A NATURAL FLOOD MANAGEMENT PILOT PROJECT
AT
HEBDEN WATER AND CRIMSWORTH DEAN BECK, HARDCASTLE CRAGS
HEBDEN BRIDGE
WEST YORKSHIRE

www.slowtheflow.net

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Date:	12th November 2016
Project Reference No.:	J3228
Revision No.:	B

A Natural Flood Management Pilot Project at Hebden Water and Crimsworth Dean Beck,
Hardcastle Crags, Hebden Bridge, West Yorkshire

Executive Summary

This report presents a proposal for a pilot project for installing interventions into water courses to interrupt and thereby slow the flow of flood water. Under normal or base flows these structures will not impede flows.

This report identifies potential sites within woodland at Hardcastle Crags following the route of Hebden Water and Crimsworth Dean Beck. This land is mostly under the ownership of the National Trust, The Scout Association also own land at Hebden Hey.

It is intended that this report will form the basis of a further grant application the purposes of which are for Slow the Flow Calderdale to undertake and/or manage these works in conjunction with our partners at the Environment Agency and the National Trust. An initial application has been successful in securing funding from Defra but only until the end of March 2017 when further funding will be required to complete the project. In addition to installing interventions into water courses river level monitoring devices are proposed along with consultancy services to study the benefits of re-using existing infrastructure, engineering consultancy for detailed design and construction of interventions and river catchment modelling. A further optional proposal to restore the woodland which will have positive benefits for slowing the flow is also included here.

A Natural Flood Management Pilot Project at Hebden Water and Crimsworth Dean Beck, Hardcastle Crags, Hebden Bridge, West Yorkshire

1.0 About Us

1.1 The Calder Valley in West Yorkshire has a long history of fluvial and pluvial flooding surrounded by steeply falling hillsides the River Calder and its tributaries respond rapidly to heavy prolonged rainfall. In 2012 the towns of Hebden Bridge and Mytholmroyd were flooded twice in the summer floods of that year. Over Christmas and Boxing Day 2015, Pennine areas had over 60mm of rain fall in 24 hours and some locations had over 100 mm. The Calder Valley suffered one of the most significant flooding events in recent times. 2,781 homes and 4,416 businesses were flooded all along the Calder Valley causing unparalleled damage.

1.2 Slow the Flow: Calderdale (StFC) was set up to look at the issue of why and how the valley floods and to look at flood prevention measures and solutions to slow the volume of water which flows down the hillsides into the River Calder. StFC is a group of dedicated engineers, scientists, landscape experts, and those working in land management. We are working with Government, The Environment Agency, Calderdale Council, The National Trust, Natural England, Treesponsibility, The Source Partnership, The Calder & Colne Rivers Trust, Pennine Prospects, Calder Futures and the Flood Wardens along the valley to seek a solution to this continuing and growing problem. SFC members are mostly local and are all volunteers giving up their time to secure a future for the Calder Valley.

1.3 Our objectives are simple – to slow the flow from the upper catchment to the main river channel thereby reducing the flood peak and limiting out of bank flow where it matters, in our towns and villages.

2.0 The Proposal

2.1 This report presents a proposal for a pilot project for installing interventions into water courses to interrupt and thereby slow the flow of flood water. Under normal or base flows these structures will not impede flows.

2.2 This report identifies potential sites resulting from two walkover surveys the first of these was undertaken on the 22nd and 24th June 2016 of the woodland at Hardcastle Crags following the route of Hebden Water. This land is mostly under the ownership of the National Trust, The Scout Association also own land at Hebden Hey. The second walkover survey was undertaken on the 12th July 2016 of the woodland adjoining Crimsworth Dean Beck at Hardcastle Crags, the land to the west of Crimsworth Dean Beck is under the ownership of the National Trust, the stream bed and land to the east of the beck is in private ownership the identity of whom is still to be determined.

2.3 It is intended that this report will form the basis of a grant application the purposes of which are for the StFC to undertake and/or manage these works alongside our partners the Environment Agency and the National Trust. An earlier edition of this report was submitted to the Environment Agency on 31st July 2016 from a group then known as the Calder Catchment Flood Studies Network (CCFSN), this report was successful in securing grant funding from Defra but this funding will only take the project through to the end of March 2017. All of the key members including the report author have now resigned from CCFSN and formed StFC, hence this project is now under the management of StFC.

2.4 In addition to installing interventions river level monitoring devices are proposed along with consultancy services to study the benefits of re-using existing infrastructure, engineering consultancy for detailed design and construction of interventions and river catchment modelling. A further optional proposal to restore the woodland which will have positive benefits for slowing the flow is also included here.

2.5 There are three types of structure that are under consideration, the first of these is a simple board (or plate) placed in the bed of a small stream or brook, the second is a leaky woody dam (LWD) constructed from felled logs, and the third type are simply strategically placed felled logs, more details of these structures follows at Section 3.0, 4.0, 5.0 and 6.0. Working with Treesponsibility who are proposing additional tree planting, balsam control and landslide treatment also within Hardcastle Crags, all of these measures have a role within an overall flood risk management strategy.

2.6 The walkover surveys were undertaken by a group member Stuart Bradshaw, a civil engineer. These surveys were undertaken following a meeting in June 2016 between Stuart Bradshaw and the National Trust (Mr Craig Best) concerning permission to install interventions in watercourses passing through their land. It was agreed at that meeting that Stuart Bradshaw would identify possible places within Hardcastle Crags where such interventions might be placed and report back, a report[15.1] was submitted to the National Trust relating to the Hardcastle Crags interventions. These proposals are now combined together with proposed interventions identified within Crimsworth Dean Beck and previously submitted[15.2] to the Environment Agency into this report, with the intention that these proposals are considered as a pilot project.

2.7 Furthermore, Stuart Bradshaw undertook to investigate whether such interventions would be acceptable to the Lead Local Flood Authority, Calderdale Metropolitian Borough Council. An approach to CMBC (Mr Mohammed Amjid) has been made and they have informed us that there are no objections in principle although any such works would require Ordinary Watercourse Consent as per Section 23 of the Land Drainage Act. We understand that there is an application fee of £50-00 per structure, although it is hoped that this can be waived or partially waived given the

importance of the proposed measures in reducing the flood peak and hence downstream flooding of our valley towns and villages.

2.8 Further enquiries have been made with Natural England (Andrew Clark) as Crimsworth Dean Beck stream bed is designated SSSI which relates to the geology exposed in the stream bed. We have informed Natural England of these proposals who have expressed their support and informed us that they wish to work with us to find locations that are compatible with existing site designations, their geologist believes there is potential for these structures to be sited within the SSSI boundary without damaging the SSSI feature. Clearly there is additional work to be done here and for this reason "in stream" works are programmed for 2017/18.

Part 1 NFM Interventions

3.0 Plate Weirs

3.1 A plate weir is essentially a board placed across a small watercourse such as a ditch, brook or small stream. Ideally the brook or ditch will have an incised channel which will act as a reservoir. The weir board has a hole cut in it to allow water to pass through, the letterbox slot weir has proved to be the most effective in attenuating heavy flows in a study carried out by Moors for the Future[15.3] (http://www.moorsforthefuture.org.uk/sites/default/files/Annex%206.Modelling%20Flood%20Risk.a.pdf).

3.2 The plate weirs will be constructed either from tanalised timber fencing materials (Type 1, Appendix A) or from felled logs (Type 2, Appendix A) provided by the National Trust as part of the proposed PAWS (Plantation on Ancient Woodland Sites) forestry management in Hardcastle Crags (see Section 7.0).

3.3 In low flow the water passes through the slot unimpeded. In heavy flows water begins to back up behind the board forming a small pond, the length and width of the pond depends on the geometry of the stream banks, the stream gradient and also on the width of the slot. The width of the slot can be adjusted by placing a plate fastened with a bolt to partially obstruct the slot, the objective is attain the longest pond (and hence the largest volume of water attenuated) without the plate weir over topping.

3.4 Some experimental plate weirs were installed on two ditches near Old Town (OS Ref. 999 292) in January 2016, photographs are available of the weirs in heavy flows (Appendix B) and they are the subject of a MSc thesis currently in preparation by Alex Clark at University of Leeds (Water @ Leeds). Pressure transducers have been placed either side of a cascade of two sets of plate weirs that will continually measure the flows over the summer months against rainfall data from a gauge placed at Old Town Slack Farm (OS Ref. 00171 29268).

4.0 Leaky Woody Dams (Large Woody Debris)

4.1 A leaky woody dam (LWD) is essentially a tier of felled logs placed across a stream or small river, they can either be secured in position or left without being secured. The stream flow forces from Crimsworth Dean Beck in flood will require any proposed LWD's to be secured to prevent them from washing out. This in itself presents a challenge as rock is present near surface in many areas throughout Hardcastle Crags and Crimsworth Dean. It is proposed to secure the LWD's in position on a rock stream bed by using steel dowels installed by coring (rather than drilling) the rock with a small coring rig which typically are used for coring masonry or concrete and are easily transportable. (Appendix C) The dowels are sized and spaced to carry the bending and shear forces from the stream flow and the forces transferred into the rock in shear and tension. Cement grout is ideal for securing the dowels, made from Ordinary Portland Cement and water mixed at site in a barrel using a simple drill powered paddle mixer. In river the holes are cored by working from wooden baulks placed in the river bed and the coring rig fixed (Appendix C) to them, or hand held coring rigs can be used. The grouting operation uses a short length of plastic tubing or casing that fits snugly into the cored hole, the bar is placed with centraliser spacers in the centre of the cored hole. Grout is poured into the casing through a short plastic pipe introduced to the base of the cored hole (a tremie), this displaces the water out of the rock socket and up through the top of the casing. Grouting ceases just before reaching the casing brim. Once the grout is cured the casing can be removed exposing the dowel or alternatively the plastic casing could be left bonded to the dowel thereby disguising it. Either way this construction process avoids contaminating the river with grout and is a well proven approach used in bored pile construction below the water table.

4.2 There may be situations where soft soils are present in the river banks and where this situation arises the LWD is secured in position by using driven tubes installed using a Grundomat (http://www.tracto-technik.com/GRUNDOMAT-32.html) The tubes are sized and spaced to carry the bending and shear forces from the stream flow and the forces transferred into the soil in shear and tension are then reinforced accordingly with steel dowels. Cement grout is ideal for filling the tubes, made from Ordinary Portland Cement and water mixed at site in a barrel using a simple drill powered paddle mixer. Where soft soil banks are present with a rock bed then a combination of Grundomat piles and cored in dowels would be used.

4.3 A Grundomat (Appendix C) is a small pneumatic soil displacement hammer driven by compressed air and requires a small compressor and a petrol driven generator. They are typically used for installing underground services without having to excavate trenches but can also be used for light piling.

4.4 There are several sites within Crimsworth Dean Beck where LWD's have formed naturally where either trees have fallen into the river and lodged with their roots still embedded on one bank or where trees or boughs of trees have been washed downstream and jammed themselves between boulders or bank side trees. It is

proposed that these sites are enhanced by further supplementation with additional logs and woody debris.

4.5 These dams are intended to allow the normal base river flows to pass underneath along with any fish or aquatic organisms and attenuate water only in higher flows, with the intention that they also create slower over bank flow, so ideally they will be placed in areas where there are wide, low, flat river banks.

4.6 Logs will be locally sourced from the National Trust as part of the proposed PAWS (Plantation on Ancient Woodland Sites) forestry management in Hardcastle Crags (see Section 7.0).[1]

5.0 Leaky Woody Dams (Small Woody Debris)

5.1 These are in principle the same as large woody debris dams but on a smaller scale for use on brooks or ephemeral streams or ditches. These may be secured or unsecured and may simply be a log placed on the ground to interrupt overland flow. The Type 2 plate weir (Appendix A) is in effect a small woody debris dam.

6.0 Strategically Placed Logs

6.1 Areas of riparian wetland are present throughout the National Trust woodland. In some cases a distinct shallow channel is present in other cases flow is ephemeral with these areas having a high water table even in dry weather. By placing large logs parallel to the main river channel flow from these wetlands can be slowed to the river and by placing logs in a staggered pattern further slowing can be effected (Appendix A).

7.0 PAWS Restoration

7.1 The National Trust is submitting a Forestry Management Planning Grant application to the Forestry Commission to review the current outdated Woodland Management Plan. In order to receive a felling licence the National Trust will require a revised and up to date Woodland Management Plan in the FC approved format. Recent conversations with the FC have indicated that the management plan grant (c.£2500) should be available for the NT to instruct a forestry advisor to review and update the existing Woodland Management Plan.

7.2 Much of the 122 ha of woodland at Hardcastle Crags is designated as PAWS (Plantation on Ancient Woodland Sites) and the ground flora is heavily shaded and in many places absent due to the dense canopy. A 30% thin targeted non-native conifers and species such as Beech and Sycamore is required to allow the woodland flora to recover. A restored and vegetated ground flora would intercept precipitation, impede surface run off, reduce erosion and sediment transport and effectively slow the rate of water flow into the system of ditches and natural water

[1] Given the location the use of logs will be more cost effective than tanalised timber, however, tanalised timber or recycled plastic 'timber' products may have lower whole of life costs when maintenance costs are factored in. As part of the pilot it would be beneficial to see how the differing material types perform by installing a small portion of the plate weirs using each of these material types.

courses throughout the woodland. The felling operations would also make available the timber resources required for the NFM interventions detailed above.

7.3 Due to the steep sided valleys at Hardcastle Crags felling and extraction of timber is extremely difficult and uneconomical. Furthermore, the timescales involved for submission of a Countryside Stewardship application for woodland management is not considered an option at this stage. The next realistic Countryside Stewardship application date is September 2017 for a January 2018 start. The September 2016 date will be unachievable given the time taken to produce a FC approved Woodland Management Plan (including public consultation). At best a Countryside Stewardship agreement would only fund c40% of the overall works. Therefore the costs of PAWS woodland management have been included in this grant application at a cost of £50,000 over three years given the positive benefits available from tree thinning noted above.

8.0 Biodiversity

8.1 Introducing woody debris in streams to slow the flow is in effect mimicking natural wild woodlands and streams where trees will have fallen naturally either by windfall, decay or at the end of their lives into stream beds. The woody debris eventually rots allowing colonisation of woodland plants and invertebrates providing food for mammals, birds and aquatic life. The process of wetting the woodland has added benefits for a richer diversity of plants.

9.0 Walkover Survey Results

9.1 Appendix D contains a list of identified sites where interventions might be placed against OS grid coordinates and suggested intervention type. It is not intended to be definitive and there may be plausible reasons why these sites cannot be used, however, it is intended as a first pass suggestion to be agreed by all parties and stakeholders in due course. Photographs of each site location have been taken and these are provided with photograph number and grid coordinates at the following link https://1drv.ms/f/s!ApPGE7wf-v9UqHyObopy1hn67sV3 photographs are geo-located and a Google Earth file is available

http://2bconsultancy.co.uk/download/CalderCatchmentRiverNetworkSurvey/

to view as part of the spatial presentation of these proposals. Approximate costs are placed against each intervention with the number of each type of intervention estimated to give a total cost at each site.

10.0 Attenuation Volumes

10.1 An estimate of the volume of water attenuated by the proposed interventions has been made in two ways as follows:

10.2 Level Survey: A level survey was undertaken at three Large Wood Debris Dam sites on Hebden Water, the bank levels were taken at the proposed dam location then an area of river and bank was estimated by adding 500 mm to this level, this being the crest of the woody dam above bank level and then transferring this level down

and across stream, the area was then multiplied by the depth attenuated (i.e. 500 mm) to arrive at a volume. One of the sites visited was the area adjacent to Hebden Hey by the stepping stones where here the width of the channel and the low banks is around 47 metres, the downstream length was estimated at 28.0 metres so the volume here is approximately 660 m^3. Two further sites were surveyed with volumes estimated at 460 and 210 m^3. The average of these three values is 443 m^3, this was considered optimistic and skewed by the higher result which is not really representative of the rest of the two valleys, indeed this is likely to be the best site in terms of volume potential. The average of the two lower values is 335 m^3, but even this was considered to be on the high side as these sites were all in the lower parts of Hardcastle Crags below Gibson Mill and it was likely that the higher reaches would be narrower in channel width as well as available bank volume, a figure of 200 m^3 has therefore been used for estimation purposes across the two valleys. The mini bunds / rock dams in Blake Dean have been removed from this bid as they feature in a Treesponsibility bid.

10.3 For the smaller structures four brooks were surveyed, three of these had only one proposed structure, the other had four structures proposed, the volumes were 2.1, 2.6, 4.2, 4.6, 5.0, 5.0 and 6.7 m^3/structure, we have based our estimations on a conservative 2.0 m^3/structure.

10.4 For Strategically Placed Logs looking on a cross section of a 500 mm diameter log lying on a 10 degree slope, with 400 mm of the log above ground level the area of water that can be attenuated is (0.4/tan 10° x 0.4)/2 = 0.45 m^2, so for a 4 metre long log the volume is 1.8 m^3, we have used 1.5 m^3. These are only cost effective for logs that are lying nearby and have been costed in at £10-00 each using volunteers, a chain saw, a turfer and crow bars to move the logs.

10.5 Using GIS: See Appendix E for further details.

10.6 The two approaches yield similar conclusions and the total attenuated volume is approximately 7000 m^3 at a capital cost of under £50,000-00, or a cost of approximately £6.89 per m^3 of storage, excluding the PAWS restoration, the river monitoring and consultancy costs. If the £21,000-00 consultancy costs and £14,360 monitoring costs are included in this calculation the cost per unit volume rises to £11-87 per m^3 approximately. The PAWS restoration work will generate an attenuation volume of its own, however, an estimate of this is not included here (see Section 14.4).

11.0 Recommendations

11.1 Leaky Woody Dams have been used successfully at Pickering and Stroud for attenuating flood water and reducing flood peaks. We have identified sites within and adjacent to Hebden Water and Crimsworth Dean Beck at Hardcastle Crags where similar approaches could be implemented with significant benefits for our downstream towns with a potential reduction in hard civil engineering solutions and the significant costs entailed with those. Such Natural Flood Management approaches are cost effective given the low material costs and their ease of

construction, the benefits for our community are potentially significant particularly if these approaches are implemented across the wider higher catchment. As a group we strongly recommend this pilot project is given serious consideration for funding given the potential for positive publicity promoting the ethos of Natural Flood Management and potentially influencing future flood risk management strategy, nationwide.

Part 2 Consultancy Services

12.0 Study for Re-Use of Existing Millpond Infrastructure

12.1 The walkover survey has revealed the existence of four millponds at Middle Dean, these are in good condition although they are heavily silted and contain many fallen trees. From north to south we have termed these as Northern, Middle (North), Middle (South) and Southern Millponds: The following summarises their current condition and approximate volumes:

Millpond	Condition	Approx. Length (m)	Approx. Width (m)	Approx. Current Depth (m)	Approx. Volume (m3)
Northern	Heavily weeded with pond plants and trees	69	15	2	2000
Middle (North)	Heavily silted with fallen trees	170	10	1	1700
Middle (South)	Heavily weeded with pond plants and trees, deep areas of silt at southern end and fallen trees throughout	162	10	1	1600
Southern	Large area of open water with heavy pond plants at southern end	79	9	2	1400

The Northern pond is situated on the west bank of Crimsworth Dean Beck and the other ponds on the east bank, an infilled aqueduct crosses Crimsworth Dean Beck and connects the Northern pond to the Middle (North) pond with a buried culvert now carrying the water, a leat connects the Middle (North) pond to the Middle (South) pond and a culvert connects the Middle (South) pond to the Southern pond. The hydraulic connectivity between the series of ponds is apparent but its functionality uncertain.

12.2 A study for re-use of this infrastructure for partial re-use for run-off interception is proposed at a fee of £5000. This would entail looking at the hydraulic connectivity of the ponds so that water running into the Northern pond eventually flows through the system to outfall at the existing outfall and breach in the Middle (South) dams, which themselves would be blocked with Leaky Woody Dams, further LWD's would then be placed downstream of these outfalls. Similarly the southern pond would also drain to its own outfall as currently but the flow would be slowed again with an LWD and further LWD's downstream. The ponds would require a general tidy up and removal of some of the vegetation and fallen trees which could be used for constructing the LWD's. CCTV surveys would be required for the culverts and clearance by jetting of these may be expected. The cill levels on all the pond outfalls could be lowered by introduction of a slot or orifice through them, this would reduce the normal level of the ponds to provide additional volume during extreme rainfall. The ponds would <u>not</u> intercept water from

Crimsworth Dean Beck only from the surrounding hillsides slowing the flow to the river.

13.0 River Level Monitoring

13.1 Presently there is just one river level gauge installed on Hebden Water at Valley Road bridge near Nutclough Mill. The way the river responds in the higher reaches to rainfall events is important if the benefits of NFM interventions are to be appraised. Inexpensive river level monitoring sensors have been used at Oxford to provide a wider understanding of the river systems and early warning of rising levels. By installing sensors on bridge soffits in Hebden Water and Crimsworth Dean Beck river level data can be collected at 15 minute intervals for the purposes of intervention appraisal. A full proposal for installing up to 10 sensors and their gateway data collection devices is included at Appendix F at a cost of £10200 including annual subscription, thereafter the annual subscription is £1200.

13.2 Additional sensors could also be installed on Colden Water for comparison and appraisal with data from Crimsworth Dean Beck as these two rivers do not have reservoirs at their source, four additional gauges for Colden Water would be at an additional cost of £1080, there would be an additional annual subscription of £480 and possibly an additional gateway at a cost of £2100 only required if the other gateways could not receive the signal from Colden Water. The final total cost for the three rivers is £14360 including the fourth gateway (if required), a one year subscription and £500 for ancillary brackets and fixings, annually there would be a subscription of £1680-00 thereafter. Savings are possible by using some of the initial ten or even eight sensors spread more thinly across the three rivers.

14.0 Engineering Consultancy Services

14.1 To date 100 voluntary man hours have been expended on investigating suitable sites for NFM interventions for this project. To move this proposal forward the sites so identified will require additional engineering input to finalise site locations and designs, enable liaison with stakeholders and supervision of construction work a sum of £6000 is included for these services.

14.2 JBA Consulting have been appointed by Calderdale MBC to undertake a modelling project for the catchment above Brierley Weir with the following brief:

- Collation, review and assessment of existing catchment datasets/mapping and other information (including Colden Clough case study)
- Catchment screening exercise (DTM analysis/assessment of surface water flood map outputs) for the catchment above Brearley Weir
- Opportunity mapping to identify target/cluster areas for potential implementation of NFM measures (See Appendix G for further details)
- Develop more detailed JFLOW models (up to 4) for analysis in target/cluster areas
- Test NFM options (as agreed with project panel)

- Quantify flood risk benefits of NFM options (inc. derivation of flood hydrographs & flood depth grids and linking to existing Calder FRM model)
- Quantify non-FRM benefits

14.3 It is not clear what work is being done within Hebden Water / Crimsworth Dean Beck by JBA that may be of interest to the pilot project presented here, however, there are obvious benefits and possible synergies in engaging the services of Dr Nicholas Odoni who did much of the modelling work on the Pickering project[(15.4)] and who has recently been engaged by Treesponsibility for a study of the Walshaw moorland[(15.5)] part of which drains through both Hebden Water and Crimsworth Dean Beck.

14.4 The work Dr Nicholas Odoni[(15.5)] has done for Treesponsibility has derived a reduction in flow peak at Hebden Bridge should the Walshaw Moor Estate be returned to sphagnum, indeed in his concluding comments Dr Odoni states, "by extending the same management to the catchment more generally, outside the WME the peak flow is further reduced". A modelling exercise of a similar nature could be used to derive an attenuated volume for revegetating the forest floor which would substantiate the PAWS restoration side of this application.

14.5 For a calibrated model study tested against two observed events for Hebden Water and Crimsworth Dean Beck with the source DEM and other data provided, a sum of £15,000 is included in this bid.

15.0 References

15.1 Report on Identified NFM Intervention Sites at Hardcastle Crags, Hebden Bridge, West Yorkshire, Calder Catchment Flood Studies Network, 3rd July 2016.

15.2 Report in Support of a Grant Application for NFM Interventions at Crimsworth Dean Beck, Hardcastle Crags, Hebden Bridge, West Yorkshire, Calder Catchment Flood Studies Network, 15th July 2016.

15.3 Milledge, D, Odoni, N, Allot, T, Evan, M, Pilikington, M & Walker, J., Restoration of Blanket Bogs; flood risk reduction and other ecosystem benefits, Annex 6, Flood risk modelling, Moors for the Future Partnerships, 2015 prepared for Defra, Environment Agency & National Trust.

15.4 Odoni N.A., and Lane S.N., 2010. Assessment of the Impact of Upstream Land Management Measures on Flood Flows in Pickering Beck using OVERFLOW. Report for Forest Research as part of "Slowing the Flow at Pickering and Sinnington Project";

see
http://www.forestry.gov.uk/pdf/stfap_final_report_appendix12_2_Apr2011.pdf/$FILE/stfap_final_report_appendix12_2_Apr2011.pdf

15.5 Odoni, N.A., A modelling study and investigation into how annual burning on the Walshaw Moor estate may affect high river flows in Hebden Bridge.

APPENDIX A

Sketches

Terrain Geotechnical Consultants Hebden Bridge West Yorkshire, HX7 8TE www.terraingeotech.com	Project: Plate Weirs				Job Ref.: J3304	
	Section: Type 1 - Fence Panel				Sheet no./rev.: 1	
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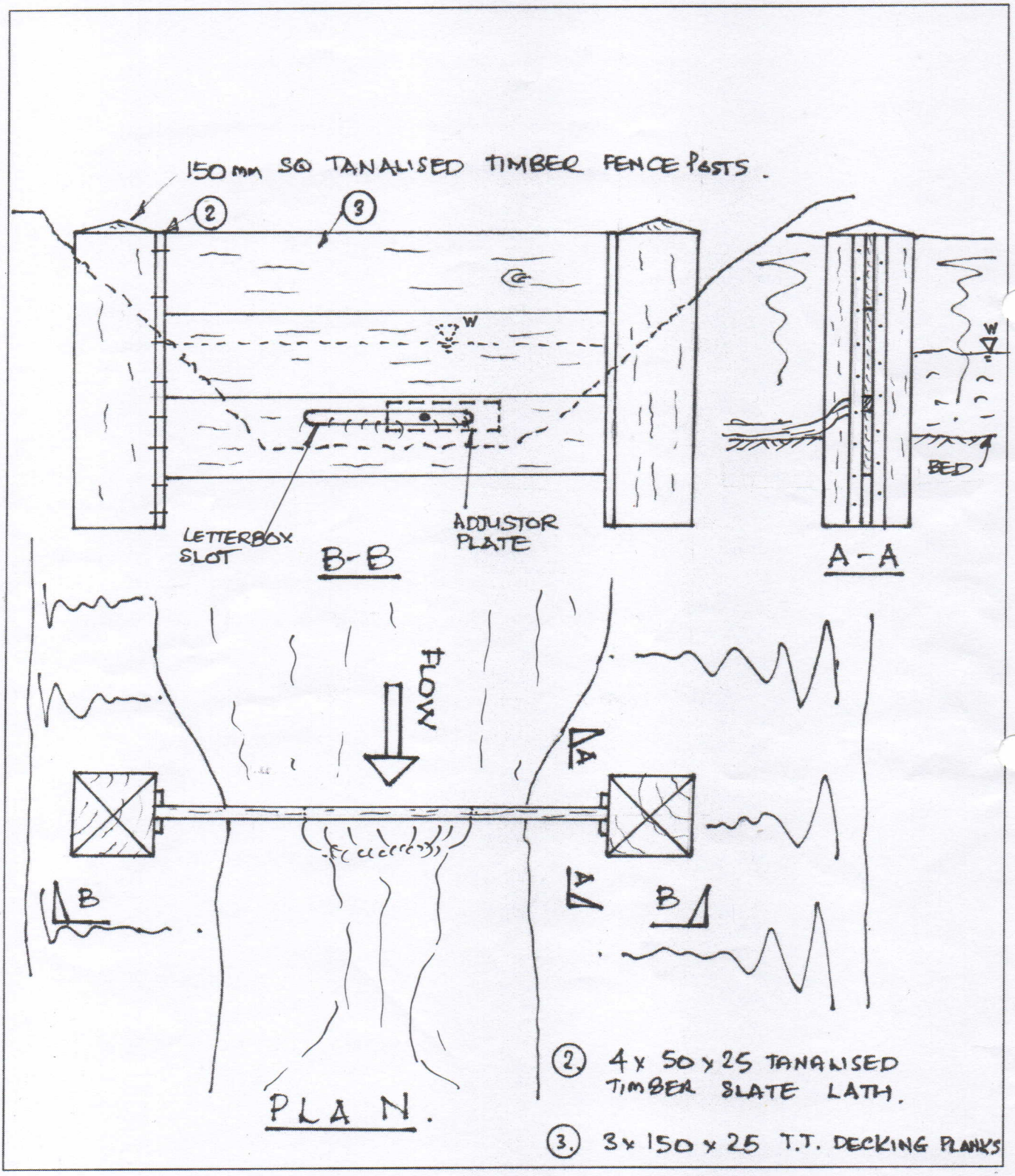

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	Section: Type 2 - Logs				Sheet no./rev.: 1 A	
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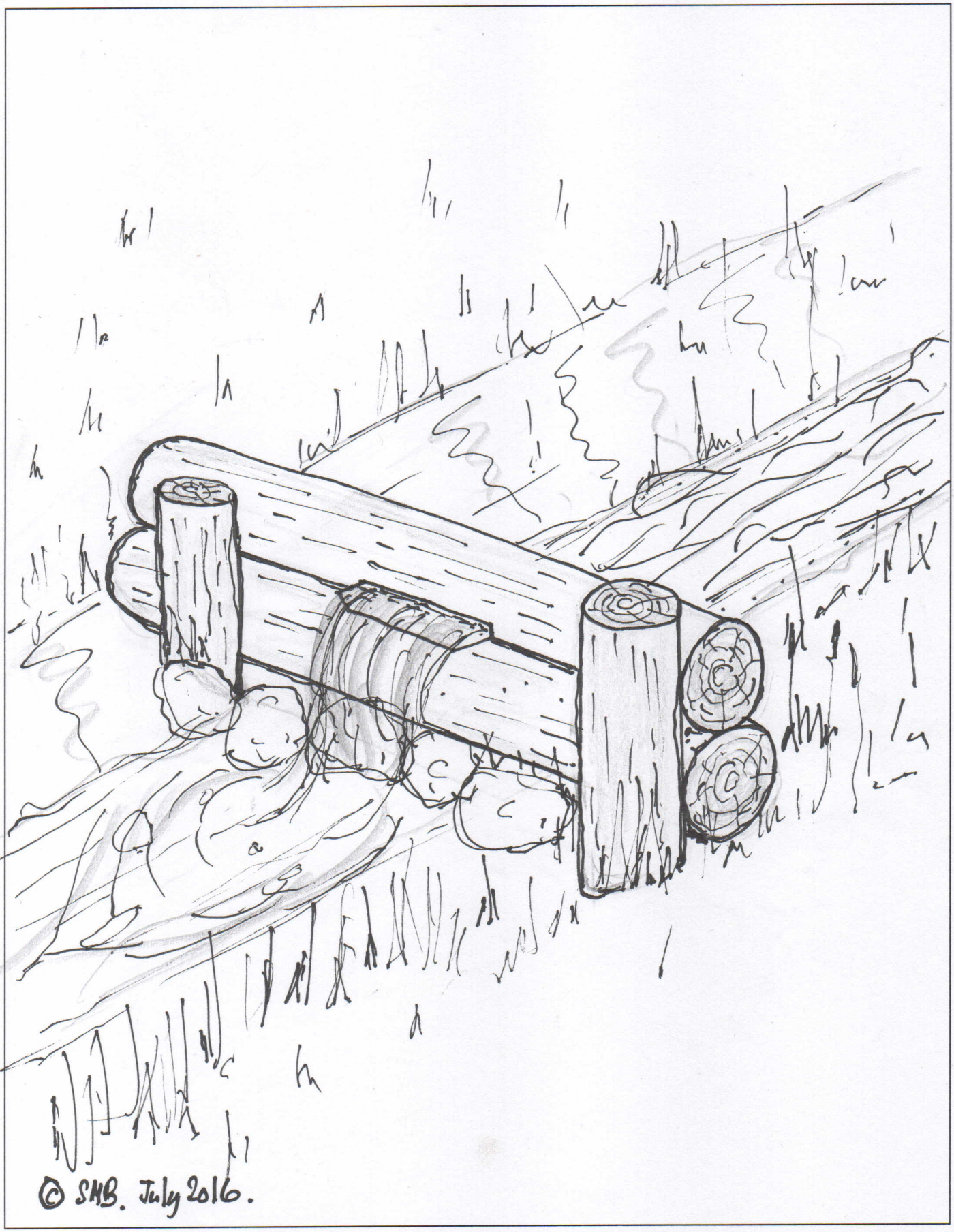

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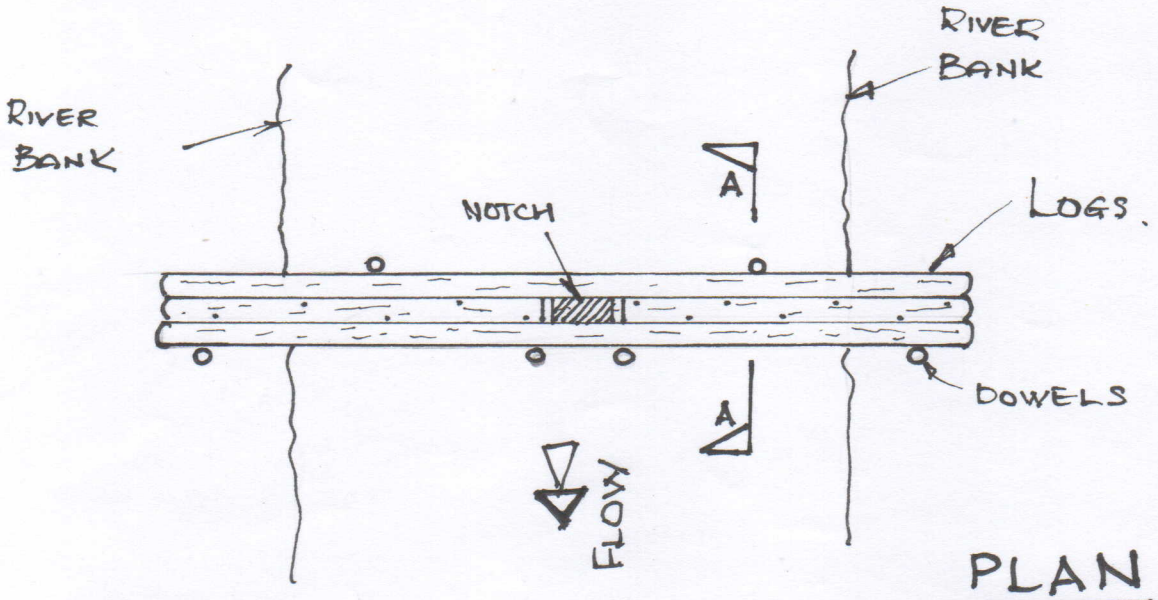

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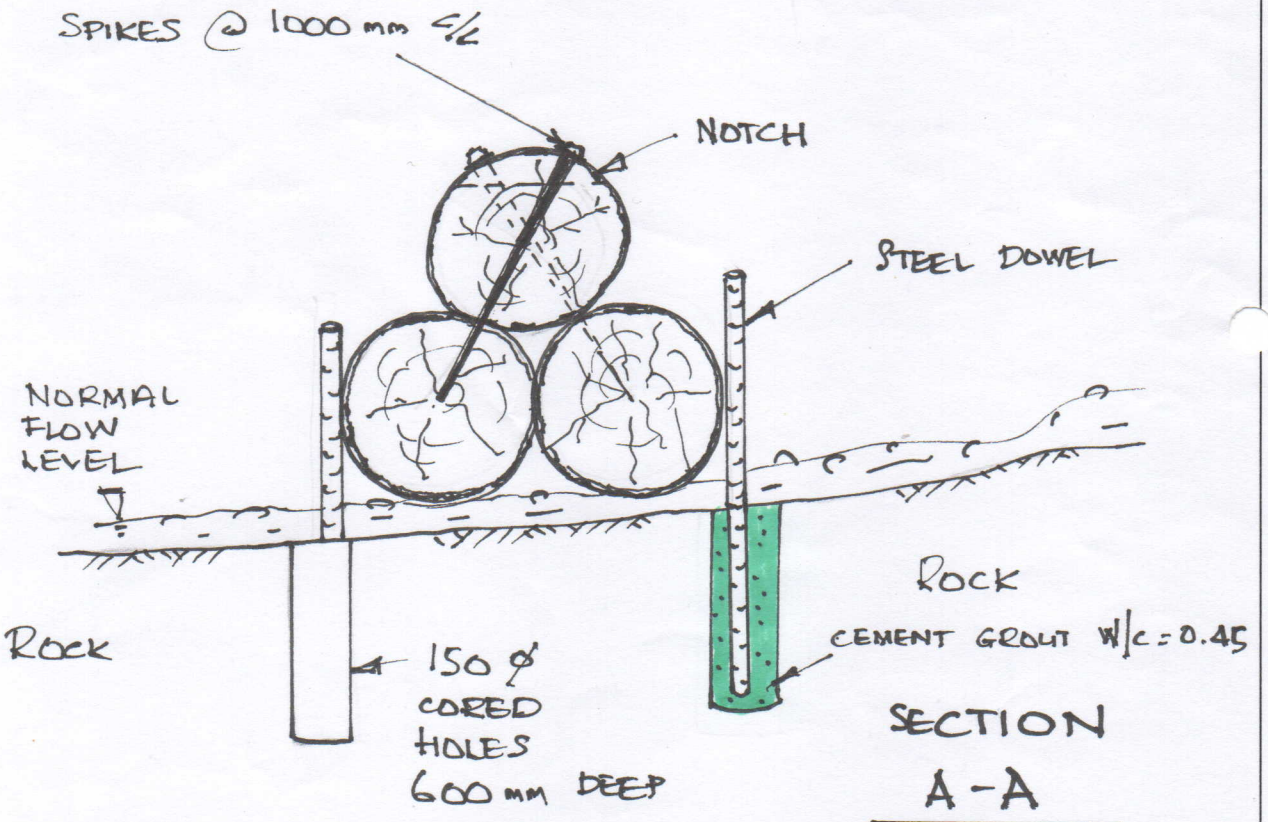
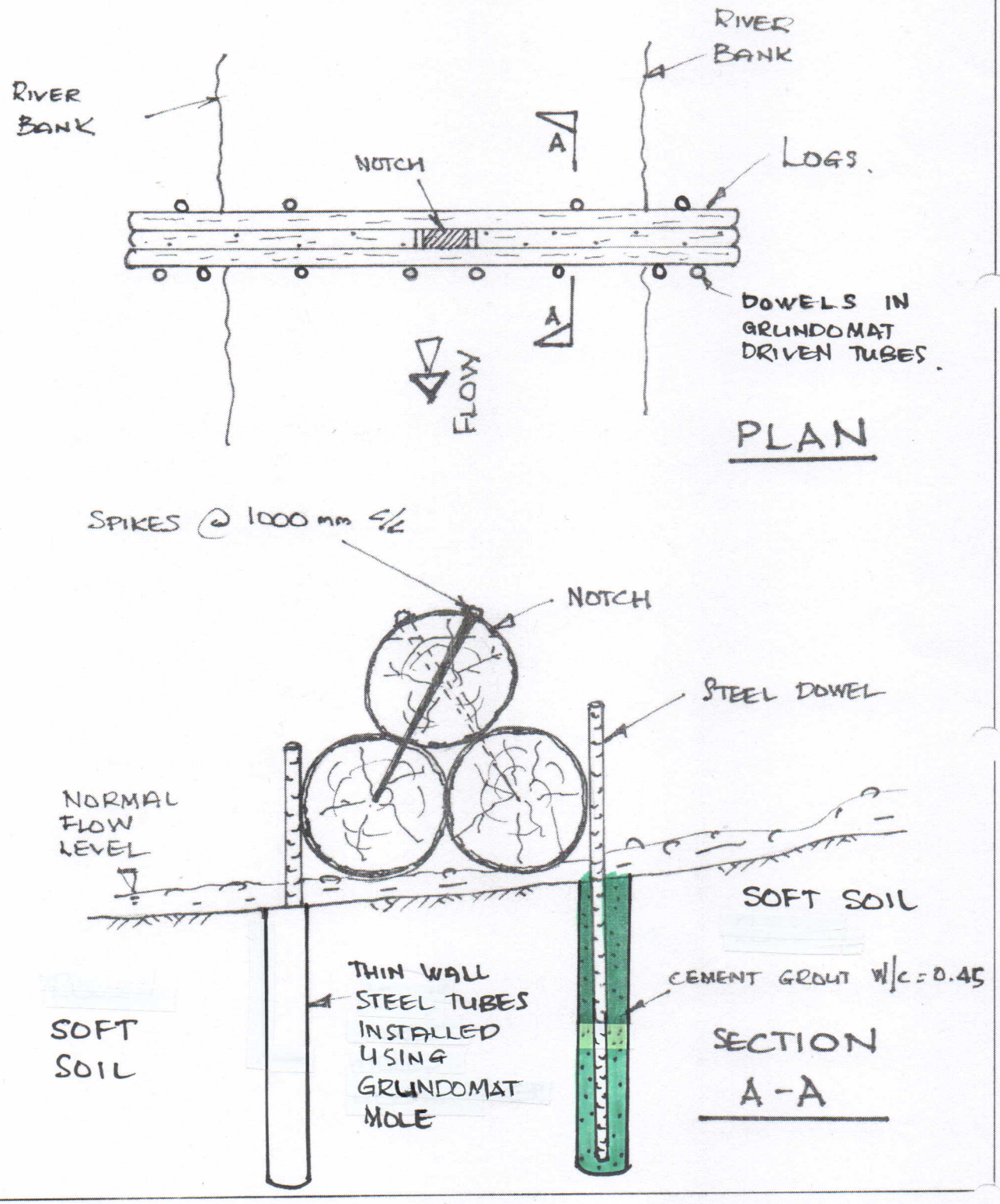
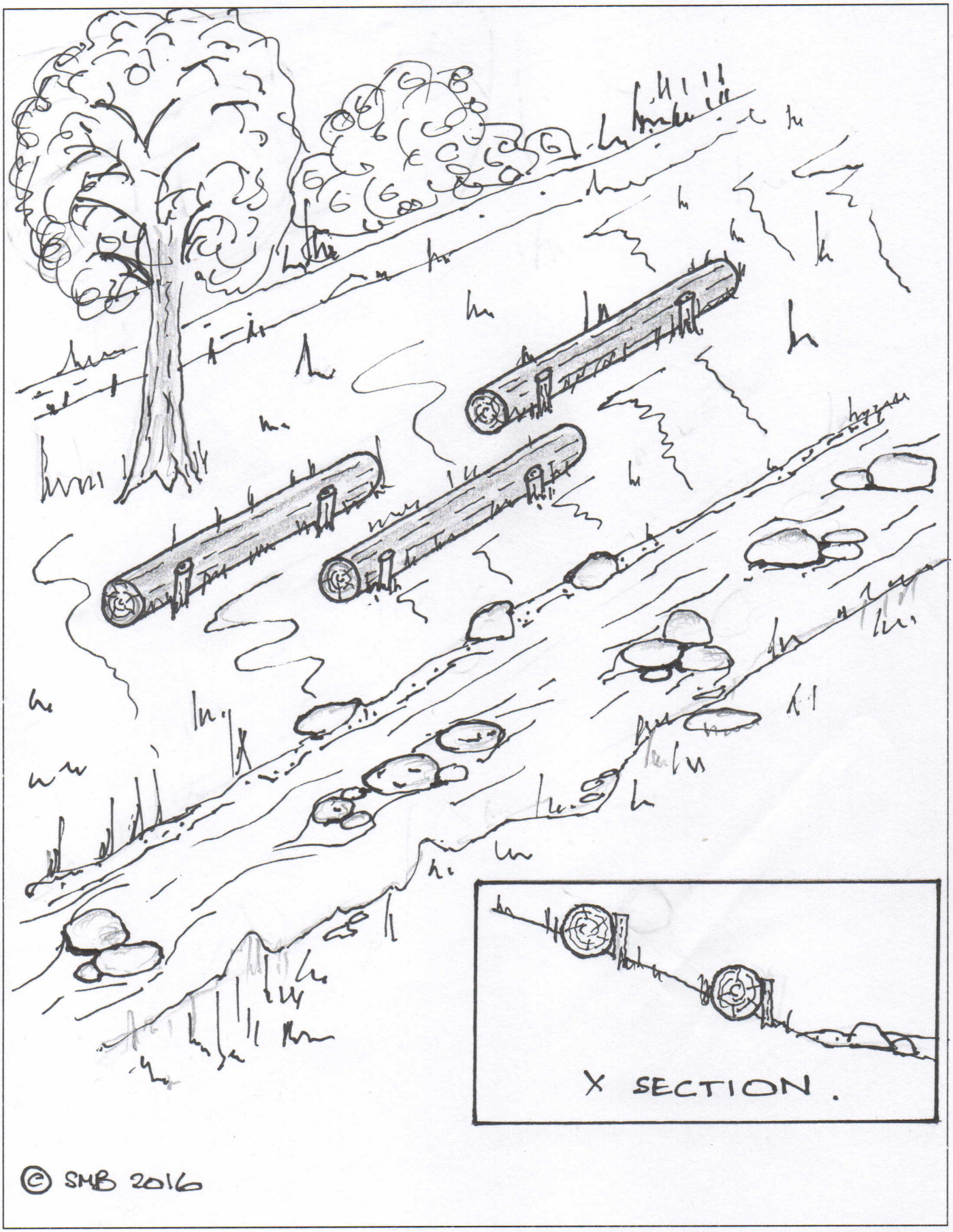


SECTION A-A

Terrain Geotechnical Consultants Hebden Bridge West Yorkshire, HX7 8TE www.terraingeotech.com	Project: Engineered Leaky Woody Dams				Job Ref.	
	Section: DOWELS IN DRIVEN TUBES.(SOIL)				Sheet no./rev.: 2 A	
	Calc. by: SMB	Date: 03-May-16	Chk'd by: AF	Date: 03-May-16	App'd by: SMB	Date: 03-May-16



SLOW the FLO Calder Catchment Flood Studies Network – Natural Flood Management	Project: Hebden Water / Crimsworth Dean Beck Pilot NFM Project			Job Ref.: J3261	
	Section: Strategically Placed Logs			Sheet no./rev.: 1 A	
	Calc. by: SMB	Date: 26/07/2016	Chk'd by: AF	Date: 26/07/2016	App'd by: SMB	Date: 11/01/2016



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APPENDIX B

Photographs of Experimental Plate Weirs

Plate 5: Experimental plate weir with 50 x 20 mm letterbox slot

Plate 6: Experimental plate weir with 3 No. 50 mm diameter orifices

APPENDIX C

Photographs of Proposed Equipment

Plate 1: Coring rig (floor mounted)
Courtesy of Brandon Hire

Plate 2: Coring tool (hand held)
Courtesy of Brandon Hire

Plate 3: Grundomat in use driving piles
Courtesy of Mini Pile Plant Hire

Plate 4: Grundomat

APPENDIX D

Spreadsheet of Proposals, for Photographs go to link in text

IDENTIFIED POSSIBLE INTERVENTION SITES (TO DATE) - HEBDEN WATER AND CRIMSWORTH DEAN BECK

													Costs						Available Spatial Data				
Counter	GPS Waypoint No.	OS Grid Ref. / Location	Label	Elevation (m AOD)	Watercourse Type/Name	Bank	Approx. Volume of Water Attenuated Per Structure(m^3)	Approx. Total Volume of Water Attenuated (m^3)	Intervention Type / Or Observation / Or Project Brief Description	Timescales	Funding/Approval Status	Stakeholders	No. Of LWD's	No. Of MB/RD's	No. Of SWD/PW's	No. Of SPL's	Cost Each	Total Cost	Photo No.	Photo No.	Photo No.	Photo No.	Links to further information
1	318	98571 29178	SWD/PW	108	Brook		2.7	2.7	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			1		150	150					https://1drv.ms/f/s!ApPGE7wf-v9UqHyObopy1hn67sV3
2	126	98448 29032	LWD	151	Hebden Water		460.0	460.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_1988	IMG_1989	IMG_1990	IMG_1991, IMG_2356	http://2bconsultancy.co.uk/download/CalderCatchmentRiverNetworkSurvey/
3	128	98367 29072	LWD	158	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_1992	IMG_1993			Ditto
4	129	98361 29107	SPL	163	Brook		**2.0**	2.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			1		150	150	IMG_1994	IMG_1995			Ditto
5	130	98352 29096	SWD/PW	163	Brook		4.3	17.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_1996	IMG_1997	IMG_1998	IMG_1999	Ditto
6	131	98295 29104	LWD	165	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2001				Ditto
7	132	98145 29044		161	Hebden Water			0.0	LANDSLIP		No funding currently secured	National Trust						0	IMG_2002				Ditto
8	133	97810 29246	LWD	171	Hebden Water		660.0	660.0	LWD (Large Woody Debris) - Hebden Hey	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2003	IMG_2004	IMG_1939	IMG_1940	Ditto
9	329	97862 29172	SWD/PW	176	Path - Brook in heavy rain		**0.5**	2.0	Turnbyes on footpath - Hebden Hey	2016/17	No funding currently secured	National Trust			4		100	400	IMG_1944				Ditto
10			SWD/PW		Brook		**2.0**	2.0	PLATE WEIR(S) or LWD (Small Woody Debris) - Hebden Hey	2016/17	No funding currently secured	National Trust			1		150	150	IMG_1927	IMG_1928			Ditto
11			SWD/PW		Brook		**2.0**	4.0	PLATE WEIR(S) or LWD (Small Woody Debris) - Hebden Hey	2016/17	No funding currently secured	National Trust			2		150	300	IMG_1938				Ditto
12	134	97779 29258	SWD/PW	172	Brook		4.3	4.3	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			1		150	150	IMG_2005				Ditto
13		Betwixt Co-Ordinates Above & Below	SPL		Hebden Water		**1.5**	13.5	Strategically Placed Logs (SPL's) 31 metres (Using fallen adjacent logs)	2016/17		National Trust				9	10	90					Ditto
14	135	97753 29272	SWD/PW	171	Brook		6.7	6.7	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			1		150	150	IMG_2006	IMG_2007			Ditto
15		Betwixt Co-Ordinates Above and 27693 29309 (WP 319)	SPL		Hebden Water		**1.5**	36.0	Strategically Placed Logs (SPL's) 80 metres (Using fallen adjacent logs)	2016/17	No funding currently secured	National Trust				24	10	240					Ditto
16	320	97585 29386	LWD	173	Hebden Water		210.0	210.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300					Ditto
17	136	97562 29399	SWD/PW	176	Brook		**2.0**	2.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			1		150	150	IMG_2008	IMG_2009			Ditto
18	137	97475 29468		177	Hebden Water			0.0	DEBRIS LINE IN TREE 2.8M ABOVE BED LEVEL		No funding currently secured	National Trust						0	IMG_2010				Ditto
19	330	97445 29498	LWD	167	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2357	IMG_2358	IMG_2359		Ditto
20	138	97428 29529	SWD/PW	177	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2011	IMG_2012	IMG_2013		Ditto
21		Betwixt Co-Ordinates Above and Below	SPL		Hebden Water		**1.5**	31.5	Strategically Placed Logs (SPL's) 70 metres (Using fallen adjacent logs)	2016/17	No funding currently secured	National Trust				21	10	210					Ditto
22	139	97388 29588	SWD/PW	177	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2014	IMG_2015			Ditto
23	331	97371 29676	LWD	171			**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2360				Ditto
24	140	97310 29858		181	Hebden Water			0.0	GIBSON MILL		No funding currently secured	National Trust						0					Ditto

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													Costs						Available Spatial Data				
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25	141	97247 29896	SWD/PW	184	Brook		**2.0**	8.0	GREENWOOD LEE FARM STREAM AND WATERFALLS	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2016	Note interventions possible upstream			Ditto
26	142	97301 29963	SWD/PW	187	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2017				Ditto
27	143	98087 29311		216				0.0	POSSIBLE WIDE WEIR/ATTEN.POND	2016/17	No funding currently secured	National Trust						0	IMG_2018	IMG_2019			Ditto
28	144	98314 292240	SWD/PW	200	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2020				Ditto
29	145	98363 29221	SWD/PW	197	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2021				Ditto
30	146	98451 29210	SWD/PW	194	Brook		**2.0**	10.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			5		150	750	IMG_2022				Ditto
31	147	98555 29198	SWD/PW	192	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2023	IMG_2024			Ditto
32	332	98657 29139	SWD/PW	166	Brook		**2.0**	12.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			6		150	900	IMG_2361				Ditto
33	148	00166 29265	SWD/PW	153	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2026	IMG_2027			Ditto
34	149	97244 29970		174				0.0	ATT. POND @ OLD MILL POND NORTH OF GIBSON MILL	2017/18	No funding currently secured	National Trust						0	IMG_2028	IMG_2029			Ditto
35	150	97208 30019	LWD	174	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2030				Ditto
36	151	97168 30059	LWD	174	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2031				Ditto
37	152	97123 30128	LWD	177	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2032	IMG_2033			Ditto
38	153	97129 30176	LWD	179	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2034				Ditto
39	154	97131 30207	SWD/PW	184	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2035	IMG_2036			Ditto
40	155	97134 30222	SWD/PW	183	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2037				Ditto
41	156	97135 30244	LWD	185	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2038	IMG_2039			Ditto
42	157	97087 36353	SWD/PW	184	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris) Upstream	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2040				Ditto
43	158	97083 30364	SWD/PW	190	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2041				Ditto
44	159	97120 30455	SWD/PW	200	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2042	IMG_2043			Ditto
45	160	97168 30594	LWD	202	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2044	IMG_2045			Ditto
46	161	97225 30665	LWD	210	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2046				Ditto
47	162	97230 30663	SWD/PW	215	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2047				Ditto
48	163	97233 30983	SWD/PW	218	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2048	Interventions upstream in tributary			Ditto
49	164	97222 31011	SWD/PW	219	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2049				Ditto

IDENTIFIED POSSIBLE INTERVENTION SITES (TO DATE) - HEBDEN WATER AND CRIMSWORTH DEAN BECK

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50	165	97206 31033	SWD/PW	220	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2050				Ditto
51	166	97193 31063	LWD	221	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2051				Ditto
52	167	9719231074	LWD	227	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2052	Note wide bank opposite			Ditto
53	168	97058 31201	SWD/PW	230	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2053				Ditto
54	169	97031 31200	SWD/PW	228	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2054				Ditto
55	170	96926 31240	SWD/PW	229	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2055				Ditto
56	171	96849 31319	SWD/PW	234	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2056				Ditto
57	172	96803 31349	SWD/PW	236	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2057				Ditto
58	173	96697 31340	LWD	229	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2058	Note wide bank opposite			Ditto
59	174	96547 31333	SWD/PW	230	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2059				Ditto
60	175	96492 31325	LWD	227	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2060	IMG_2061			Ditto
61	176	96286 31305	LWD	228	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2062				Ditto
62	177	96075 31358	LWD	232	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2063				Ditto
63	178	96004 31370	MB/RD	232	Hebden Water		**0.0**	0.0	MINI BUND or ROCK DAM (i.e. Larger LWD) nr Black Dean	2017/18	No funding currently secured	National Trust		1				0	IMG_2064				Ditto
64	179	95909 31411	MB/RD	235	Hebden Water		**0.0**	0.0	MINI BUND or ROCK DAM (i.e. Larger LWD) nr Black Dean	2017/18	No funding currently secured	National Trust		1				0	IMG_2065				Ditto
65	333	TBA	LWD	TBA	Hebden Water		**200.0**	200.0	LWD (Large Woody Debris), Suppliment existing fallen log	2017/18	No funding currently secured	National Trust	1				300	300	IMG_2362	IMG_2363			Ditto
66	180	96790 31380	SWD/PW	239	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2066				Ditto
67	181	96925 31326	SWD/PW	229	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2067				Ditto
68	182	97056 31245	SWD/PW	222	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2068				Ditto
69	183	97311 30999	SWD/PW	214	Brook		**2.0**	8.0	LWD (Small Woody Debris on Brook)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2069				Ditto
70	184	97277 30546	SWD/PW	225	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris)	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2070				Ditto
71	185	97285 30510	SWD/PW	224	Brook		**2.0**	8.0	PLATE WEIR(S) or LWD (Small Woody Debris) Upstream	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2071				Ditto
72	267	98894 29128	LWD	139	Crimsworth Dean Beck	In stream	**200.0**	200.0	LWD (Large Woody Debris)	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England	1				300	300	IMG_2217				Ditto
73	268	98896 29289		142	Crimsworth Dean Beck	East		0.0	Landslip on East Bank, fascines	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England					500	0	IMG_2218				Ditto
74	269	98870 29435	SWD/PW	154	Brook	West	**2.0**	6.0	Brook enters at high level, possible LWD's or PW's higher up on this brook	2016/17	No funding currently secured	National Trust			3		150	450	IMG_2219				Ditto
75	270	98897 29515	SWD/PW	162	Spring issues	West	**2.0**	2.0	On west bank above aqueduct spring issues, LWD (Small)	2016/17	No funding currently secured	National Trust			1		150	150	IMG_2220	IMG_2221			Ditto

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76	271	98888 29559	SWD/PW	163	Spring issues	West	**2.0**	4.0	On west bank spring issues, LWD's (Small)/PW's	2016/17	No funding currently secured	National Trust			2		150	300	IMG_2222	IMG_2223			Ditto
77	272	98879 29589	SWD/PW	164	Brook	West	**2.0**	8.0	Small level brook, LWD's (Small)/PW's	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2224	IMG_2225	IMG_2226	IMG_2227	Ditto
78	273	98878 29656	SWD/PW	170	Brook	West	**2.0**	12.0	Small level brook, LWD's (Small)/PW's	2016/17	No funding currently secured	National Trust			6		150	900	IMG_2229	IMG_2230	IMG_2231	IMG_2232	Ditto
79	274	98878 29701	LWD	175	Crimsworth Dean Beck	In stream	**200.0**	200.0	Supplement existing natural LWD (Large)	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England	1				300	300	IMG_2233				Ditto
80	275	988840 29820	LWD	186	Crimsworth Dean Beck	In stream	**200.0**	200.0	Existing boulders & fallen trees, supplement existing obstructions with fallen logs, fascine repairs to landslip	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England	1				500	500	IMG_2234	IMG_2235	IMG_2236		Ditto
81	276	98881 29882	LWD	197	Crimsworth Dean Beck	In stream	**200.0**	200.0	Fell large beech tree on west to create Large LWD, use smaller beech tree on east bank as reaction	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England	1				300	300	IMG_2237	IMG_2238			Ditto
82	277	98903 29936	LWD	196	Crimsworth Dean Beck	In stream	**200.0**	200.0	Fell large beech tree on east bank to create Large LWD, use large rock on west bank as reaction	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England	1				300	300	IMG_2239	IMG_2240			Ditto
83	278	98886 30025	LWD	201	Crimsworth Dean Beck	In stream	**200.0**	200.0	Fallen trees west and east banks, some additional felling possible to supplement existing large LWD, fascine repairs to landslip	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England	1				500	500	IMG_2241	IMG_2242	IMG_2243	IMG_2257 from above	Ditto
84	279	98912 29917	SWD/PW	206	Brook	East	**2.0**	10.0	Brook enters mill leat from east bank, possible LWD's (Small)/PW's upstream	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England			5		150	750	IMG_2244				Ditto
85	280	98905 29882		205	Middle (South) Millpond	East		0.0	Middle south mill pond northern co-ordinate, middle south pond is 162 x 10 x 1 = 1620 m3 approx.		No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England						0	IMG-2245				Ditto
86	281	98955 29728	SWD/PW	203	Middle (South) Millpond	East	**2.0**	10.0	Below outfall from middle south mill pond, LWD's(small) in brook	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England			5		150	750	IMG_2246 & IMG_2251	IMG_2248 shows outfall	IMG_2251 shows southern outfall	IMG_2252 & 53 shows below southern outfall	Ditto
87	282	98963 29658		205	Southern Millpond	East		0.0	Southern mill pond northern co-ordinate, southern pond is 79 x 9 x 2 = 1422 m3 approx.		No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England						0	IMG_2249				Ditto
88	283	98997 29587		206	Southern Millpond	East		0.0	Southern mill pond southern co-ordinate		No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England						0	IMG_2247	IMG_2248			Ditto
89	284	99963 29724		202	Culvert	East		0.0	Culvert location between middle south and southern millpond		No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England						0	IMG_2250				Ditto
90	285	99939 29770		201	Cross wall	East		0.0	Co-ordinates of cross wall in middle south millpond		No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England						0	IMG_2254				Ditto
91	286	98919 29817	SWD/PW	200	Middle (South) Millpond	East	**2.0**	4.0	At overflow weir on middle south pond, falls to clough LWD's (small) from fallen trees above	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England			2		150	300	IMG_2255				Ditto
92	287	98898 29984		198	Middle (North) Millpond	East		0.0	Southern co-ordinate of middle (north) millpond, this pond is 170 x 10 x 1 = 1000 m3 approx.		No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England						0	IMG_2256				Ditto
93	288	98846 30076		195	Northern Millpond	West		0.0	At overflow weir on northern millpond		No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England						0	IMG_2258				Ditto
94	289							0.0			No funding currently secured							0					Ditto
95	290	98843 30145		193	Northern Millpond	West		0.0	Northern millpond north co-ordinate, this pond is 69 x 15 x 2 = 2100 m3.		No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England						0	IMG_2259				Ditto
96	291	98846 30154	LWD	190	Crimsworth Dean Beck	In stream	**200.0**	200.0	Beech tree damming river fallen from east bank, fell adjacent beech tree on west bank to supplement LWD (Large)	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England	1				300	300	IMG_2262	IMG_2263	IMG_2264		Ditto
97	292	98840 301191	LWD	191	Crimsworth Dean Beck	In stream	**200.0**	200.0	Beech or sycamore overhangs river, roots disturbed, fell and create LWD (large)	2017/18	No funding currently secured	Private landowners not currently identified, stream bed SSSI - Natural England	1				300	300	IMG_2265				Ditto
98	293	98834 30213		191	Crimsworth Dean Beck	West		0.0	Fast flowing brook enters leat, may be same brook as waypoint 309	2016/17	No funding currently secured	National Trust						0	IMG_2266				Ditto
99	294	98845 30249	SWD/PW	196	Gully	West	**2.0**	2.0	Above weir on west bank dry gully block with PW	2016/17	No funding currently secured	National Trust			1		150	150	IMG_2267				Ditto
100	295	98827 30304	SWD/PW	202	Brook	West	**2.0**	12.0	Brook on west bank, LWD's (small)/PW's	2016/17	No funding currently secured	National Trust			6		150	900	IMG_2268	IMG_2269			Ditto
101	296	98789 30305	SWD/PW	208	Brook	West	**2.0**	14.0	Same brook at waypoint 295, LWD's(small/PW's	2016/17	No funding currently secured	National Trust			7		150	1050	IMG_2270				Ditto
102	297	98773 30362	SWD/PW	214	Brook	West	**2.0**	8.0	Brook on west bank, LWD's (small)/PW's, soft banks	2016/17	No funding currently secured	National Trust			4		150	600	IMG_2271	IMG_2272			Ditto
103	298	98708 30384	SWD/PW	225	Brook	West	**2.0**	30.0	Same brook at waypoint 297, LWD's(small/PW's	2016/17	No funding currently secured	National Trust			15		150	2250	IMG_2273	IMG_2274			Ditto
104	299	Not used						0.0										0					Ditto
105	300	98806 30384	SWD/PW	200	Brook	West	**2.0**	10.0	Brook on west bank, LWD's (small)/PW's, soft banks	2016/17	No funding currently secured	National Trust			5		150	750	IMG_2275				Ditto
106	301	98797 30383	SWD/PW	205	Brook	West	**2.0**	10.0	Same brook at waypoint 300, LWD's(small)/PW's	2016/17	No funding currently secured	National Trust			5		150	750	IMG_2276				Ditto
107	302	98818 30417	SWD/PW	199	Brook	West	**2.0**	10.0	Brook on west bank, LWD's (small)/PW's, soft banks	2016/17	No funding currently secured	National Trust			5		150	750	IMG_2271				Ditto
108	303	98811 30437	SWD/PW	206	Brook	West	**2.0**	20.0	Brook on west bank, LWD's (small)/PW's, soft banks	2016/17	No funding currently secured	National Trust			10		150	1500	IMG_2278	IMG_2279			Ditto
109	304	Not used						0.0										0					Ditto
110	305	98775 30457	SWD/PW	216	Brook	West	**2.0**	10.0	Same brook at waypoint 303, LWD's(small/PW's	2016/17	No funding currently secured	National Trust			5		150	750	IMG_2280				Ditto
111	306	98785 30478	SWD/PW	218	Brook	West	**2.0**	10.0	Brook on west bank, LWD's (small)/PW's, at boundary of NT land	2016/17	No funding currently secured	National Trust			5		150	750	No pic.				Ditto
112	307	98800 30514	SWD/PW	220	Brook	West	**2.0**	20.0	Brook on west bank, LWD's (small)/PW's, soft banks	2016/17	No funding currently secured	National Trust			10		150	1500	No pic.				Ditto
113	308	98798 30477	SWD/PW	216	Brook	West	**2.0**	10.0	Same brook at waypoint 306, LWD's(small/PW's	2016/17	No funding currently secured	National Trust			5		150	750	No pic.				Ditto

IDENTIFIED POSSIBLE INTERVENTION SITES (TO DATE) - HEBDEN WATER AND CRIMSWORTH DEAN BECK

													Costs						Available Spatial Data				
Counter	GPS Waypoint No.	OS Grid Ref. / Location	Label	Elevation (m AOD)	Watercourse Type/Name	Bank	Approx. Volume of Water Attenuated Per Structure(m^3)	Approx. Total Volume of Water Attenuated (m^3)	Intervention Type / Or Observation / Or Project Brief Description	Timescales	Funding/Approval Status	Stakeholders	No. Of LWD's	No. Of MB/RD's	No. Of SWD/PW's	No. Of SPL's	Cost Each	Total Cost	Photo No.	Photo No.	Photo No.	Photo No.	Links to further information
114	309	98784 30214	SWD/PW	212	Brook	West	**2.0**	20.0	Brook on west bank, LWD's (small)/PW's, could lead to waypoint 293	2016/17	No funding currently secured	National Trust			10		150	1500	No pic.				Ditto
115	-	-	-	-	-	-	-	-	PAWS Restoration	2016 - 2019	No funding currently secured	National Trust					50000	50000	-	-	-	-	Ditto
116	-	-	-	-	-	-	-	-	River monitoring of Hebden Water, Crimsworth Dean Beck and Colden Water	2016/17	No funding currently secured	Calderdale MBC, Environment Agency, Yorkshire Water					13860	14360	-	-	-	-	Ditto
117	-	-	-	-	-	-	-	-	Engineering consultancy for design and supervision of in river structures for Crimsworth Dean and Hebden Water, liason with CMBC, NT & NE	2016/17	No funding currently secured	Private landowners not currently identified, where stream bed SSSI - Natural England					6000	6000	-	-	-	-	Ditto
118	-	-	-	-	-	-	-	-	Engineering study for re-use of millponds, Option 1 as water interceptors	2016/17	No funding currently secured	Private landowners not currently identified, feasibility assumes landowner agreement and this will be investigated before proceeding					4000	5000	-	-	-	-	Ditto
119	-	-	-	-	-	-	-	-	River catchment modelling engaging the services of Dr Nick Adoni	2016/17	No funding currently secured	Calderdale MBC, Environment Agency, Yorkshire Water					15000	15000	-	-	-	-	Ditto
								7099.7					29	2	239	54		139250					

CRIMSWORTH DEAN, MILLPONDS FOR ADDITIONAL STUDY

		Easting	Northing	Diff. Easting	Diff. Northing	SRSS (m)
North Co-Ord	Middle (South) Millpond	98905	29882			
South Co-Ord	Middle (South) Millpond	98955	29728	50	154	161.9
North Co-Ord	Southern Millpond	98963	29658			
South Co-Ord	Southern Millpond	98997	29587	34	71	78.7
	Culvert	99963	29724			
	Cross wall	99939	29770			
South Co-Ord	Middle (North) Millpond	98898	29984	55	161	170.1
North Co-Ord	Middle (North) Millpond	98843	30145			
South Co-Ord	Northern Millpond	98846	30076	3	69	69.1
North Co-Ord	Northern Millpond	98843	30145			

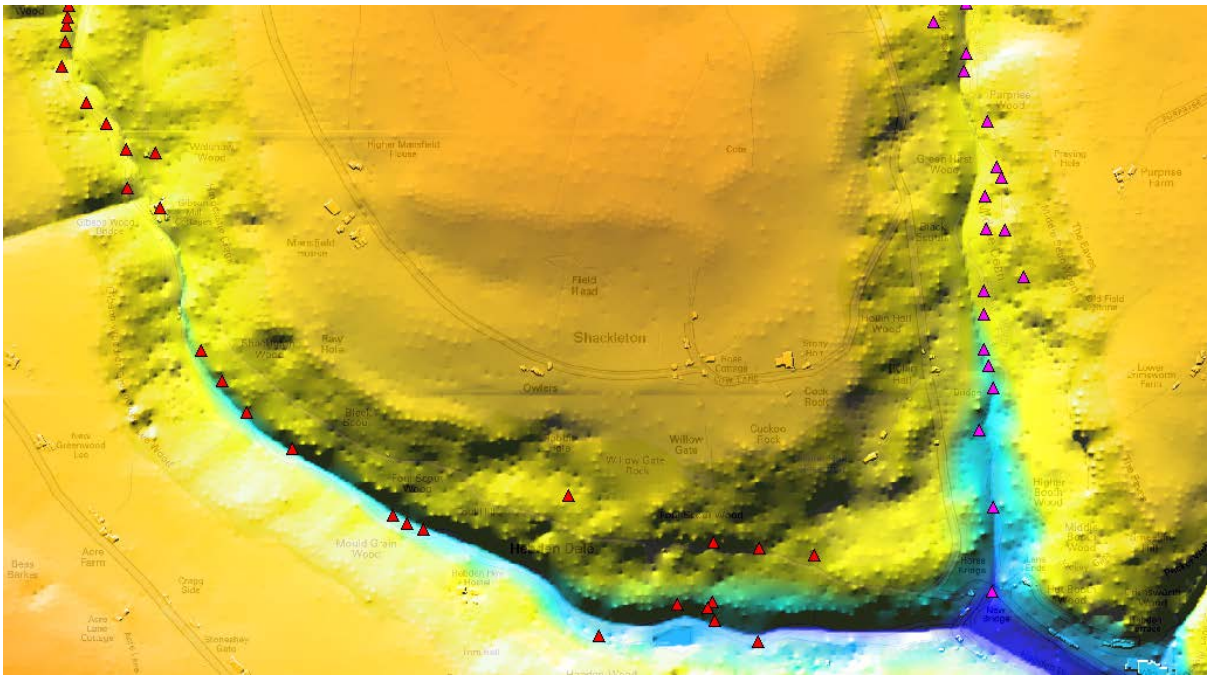
APPENDIX E

Attenuation Volumes Using GIS

Natural Flood Management Attenuate Volumes – Crimsworth Dean & Hardcastle Crags (July 2016)

Step1: The following file was loaded in to a GIS software package to show the identified location of NFM measures which total around 300 structures between the two sub-catchments.

- Hardcastle Crags + Crimsworth Dean Identified NFM Sites Rev. B.xls

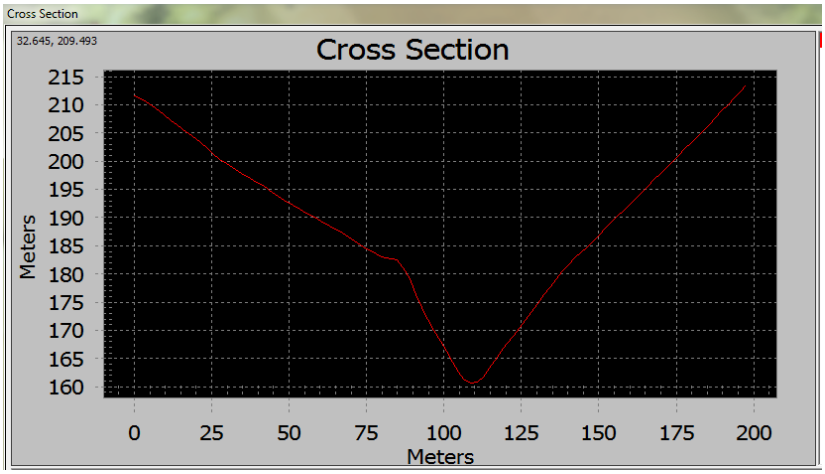


Ref1: Example screen shot of DTM and imported nodes (not all nodes showing)

Step2: A cross section was drawn at each NFM site node location, spanning the river channel, apart from NFM locations on small ditches where the watercourse was too small to be picked up by the low resolution DTM. This resulted in approximately 28 structures assessed in the main channel.

Step3: Attenuated water levels upstream of each NFM structure were calculated at each cross section based on the following assumptions:

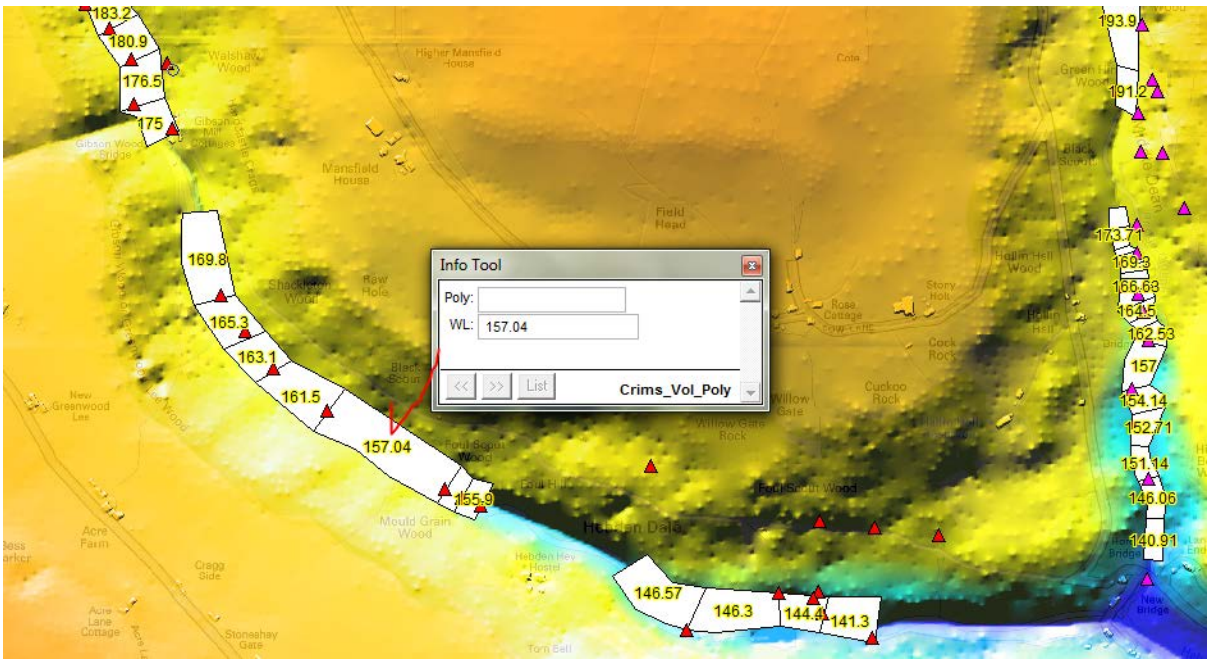
- It has been assumed that the DTM elevation within the channel represents the water level.



Ref2: DTM cross section

- It has been assumed that all NFM measures are woody debris (500mm diameter) spanning the river banks (i.e. top of woody debris is 500mm above assumed water level).

Step4: An upstream ponded area/polygon was drawn upstream of each cross section and the calculated water level added to the polygon field (column within the table that is associated with the polygon).

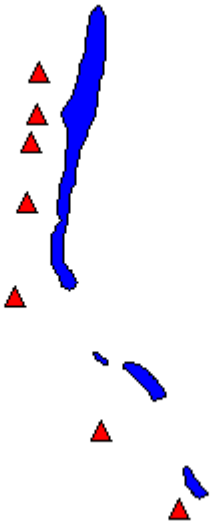


Ref3: Peak water level polygons

Step5: A grid of peak water level of the attenuated water behind the NFM structures was created from the polygon.

Step6: A grid calculation was undertaken, whereby the underlying DTM grid was deducted from the peak water level grid. This created a peak water depth grid (volume of water stored)

Step7: A flood extent / ponded water outline was created from the peak water depth grid.



Ref4: water extents

Step8: The water depth grid was used to calculate the volume of attenuation provided by the NFM structures assessed. This was done using two methods: 1) histogram, 2) ASCI Volume Tool.

Given the assumptions/discrepancies in both approaches, an average of the two volumes was calculated which gives an approximate attenuated volume of 6500m^3 behind the NFM measures located within the main watercourses.

As mentioned previously the above calculations have only been undertaken for approximately 28 of the identified NFM locations on the main channel, with around another 230 located on smaller tributaries and ditches. Although it has not been possible to calculate the volume of storage behind these smaller NFM structures using GIS, it would be a fair estimate to say that the total volume of storage behind all NFM structures on the Crimsworth Dean & Hardcastle Crags subcatchments is approximately 7000m^3.

Total Capital Costs = Approximately £50,000

Cost per m3 of storage = £7.00

Note/ These calculations are based on the most accurate data available and deemed to be representative of the approximate volumes that can be stored.

APPENDIX F

Flood Network Proposal

Flood Network Proposal

A Flood Network system for Hebden Water

29 Jul 2016

Summary

Flood Network will supply hardware and software to Calder Catchment Flood Studies Network (CCFSN) to allow historical and real-time water level monitoring in the areas upstream from Hebden Bridge.

The Flood Network system uses Internet of Things technology to enable a low-cost network of low-profile sensors which help incident managers and the public to react more effectively to flooding and collect historical data. It monitors water levels, combining data from critical locations and sensors installed around the community to give a better picture of the situation on the ground.

The quote below is a for 6-8 sensors and includes the hardware and software components of the system.

Goal

- Allow baseline measurements to verify and understand current catchment response
- Collect measurements to allow review of peak events
- Understand if the natural flood management techniques have been successful
- Allow Hebden Bridge residents to respond more effectively to flood incidents

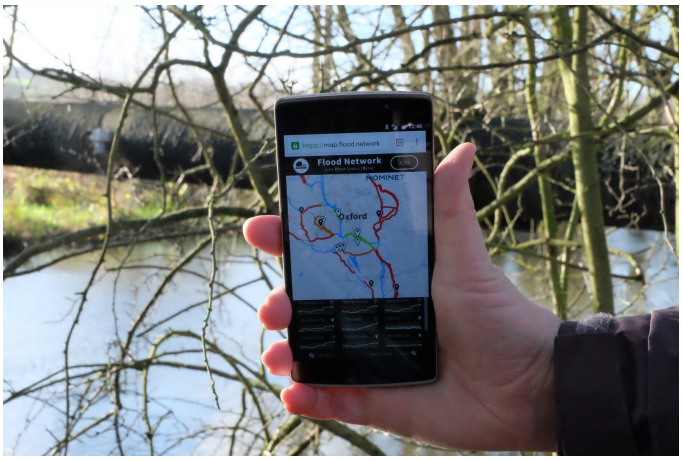
How & Why

By installing between 6-8 sensors upstream of Hebden Bridge a high density of sensors would provide information previously uneconomical to collect about the impact of Natural Flood Management (NFM) on the catchment.

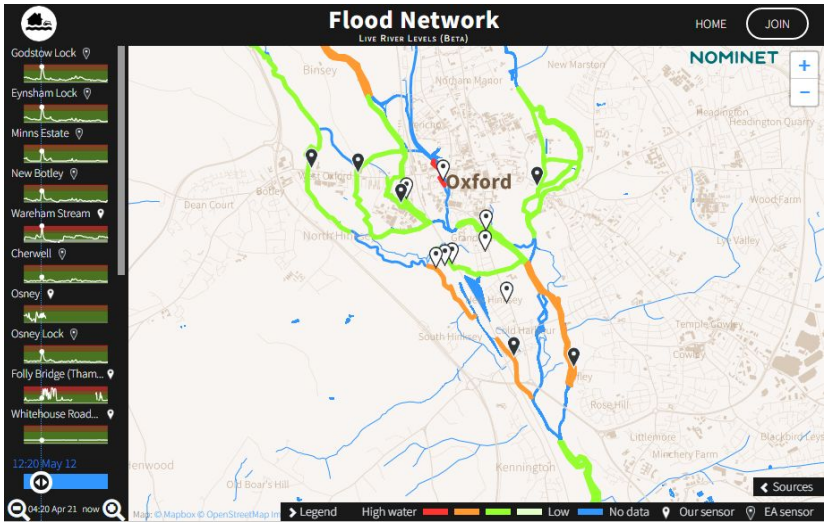
The sensors would be mounted on bridge sofits and overhangs above water at number of critical points and report their water level readings back using long-range wireless technology to the gateways at elevated positions around the valley, then on to the Internet where they can be viewed.

This will allow CCFSN to gather evidence about the impact of NFM on the catchment whilst presenting that information to the public on a map, visible on a public facing website, which can also be used for real-time flood risk awareness.

The sensors are low-cost and low profile so can be installed in locations previously uneconomical to monitor. For example, a pair of devices either side of a culvert trash screen can monitor the difference in levels, indicating a blockage. They are easy to install and calibrate, requiring only basic DIY skills.



Sensors can operate on battery power for around a year and transmit readings at 15 minute intervals. Level and temperature data is reported back to the Flood Network system using a long-range low-power wireless technology independent of the mobile network. This provides historical data which can be viewed as graphs and used to understand trends or as calibration data in future flood modelling.



The level and warning data is visible using a mobile friendly web application suitable for use in the field. There is also a desktop view for control room or on-call use and decision making.

We also provide an SMS alert service (currently under development) which can be managed by the user to provide early warning to a small user group.

The system is currently in development and customer feedback allows us to develop our products to address critical needs.

Costs

The most appropriate solution for your needs is a Flood Monitor Kit (Medium) which includes 8 sensors and 3 gateways and 2 additional sensors to bring it up to 10. The number of gateways needed versus the number of sites covered can be discussed as it depends on topography and distance.

Item	Price
Flood Monitor Kit (Medium) - 8 x Flood Sensor - 3 x gateways including outdoor kit and basic antennas	**£8,460**
2 x additional Flood Sensor @ £270 each	**£540**
Flood Network annual subscription - £10/mth/sensor x 10 sensors	**£1200/yr**
Total (ex VAT)	**£10,200**

Prices are provided without VAT (we are not VAT registered).

What Flood Network will provide

Flood Network will provide the service and the items listed below. A subscription gives access to the raw data, analytics tools and device management system.

What this quote includes:

- Hardware
  - 8 sensors using long-range wireless. Batteries and antennas included
  - Gateway devices, weatherproofing kit, a basic outdoor antenna (3m cable)
- Software
  - A Flood Map visualisation system showing a simplified public view of any sensor you choose to publish at http://map.flood.network highlighting levels in real time.
  - A backend system which allows you to manage and troubleshoot your devices
  - Access to the raw data collected
  - Analytics tools which provide tools to further investigate the level data collected, along with export options

- The Internet of Things collection system, gathering data from the sensors and uploading it to a cloud-based backend
- An alert and SMS notification system (once available)

What this quote doesn't include:

- Installation of the hardware
- Ongoing maintenance of hardware
- Mounting brackets for the sensors - each location has different requirements
- SLA - We do not currently provide an SLA, but we will ensure best endeavours support to keep the backend system running, backed by Nominet's team.
- Site rental and acquisition - Although the sensors are small and unobtrusive some sensor sites and gateway locations may need agreements.
- Backhaul - Broadband will be needed at the gateway locations. The system requires only a trickle of data, so would be easily shared with an existing consumer or business broadband installation.

Consultancy is available to assist with radio planning and site selection and is charged at £600/day + expenses.

Although installation is not included we may have local contacts who can assist with finding gateway sites for example. There is also likely to be some interest from local groups to host gateways in more informal locations, greatly reducing cost.

About Us

Flood Network

To make sense of the effects unpredictable weather and urbanisation are causing to our rivers, watercourses and drainage systems our network uses Internet of Things (IoT) technology to create a low-cost network of low-profile sensors. This helps incident managers react more effectively to flooding, allowing them to monitor water levels and combine data from critical locations and sensors installed around the community to give a better picture of the situation on the ground.

The data collected in both high- and low-flow periods can also be used to improve the accuracy of flood models and predict future events, informing planning decisions and building resilience into communities and target areas where it matters.

The company is run by **Ben Ward**. Ben is a network architect, respected within the Internet of Things sector and with a deep understanding of IoT. Having built an environmental sensing company, **Flood Network**, and a wireless & IoT consultancy, he's able to apply over 20 years experience of technology to real-world problems.

Nominet

Nominet is best-known as the organisation responsible for the smooth and secure running of the .UK internet infrastructure. Building on its roots as the .UK domain name registry it's exploring a wide range of technologies based on understanding its data and the future internet. As part of its public benefit agenda, it's committed to developing a secure internet space that supports a thriving digital economy. Nominet's Internet of Things tools power the back-end data storage, device management, and visualisation systems for Flood Network.

Next Steps

If this proposal meets your requirements all we need to get started is a 50% deposit, which will allow us to place a hardware order. We look forward to helping you make the most of your flood sensors and growing Flood Network in such a critical area.

To move forward please sign below and return:

Name: _____

Title: _____

Signature: _____

Ben is available on **07771 537574** or you can email **ben@flood.network**

Terms

1. 50% Payment required before work starts.
2. This proposal is valid for a period of 60 days unless stated otherwise.
3. Payment must be made within fourteen days of invoice.
4. Overdue payments will result in the cessation of all work until payment is received in full. Interest will be charged on overdue payments under the terms of the Late Payment Act.
5. Any work in addition to that stated in the proposal, will require a written instruction to be issued to the team the costs of which will either be at an agreed rate which will be stated in the instructions, or failing this based upon the team day rates for all time involved and for any delays incurred.

APPENDIX G

NFM Opportunity Mapping (JBA work in progress)

1 Natural Flood Management Opportunity Mapping

1.1 Introduction

JBA have undertaken some initial strategic mapping across the Upper Calderdale catchment to assist in the identification of potential locations where a natural flood management (NFM) approach could be undertaken. The mapping also includes a range of other relevant spatial data sets that will hopefully be helpful in discussions about the acceptability of an NFM approach in the Upper Calderdale headwaters.

1.2 JBA Runoff Attenuation Feature Finder

The JBA Runoff Attenuation Feature Finder (JRAFF) consists of a suite of ArcGIS tools for identifying NFM measures such as runoff attenuation features or opportunity pond storage. The potential locations for these features are determined from a spatial analysis of the surface water flood depth grids derived for the updated Flood Map for Surface Water (uFMfSW). The uFMfSW is available to view on the Environment Agency web site:

http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?topic=ufmfsw#x=357683&y=355134&scale=2

Based on some pre-defined headwater catchment boundaries (typically ranging in size from about 1km^2 to 10 km^2) JRAFF has been used to identify areas of potential runoff attenuation features and opportunity pond storage.

1.3 Runoff Attenuation Features (RAFs)

Within each headwater catchment individual (unconnected) Runoff Attenuation Features have been identified with surface areas ranging between 100-5,000m^2. These RAFs have been defined based on locations of natural depressions in the landscape which are predicted to naturally store surface water (for the 1 in 1,000 year rainfall event) following analysis of the uFMfSW flood depth grids. A number of constraints have filtered potential RAFs, where these are located within urban areas, and the immediate vicinity of buildings and roads. As these RAFs represent depressions in the landscape where surface runoff will naturally accumulate then they also represent locations where the flood storage and attenuation effects could be actively enhanced through some form of shallow excavation and/or earthen bund building.

1.4 Woodland Creation

The Forest Research Woodlands for Water (WfW) database was used to identify potential areas of new woodland creation which may provide natural flood management benefits (e.g. resistance to flow, rainfall interception, enhanced soil infiltration). The "Potential New Woodland to Reduce Rainfall Runoff" opportunity data were filtered to determine: (i) areas with impermeable soils that have a Standard Percentage Runoff (SPR) >50% where new woodland could be planted and (ii) riparian woodland areas (within a 50m margin next to a watercourse). Floodplain woodland areas (iii) were also identified separately, which can overlap with (i) and/or (ii). Floodplain woodland represents potential woodland creation within the Environment Agency's Fluvial Flood Zone 2 and outside of the constraints area. The woodland opportunity maps exclude a designated 'Constraints' area, which combines all urban areas, open water, existing woodland and deep peat.

1.5 Environmental Designations

A number of environmental designation spatial datasets have been acquired for the Upper Calderdale, which could potentially act as a constraint to NFM implementation in certain circumstances. These are:

- Sites of Special Scientific Interest (SSSIs)
- Special Areas of Conservation (SACs)
- Special Protection Areas (SPAs)
- Ancient Woodland Inventory
- Common Land
- Protected Land (Development that would prejudice the consideration of the future of this land in the context of Development Plan review will not be permitted)
- Local Geological Sites
- Local Wildlife Sites
- Sites of Ecological or Geological Interest
- Calderdale Wildlife Habitat Network

1.6 Mapping

A set of strategic maps have been generated that cover the Upper Calderdale study area, which has been split into 5 separate mapping areas. The strategic maps are:

- Strategic Mapping – Potential Runoff Attenuations features, including environmental designations
- Strategic Mapping NR - Potential Runoff Attenuations features, excluding environmental designations
- Woodland for Water (WfW) opportunity mapping
- Strategic Mapping WHM – local environmental designations