Engaging with river restoration: the performance of habitat enhancement in the River Rother, West Sussex, as a rich learning resource.

Final Project Report

University of Portsmouth

January 2016

Contents

1. Introduction

The River Rother is the only river to have its catchment fall entirely within the South Downs National Park boundary and experienced a long documented history of use spanning as far back as at least 1086 but is now a place of recreational fishing and leisure - an important resource for the health and wellbeing of local communities. In addition, the river has the potential to provide unique habitats for several Biological Action Plan (BAP) priority species, and as such it has been designated as a Site of Nature Conservation Importance.

Although the river is an important feature in the heart of the National Park, unfortunately it is failing to achieve 'good ecological status', as specified by criteria under the EU Water Framework Directive (WFD), primarily due to poor fisheries. This is attributed to the physical modification of the river and in stream sedimentation which tends to reduce the physical habitat diversity of the channel and smother spawning gravels (notably for salmonids) where they exist.

This project centres on an evaluation of a small river restoration project implemented by the Arun & Rother Rivers Trust (ARRT) in August 2013 and involved the creation of a riffle feature and provision of associated physical habitats. The project is located near Shopham, approximately 5.5km south of Petworth. The project was funded by Defra's Catchment Restoration Fund, a competitive award allocated to only a small number of projects judged to have potential for making a marked improvement to ecological status under the WFD.

River restoration approaches are now accepted as a means of achieving sustainable river management, with schemes becoming more common within the UK. A separate project has already been completed on the Rother, which involved reinstating the sinuous channel at Shopham Loop. However, many programmes have not considered rigorous post-restoration monitoring, which is essential to evaluate whether projects have met their design objectives over the short and longer time scales.

The emphasis here is to conduct a series of monitoring surveys, collect datasets on river velocity and bed elevation in order to show time-sequential changes in physical conditions and to make inferences on the changing nature of physical habitat provision afforded by the riffle feature in the context of the flow regime experienced since installation.

2. Objectives

The project comprised two components:

i) *Performance assessment*: A geomorphological monitoring programme over an 18 month period to assess morphological and physical habitat change based on data collected using an Acoustic Doppler Current Profiler (ADCP);

ii) *Project dissemination*: Engagement with the community at the academic, practitioner and school levels to raise awareness of river restoration, promote the River Rother as a special feature of the National Park and disseminate the scientific research findings.

The initial project proposal involved a broader community engagement component as funding was originally sought from the SDNPA Sustainable Communities Fund. However, funding was made through a separate research fund of the SDNPA and the 'engagement' objective was reduced in scope. Despite this, though, the project has supported engagement through a river management event held at the University of Portsmouth for pupils from local schools, as well as a series of other dissemination events.

3. Performance Assessment

3.1. Field campaign and data analysis

The project undertook a geomorphological monitoring programme of the artificial riffle-glide feature installed in August 2013 downstream of Shopham Bridge as part of the wider Western Rother Fishery Habitat Enhancement Project of the ARRT. Over an 18 month period, surveys were conducted to measure 3D velocity patterns and map channel bathymetry within a 180m reach, inclusive of the 60m long feature, using an Acoustic Doppler Current Profiler (ADCP). A baseline survey was completed in July 2013 and a post-construction survey was undertaken in August 2013, both during low flow conditions. Then, additional post-construction surveys were completed at 1, 3, 7, 12, and 18 months to capture the geomorphological response of the feature and over a range of flows (Table 1). During this time period the reach experienced multiple out of bank flows. In particular, the 2013/14 winter flooding was considered to be at least a 100 year event (having discussed the significance with EA staff), with a considerable duration over multiple hydrographs that restricted access to the site for approximately a 2 month period between January and February 2014 (hence the targeted 6 month survey became the 7 month survey).

Survey	**Date Completed**	**Discharge (m^3s^{-1})**
Baseline	26 / 07 / 2013	1.8
As-built	08 / 08 / 2013	1.9
1 Month	04 / 09 / 2013	1.7
3 Months	09 / 11 / 2013	8.5
7 Months	02 / 03 / 2014	13.1
12 Months	05 / 08 / 2014	2.1
18 Months	24 / 01 / 2015	8.1

Table 1: Monitoring survey details

The application of the ADCP to river restoration monitoring is novel, and so a post-processing protocol was developed at the University of Portsmouth to process the ADCP data and create Digital Elevation Models (DEMs) and velocity maps for each survey at 5 elevation levels above the bed (20%, 40%, 60%, 80% and 100% of the recorded depth). The DEMs were analysed using a DEM of Difference technique to investigate elevation change in the reach. These elevation changes were then mapped to visualise geomorphological change between successive surveys and also relative to the as-built condition, to assess the resilience of the feature. This report also includes a preliminary assessment of physical habitat provision within the reach for two fish species; Brown Trout (*Salmo trutta*), a target species of the scheme, and Grayling (*Thymallus thymallus*). Grayling was chosen as an indicator species of general health for coarse fish species. Fishing rights on the site belong to the Petworth and Bognor Angling Club, with Shopham Bridge considered to be a popular site for catching Grayling (based on their website). Using published habitat suitability curves of velocity and depth, a Habitat Suitability Index (HSI) ranging from 0 (unsuitable habitat) to 1 (ideal conditions), was mapped over the reach for each survey. These habitat suitability curves are published in a report by Bullock *et al* (1991) which is available from http://nora.nerc.ac.uk/7351/1/IH_115.pdf.

3.2. Results

3.2.1. Morphological Change

The DEMs for each survey show elevation above ordinance datum (AOD) and are presented in Appendix A. The baseline survey (July 2013) DEM of the reach prior to riffle construction indicates a relatively uniform bed morphology. The as-built survey (August 2013) DEM shows the feature as initially constructed, clearly illustrating how bed elevations gradually ramp up in the downstream direction towards a topographic high over the tail of the feature. The DEM of Difference maps are shown in Appendix B and portray elevation change (m) over the reach as a deviation from the as-built design, and also as the change between successive surveys.

In the first three months post-construction a degree of deposition occurred over the riffle and bed scour was experienced downstream of the feature but the structural integrity of the feature remained. After 7 months post-construction (March 2014) and with a 1 in 100 year flood event experienced, significant structural modification to the feature can be observed together with other morphological responses over the wider reach (both scour and fill). The main features include deep scour of approximately 1m in both the upstream and downstream pools and significant scour immediately downstream of the feature. Deposition in excess of 0.5m over the head of the artificial feature in combination with scour over the tail of the feature resulted in a tilting of the feature such that the designed topographic high over the tail shifted to the riffle head (perhaps more representative of natural riffles in gravel-bed rivers). Furthermore, the feature appeared to extend its length in the downstream direction through sedimentation. The maps of elevation change between surveys suggest that most of the change observed in the reach occurred during the 3 to 7 month post-construction period (November 2013 to March 2014). After 12 months (August 2014) and 18 months (January 2015) post-construction, the modified shape of the feature appeared to remain intact with the topographic high of the reach sited over the head of the feature. Seasonal deposition is indicated through the reach and between the 7 and 12 month surveys (March to August 2014) blanket deposition appears to have occurred throughout the reach as flows seasonally decrease (not to be unexpected) and conceivably as mobilised sediment from the flooding works its way along the course of the river. As flows increase in magnitude through autumn/winter it is interesting (but again perhaps not unsurprising) that sediment is then remobilised, as evidenced in the illustrated changes between the 12 and 18 month surveys (August 2014 to January 2015), revealing the dynamic and seasonally-driven nature of sediment transport through the reach.

3.2.2. Velocity

The series of velocity maps are provided in Appendix D and highlight the typical variation of slower velocities observed near the bed (20% depth), influenced by channel roughness, to maximum velocities nearer the surface. The depth-average velocity map (approximated by the 40% depth level, measured from the bed) for the baseline survey suggests the pre-restoration velocity patterns were characteristically uniform with little of the diversity at low flow found in natural, unimpacted rivers. Immediately post-construction (August 2013) and 1 month post-construction (September 2013) low flow velocities were considerably more varied with peak velocities over 1 ms^{-1} sited over the highest elevations of the feature. After 12 months (August 2014) and after the notable flood events, the reach was surveyed under low flow conditions again; however significant morphological change had modified the velocity patterns within the reach. The highest velocities previously located over the riffle tail are no longer present, with maximum velocities in the reach now sited nearer the head and left bank of the feature (in the vicinity of greatest deposition). As such, the river channel velocity adjusted in accordance to the morphological changes driven by the flooding. Despite the disappearance of the very high peak velocities at low flow, velocity patterns 12 months post-construction appear to be more diverse than both the baseline and as-built survey conditions, which is an important finding. The velocity 'range' decreased but overall 'diversity' improved as the feature was reworked.

Unfortunately, moderate and high flow baseline surveys were not captured (a limitation of the project but a known constraint from the outset) and therefore it was not possible to compare the 3, 7, and 18 month surveys (November 2013, March 2014, and January 2015) to a baseline condition of similar flow magnitude. However the 3 and 18 month surveys were captured pre-and post-flood respectively at a similar moderate flow, presenting an opportunity to compare the effects of flooding on the feature at a reasonable within bank event. During the 3 month survey velocities were highest over the feature and the core of maximum velocity is observed to have a generally central location through the reach. The 18 month survey exhibited a similar pattern in general but with the higher velocities extending further upstream and downstream over the riffle, associated with deposition and lengthening of the feature. The 7 month survey was captured at a bankfull discharge as the flood water receded and here velocities can be seen to exhibit similar characteristics to those observed at a moderate flows. Although there is no comparable pre-restoration high flow dataset for the 7 month survey, the results suggest (unsurprisingly) that the influence of the feature on flow patterns becomes drowned out as depth increases.

3.2.3. Physical Habitat

Physical habitat provision, defined by suitability to velocity and depth, was assessed for the two species of Brown Trout (Appendix E) and Grayling (Appendix F), at 4 life stages (spawning, fry, juvenile and adult). Suitability here is characterised on the basis of depth and velocity alone. The baseline survey reveals conditions highly suitable for Adult and Spawning Grayling and Juvenile Brown Trout, but less favourable for Spawning and Adult Brown Trout. The installation of the feature appears to have reduced somewhat the habitat suitability for Adult, Spawning and Juvenile Grayling, and habitat becomes more 'patchy' after the flood events. However, habitat suitability for Adult and Spawning Brown Trout tends to improve with the addition of the feature to the reach as shown by the as-built survey and post-flood 12 month survey (both low flows), but notably the topographic highs in both surveys appear to be locations of less suitable habitat. Moderate flows also appear highly suitable for these life stages of Brown Trout both pre and post flood, but habitat provision at high flow becomes reduced and highest quality habitat becomes more confined to the channel margins. The quality of habitat for Juvenile Trout is retained throughout the monitoring surveys, with some losses of habitat observed as the pools deepened following the flood events.

Fry habitat provision for both Grayling and Brown Trout was poor prior to restoration and remained poor throughout the whole monitoring survey; high quality habitat where present was confined to the channel margins. This is perhaps an area for concern as a lack of fry habitat may be creating a bottleneck for the life-stage progression of these species.

Research on the implications for habitat provision are ongoing at the University of Portsmouth, utilising analytical measures of spatial variability to better evaluate the success of the scheme over the 18 month monitoring period. It is anticipated that final results on this strand of the research will be presented in a subsequent academic publication(s).

3.3. Key findings and recommendations

The structural integrity of the riffle-glide feature was not unaffected by the significant flood event (assumed to be of the order of a 100 year flow). This is not considered to be failure as riffle sediments are rarely designed to be static-stable in restoration schemes for events exceeding bankfull. The findings reveal that the feature was re-shaped by the natural fluvial processes and (perhaps unsurprisingly) the high elevations shifted to an emerging crest at the head of the riffle (not dissimilar to natural riffles in gravel bed rivers). A success of the scheme is in the promotion of overall bed form diversity through scour and fill processes, a result of both the project and flood event experienced (within only six months of implementation). Beyond the feature, existing pools appear to have deepened significantly. The construction of the feature had initially diversified flow patterns within the reach and increased the maximum velocity experienced from approximately 0.3 m s^{-1} to 1 m s^{-1} at a low flow. These peak velocities, though, were short-lived as a result of the autogenic reworking of the feature during and after the flooding. The modified bed morphology, however, now appears to support a larger area of elevated velocities than the original design at low flows (although this advantage is reduced at higher flows).

Geomorphologically, the design was not entirely resilient, but has performed well in light of the flooding experienced. The feature has diversifying physical conditions overall and, therefore, has restored a degree of ecological functioning to the reach (especially during low flows). However, future restoration work may like to consider methods of diversifying velocity patterns at a range of flows and also to focus more on coupling the needs of all life stages of target species – potentially by linking this type of rehabilitation measure to other methods in close proximity to each other (improving the potential for the bed features, river banks and vegetation to support habitats). The nature of the sediment composition associated with siltation over the gravels of the feature was not investigated as part of this project but it can be reported that the feature had clean gravels in areas of higher velocity following the flood events in August 2014. Only further monitoring would confirm whether there is a tendency for fining of the particle size distribution over time or if indeed the reach acts to flush finer sediment through the reach seasonally. The site has been subsequently adopted by the Sediment and Mitigation Options for the River Rother (SMART) project, (involving SDNPA and the University of Northampton) which upon completion might reveal the extent of sediment 'mixing' over the feature.

As constructed, the artificial riffle glide feature improved habitat for the target fish species Brown Trout. Although the structural integrity of the feature as designed did not completely withstand a significant flood event, the present feature is still providing a valuable Brown Trout habitat. A lack of fry habitat within this general area of the Rother remains an area of concern and should be treated as an impetus for research studies and a focus for further restoration efforts. In particular, it is recommended that future works give more attention to creating fry habitat and refugia during flood events, while linking these areas spatially to improved conditions for Juvenile/Adult habitat. Prior to restoration the site was providing a reasonably good habitat for grayling, but both the designed and subsequently adjusted feature may have somewhat fragmented this habitat within the study reach, which is unfortunate, although conceivably other areas of high quality habitat may exist in reasonable close proximity so as not to adversely impact on this species.

4. Dissemination

The key findings of this project have been widely disseminated to academics, practitioners and schools, through the attendance and organisation of relevant events. At all events the South Downs National Park Authority has been gratefully acknowledged for its support on this project.

4.1. Conferences

The key findings of this project have been disseminated at 5 conferences by Jennifer Cox and Philip Soar. Project findings have been disseminated at the South Downs Student Conference at the South Downs Centre, Midhurst both in 2014 and 2015. In 2014, the conference theme was "Healthy Environment, Healthy Lives: Towards a 21st Century Park" and an oral presentation was delivered on the preliminary findings of the feature's performance in light of the 2013/14 flood events. The presentation was titled 'Resilience and morphological performance of an artificial riffle on the river Rother, West Sussex'. In 2015 the conference theme was 'Embracing the future: Managing the environment, heritage and change in the South Downs National Park', where the findings of the project were disseminated in the oral presentation titled 'Lessons for the future: Learning from river restoration in the National Park'.

Preliminary findings on the performance of the feature were presented as a poster at the British Society for Geomorphology (BSG) Annual General Meeting on1st-3rd September 2014 at the University of Manchester. The conference theme was 'Geomorphology: Past, Present and Future'. The poster received a commendation by the BSG. The conference, attended primarily by academics but also practitioners, hosted a dedicated session to river restoration which highlighted the importance of geomorphology and monitoring in river restoration practice.

The monitoring programme of the River Rother habitat enhancement scheme to showcase the utility value of the ADCP, project performance up to 12 months post-construction was disseminated at the 14th Annual River Restoration North West (RRNW) Symposium, Skamania Lodge, Washington, USA on 2nd-5th February 2015. An oral presentation was delivered on 'the application of the Acoustic Doppler Current Profiler for river restoration monitoring and appraisal'. The conference was attended by over 400 academics and practitioners.

A summary of the project and key findings was delivered in an oral presentation 'Experiences of restoring physical habitat with an artificial riffle' at the River Restoration Centre's (RRC) 16th Annual Network Conference at Whittlebury Hall, Northampton on 19th and 20th May 2015. A copy of this presentation is available via the ARRT website, and project findings are to be summarised for the RRC, which they will make available to practitioners via the RRC new bulletin or the RiverWiki.

4.2. Engagement events

Wider engagement was focused through two events. First a site visit was conducted to the restoration site at Shopham Bridge. This was attended by members of the Wild Trout Trust, SDNPA and ARRT in August 2014. During the site visit, the attendees were updated on the progress of the project and performance of the artificial feature. Furthermore, members of the SDNPA and ARRT undertook some basic training on the application of the ADCP for rapidly collecting discharge, depth and 3D velocity datasets. Second, the project ran a River Management and GIS Taster Day on 22nd June 2015 at the University of Portsmouth for local key stage 4 and 5 school pupils. The event was well attended by over 30 local pupils and their teachers.

The day was aimed at engaging pupils with the River Rother as a local river management case-study. The day began with an introduction to river management by Jennifer Cox, PhD researcher at the University of Portsmouth, to gauge their current involvement and perception with river management. This was followed by 3 guest talks which outlined the roles of the National Park, fluvial geomorphology and GIS in river management, the presenters where Chris Manning (Water Policy Officer at the South Downs National Park Authority) Philip Soar (Senior Lecturer in Physical Geography) at Alastair Pearson (Principal Lecturer in Geography).

The guest lectures were followed by a GIS workshop; the pupils were given the opportunity of gaining hands on experience with GIS software to explore historical land use change in the River Rother catchment using 19th century Tithe maps. In the afternoon, the pupils undertook a problem solving activity in small groups involving the re-design of a degraded straightened section of the River Rother. They were tasked with creating a physical model of their design using a vast range of materials provided, and prizes were awarded to the most effective and justified designs. The day received excellent feedback from both students and staff who attended the event. The event connected local pupils to the River Rother, and promoted the river as a special feature within the national park. Furthermore, the event raised the aspirations of local pupils of higher education with many providing feedback that they were likely to attend university as a result. Particular thanks is given to Chris Manning for helping to coordinate the day.

4.3. Publications

The findings of this research project are currently being written up as a manuscript for submitting to a relevant peer-reviewed journal. The draft title is *'Monitoring river restoration using an ADCP'*. The aim is to submit the article in the coming months and will be made available to SDNPA for comment prior to publication.

The images provided in the appendices here will be made available to SDNPA separately as TIFF files.

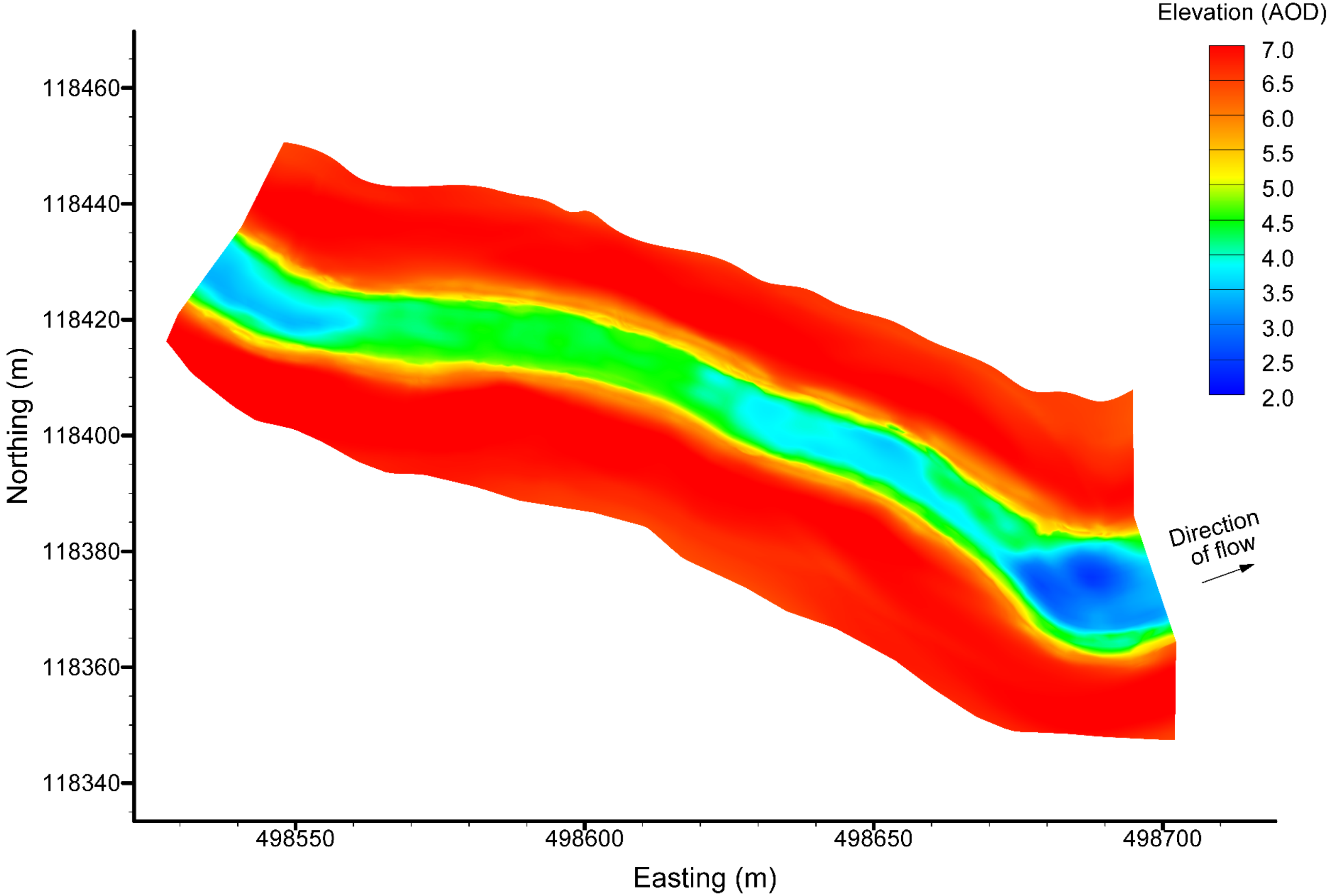
5. Budget

Project expenditure progressed reasonably to the original plan with no significant deviations to the proposal.

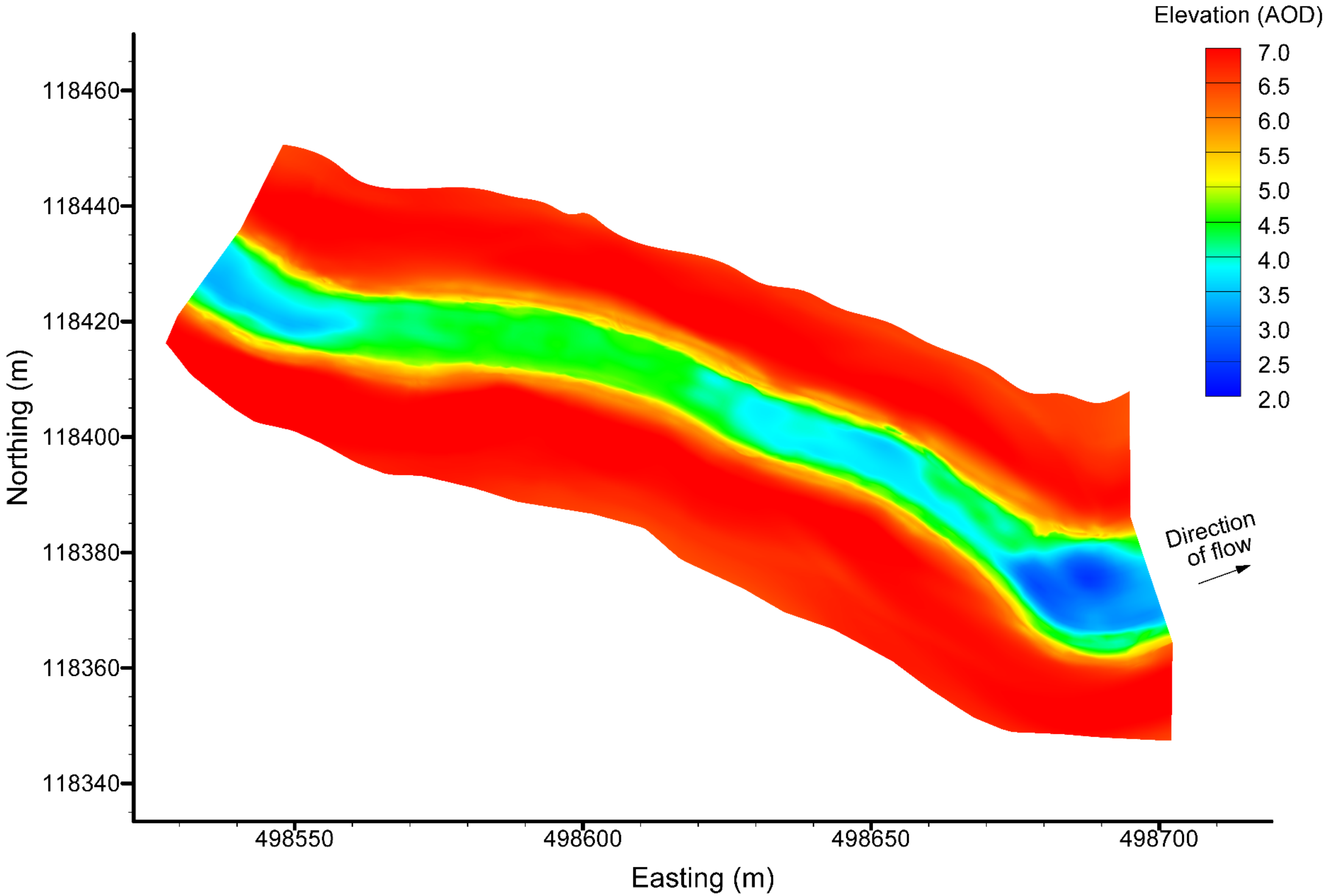
There is an underspend of £499.76 as savings were made on running costs and this will be returned to SDNPA in due course.

Appendix A: Digital Elevation Models (DEM)

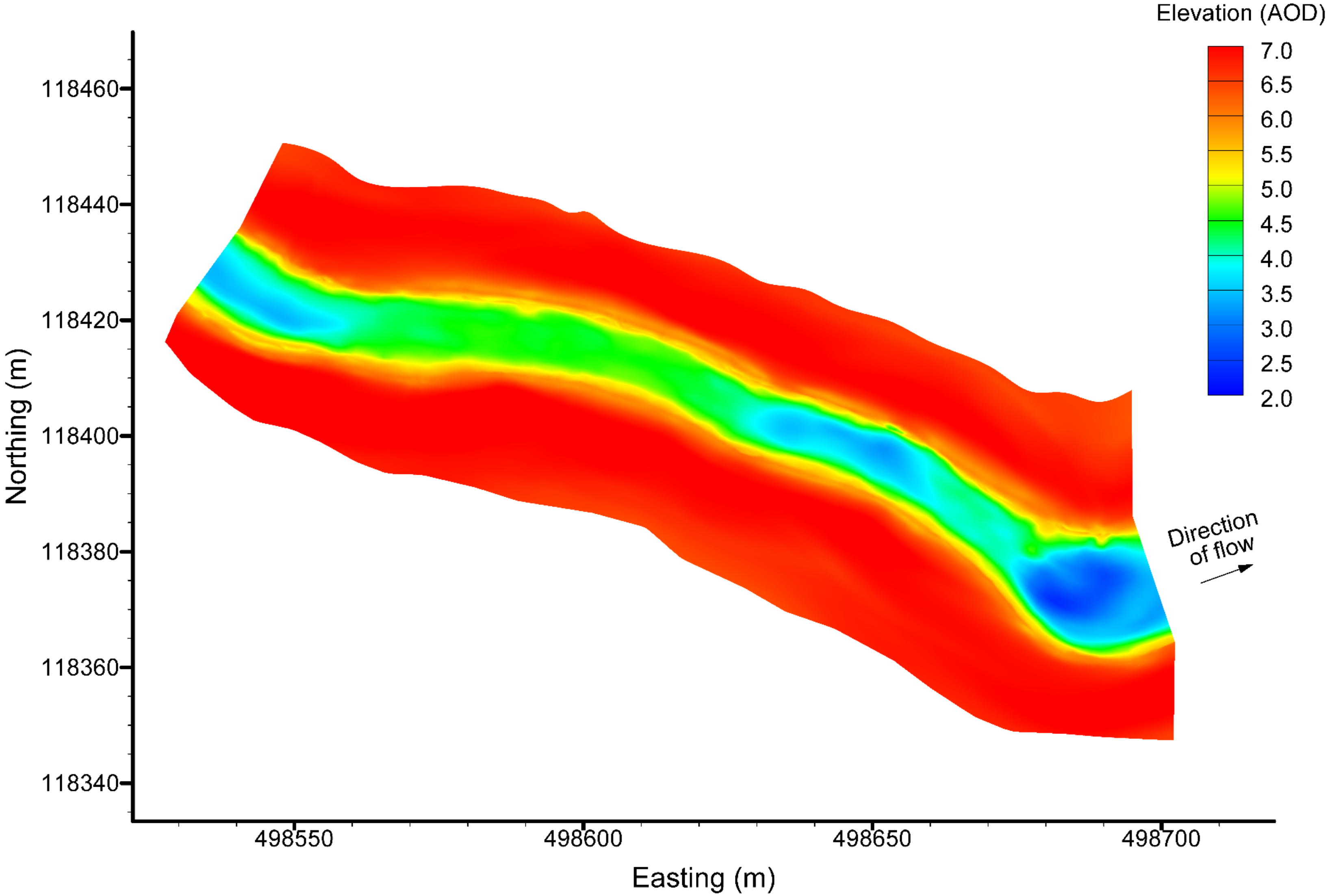
August 2013: as built survey



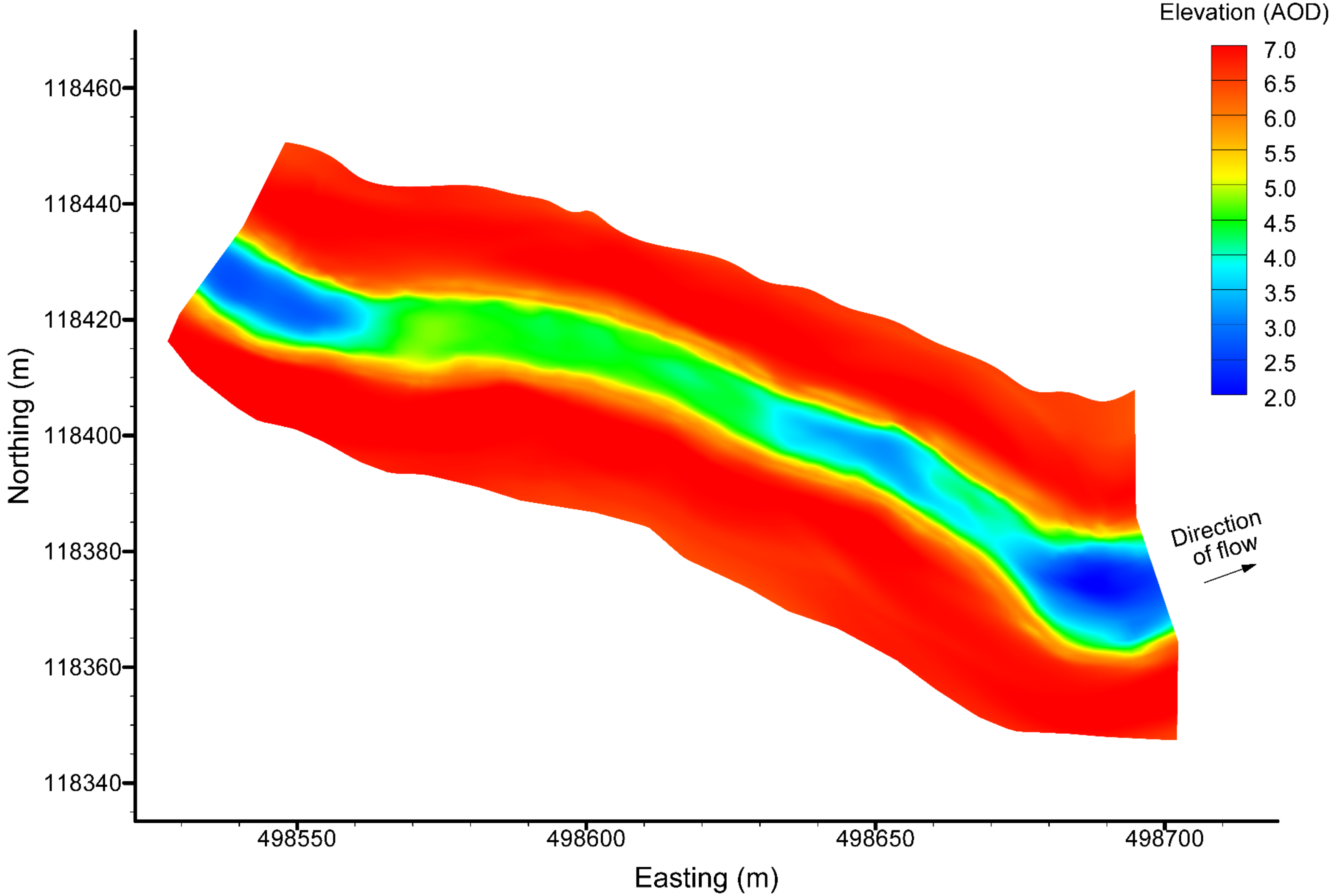
September 2013: 1 month survey



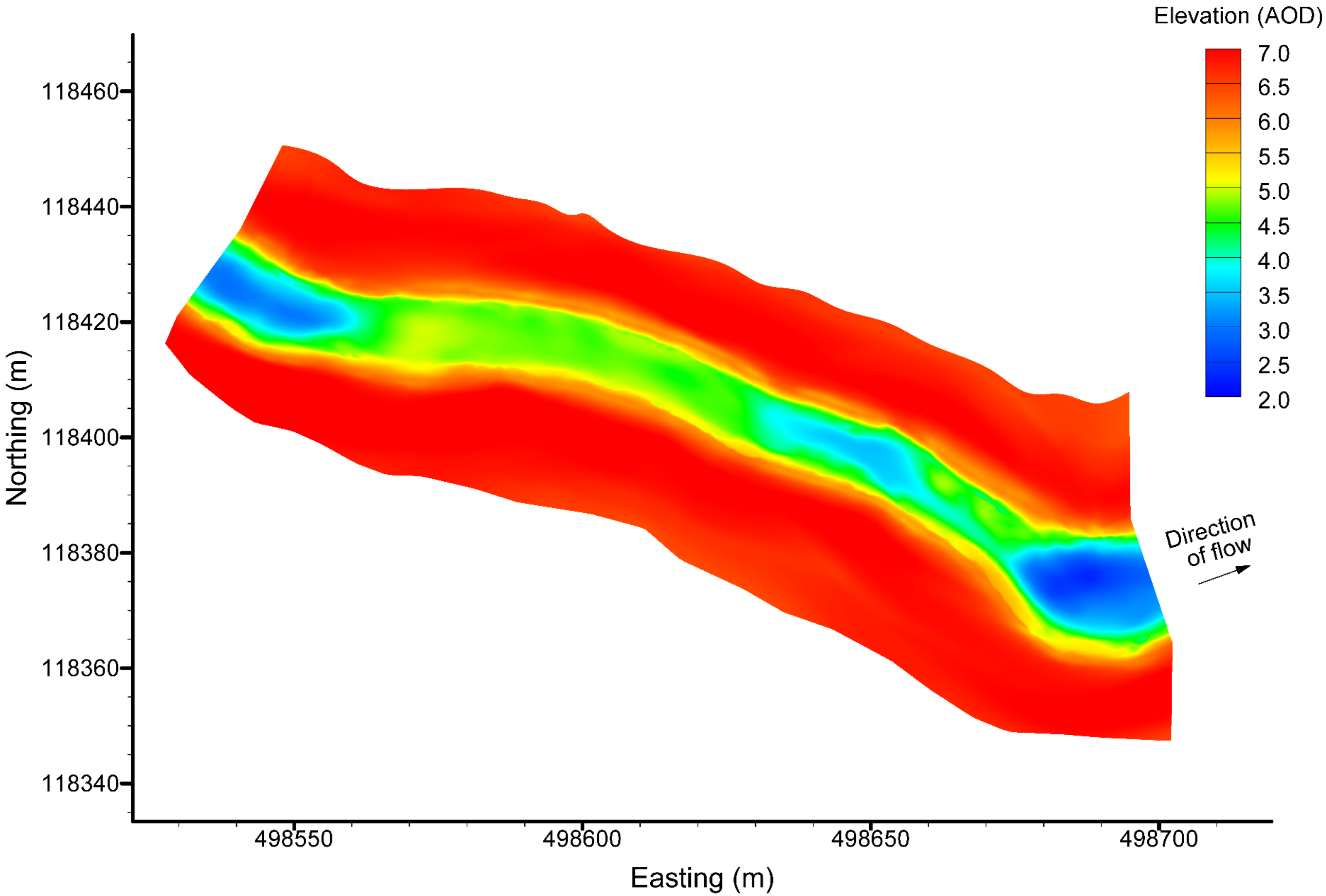
November 2013: 3 month survey



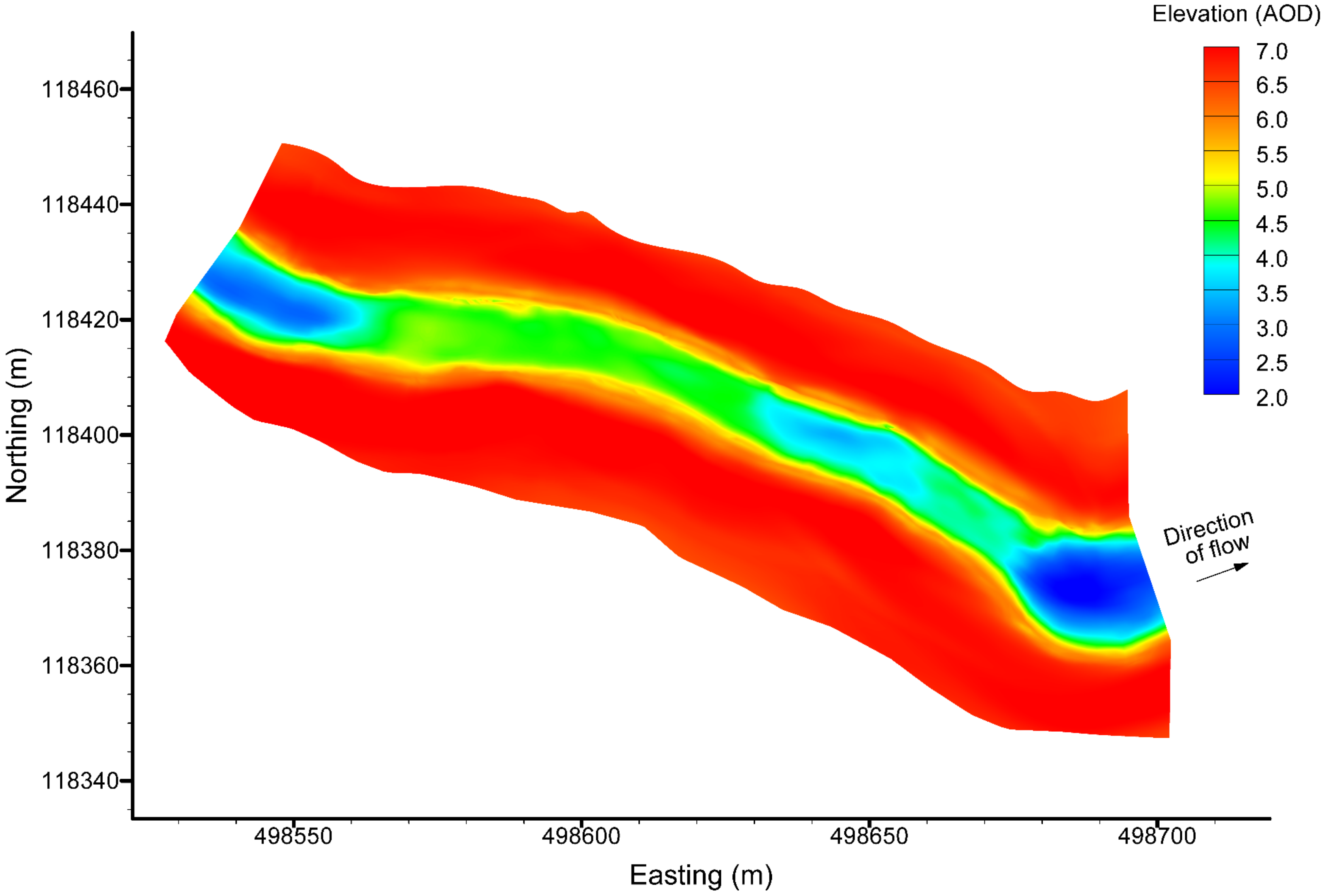
March 2014: 7 month survey



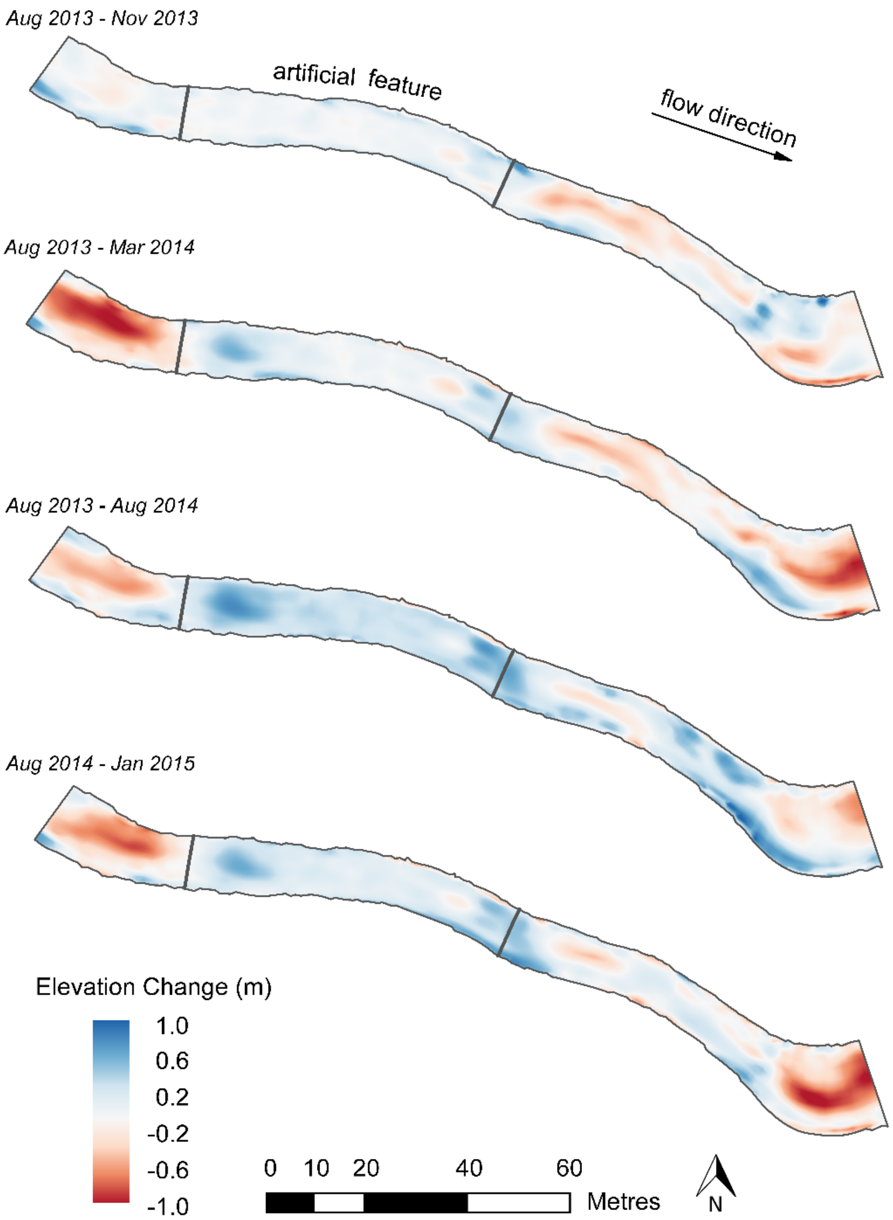
August 2014: 12 month survey



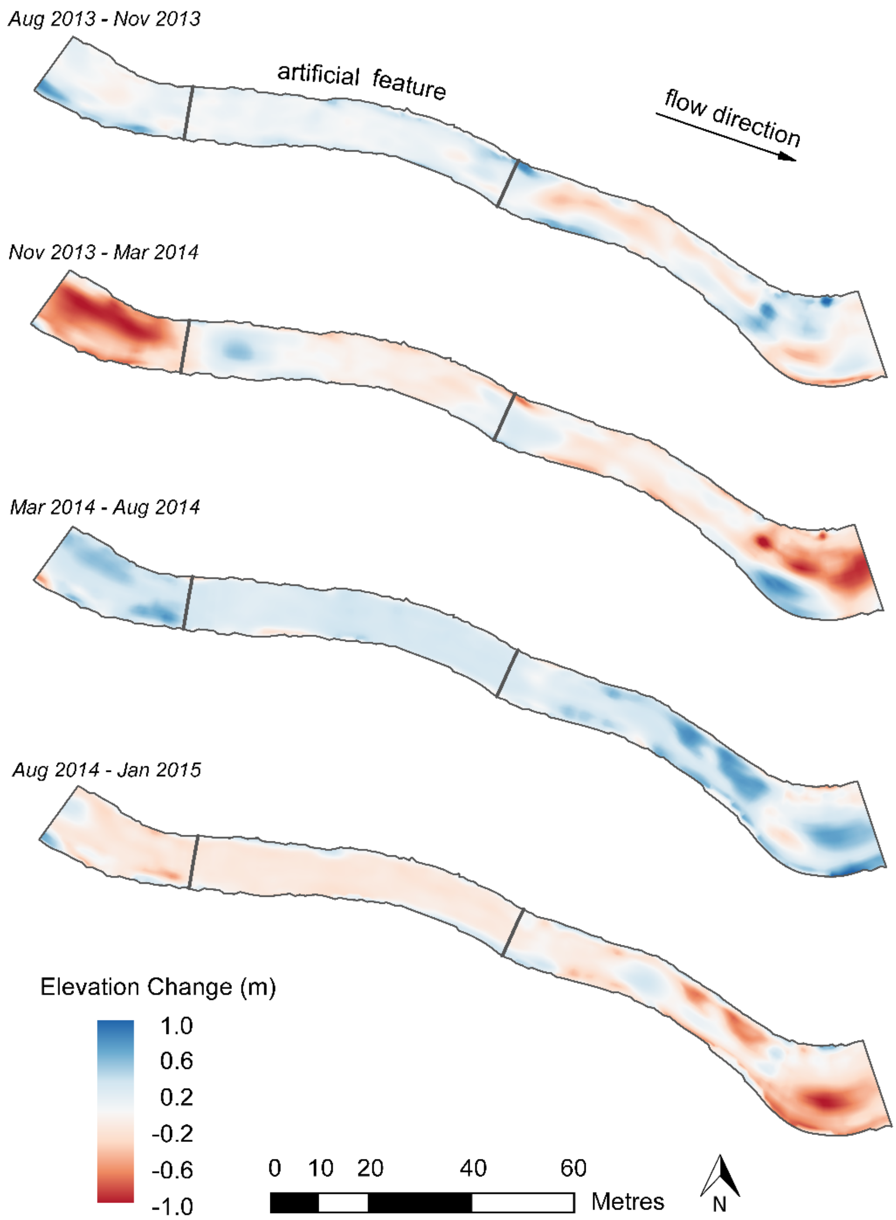
January 2015: 18 month survey



Appendix B: DEM of Difference plots



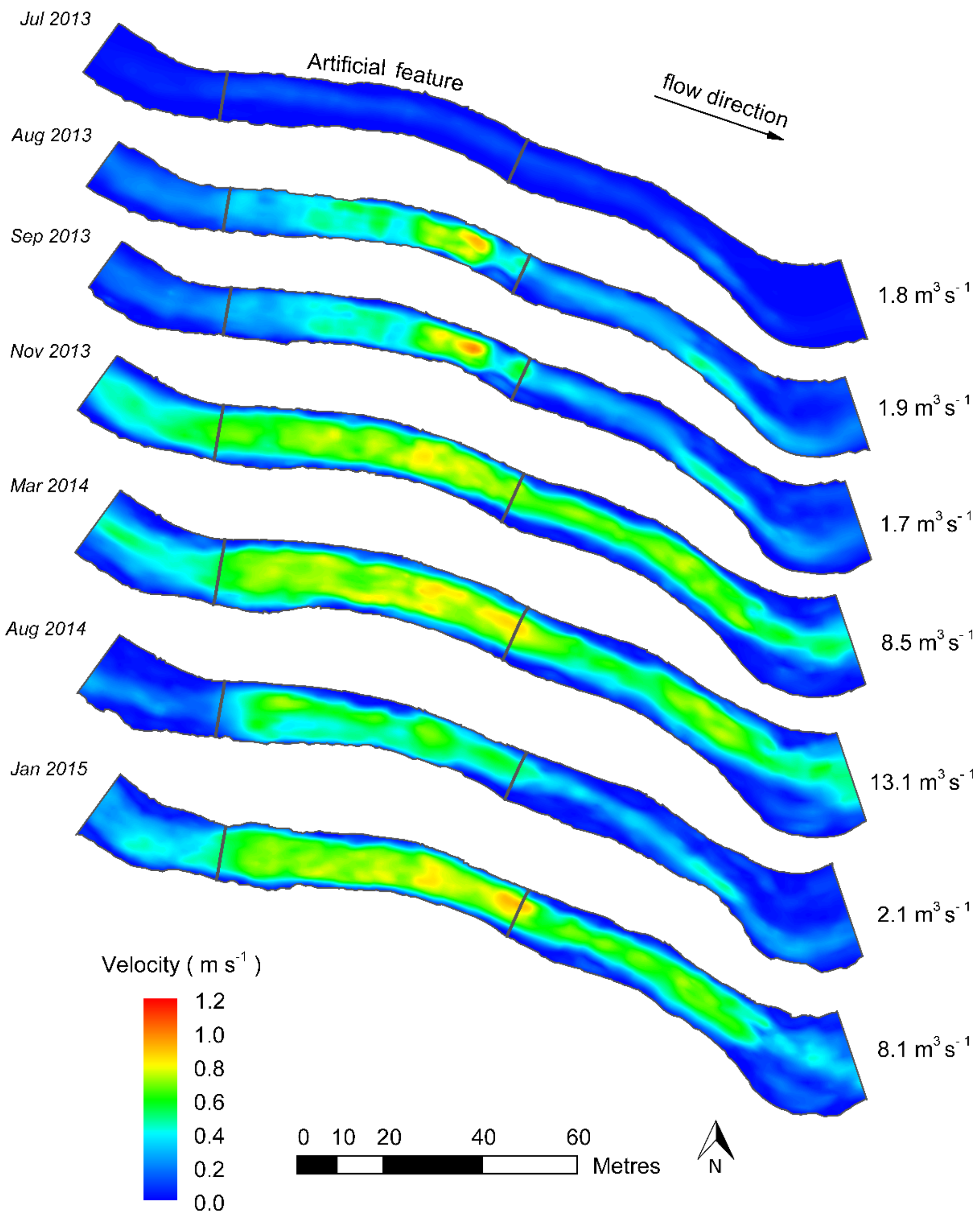
Aug 2013 - Nov 2013
artificial feature
flow direction
Aug 2013 - Mar 2014
Aug 2013 - Aug 2014
Aug 2014 - Jan 2015
Elevation Change (m)
1.0
0.6
0.2
-0.2
-0.6
-1.0
0 10 20 40 60
Metres
N



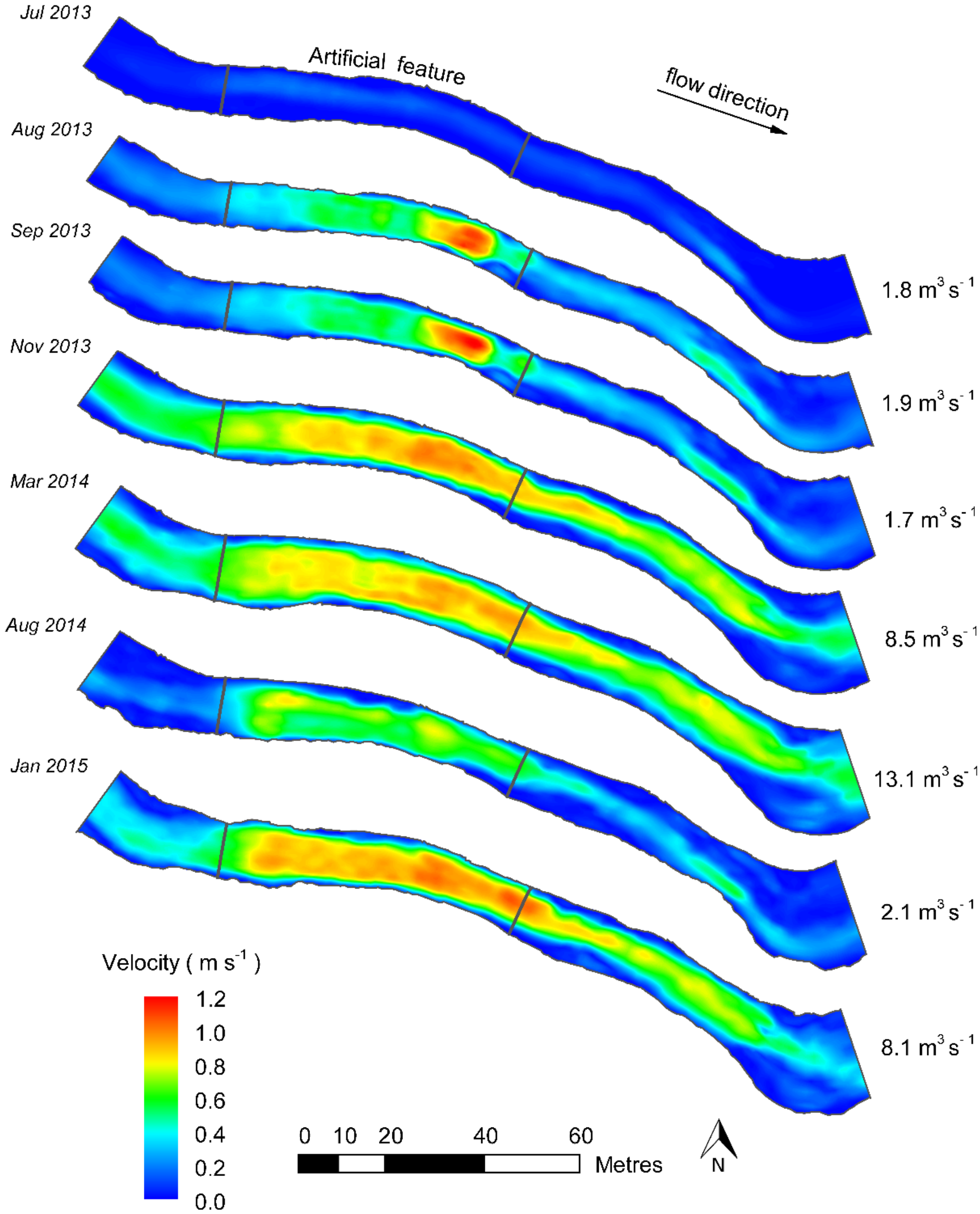
Aug 2013 - Nov 2013
artificial feature
flow direction
Nov 2013 - Mar 2014
Mar 2014 - Aug 2014
Aug 2014 - Jan 2015
Elevation Change (m)
1.0
0.6
0.2
-0.2
-0.6
-1.0
0 10 20 40 60
Metres
N

Appendix C: Velocity maps

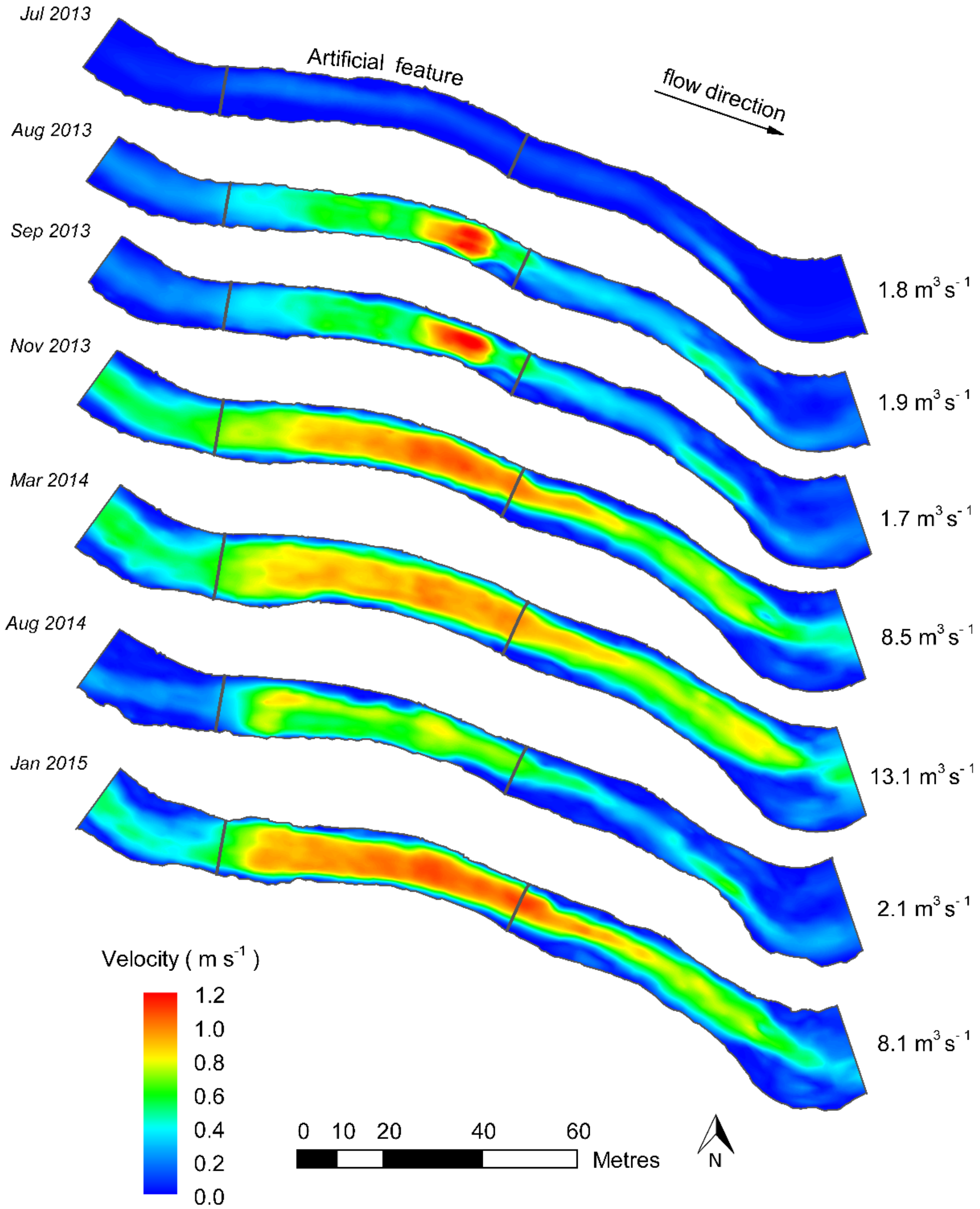
Velocity plot: 20% above the bed



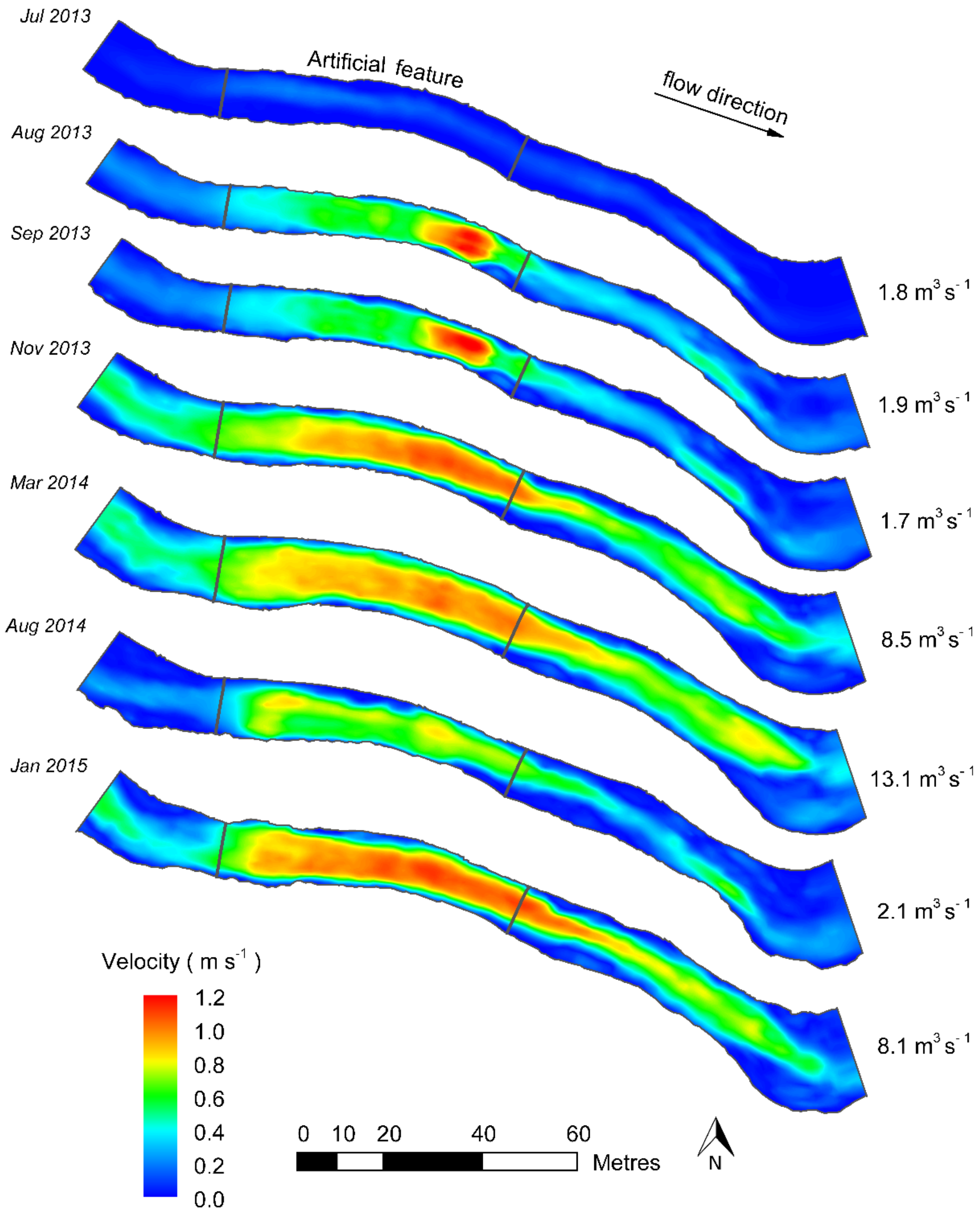
Velocity plot: 40% above the bed



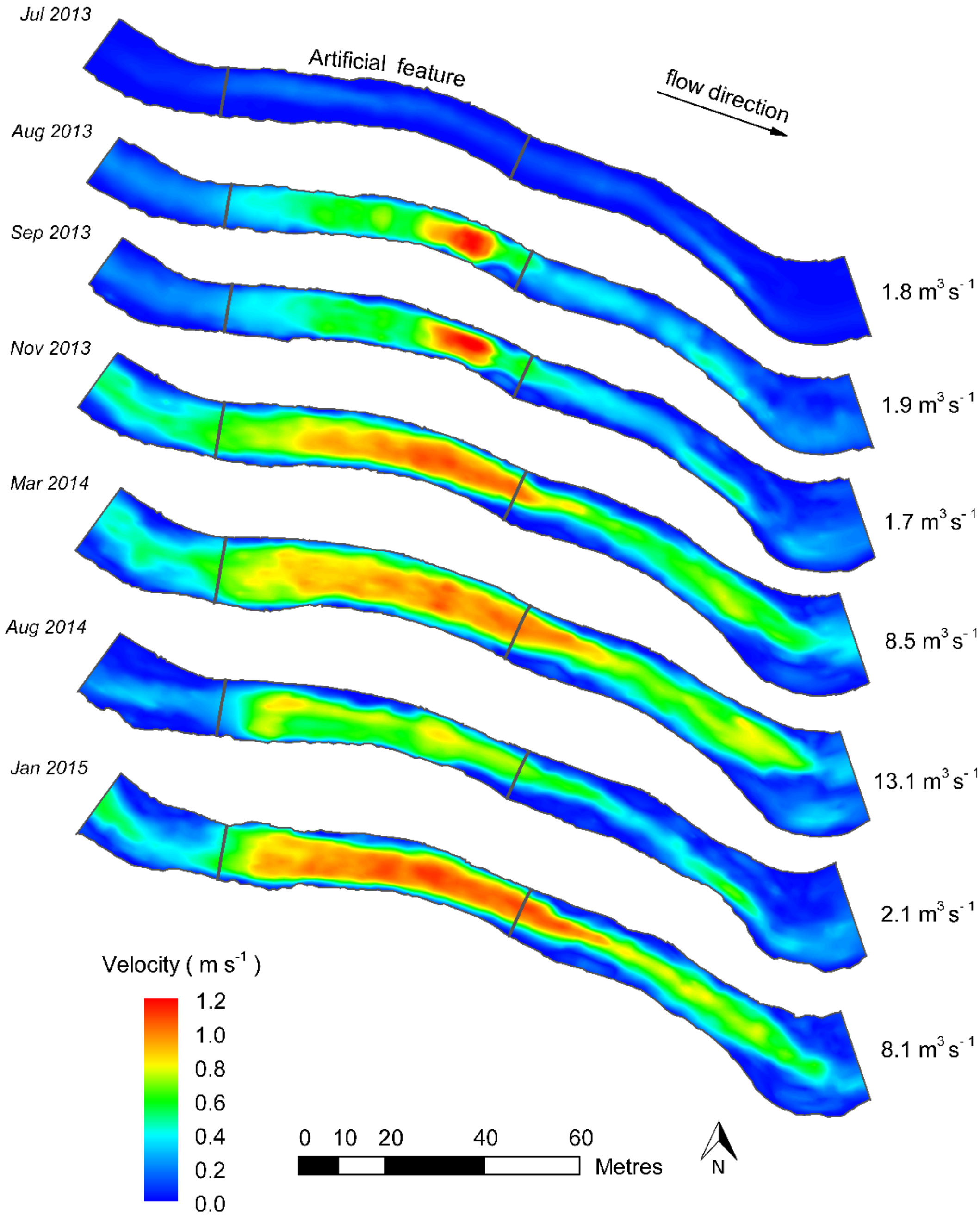
Velocity plot: 60% above the bed



Velocity plot: 80% above the bed

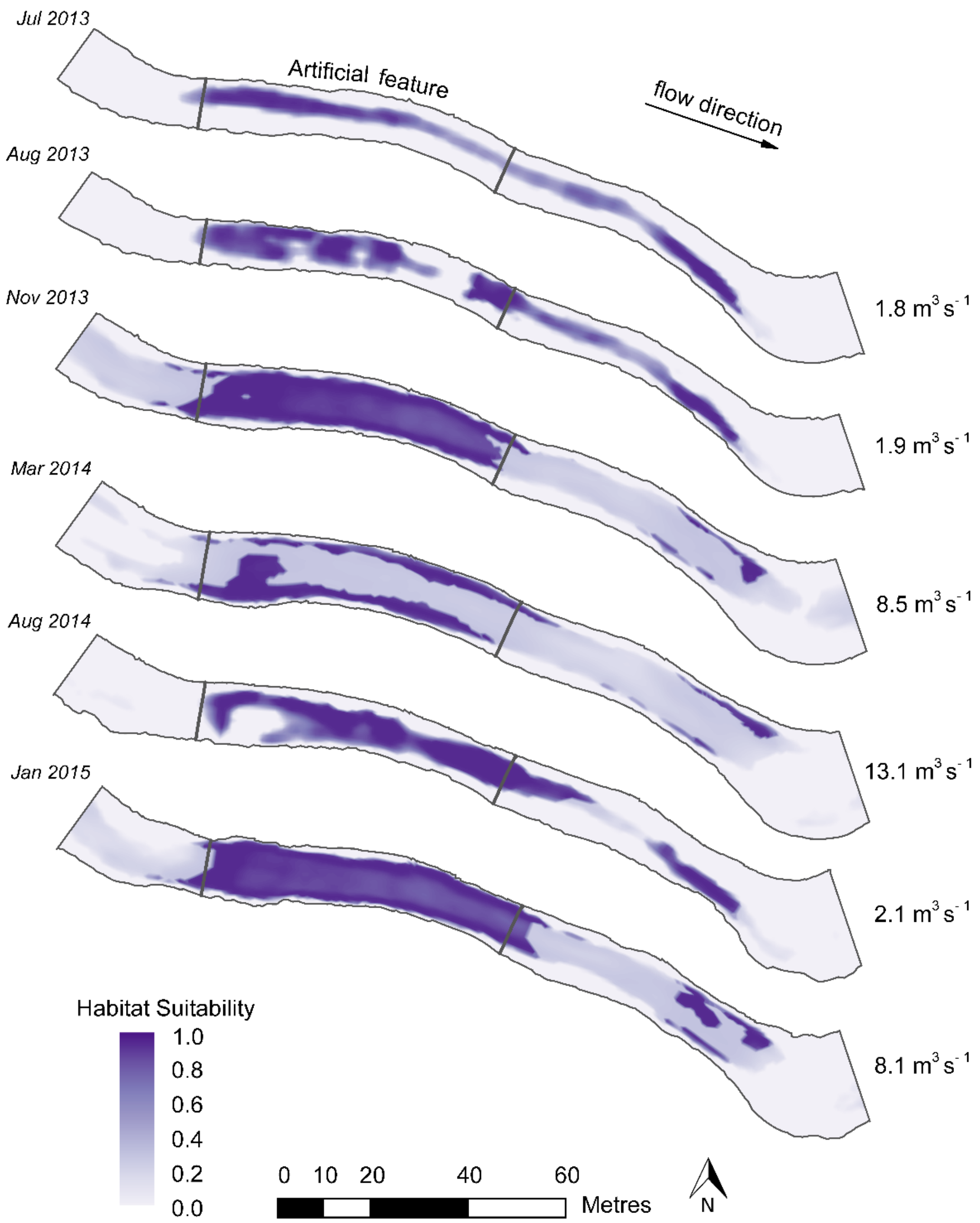


Velocity plot: 100% above the bed

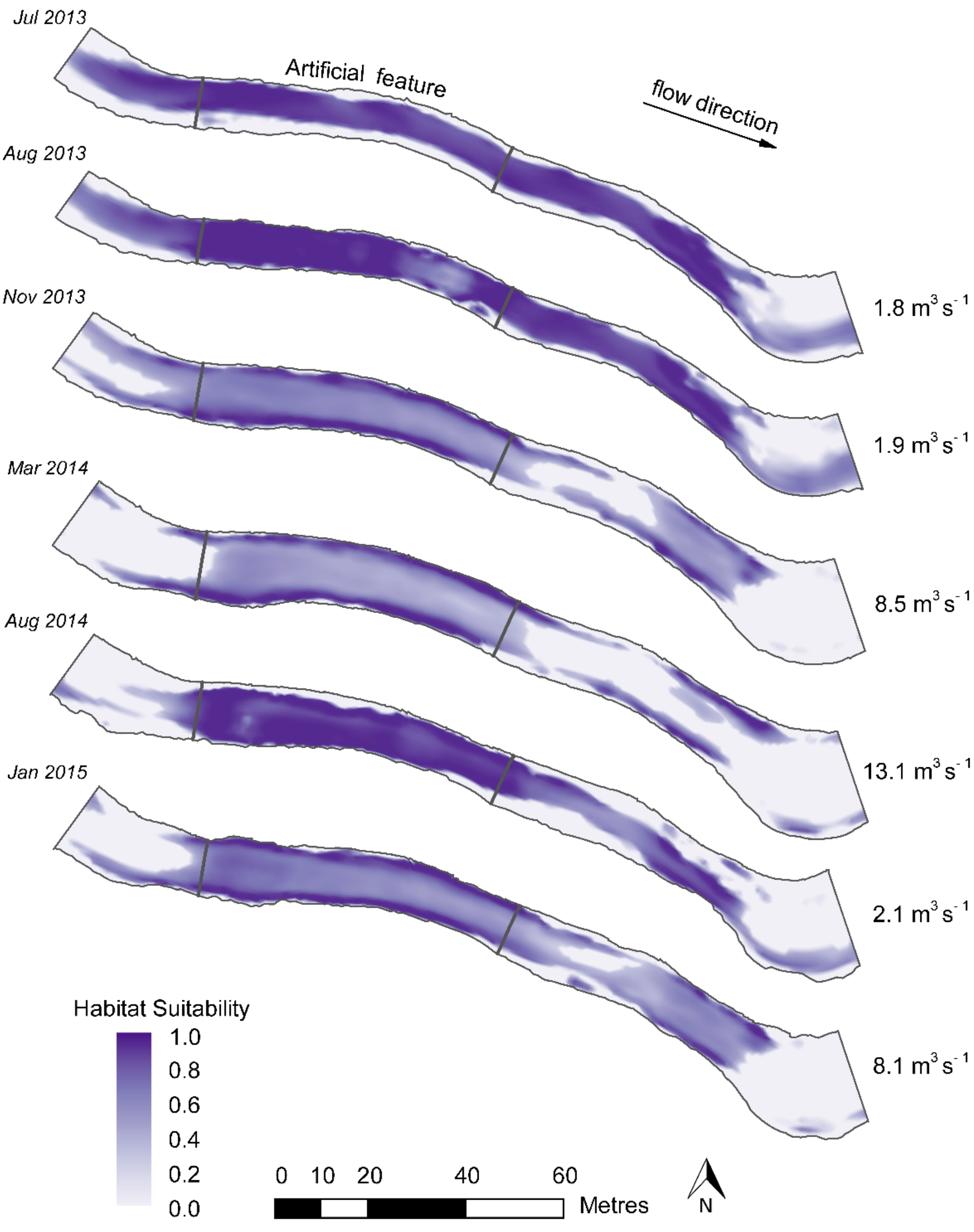


Appendix D: Habitat Suitability Maps for Brown Trout

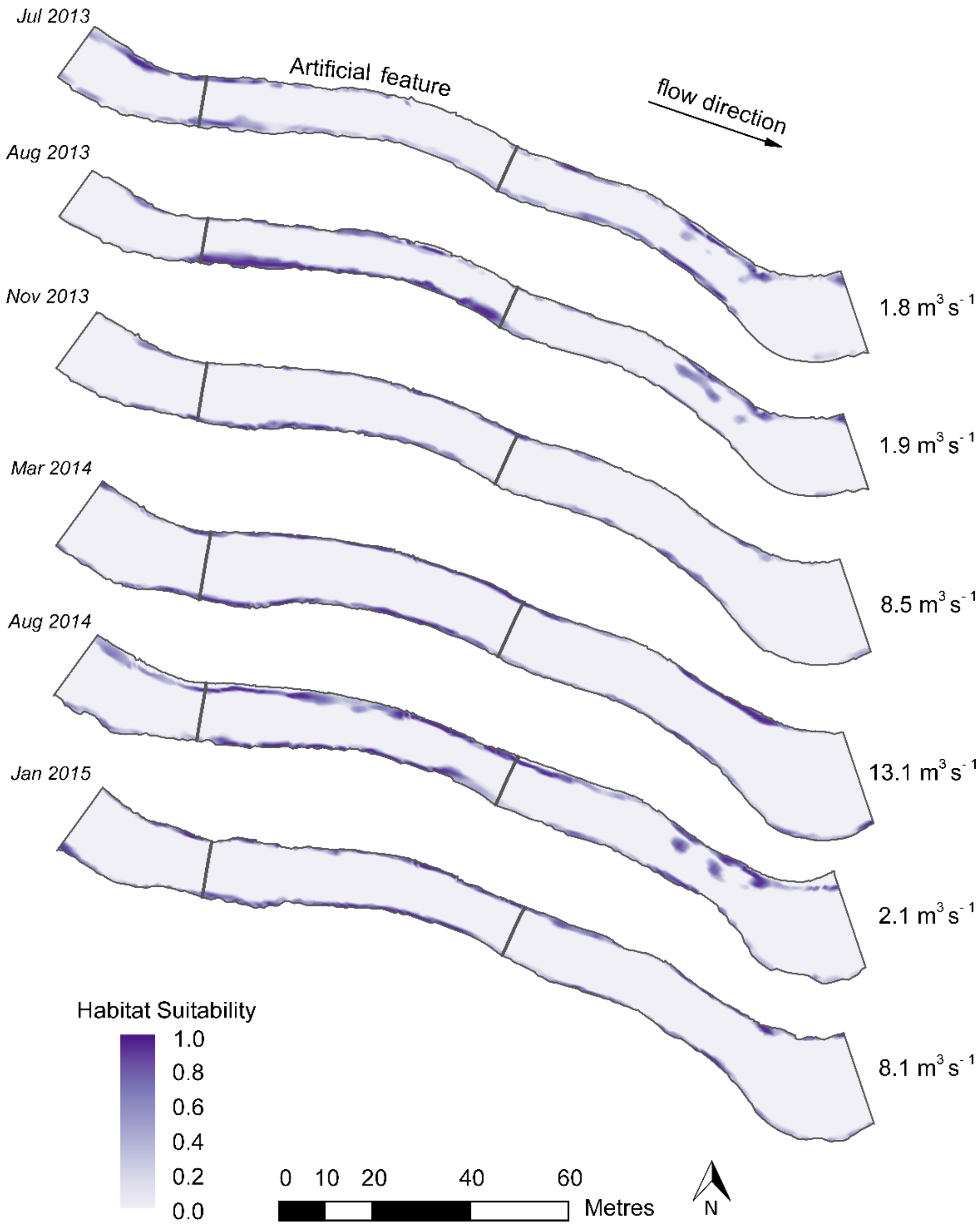
Adult Brown Trout



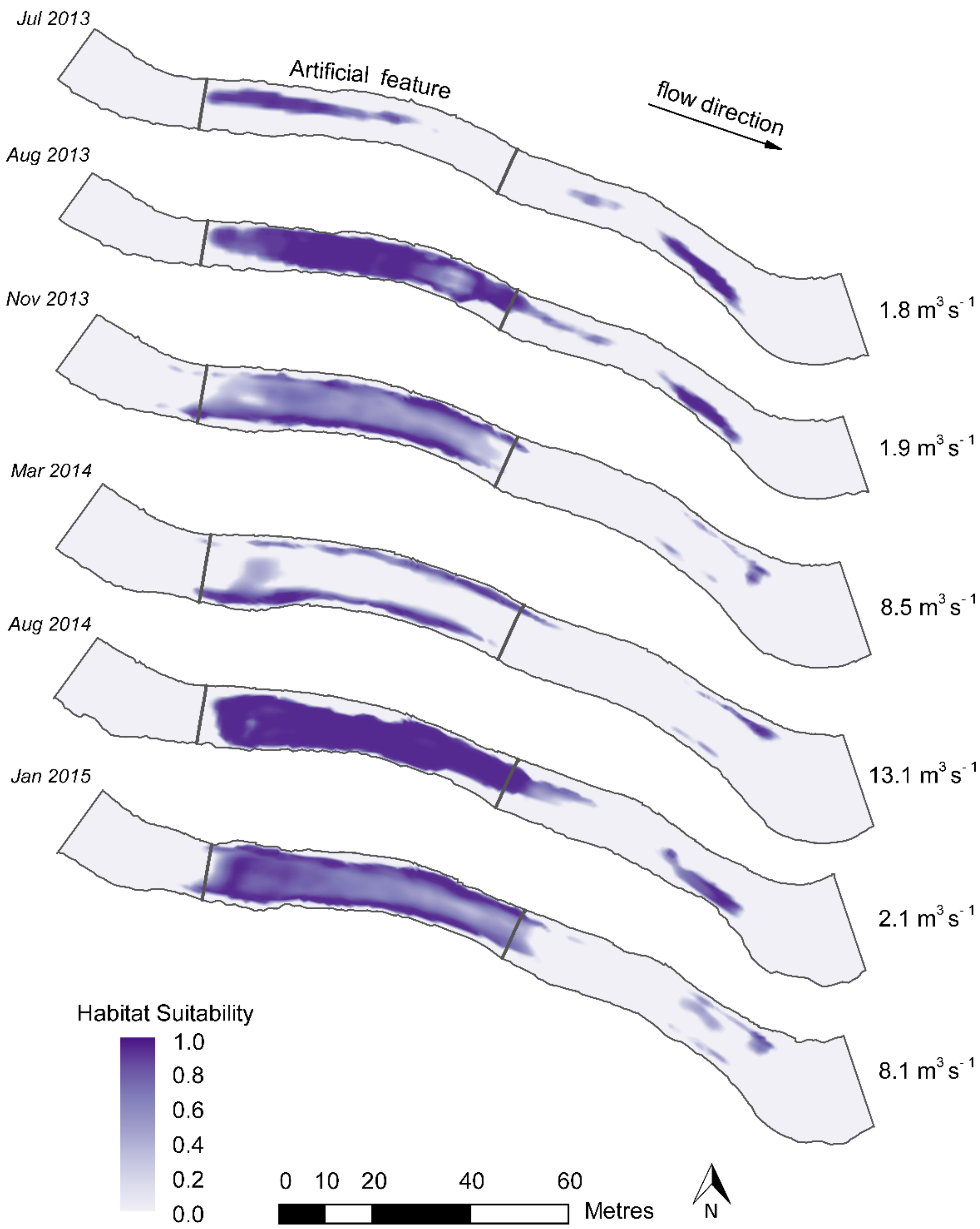
Juvenile Brown Trout



Fry Brown Trout

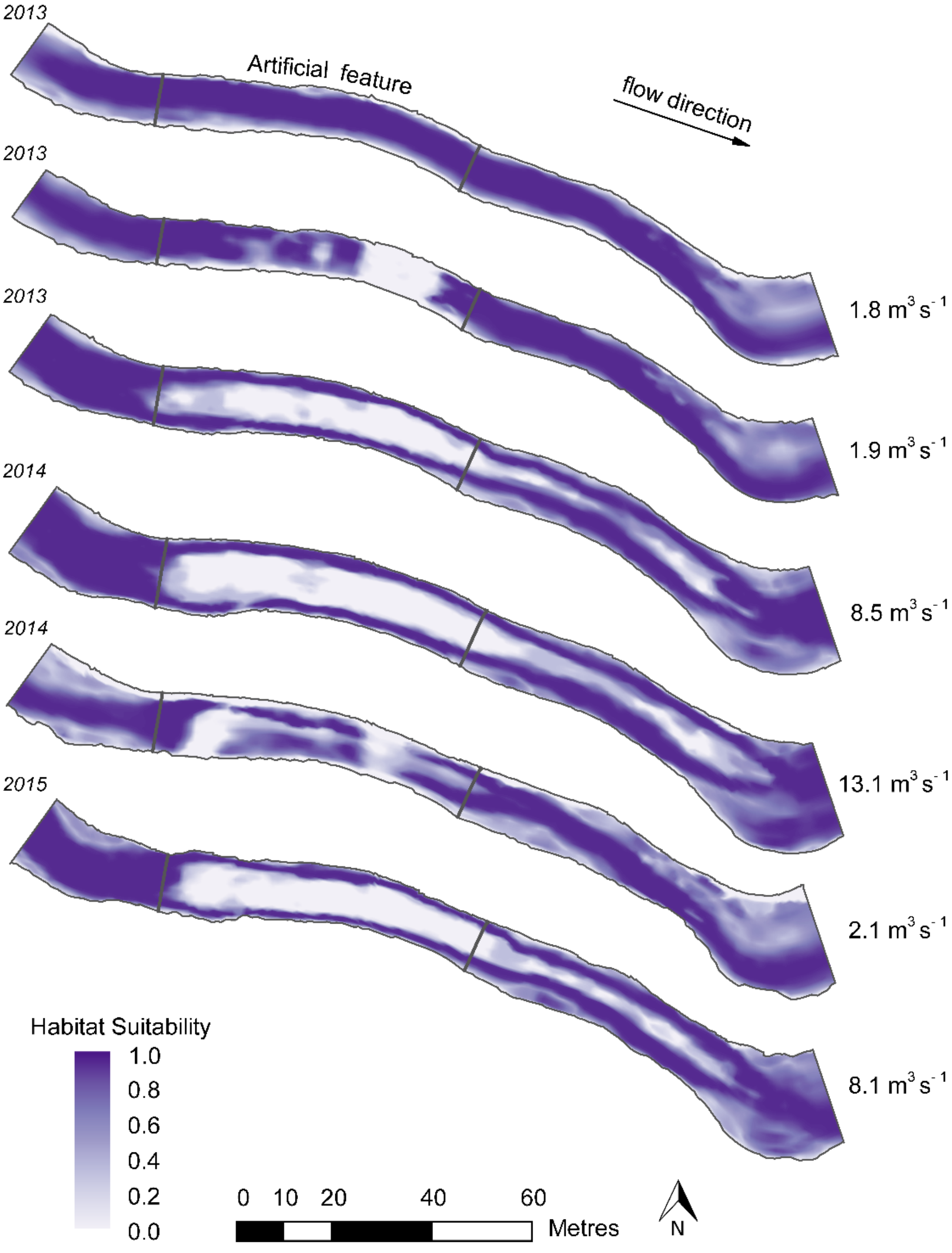


Spawning Brown Trout

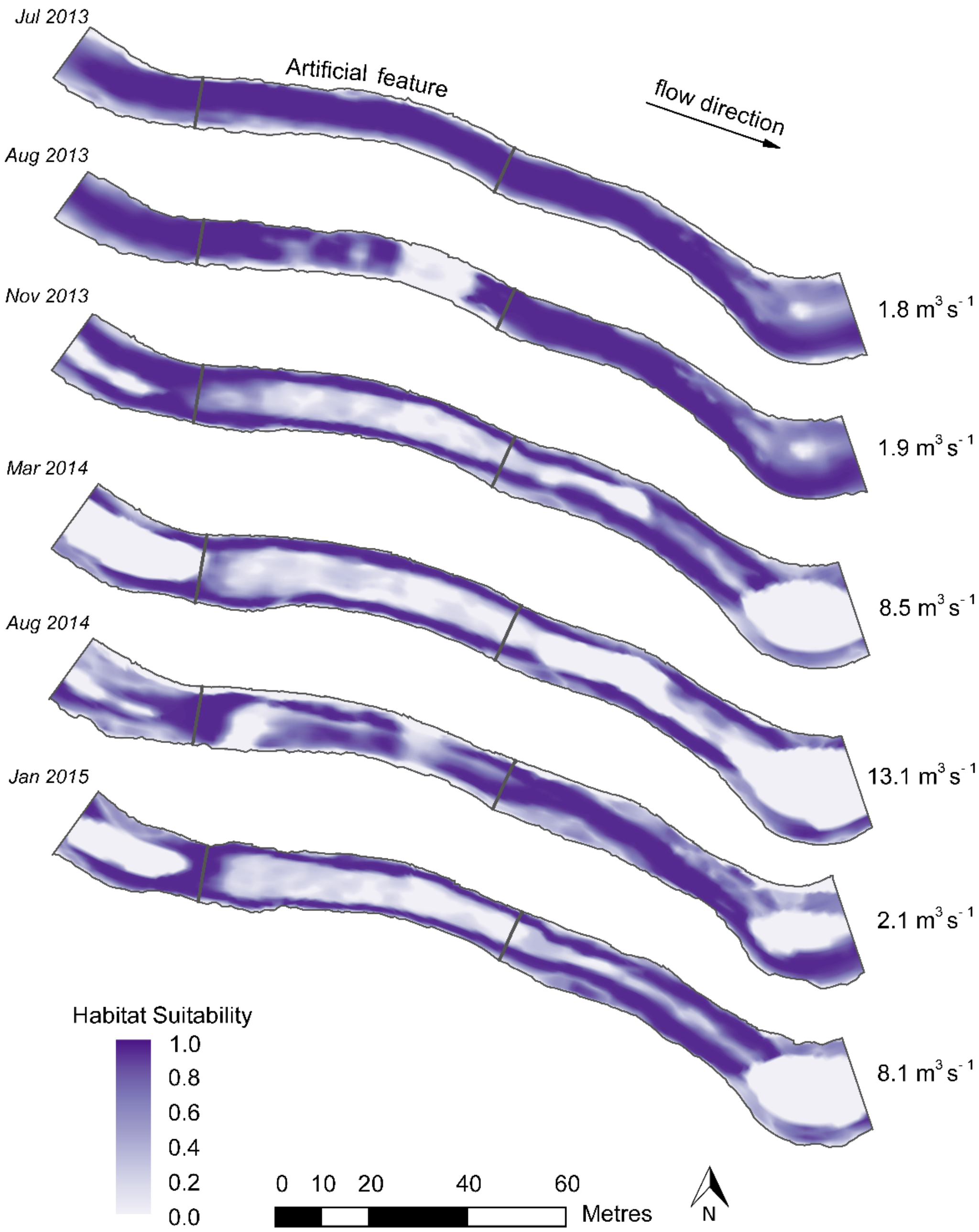


Appendix E: Habitat Suitability Maps for Grayling

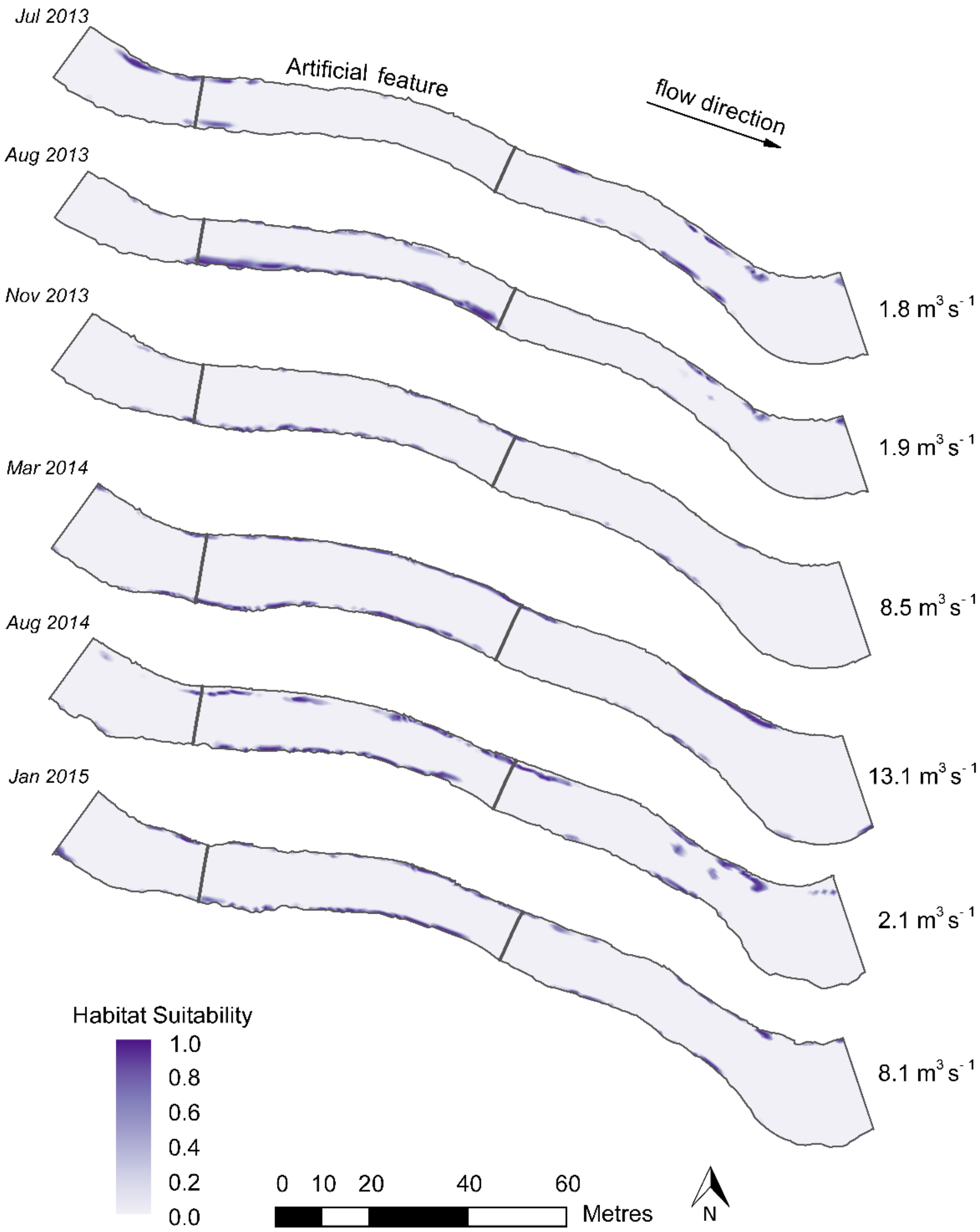
Adult Grayling



Juvenile Grayling



Fry Grayling



Spawning Grayling