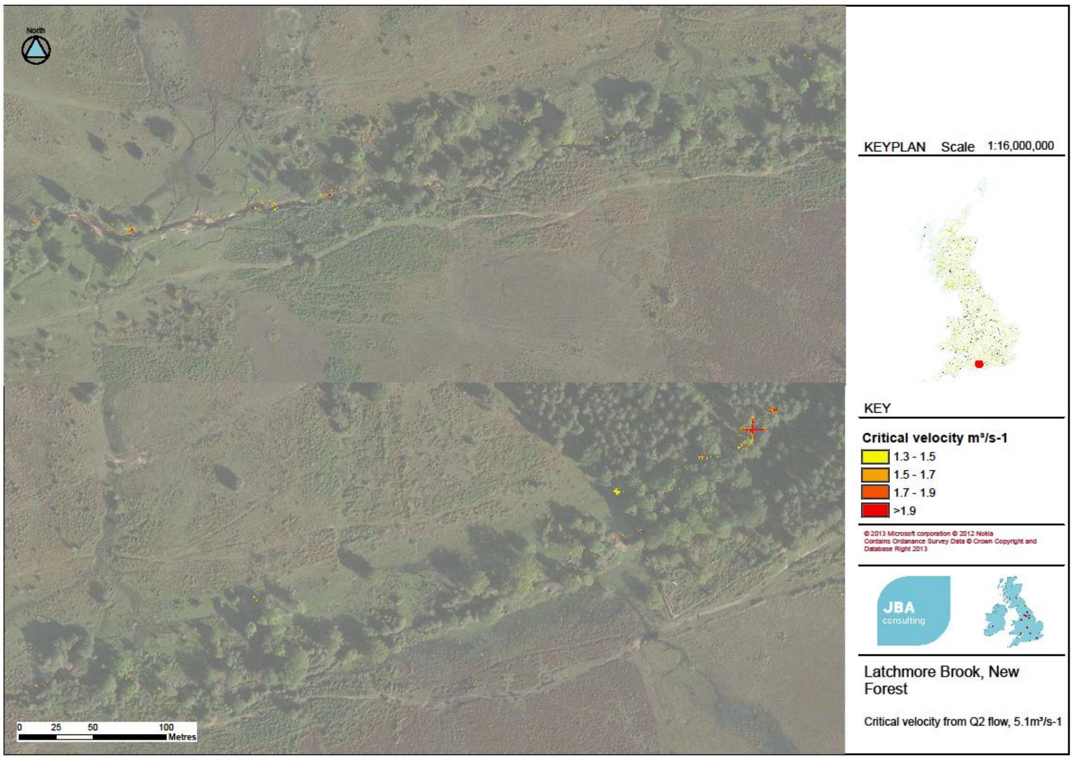


Figure 4-6: Plot of shear stress distribution for the 2 year return period flow along the current Latchmore Brook

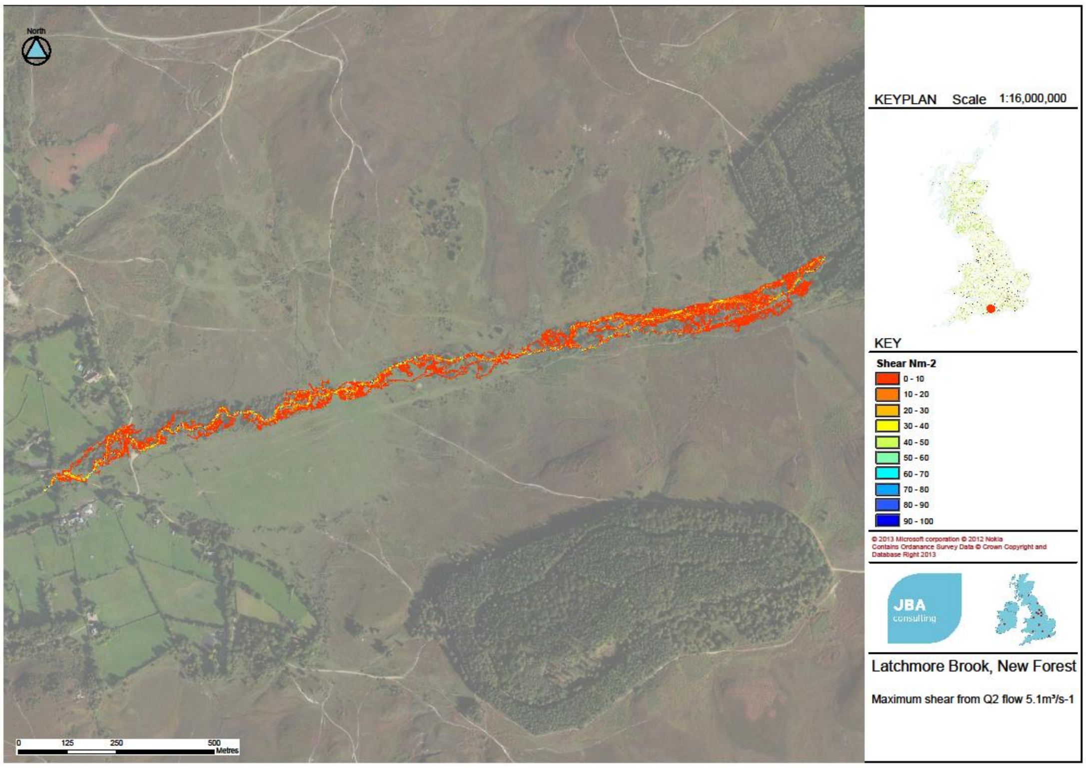
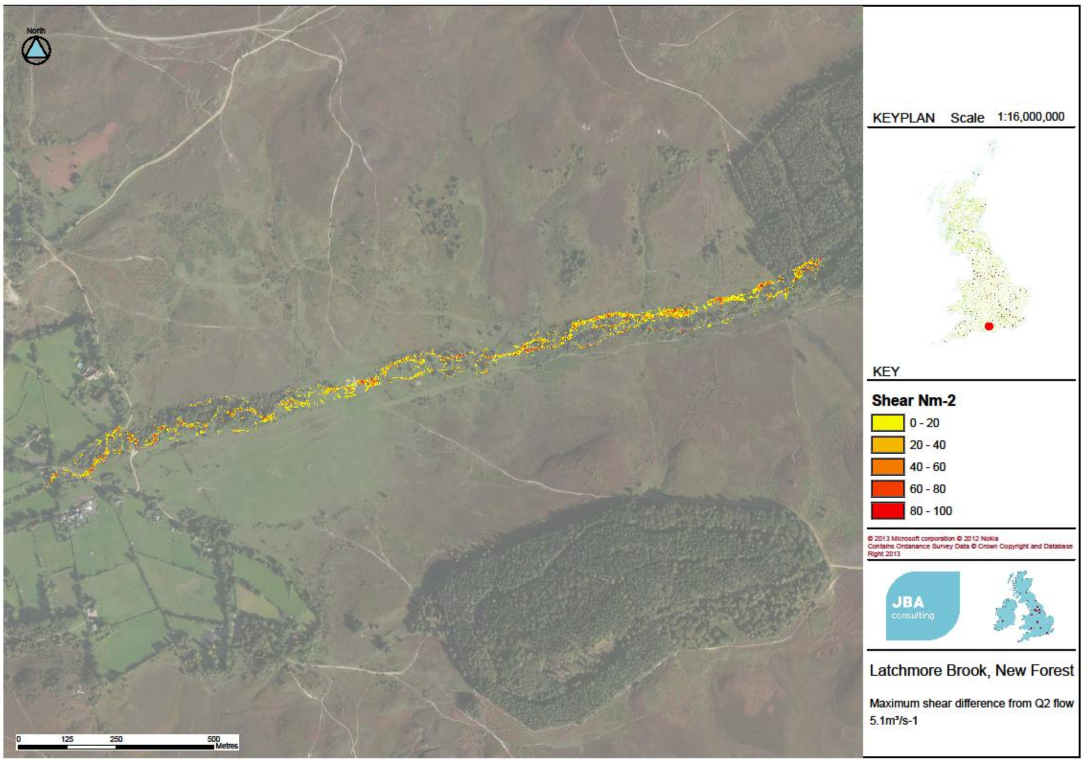


Figure 4-7: Plot of critical shear stress sites for the 2 year return period flow along the current Latchmore Brook



4.4 Hydraulic character of a re-meandered channel

The Forestry Commission re-meandered channel route was stamped into the DEM of Latchmore Brook and the current straightened channel infilled. The JFlow model was run using the 2 year return period flow simulated hydrograph (Figure 4-1) using this modified DEM of Latchmore Brook. Hydraulic outputs of flow depth and velocity were recorded and these data were converted to shear stress using the duBoys equation. Plots of velocity, critical velocity highlighting areas susceptible to bank erosion, shear stress and critical shear stress for gravel movement are illustrated below in figures 4-8 to 4-11.

Figure 4-8: Plot of velocity distribution for the 2 year return period flow along the re-meandered Latchmore Brook

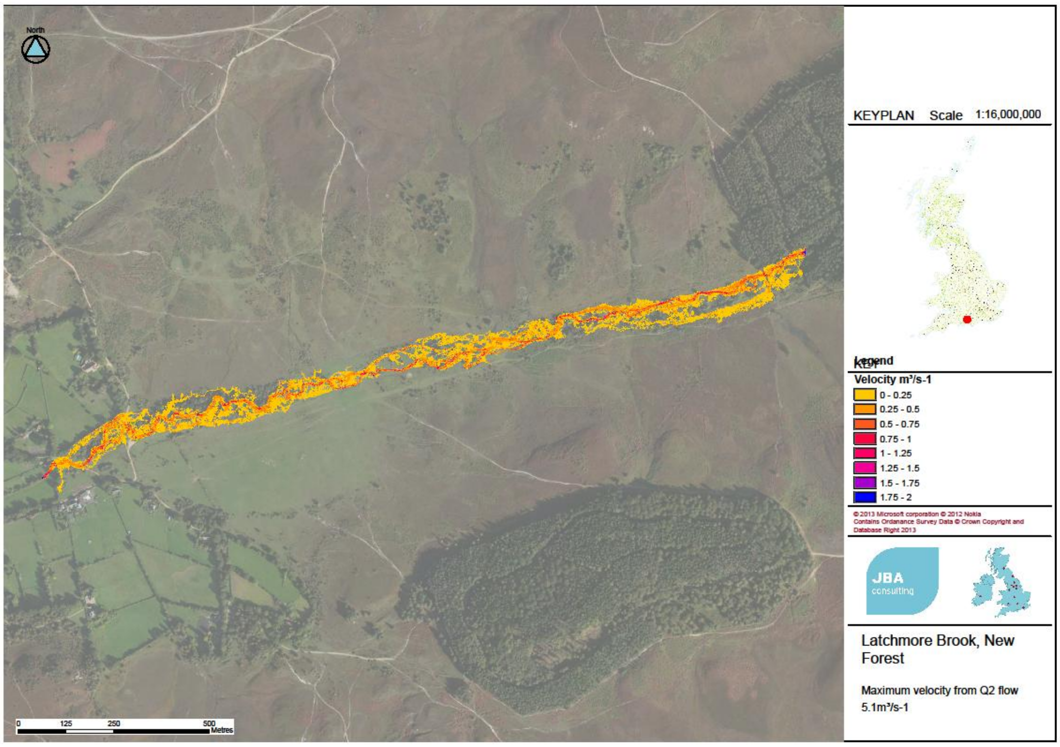


Figure 4-9a: Plot of critical velocity sites for the 2 year return period flow along the re-meandered Latchmore Brook

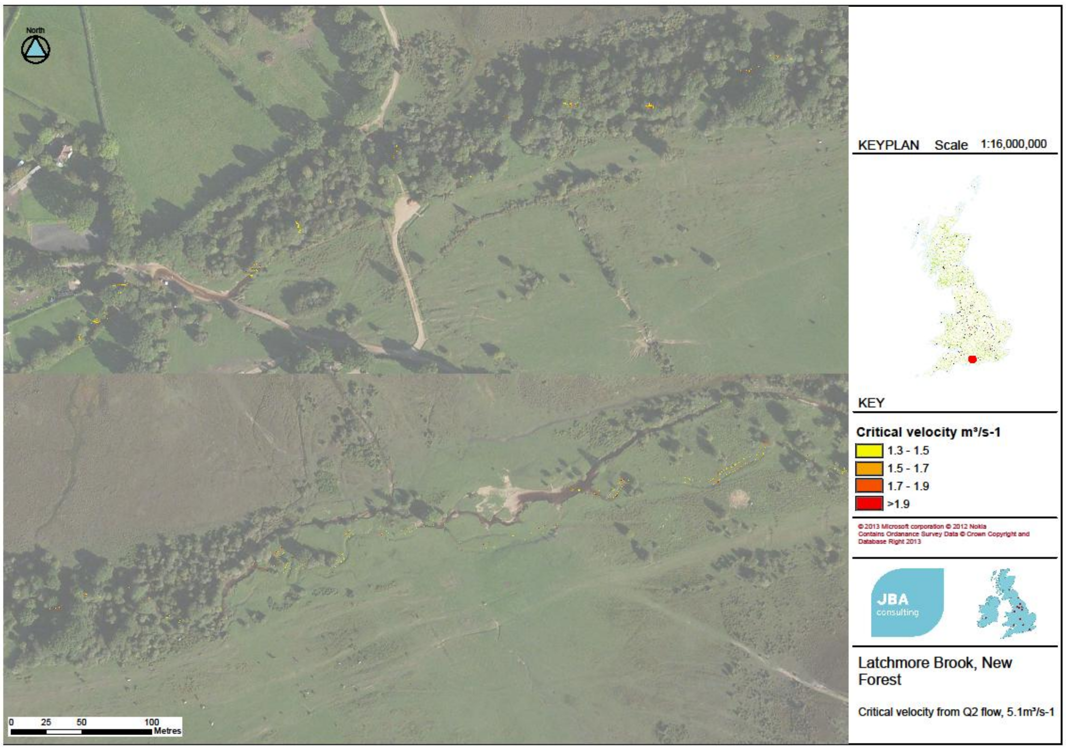


Figure 4-9b: Plot of critical velocity sites for the 2 year return period flow along the re-meandered Latchmore Brook

Figure 4-10: Plot of shear stress distribution for the 2 year return period flow along the re-meandered Latchmore Brook

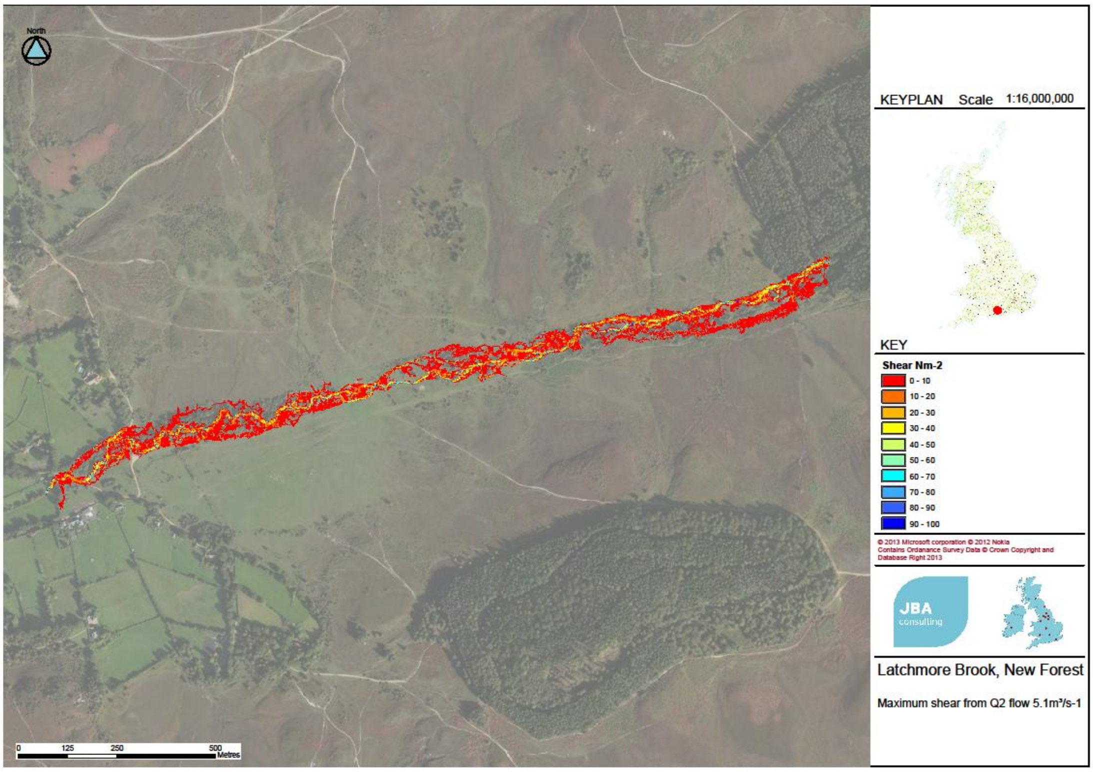
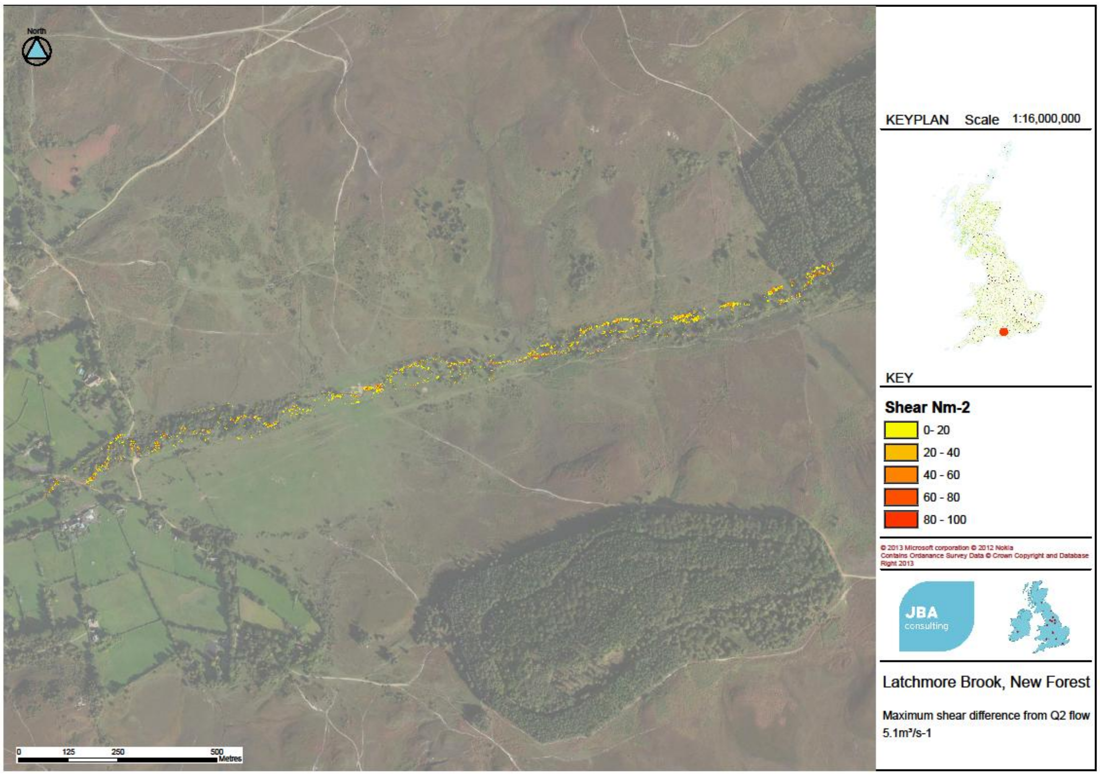


Figure 4-11: Plot of critical shear stress sites for the 2 year return period flow along the re-meandered Latchmore Brook



4.5 Hydraulic character of an anastomosed channel

The proposed naturalising anastomosed channel route created through selective channel blocking was stamped into the DEM of Latchmore Brook. The JFlow model was run using the 2 year return period flow simulated hydrograph (Figure 4-1) using the unmodified DEM of Latchmore Brook. Hydraulic outputs of flow depth and velocity were recorded and these data were converted to shear stress using the duBoys equation. Plots of velocity, critical velocity highlighting areas susceptible to bank erosion, shear stress and critical shear stress for gravel movement are illustrated below in figures 4-12 to 4-15.

Figure 4-12: Plot of velocity distribution for the 2 year return period flow along the naturalising anastomosed Latchmore Brook

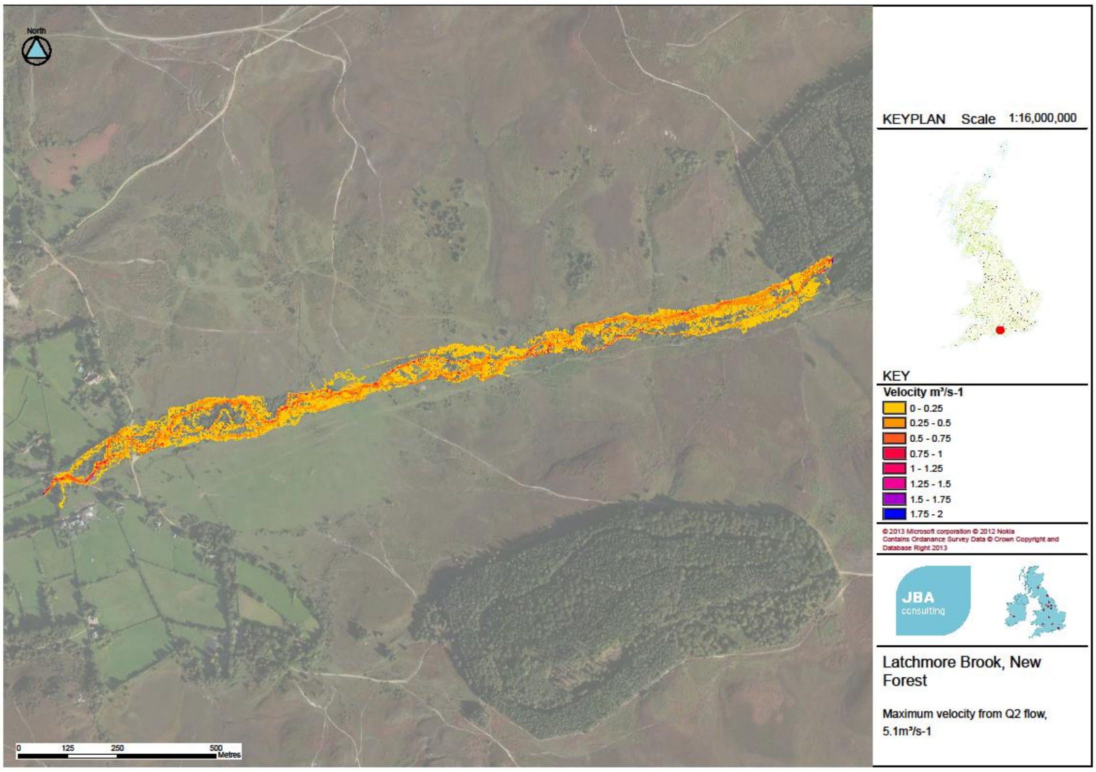


Figure 4-13a: Plot of critical velocity sites for the 2 year return period flow along the naturalising anastomosed Latchmore Brook

Figure 4-13b: Plot of critical velocity sites for the 2 year return period flow along the naturalising anastomosed Latchmore Brook

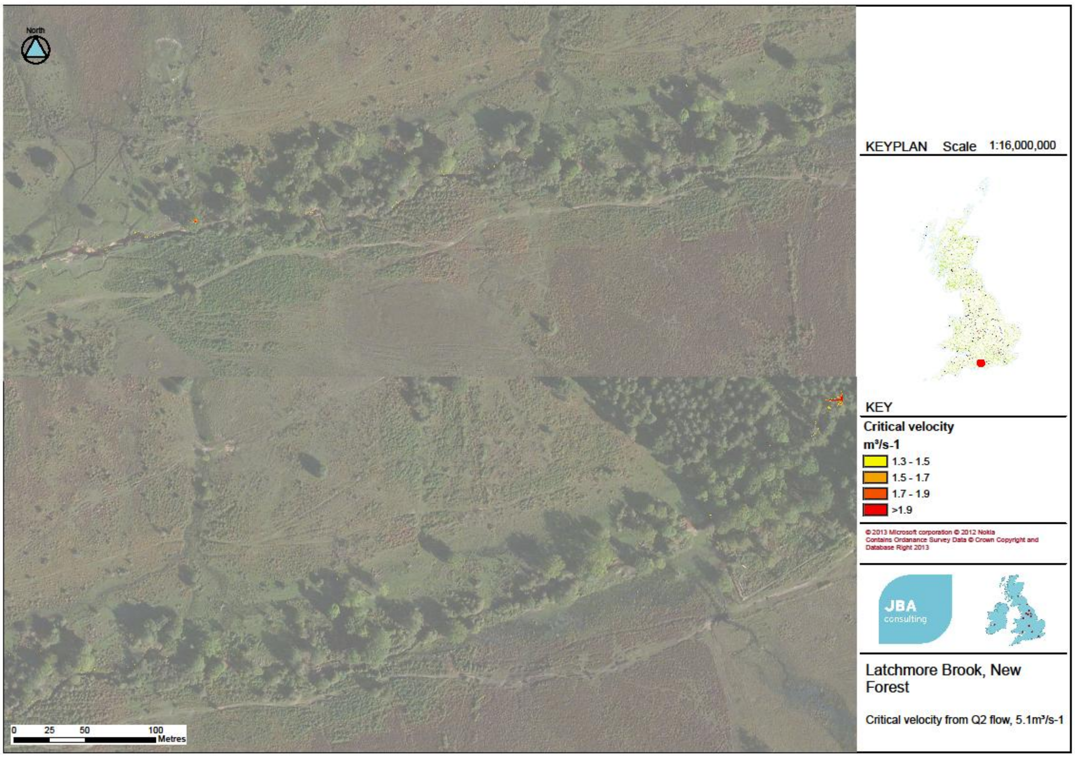
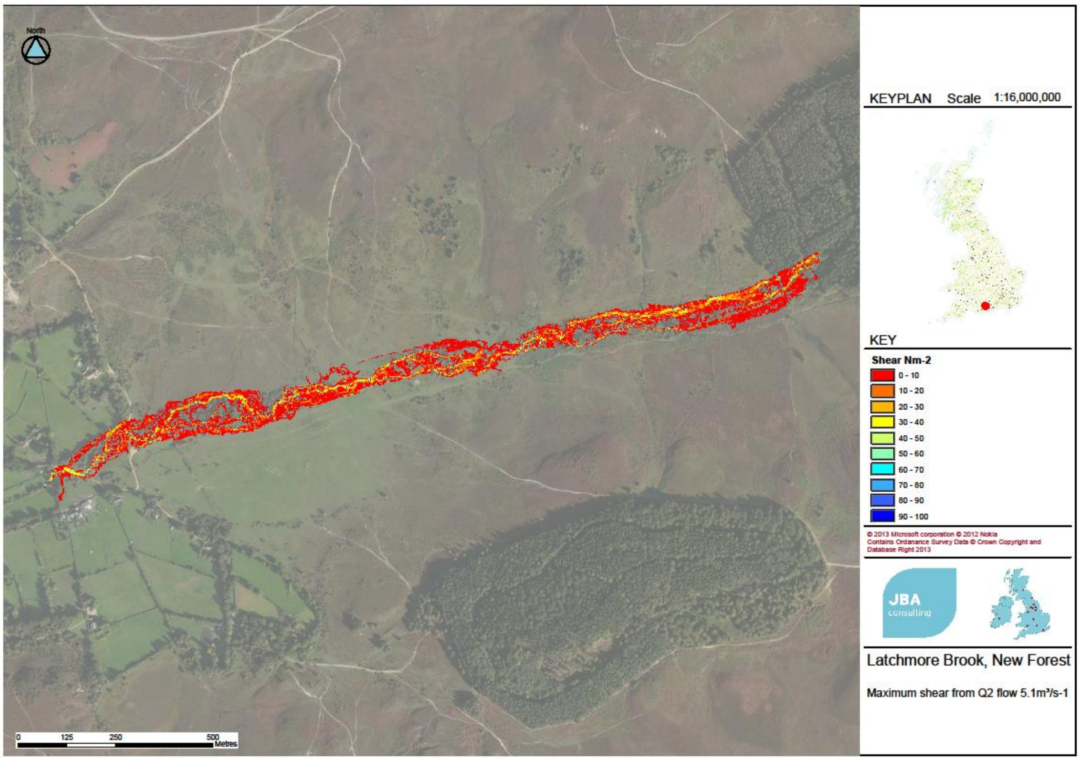


Figure 4-14: Plot of shear stress distribution for the 2 year return period flow along the naturalising anastomosed Latchmore Brook



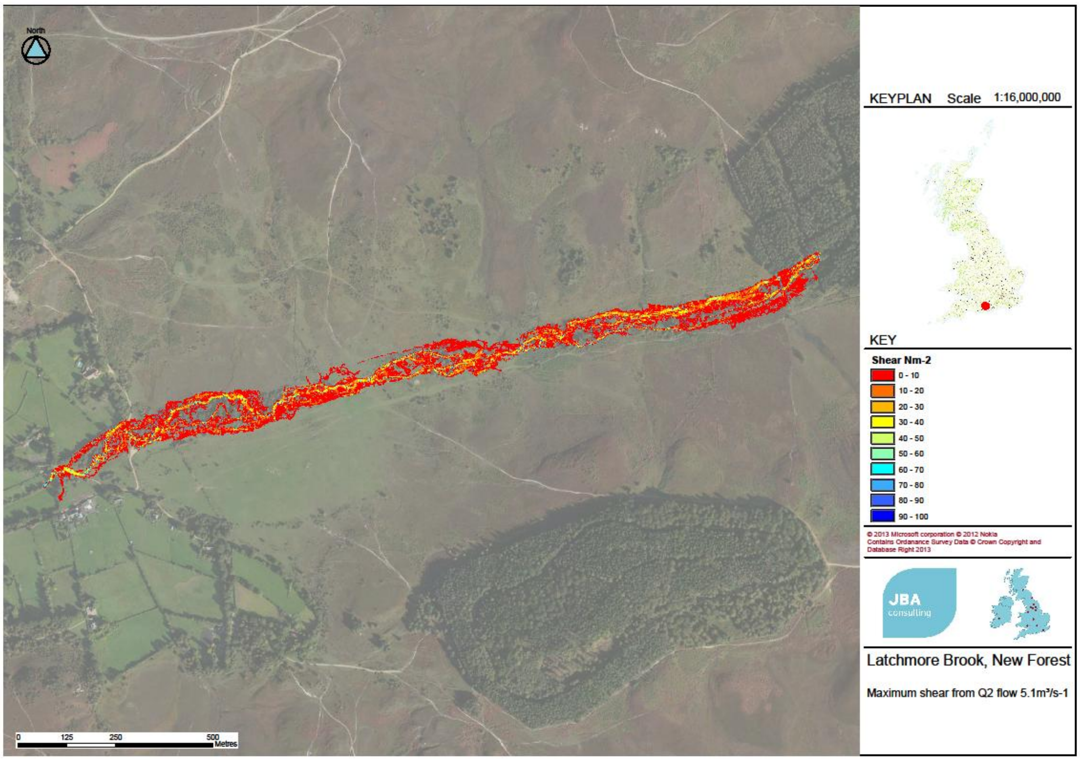
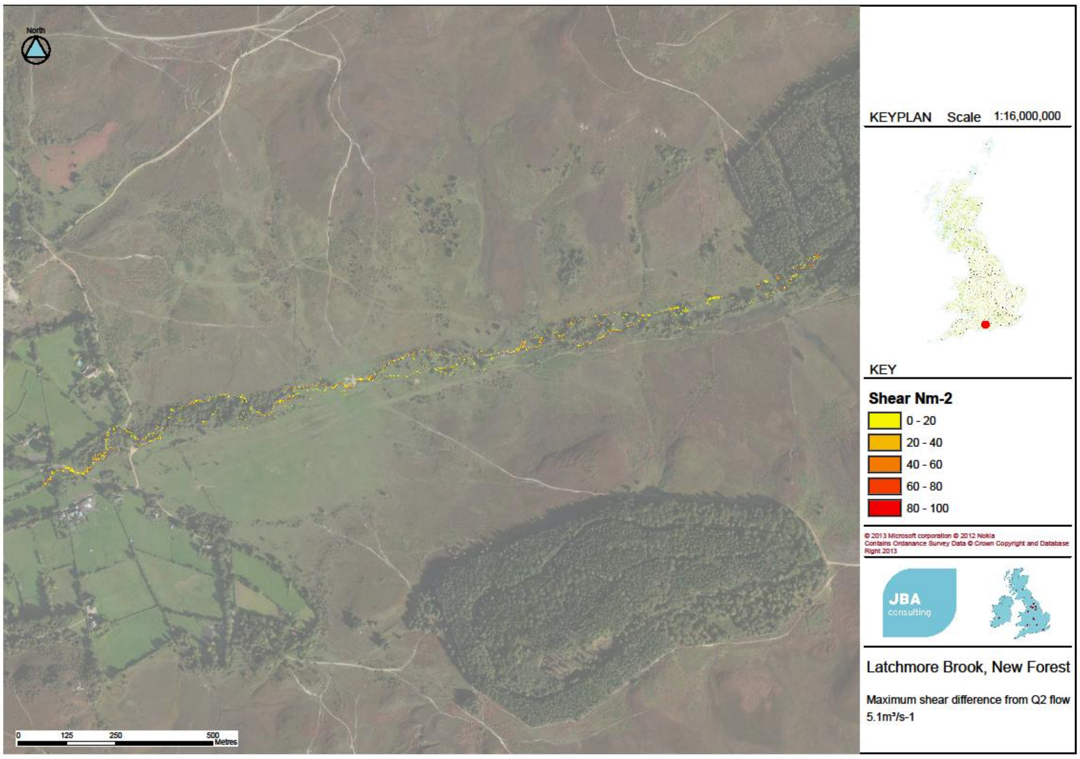


Figure 4-15: Plot of critical shear stress sites for the 2 year return period flow along the naturalising anastomosed Latchmore Brook



4.6 Modelling summary

The modelling approach adopted here utilises good quality LIDAR data within an industry standard 2D flow simulation software package (JFLOW) to generate detailed spatial predictions of flow hydraulics. As such inundation patterns will be reliable. Prediction of shear stress values involves the use of the duBoys equation which is a simplification of more complex hydraulic conditions. As such the patterns of stress levels may be relied upon but the magnitudes may be in error. This will impact on the potential instability predictions and the mapped zones should be taken as indicative only.

The two year return period flow is energetic enough to mobilise gravels and to initiate bank erosion at a number of points along the present channel (Figure 4-5 and 4-7). This is in line with observations during the field survey where bank erosion and loose gravels were noted along the SSSI reach. It is also to be expected in an energetic system. The variably incised nature of the straightened channel is concentrating high flows, restricting floodplain inundation and heightening the potential for erosion. This effect is apparent when the velocity and shear stress values for the present channel (Figure 4-4 and 4-6) are compared with those modelled in the anastomosing channel option (Figure 4-12 and 4-14). Flow in the northern palaeo-channel is strong (Figure 4-6) suggesting a strong connectivity with this portion of the floodplain.

Re-meandering the channel coupled with channel infilling creates a significantly different flow pattern during the 2 year return period discharge (Figure 4-8). In-channel velocity and shear stress predictions remain quite high and sediment mobilisation is predicted for long lengths of the restored channel (Figure 4-9 and 4-11). This will maintain sediment continuity with the downstream reach. Cohesive banks and those protected by live woody vegetation should remain generally resistant to erosion (Figure 4-9). It should be noted that the degree of change to the flow hydraulics will be dependent on the depth of excavation of the new channel with inundation extent and frequency reducing with increasing excavated channel depth.

Naturalising the channel using selective channel blocking at likely avulsion sites generates a more varied pattern of flow for the 2 year return period discharge (Figure 4-12) with increased floodplain inundation and palaeo-channel activation and slightly reduced overall velocity and shear stress predictions (Figure 4-12 and 4-14). These lowered values are reflected in a more stable overall channel pattern although there are several zones of gravel transport predicted (Figure 4-13 and 4-15). This will maintain sediment continuity with the downstream reach.

5 Conclusions

5.1.1 Latchmore Brook

It would appear from historic evidence that the natural channel style prior to historic channel engineering, floodplain modification and altered land management practices was one of a stable, multi thread, shallow anastomosing system with frequent floodplain inundation and changes to the channel pattern but little overall erosion. Aerial photograph evidence (Figure 2-12) also suggests that if left undisturbed, floodplain wet woodland with an associated anastomosed channel network would develop. This system has, however, suffered historic disruption and continued land management which is largely preventing significant recovery. Modelling of the present situation and potential meandered and anastomosed channel configurations suggests that the current channel is energetic and is actively evolving as is evidenced by frequent local bank erosion and the development of in-channel gravel features. The system is presently in a low intensity cut and fill cycle, resulting in a fluctuating hydromorphology and a long-term variable water table. This medium term dynamism, coupled with land management practices, is leading to a degraded ecology with little prospect of recovery to a near natural state.

Re-meandering or selective channel blocking to encourage anastomosing results in a moderately energetic channel network with gravel mobilisation predicted for channel forming flows (approximated by the 2 year return period). The anastomosing approach results in a wider level of floodplain and associated palaeo-channel activation and retains some flow and hydraulic habitat value in the straightened channel.

The opportunities and constraints associated to the re-meandering and channel blocking approaches are provided in the table below.

Table 5-1: Opportunities and constraints associated to preferred restoration options

Restoration approach	Opportunities	Constraints
Re-meandering	Sediment mobilisation will continue - maintaining continuity with downstream reach. Cohesive and wooded banks will remain generally resistant to erosion. Floodplain inundation will be increased. Increased sinuosity will generate greater in-channel hydraulic variation.	Construction costs will be higher due to machinery requirements and the degree of channel infilling. Short term damage to surrounding habitats will he higher using this approach due to the degree of works required. Less impact on diversity of the flow regime compared to the channel blocking method. Velocities and shear stresses remain higher than the channel blocking approach, providing less stable channel conditions. Channel infilling will destroy extant habitats.
Channel blocking	More varied flow patterns and dynamics. Increased floodplain inundation and palaeo channel activation. Lower velocities and shear stresses compared to re-meandering approach, although some section will still transport gravel to downstream reaches. Lower constructions costs and less channel infilling and machinery required. Lower risk of damage to surrounding habitats. Retains some backwater habitat where existing main channel areas remain unfilled.	Erosion can still be expected with this approach. Limited isolated backwater areas may trap fish after floods. Risk of reactivation of straightened reaches if incorrectly designed

5.1.2 Tributary and feeder drains

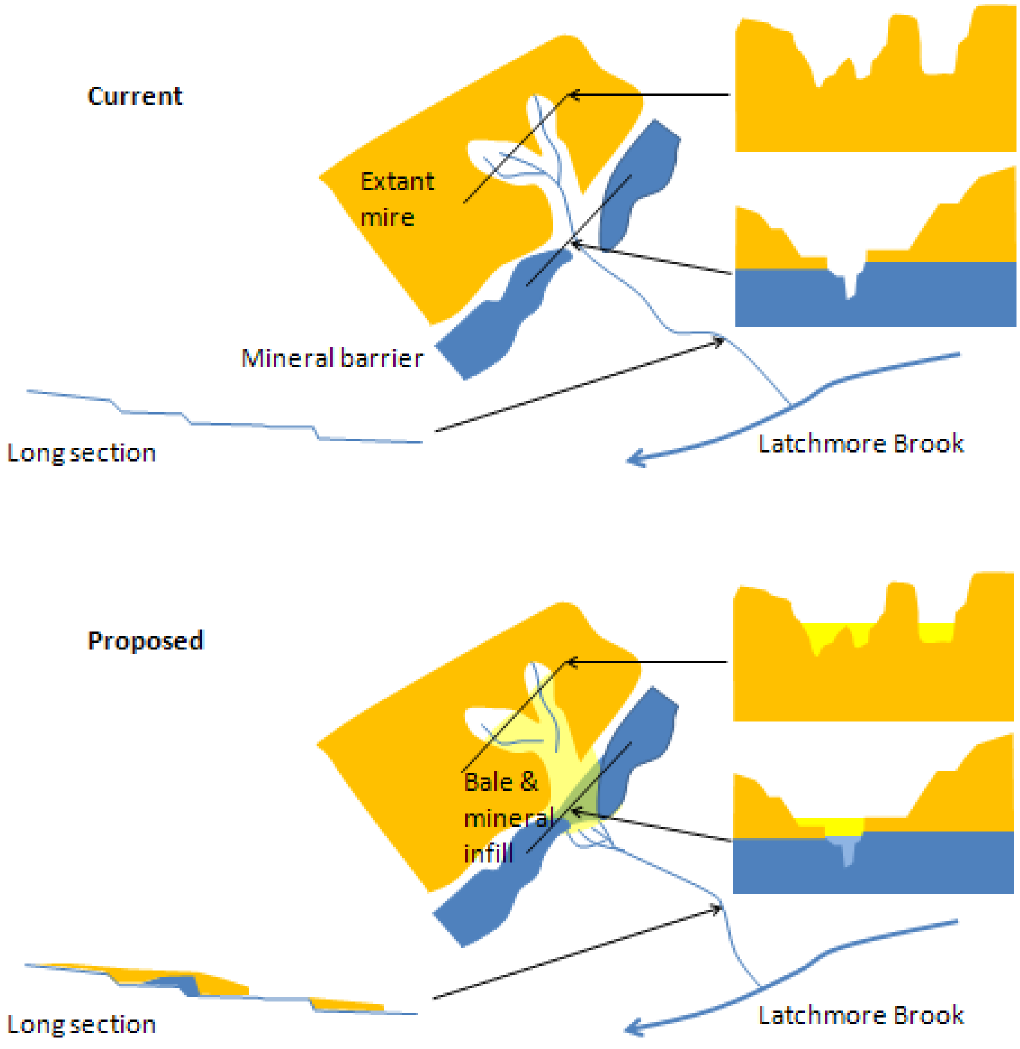
Five significant watercourses enter the Latchmore Brook from the north associated with the mire catchments of Thompson's Castle, Latchmore Mire and Watergreen Bottom. Three of these systems presently exhibit significant instability and are severely incised with a number of active knick points moving up the watercourses. Several of these knick points are eroding into mire areas leading to destruction of these habitats. These instability points must be controlled to avoid further degradation, to control the delivery of mixed sediment to the Brook and to prevent damage to the mire systems.

Heather bale dams have been tried previously (Figure 5-1) but have failed progressively due to undercutting and outflanking in these steep high energy systems. As such similar approaches should be avoided as they are unsustainable here. Successful sensitive restoration on such high energy systems has not been reported.

It is suggested that an alternative design be considered that mimics the naturally stable seepage mire transitions zones present elsewhere. Breaches in glacially derived mineral barriers extending across the area to the north of the river should be repaired to recreate the lower energy peat forming conditions behind the obstruction. Flows exiting past the barrier are naturally diffuse with the majority of the discharge occurring as throughflow. This should be mimicked with the upstream section and upper layer of the breach repair unfilled with heather bales to encourage internal flow and occasional diffuse surface flow. This is summarised in Figure 4-17.

Figure 5-1: Failed heather bale dam on steep tributary of Latchmore Brook

Figure 5-2: Proposed restoration for breached mineral barrier sites



Control of knick points along the incised lower reaches where the channel flows through mineral deposits is equally problematic and requires alternative techniques to staked heather bales used previously. Complete or substantive channel infilling with an organic porous base and mineral top layer could be attempted in the most severely eroding reaches. This would be a radical approach and requires detailed design which is outside of the scope of this report.

5.2 Restored channel monitoring requirements

It is anticipated that the proposed restoration works will create a dynamic, channel network with some anastomosed sections and improved floodplain connectivity. Overbank flooding frequency will be heightened and there will be increased potential for local channel switching in response to natural debris blocking. This pattern of development is difficult to document accurately due to the complex nature of the river network and the difficult surveying conditions. As such a qualitative monitoring approach is recommended with automated time lapse photography employed at key restoration points to record daily images of flow types, morphology and vegetation character. This could be undertaken alongside two-yearly reconnaissance audits to determine hydromorphological change over the entire reach, which fixed point photography will not cover. The daily photographic records should be analysed to estimate and record the parameters detailed in Table 5-2.

Table 5-2: Monitoring parameters, frequency and suggested approaches for Latchmore Brook

Parameter	Approach	Frequency
Morphologic unit change	Time lapse camera / audit	Daily (Annual statistical summary)
Flow change	Time lapse camera / audit	Daily (Annual statistical summary)
Sedimentology	Time lapse camera / audit	Daily (Annual statistical summary)
Vegetation change	Fixed point camera survey	Biennially
	Fixed point quadrat survey	Biennially
	Fixed point aquatic macrophyte survey	

Appendices

A Appendix - Forestry Commission Restoration Plan for Latchmore Brook

UNIT NAMES: Latchmore Shade (part), Watergreen Bottom
UNIT NUMBERS: 48 (part), 49
LOCATION: East of Frogham, New Forest.
GRID REFERENCE: SU19421270
SITE ACCESS: Site access can be either via gravel tracks through Alderhill Inclosure to the east, or the public road to Ogdens to the west.
PUBLIC CAR PARKS: Ogdens and Fritham (FC), Abbotswell (HCC).

A.1 Where it is

The Latchmore Brook and associated mire systems are on the Open Forest, to the south of the Hampton Ridge. The site is approximately 1km east of the public car parks at Ogdens and Abbotstwell. The Latchmore Brook arises in Howen Bottom and Claypits Bottom to the north east, flowing through Island Thorns, Amberwood and Alderhill Inclosures before emerging again onto the Open Forest at Latchmore. The site as a whole includes the mire catchments of Thompson's Castle, Latchmore Mire and Watergreen Bottom, whilst the Latchmore Shade SSSI unit (along the watercourse itself) includes wet heath and lawn habitats. The Latchmore Brook flows in a straightened deepened drain channel for approximately two thirds of its length across Latchmore Bottom, before leaving the western edge of the Open Forest at Ogdens.

A.2 Why it's a problem

These SSSI units are in unfavourable recovering condition having been adversely impacted by artificial drainage, which is causing increased erosion within the mire systems, wet heath and grassland habitats. As a result of the artificially deepened and straightened Latchmore Brook, there is increased erosion of the river bed and limited channel habitat diversity, as well as limited seasonal inundation of the surrounding grassland habitats and therefore an inconsistent interaction with the floodplain, with the effect that these adjacent habitats are negatively affected.

A.3 What needs to be done to restore it

This site has been divided into two sections; it was intended that the downstream section was restored in 2011, with the upstream stretch being restored in 2012. Due to budgetary constraints, the downstream section was not restored in 2011 – as a result, the entire site will be restored in 2012. As approval has already been given for the downstream section (FDC Reference: ADA 4763), this restoration plan relates specifically to the upstream stretch.

The meander restoration will begin just inside Alderhill Inclosure at SU19811286, where the meander route is evident to the north of the existing channel. Levels will be taken from approximately 50m upstream and graded in to the original meander bed level. The original meander course occupies the lowest point in the floodplain, to the north of the existing drain channel, for the entirety of this upstream section of the Latchmore site. It runs through wet grassland, with areas of both scattered and dense scrub and collapsed willow. At the downstream end of this upstream section at SU19141266, the restored meander will cross the existing drain line and link into the start of the downstream section. Once the meandering course has been restored, the redundant drain channel will be infilled.

There is a short stretch of localised erosion within the Watergreen Bottom SSSI unit, where the water flowing out of the mire drops into a deeply incised channel for approximately 25m. This will be partially infilled with hoggin and heather bales to create a shallower vegetated channel, to support the mire. Where evident, spoil heaps will be levelled and the material used as infill.

There is a gravel ford at SU19771280, which crosses the existing drain channel beside the Inclosure fenceline. Either side of the existing channel there is soft ground, which to the south in particular, is a significant barrier to operational and recreational access. The gravel ford will be relocated to the line of the restored meander course, and the approach to the junction with the driftway at SU19791274 made good.

A.4 Sensitivities

A.4.1 Public Access

This area is very popular with both locals and visitors during the summer, with public car parks at Ogdens and Abbotstwell only 1km to the west. A National Cycle Network route runs from Fritham through the Inclosures and across Hampton Ridge.

Despite a number of on site talks and guided walks in the local area, some members of the local community remain strongly opposed to the work being undertaken. Their concerns are that they feel that they, as a local community, have not been consulted on whether the work should take place, and that they cannot accept that the wetland restoration work being undertaken (both at this site and others across the Forest as a whole) is of benefit to either wildlife or recreational forest users. Demonstrations of support for the Forestry Commission's wetland restoration work on this site and elsewhere in the Forest by Natural England, the National Park Authority, the New Forest Association, the Hampshire and Isle of Wight Wildlife Trust, the Verderers and the Commoners Defence Association (in person, in response to correspondence and in the local press), have not changed the opinion of this group of campaigners. Therefore, with the ongoing support of the statutory agencies and partner organisations, Forestry Commission are still intending to undertake the restoration of this watercourse and associated mires this summer. Public awareness of the works and access will be managed using interpretation and signage at car parks and on the approaches of well-used routes, and the Parish Council will be kept informed. It will be the contractor's obligation to provide and erect on-site safety signage.
Contact: Jane Smith (FC Head of Environment and Planning), Richard Daponte (FC Recreation Ranger)

A.4.2 Vehicular Access

The locations of the stockpile areas close to Ogdens car park and just inside Alderhill Inclosure mean that the lawns along the edge of the Latchmore Brook will have numerous vehicle passes. Where necessary, the watercourse will be crossed either using culvert pipes, or via existing fording points (only occasionally under low flow conditions). The impact on the lawns will be carefully monitored, particularly in relation to wet weather working.
Contact: FC Forest Works Manager to liaise with contractor

A.4.3 Archaeology

There are a number of sites of archaeological interest recorded in the area. A walkover archaeological survey has been undertaken, covering a 25m wide corridor centred on the existing artificial channels, intended meander routes, proposed machinery access routes and materials storage areas. Machinery access routes will be amended accordingly to ensure that vulnerable features (ie bee gardens) are not affected by the works; any enclosure banks will only be crossed at existing breaches.

The Principal Contractor undertaking the restoration work (Alaska Environmental Contracting Ltd) will be made aware of any archaeological constraints before works on site commence. Any sensitive areas will be clearly marked on the ground before any groundworks start, to prevent accidental damage.
Contacts: Contractor (AC Archaeology), Frank Green (National Park Authority).

A.4.4 Ordnance

Latchmore is situated within what was formerly Practice Target Area of the Ashley Walk Bombing Range, active from 1940 to 1946. Evidence indicates that there is still ordnance present, and therefore suitably qualified contractors have been engaged to safely locate, clear and dispose of any remaining ordnance prior to Alaska commencing restoration works in the area. However, it will not be possible to check all areas (eg areas of deep water along the watercourse) before groundworks commence, and therefore ongoing liaison between Alaska and EOD Contracts Ltd will be needed in order to utilise watching briefs, as required. All staff will be given a toolkit talk before being allowed to work on the site.
Contacts: Andy Hill (Alaska), Shane Meaker (EOD Contracts Ltd)

A.4.5 Commoning

The quality of the lawn habitat will be improved by the removal of the colonising trees and scrub, and a raised water table will reduce the density of bracken in some areas. All flows coming off the mire will be linked into the restored meander route.
Contact: Richard Stride (CDA)

A.4.6 Invertebrates

Southern damselfly and scarce blue-tailed damselfly are present in and around the channels flowing off the mire at Gypsy Hollies and Lay Gutter Valley. These should not be directly affected by the works, but the populations will be monitored and maintenance of side drain linkages will be managed carefully in this area, with guidance from a local expert.

There is an area of floodplain grassland that has a high density of anthills. These will not be affected by the main access routes, and vehicular movement within the area they occupy will be kept to a minimum. The importance of minimising damage and disturbance in this area will be emphasised to all machine operators working on site. It is unknown whether increased inundation will affect their range locally, but this is a common species that is not under threat, and therefore further mitigation for this feature is not required.

Bed material will be recovered from the existing drainage channel bottom and dispersed along the restored meanders, to help the recolonisation process for invertebrate fauna.
Contacts: Sarah Oakley (Ecologist), Derek Jenkins.

A.4.7 Fish

The work will be undertaken during the summer months, to minimise the impact on migratory fish (sea trout). Fish rescue will be undertaken by the Environment Agency’s Fisheries team immediately prior to the commencement of works.

The Latchmore Brook is one of the survey sites being monitored by Southampton University, to look at the effect of stream restoration on the number and variety of fish species present.

Bed material will be recovered from the existing drainage channel bottom and dispersed along the restored meanders, to mitigate for spawning habitat loss. This will also help the recolonisation process for invertebrate fauna.
Contact: Environment Agency, Prof Terry Langford (Southampton University)

A.4.8 Birds

Tree felling will be undertaken outwith the breeding season. The potential impact of the works on any sensitive sites in the area will be reviewed with the local Keeper before work commences. The clearance of colonising scrub and young trees will increase potential wader habitat and reduce vantage points for corvids.

A kingfisher survey has been undertaken for this stretch, in advance of the tree felling work. Whilst kingfishers may use this area to feed, no active nest sites were evident (in part due to the encroaching scrub and bankside vegetation). Suitable nesting habitat is available both up and downstream.
Contact: Andy Page (Head Keeper), Dr Manuel Hinge (kingfisher specialist)

A.5 PROGRAMME OF WORKS

Start: SU19811286
End: SU19141266

A.5.9 Site Clearance

Sufficient trees and scrub have been felled and cleared along the routes of the drain to be infilled and the meanders to be reinstated to facilitate working and access. The majority of this consisted of mostly alder and willow along the line of the drain and on spoil heaps. Further felling to clear scattered gorse, thorn scrub and young oaks that have colonised the lawns beside the meanders will be undertaken in late summer, once the restoration work is complete. A felling licence for the above works was obtained in December 2010. All trees to be felled have been spot-marked by Forestry Commission staff. All felling work will be carried out by chainsaw to minimise ground disturbance, and undertaken outwith the bird breeding season.

A.5.10 Restoration of the natural stream course and bed level raising of mire channel

Approximately 790m of restored meander will replace 750m of artificial drain along this section of the site. The existing bed level will be graded for approximately 30m in total, upstream of the meanders (within Alderhill Inclosure). In addition, the bed level of 25m of eroded drainage channel flowing out of Watergreen Bottom mire will be raised, using staked heather bales.

Due to its earlier history as part of the Ashley Walk Bombing Range, ordnance survey and disposal has been undertaken along the lines of existing drains, intended meander routes, proposed machinery access routes and materials storage areas. Whilst every effort has been made to make the site accessible for restoration works, it has not been possible to check all areas (eg within the watercourse itself during winter flows). As vegetation must be removed to facilitate ordnance survey, NO vegetation over 20cm high is to be driven over, as it will have not been checked for ordnance. Regular, clear communication between Alaska and EOD Contracts Ltd is therefore essential. All staff will be given a toolkit talk before being allowed to work on the site. In some areas, watching briefs will be used to survey areas in conjunction with Alaska's machine operators.

The work should be undertaken in the following order. These numbers are cross-referenced on attached map 'Latchmore Restoration Plan 2012'. The techniques used will follow the guidelines set out in Method Statements 1-5.

- The meander route to be restored will follow the contours of the visible meanders, where evident. The route will be clearly marked out in advance, and will require careful excavation to restore the original channel dimensions. Prepare the meanders along the length of the site (refer to Method Statement 1 – Meander excavation). The linkage to the existing straightened channel upstream (within Alderhill Inclosure) should be left unexcavated until the meander preparation has been completed.
- The transition from the deeper existing channel upstream will require bed level raising to create a steady gradient into the first meander, starting from approximately 30m upstream of the first meander (refer to Method Statements 2 and 3 – Partial drain infill and Crossing drains using clay plugs).

- At the downstream end of this section of the Latchmore Brook restoration, at SU19141266, the restored meander will cross the existing drain line and link into the start of the downstream section (refer to Method Statements 2 and 3 – Partial drain infill and Crossing drains using clay plugs). There are a number of side drain linkages coming across from the mire catchments to the north. These will need to be brought across to the restored meander route, and graded in to the restored meander bed level. Refer to Method Statement 2 – Partial drain infill.
- The short stretch of localised erosion within the mire system of Watergreen Bottom will require bed level raising using staked heather bales.
- Carefully remove the existing vegetation on the line of the channel and temporarily store adjacent to it, maintaining the surface layer for final habitat reinstatement. Excavate any loose material and square off the section of drain channel to be partially infilled. Infill will be achieved using a layer of compacted hoggin topped with staked heather bales, with the retained mire vegetation reinstated over the top. (Refer to Method Statement 5 – Drain infill using heather bales.)
- The ford at SU19771280 is to be relocated to the line of the restored meander course, and constructed as a gravel ford crossing sided up with oak boards. The approaches will be made good, and the flows from Watergreen Bottom linked in.
- Once the meander route is fully prepared, the water can be diverted from the drain channel into the first meander. Bed material must be recovered from the existing straightened channel bottom, and dispersed along the restored meanders, prior to drain infill. Any significant amounts of water remaining in the straightened channel will be required to be pumped out to provide a dry working environment for the completion of ordnance survey checks and subsequent drain infill.
- The straightened channel should then be infilled (see Method Statement 4 – Drain infill). Excavate any loose material and square off the section of drain channel to be infilled. Infill will be achieved using hoggin, held in position with clay plugs at periodic intervals. Spoil heaps resulting from the straightened channel creation and subsequent dredging operations will be levelled and the material used as drain infill and surface dressing. This will be surface dressed with any stored excavated material and the retained vegetation, up to the level of the surrounding ground.

Activity: Excavation/clearing out of natural meanders and excavation of new sections of meander to redirect existing water flow (including vegetation translocation)	Method Statement No: 1
Location: From SU19811286 downstream to SU19141266 (790m in total)	

Risks: Overturning of plant machinery, crush injuries, collapse of earth banks, falling trees and branches, collision with other plant machines, pollution to watercourse, machine strike to persons, insect bites and allergic reactions, snake bites, manual handling.

General Method of Work :
Client and Principal Contractor to identify area of works.
Check line of works for any trees to be removed, branches cut back etc. to ensure safe passage for machine.
NO vegetation over 20cm high to be driven over due to ordnance survey constraints.
Carefully remove existing overburden/organic material on the line of the natural channel, taking particular care with turf on lawn habitats. Temporarily store adjacent to the drain to be infilled, maintaining the surface layer for final habitat reinstatement.
Excavate/scrape down to the old riverbed using a 360o hydraulic excavator.
The level of excavation should be indicated by an existing gravel layer. The depth of excavation will vary due to the old meander bed level rising and falling.
This method will be used along the whole length of the meander excavation.
Prior to meander excavation, the planform and channel profile will be marked out and discussed, and levels will be marked out on site.
Once the meanders have been excavated, the section of bank on the upstream point of the meander will be removed to divert the river flow.
The existing bed level upstream will be graded in to match the new levels on the old excavated meander.
Immediately prior to diversion of flow to this channel, excavate some of the gravel bed from drain and place in this channel (mitigation for fauna present in gravels).

Control Measures or Modifications
No smoking in works area.
If any tree felling/vegetation clearance is required, site manager to contact ordnance contractor.
All re-fuelling will take place at least 20m away from the watercourse, next to the fuel bowser.
Be vigilant for members of public / pets / stock / wild animals entering works area.
Be aware that there are snakes and ticks in this part of the forest. Take care when walking to and from machines (make site management aware of risks - disease (ie Lymes) & allergic reactions).
Ensure bucket is lowered to the ground when machine is not in use.
When visitors are on site, stop work & lower bucket to ground if they enter the works safety area.
If working with a Banksman ensure that he is in a position where you can see him.
Beware of machine blind spots when slewing and turning, especially with regard to tree branches
Be aware of any taped off areas/sites that will be of conservation, archaeological or other special interest. Do not enter these areas with any machinery.
Sediment control: Use heather bale dams at strategic intervals to filter coarse sediments. Pollution and silt booms to be erected at the downstream end of the works.
All operators to be competent and certificated on the machines they operate.
All incidents relating to safety or pollution of any kind are to be reported to Forestry Commission as soon as it is safe to do so.
All staff and visitors to wear the appropriate PPE for the site conditions they encounter.

Plant and Equipment Used:
Hydraulic excavators, 13 tonne size, steel tracked with a selection of buckets. 13 tonne excavator for loading the 8 tonne tracked dumpers. Chainsaws and hand saws as required to clear trees and branches. 5-7 tonne excavator available for some works in very tight sections.

Activity: Bed level raising (partial infill) of drainage channel	Method Statement No: 2
Location: At the upstream transition into the meander course, within Alderhill Inclosure, starting at SU19851287 (for approximately 30m).	
Risks: Overturning of plant machinery, crush injuries, collapse of earth banks, falling trees and branches, collision with other plant machines, pollution to watercourse, machine strike to persons, insect bites and allergic reactions, snake bites, manual handling.	
General Method of Work : Client and Principal Contractor to identify area of works. Check line of works for any trees to be removed, branches cut back, stumps to be removed etc. to ensure safe passage for machine. NO vegetation over 20cm high to be driven over due to ordnance survey constraints. In order to ensure a dry working environment, the water will be pumped over between sections of restored meander to enable these stretches of partial infill to be completed. Excavate and set aside some of the gravel bed from the existing drain, to mitigate for potential loss of fauna present in the gravel bed. Bed level raising may be done using hoggin and/or rejects as the infill material. Transport hoggin/rejects using tracked dumpers, from the stockpile area to area of drain that is to be partially infilled. The partial infill of the drain may involve the installation of clay plugs every 10-20 metres. Clay and/or hoggin/rejects are to be built up to the new bed level height (to grade in to match the levels on the restored meanders) in manageable layers, and dynamically compacted using the excavator bucket. Between the clay plugs, the drain will be partially infilled with a combination of imported hoggin (packed down in layers) and rejects. The surface of the hoggin/rejects is to be dressed with the previously rescued bed material and/or vegetation.	
Control Measures or Modifications If any tree felling/vegetation clearance is required, site manager to contact ordnance contractor. Check bank stability before work starts. Do not stand excavator too close to edge of drain. Be aware of any taped off areas/sites that will be of conservation, archaeological or other special interest. Do not enter these areas with any machinery. Be vigilant for members of public / pets / stock / wild animals entering works area. Use a banksman for reversing dumpers to tip areas. Sediment control: Use heather bale dams at strategic intervals to filter coarse sediments. Pollution and silt booms to be erected at the downstream end of the works. Re-fuelling to take place at least 20m from the watercourse. All operators to be competent and certificated on the machines they operate. Be aware that there are snakes and ticks in this part of the forest. Take care when walking to and from machines (make site management aware of risks - disease (ie Lymes) & allergic reactions). All incidents relating to safety or pollution of any kind are to be reported to Forestry Commission as soon as it is safe to do so. No smoking in works area. Fire precautions will be outlined by Forestry Commission site controller. All staff and visitors to wear the appropriate PPE for the site conditions they encounter.	
Plant and Equipment Used: 13 tonne hydraulic excavator, 8 tonne tracked dumpers, chainsaws and hand saws as required.	

Activity: Where the natural meander route meets or crosses a drain, installation of clay plugs to divert flow into the meanders.	Method Statement No : 3
Location: At the downstream end of the site, where the meander route crosses from the northern to the southern side of the existing drain, at SU19141266.	
Risks: Overturning of plant machinery, crush injuries, collapse of earth banks, falling trees and branches, collision with other plant machines, pollution to watercourse, machine strike to persons, insect bites and allergic reactions, snake bites, manual handling.	
General Method of Work : Client and Principal Contractor to identify area of works. Check line of works for any trees to be removed, cut back to ensure safe passage for machine. NO vegetation over 20cm high to be driven over due to ordnance survey constraints. Remove existing overburden/organic material from the natural meanders down to the level of the old streambed using a 360º hydraulic excavator. Store excavated material adjacent to the drain to dress the surface of the infilled drain once redundant. Transport clay from stockpile area to junction of drain and meander route using a tracked dumper Using a 360, insert a clay plug upstream and downstream of the section of stream to be worked on. Position a pump on the upstream side of the clay plug and over pump water, to create a dry working environment. Insert a clay plug in the dry channel at the upstream entry/crossing point of a meander, packing the material down in layers. The face of the plug will be shaped to deflect the flow into the entrance of the natural meander. Should the bed level in the drain require raising to the meander level, hoggin will be placed in the dry channel in manageable layers, & dynamically compacted using an excavator bucket. Downstream of the meander crossing point/where the water leaves a raised bed level section, a second clay plug will be inserted, again packing the material down in layers. The face of the plug will be shaped to deflect the flow into the next meander section. The drain channel upstream of this point will then be completely infilled, as described in the Drain Infill Method Statement.	
Control Measures or Modifications If any tree felling/vegetation clearance is required, site manager to contact ordnance contractor. Be aware of any taped off areas/sites that will be of conservation, archaeological or other special interest. Do not enter these areas with any machinery. Be vigilant for members of public / pets / stock / wild animals entering works area. When visitors are on site, stop work & lower bucket to the ground if they enter works safety area. Check bank stability before work starts. Do not stand excavator too close to edge of drain. Use a banksman for reversing dumpers to tip areas. All operators to be competent and certificated on the machines they operate. Ensure bucket is lowered to the ground when machine is not in use. Check with Site Supervisor on compaction standard of material in first section. Then repeat process on other sections. Sediment control: Use heather bale dams at strategic intervals to filter coarse sediments. Pollution and silt booms to be erected at the downstream end of the works. Re-fuelling to take place at least 20m from the watercourse. All incidents relating to safety or pollution of any kind are to be reported to Forestry Commission as soon as it is safe to do so. Be aware that there are snakes and ticks in this part of the forest. Take care when walking to and from machines (make aware of risks - disease (ie Lymes) & allergic reactions). No smoking in works area. Fire precautions will be outlined by Forestry Commission site controller. All staff and visitors to wear the appropriate PPE for the site conditions they encounter.	
Plant and Equipment Used: 5-7 & 13 tonne hydraulic excavators, 8 tonne tracked dumpers, chainsaws & hand saws as required.	

Activity: Complete infill of redundant drainage channel (including vegetation reinstatement)	Method Statement No: 4
Location: From SU19811286 downstream to SU19141266 (750m in total).	
Risks: Overturning of plant machinery, crush injuries, collapse of earth banks, falling trees and branches, collision with other plant machines, pollution to watercourse, machine strike to persons, insect bites and allergic reactions, snake bites, manual handling.	
General Method of Work : Client and Principal Contractor to identify area of works. Check line of works for any trees to be removed, cut back to ensure safe passage for machine. NO vegetation over 20cm high to be driven over due to ordnance survey constraints. Square off channel to be infilled to ensure infill material will be suitably compacted. Retain vegetation for surface dressing. Transport clay and/or hoggin/heather bales using tracked dumpers, from the stockpile area to the area of drain to be infilled. Infill of drain will involve installation of clay plugs every 15-20 metres. Clay and/or hoggin are to be built up to bank height in manageable layers, and dynamically compacted using the excavator bucket. Between the clay plugs, the drain will be infilled with a combination of imported hoggin (packed down in layers), tree trunks felled during the restoration work (no more than 15% of infill), and the surface dressed with any available spoil. Top dress with vegetation retained from meander excavations and drain infill preparatory works.	
Control Measures or Modifications If any tree felling/vegetation clearance is required, site manager to contact ordnance contractor. Check bank stability before work starts. Do not stand excavator too close to edge of drain. Be aware of any taped off areas/sites that will be of conservation, archaeological or other special interest. Do not enter these areas with any machinery. Be vigilant for members of public / pets / stock / wild animals entering works area. Use a banksman for reversing dumpers to tip areas. Pollution and silt booms to be erected at the downstram end of the works. Re-fuelling to take place at least 20m from the watercourse. All operators to be competent and certificated on the machines they operate. Be aware that there are snakes and ticks in this part of the forest. Take care when walking to and from machines (make site management aware of risks - disease (ie Lymes) & allergic reactions). All incidents relating to safety or pollution of any kind are to be reported to Forestry Commission as soon as it is safe to do so. No smoking in works area – Fire risk. Fire precautions will be outlined by Forestry Commission site controller. All staff and visitors to wear the appropriate PPE for the site conditions they encounter.	
Plant and Equipment Used: 13 tonne hydraulic excavator, 8 tonne tracked dumpers, chainsaws and hand saws as required.	

Activity: Drain infill using heather bales	Method Statement No: 5
Location: Watergreen Bottom, at SU19811272 for 25m.	
Risks: Overturning of plant machinery, crush injuries, collision with other plant machines, pollution to watercourse, machine strike to persons, trip hazard of bale strings, insect bites and allergic reactions, snake bites, manual handling.	
General Method of Work : Client and Principal Contractor to identify area of works. Check line of works for any trees to be removed, cut back to ensure safe passage for machine. NO vegetation over 20cm high to be driven over due to ordnance survey constraints. Check ground conditions and identify areas of soft ground to be avoided. Agree and define machine access routes and working areas and mark out constraints (eg archaeology, rare flora). Carefully remove the existing vegetation on the line of the drain and temporarily store adjacent to it, maintaining the surface layer for final habitat reinstatement. Square off the channel to be infilled to ensure infill material will be suitably compacted. Transport heather bales to site and stack adjacent to the drain using tractor and trailer to minimise number of passes. Transport heather bales/clay from the stockpile area to the drain using tracked dumpers. If the dimensions of the drain to be infilled do not correspond to entire bales, either a layer of compacted hoggin or older 'broken' bales can be used as an initial 'packing' layer of infill below and around entire bales. Infill of drain may involve installation of clay plugs every 15-20 metres. Clay plugs to be built up to bank height in layers, and compacted using the excavator bucket. Pack the heather bales into the squared off drain using an excavator bucket, and dynamically compact them to ensure that there are no holes that could create a hazard for people/livestock. Stake each heather bale in place using 4' long, 2"x2" wooden stakes, two per bale. Cut off the top of the stakes where necessary to ensure that they lie flush with the surface of the heather bale. Reinstatement: Spread any available spoil and retained vegetation over the surface of the bales, to accelerate colonisation and help with stabilisation. Leave the finished infill slightly proud of the surrounding ground level, to allow for settlement.	
Control Measures or Modifications Check ground conditions before work starts. Identify and avoid soft ground where machines are likely to become bogged/repeated machine movements would cause unacceptable levels of ground damage. If necessary leave these areas until the ground is hard or dry. Do not stand excavator too close to edge of drain. Be aware of any taped off areas/sites of conservation, archaeological or other special interest. Do not enter these areas with any machinery. Be vigilant for members of public / pets / stock / wild animals entering works area. Use a banksman for reversing dumpers, where appropriate. If appropriate, pollution and silt booms to be erected at the downstream end of the works. Re-fuelling to take place at least 20m from the watercourse. All operators to be competent and certificated on the machines they operate. Be aware that there are snakes and ticks in this part of the forest. Take care when walking to and from machines (make site management aware of risks - disease (ie Lymes) & allergic reactions). All incidents relating to safety or pollution are to be reported to FC as soon as it is safe to do so. No smoking in works area due to risk of fire. Fire precautions will be outlined by the Forestry Commission site controller. All staff and visitors to wear the appropriate PPE for the site conditions they encounter.	
Plant and Equipment Used: 5-7 tonne excavator, 8 tonne tracked dumpers, chainsaws and hand saws as required.	

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