An Assessment of some Environmental Effects of Flood Protection Schemes on Rivers: a Case Study of River Ems, UK

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SUMMARY

This paper assesses some of the environmental effects of Flood protection schemes (FPS) on river ecology in the face of climate change. The methodology includes a case study, Geographic Information System and field survey. The results show that FPS have a significant environmental effect on river systems and their ecology. Though it facilitates the reduction of flood risk, there are various negative effects, which are less recognised including, changes to the physical shape of the river, damage to the natural environment and the river ecology. The paper highlights the need to reduce the negative effects of FPS, which is currently uncertain, due to the recurrence of flooding events globally due to climate change. It is clear, therefore, a balance needs to be met between, flood protection and safeguarding the natural environment of rivers. The paper identifies ‘given water space’, catchment-wide flood risk management and softer engineering approach as sustainable FPS strategies worth pursuing because they have limited effects on the environment and they tend to offer holistic flood protection without severely compromising the river ecology.

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1. INTRODUCTION

River floods are one of the most common natural hazards in the last decade, causing devastating effects worldwide (Tanoue et al. 2016). This is because, for centuries, human populations have been attracted to the possibilities of transportation, renewable energy, recreational uses and also the aesthetics that rivers can provide (Knighton, 1998). This attraction led to the continual development of settlements in river flood plains and estuaries. Many fluvial systems have been converted to a “use” or settled environment and in most cases, the human activities and development impedes the natural fluvial processes due to the development/construction of Flood Protection Schemes (FPS) in the form of floodwalls, culverts, weirs and sluice gates and dredging to protected human settlements (Ackers & Bartlett, 2009). The increase in population settlement and human activities in river floodplains have increased the demand for more flood protection over the years and therefore rivers have been forced to adapt to human influences (Manfreda and Samela 2019).

Undoubtedly, anthropogenic global warming, climate change and associated increased global precipitation have recently led to the increased flood risk worldwide (Dixon et al. 2016). Arnell and Gosling (2016) have estimated that global flood risk would increase by approximately 187 % by 2050. This level of risk according to their assessment will affect approximately 450 million people living in flood-prone areas of the world and 430 thousand km2 of flood-prone cropland worldwide. This increasing exposure to flood risk is predicted to increase in frequency as a result of extreme weather events due to climate change (Dixon et al. 2016). This will have severe consequences on the existing development/settlement in the vulnerable river and coastal areas. This challenge is supported by the prediction of increases in flood magnitude and frequency by the Intergovernmental Panel on Climate Change [IPCC] (2014). This has led to increased demand for more conventional structural flood protection (Manfreda and Samela 2019) with limited consideration on how human activities and stressors effect on the natural environment of rivers and the ecosystem service they provide. In most cases, FPS focuses on the prevention of flooding, protecting life and properties and not protecting the natural environments.

River systems, their ecology and evolution over time have always been fundamental to the environment. River ecosystem refers to the sum of interactions between plants, animals (flora and fauna) and microorganisms and between them and non-living physical and chemical components of a river watercourse in a particular natural environment. A natural river watercourse, in essence, provides transport of water from land to the ocean, which in turn causes erosion and carries sediment downstream, depositing it primarily in the estuaries and the ocean (Knighton, 1998). These river processes provide habitats for many plants and animal species and numerous ecosystem services such as recreation, transportation, Bacteria presence, fish food, photosynthesis for aquatic plants, food (fish and shellfish) to mention, but a few (Gilvear

and Jefferies, 2017). Increased population and climate change have increased the construction of FPS on rivers. Developing FPS on rivers have led to significant loss of habitat areas, habitat variety and ecological damage such as loss of spawning grounds (Gilvear and Jefferies, 2017). Flood Protection Schemes (FPS) upon rivers is under-researched, because historically, the attention was predominantly, on flood prevention rather than environmental protection. Thus, less attention was given to the assessment of the effects FPS on rivers and its ecosystem. However, there seems to be some attention in recent times. The European Union Water Framework Directive requires member states to assess the ecological quality of rivers, lakes and wetlands and to restore loss functioning where possible (European Union, 2000). The aim of this paper is to assess the effects of existing FPS on the natural environment of rivers using the Ems River in the UK as a case study. The assessment of the effects of FPS on the River could provide detail understanding and knowledge for more sustainable and efficient FPS policies. The paper investigates both the direct and indirect effect of FPS on rivers as well as providing a set of sustainable flood management policies, which could be adopted elsewhere.
The most recent river basin management plans, prepared under the UK Water Framework Directive, for South-eastern England were published in December 2009. The plan looks to assess the actions required to protect and improve the water environment. One of the key areas highlighted for improvement was the physical modification of water bodies (Environmental Agency, 2009). This river basin management plans have also indicated that there is a need for balance between protecting the physical shape of watercourses and ecological health of rivers, as such balance can provide essential benefits to human health and safety (Environmental Agency, 2009).

Rouillard et al. (2015) have presented a paper in which they asses the policy implementation of catchment-wide schemes in England and Scotland. The paper identifies the difficulties of policy implementation. Fleming (2016) has discussed the little progress made in terms of FPS policy. He argued that every time there is a flooding incident somewhere, the national/local government announces a need for new strategies, however, once the disaster is over, they turn to forget the implementation of the strategy. For instance, since the publication of '*learning to live with rivers'* in 2002 in the UK, which recommended a catchment-wide strategy, and protection of river ecology.

Conceptually, FPS is not meant to prevent flooding, but to reduce its effects. The word alleviate means to make something 'less severe' therefore by nature FPS do not eliminate flooding, however, they only reduce it. To what extent can we reduce flooding? Brierley and Fryirs (2008) recently argued, the development of the western world, in particular, has seen the physical transformation of many rivers which are now under pressure to receive rehabilitation and restoration of their ecology. This is based upon the improved knowledge on the benefits of ecosystem services of rivers and the unsustainable nature of past FPS (Matczak, Lewandowski, Chorynski, Szwed, and Kundzewicz, 2018). Therefore designing FPS to reduce flood damages is not sufficient, more work must be done to provide sustainable protection, which involves working with rivers and their processes, as fighting against nature is not the solution (Lamond, Booth, Hammond & Proverbs, 2012).

The application of the traditionally hard structural FPS has been recognised as unsustainable (Dixon et al. 2016). There is an increasing appreciation that non-structural/soft engineering flood mitigation strategies may be the sustainable approach to future flood risk management. These include catchment-based interventions, based on the manipulation of land use, channel geometry and floodplain topography are the principal variables that affect flooding. River managers are also exploring options for restoring river channel and floodplain morphology in order to modify the flood hydrograph for the benefit of downstream communities and river ecology (Nisbet et al. 2011; Wong et al. 2015). Such strategies could benefit the natural environment of rivers and improve the ecosystem services they provide.

Changes to the channel morphology can be calculated if management strategies are to be employed to regulate sediment transfer, however, studies covering a full watercourse using historical comparisons are scarce and there continue to be uncertainties (Landemaine, Gay, Cerdan, Salvador-Blanes & Rodrigues, 2014). There are two types of change to rivers: autogenic changes and allogenic changes were established. Autogenic changes are those that occur naturally within the river regime whereas allogenic changes occur due to human influences (Garde, 2016). The allogenic changes (dams and FPS) tend to have negative effects on the geomorphology and ecology (Huggett, 2011), sediment transport (Kemker, 2014), water quality (Ji, 2008; Oram, 2014) and ecosystem services of river systems (Ji, 2008).

There are many types of FPS (Table 1). Some of these techniques may be referred to as sustainable drainage systems (SUDS). These are a group of techniques (soft and hard engineering), which involve the infiltration or storage of water from the river system. Table 1 highlight the fact that soft FPS tend to enhance river ecology though some may have a damaging effect on river geomorphology.

Embankment	It is normally made from earth materials like fine, firm clay which is impermeable. It is crucial to ensure that embankments contain impermeable materials that will not only stop water from passing through it but also strong and stable enough to prevent breaching. It is therefore important to ensure that embankment is insulated against erosion, which will lead to instability. It is normally used in rural areas and outskirt of towns where there is enough space (McAleenan & Oloke, 2010). This approach tends to destroy river habitat, particularly in floodplains as it restricts the river to its channels. However, some plants, animals and microorganisms thrive on the embankment
Flood walls	Flood walls are similar to embankments however they are made of solid material such as concrete and steel sheet piles and are utilised where there is limited space, generally in built-up urban areas (McLeod, 1975). Unlike embankment, floodwalls do not allow plant and animals species to grow due to the materials used in constructing them.
Flood storage	There are 2 main types of flood storage: online and offline. Online storage allows the floodwaters to be briefly held within the river channel and its floodplain. Whilst in the case of offline storage the flood water is directed away from the river channel to a basin or reservoir, this is subsequently directed either further downstream or to a separate watercourse. Flood storage is a technique used to restrict peak flood flow sent downstream, which will, in turn, extend the time in which the overall floodwater takes to travel downstream. With the increase in catchment urbanisation, where water overwhelms built-up areas due to fast run-off, the extended peak flood flow is significant (Ackers & Bartlett, 2009). This approach has a limited impact of river ecology, in the instance where floodwaters are stored offline, the approach extends river ecology.
Swales	Wide shallow channels with appropriate vegetation coverage. This allows the water to either be stored or transported, there may also be scope for the water to infiltrate the ground depending on the soil conditions (Jose et al. 2015). This approach enhances river ecology.
Infiltration Basins	'Depressions' in the ground which the water is initially stored in and then begins to infiltrate through the ground (Jose, et al. 2015). This does not allow river ecology to flourish. It tends to reduce ecosystem services of rivers.
Wet Ponds	A pond which permanently contains water and can provide storage for floodwaters causing the permanent water level to rise. The water can be treated and they can also provide environmental benefits (Jose, et al. 2015).
Extended detention basins	Mostly dry when not in flood however can contain small permanent areas of water at the inlet and outlet. Water can be held and treated once in the basin (Jose, et al. 2015).
Constructed wetlands	Basins which contain water with shallow regions throughout, providing a good habitat for both wildlife and vegetation. This can be used to aid pollutant removal (Jose, et al. 2015).

Table 1: Types Flood Protection Schemes and their effect on river ecology (After Jose, et al. 2015; Ackers & Bartlett, 2009; McLeod, 1975).

Jose et al. (2015) have acknowledged that 'SUDS not only control water quality and quantity but also provide cultural and social benefits'. However, McAleenan & Oloke (2010) have identified the limitations of SUDS arguing that open water can be a hazard and access must be appropriately restricted. Also due to the reduced flow, the basins will begin to silt-up and that SUDS requires careful maintenance throughout their lifetime.

Ledouxa et al. (2004) put forward a view for the use of river rehabilitation to reduce flood risk. They believe the policies in place for flood protection are not sustainable due to the effect of climate change and the increasing costs of flood defence. They also argue that whilst upgrading existing defences is an option it can be perceived incorrectly and create tensions amongst the ‘economic, environmental and social actors that are required for sustainability.’ However, it is important to note that building floodwalls upstream to protect settlements may cause greater flow downstream, thereby increasing the flood risk (Fleming (2001).

2. MATERIAL AND METHODS

Case study, geographic information system (GIS) assessment and field survey were among the methodology applied in this assessment. A detailed literature review was conducted to develop a better understanding of the existing knowledge on flood risk management policies on rivers and how it considers the effects of such policies on the natural environment of rivers. This gave a good background knowledge on the problem and facilitated the identification of a gap in the knowledge, which was the limited attention given to the effects of FPS on the natural environment of rivers. We found that the focus of FPS, in most cases, is on the prevention of flooding and therefore, either limited or no attention is given to protecting the natural environment. A case study was identified to be the best approach to facilitate the development of a detailed understanding of the effects of FPS on rivers ecology.

2. 1 The case study of River Ems

The River Ems was chosen as the case study for a number of reasons. First, the Ems presents a complex channel system created by human intervention and there have clearly been many FPS implemented upon the river. Yet, it is currently considered as a flood risk area (UK Environment Agency, 2015), which means still FPS considerations are ongoing. The River Ems is located in the South of England (Figure 1) on the border of Hampshire and Sussex. River Ems takes its sources approximately 2.5 km Northeast of Stoughton (Figure 1). It travels through two notable settlements that are Westbourne and Emsworth. The Ems has a catchment area of approximately 60Km² (UK Environment Agency, 2013).

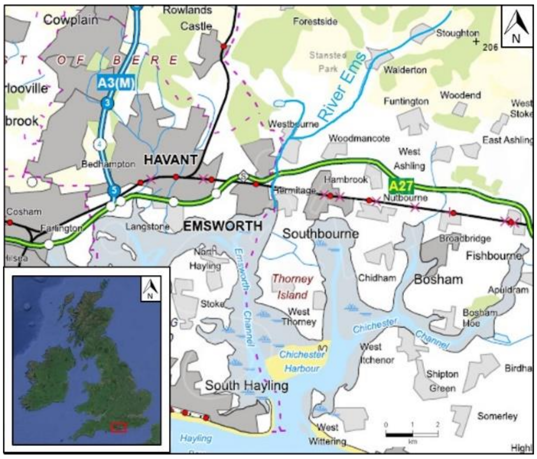


Figure 1. Map indicating the location of River Ems. (Digimap Ordnance Survey, 2015)

The River Ems has a history of flooding and still is at risk (Figure 2). The flood risk at the estuary may be due to the tidal effect, however, the inland flood risk is certainly due to fluvial flooding. The flood risk has led to the development of many FPS along the course of the river. The numerous FPS (culverts, embankments, canals, millponds, floodwalls, flood storage, channel diversion and others) have undoubtedly disorientated the entire river system and this might have had a significant effect on the River ecosystem. In spite, of the many FPS that have been implemented over the years, recent flood risk assessment of Emsworth has established that the town is at high risk of flooding. This has resulted in the Environment Agency have to identify Emsworth as a high priority area. This means that there is a need to develop an FPS to decrease the flood risk in Emsworth (Environment Agency, 2015).

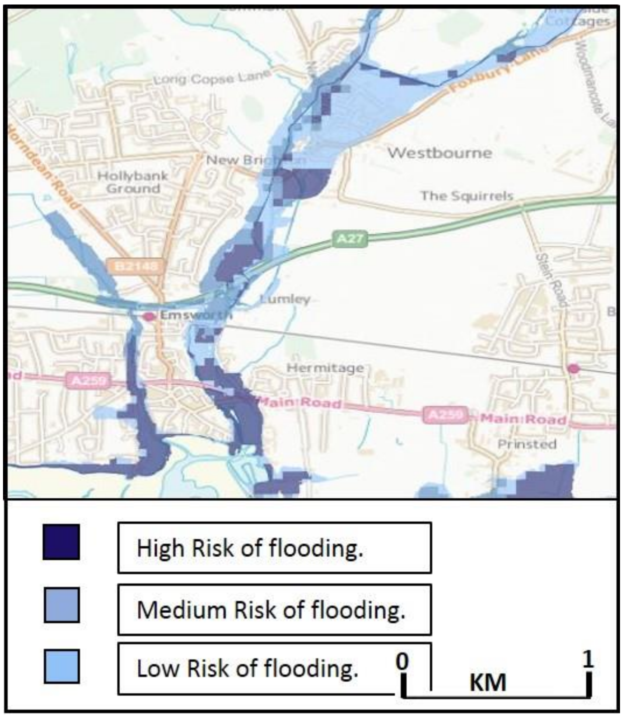


Figure 2. River Ems flood risk (UK Environment Agency, 2015)

2.2 GIS Assessment and Field Survey

GIS assessment of historical maps (1853) and current maps (2015) of the River course where many FPS have been implemented over the years was processed with all the FPS marked on them. Both historic and current maps were overlaid and used to determine changes to the river course over the years and highlight the possible physical and environmental effects of the FPS. The Historical maps were acquired from Digimap and brought straight into ArcGIS. A ‘street view’ backing map was utilised within the ArcGIS programme. Using google earth pro and the tools available within this programme, the river, floodplain and FPS were drawn using polygons. This provided a comprehensive knowledge of the river and FPS that has been implemented upon the River over the years. A series of images were saved in plain view of the digitalised Google Earth map, which made up the overall area of interest maps. These individual images were then geo-referenced to the ‘street view’ backing map. In order to attain a clearer map, shapefiles of the digitalised Google Earth (2016) images were created. Therefore, the historic map showing the past channel of the Ems River and its FPS can stand alone and compare with the present map (2016) with the current river, FPS and Floodplain.

A field survey was conducted for ground-truthing and to attain a better understanding of River Ems and the current state of FPS. In all, seven (7) locations along the River were identified for the field survey. Later the entire lower course of the river was also assessed as location 8 (Figure 3). Before the survey, a site data sheet was created. The site datasheet comprises checklist and spaces for sketches and notes taking of potential features found on-site and site photographs. Data gathered from the field were assembled into site proformas which aided the analysis and discussion of the effects of FPS on the Ems River. The Literature review, the GIS assessment Figures 4 to 6 and the site Proformas (Table 2) were synthesis for detailed analysis and identification of key effects of the FPS on the natural environment of the river.

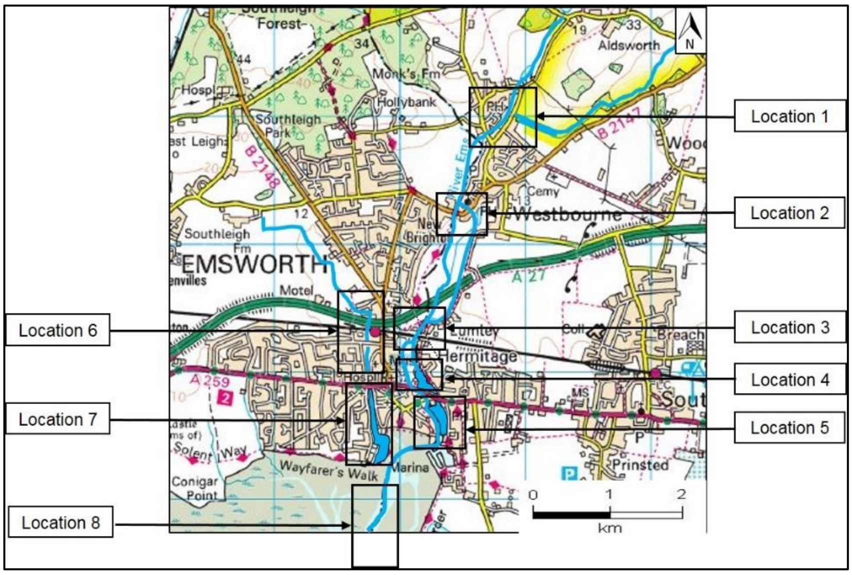


Figure 3. Map of Sampled site Locations

3. RESULTS

The outcome of the GIS assessment (section 3.1) highlights the different FPS that has been implemented on the Ems River over the years and the field survey (3.4) develop the understanding of the effects of those FPS on the river.

3.1 GIS assessment

The GIS overlay maps (Figures 4 to 6) have been formatted so as to make clear the changes that have occurred along the river course between 1853 and 2016 as a result of development and FPS schemes over the period. The past (1853) and present (2016) street view digitisation maps are provided so as to show how the River Ems channel has suffered from human interventions in the form of development and FPS.

On Figure 4, location 1, the main river approaches from the East and enters the Watersmeet canal. The 1853 map shows the canal was much larger than the present. The land between the Main River and the Millstream on the south side of North Street marked (K) has been developed, therefore the Floodwall in place along the bank of the Main River was most likely erected as a result of the development. On Figure 4 location 2, the river heads southward, but artificially the Millstream is diverted southeastward. The Millstream channel is completely concrete and the reason might be to protect the development at both sides of the channel from flooding. In fact, the land between the main river and the Millstream (L), either side of the Westbourne road, has since 1853 been developed and protected by FPS, in the form of channel regulation. Figure 4, location 3 shows that the three channels heading southward have all been culverted and the River even diverted in order to allow the construction of the road A27.

Figure 4: GIS assessment FPS at site location 1 to 3

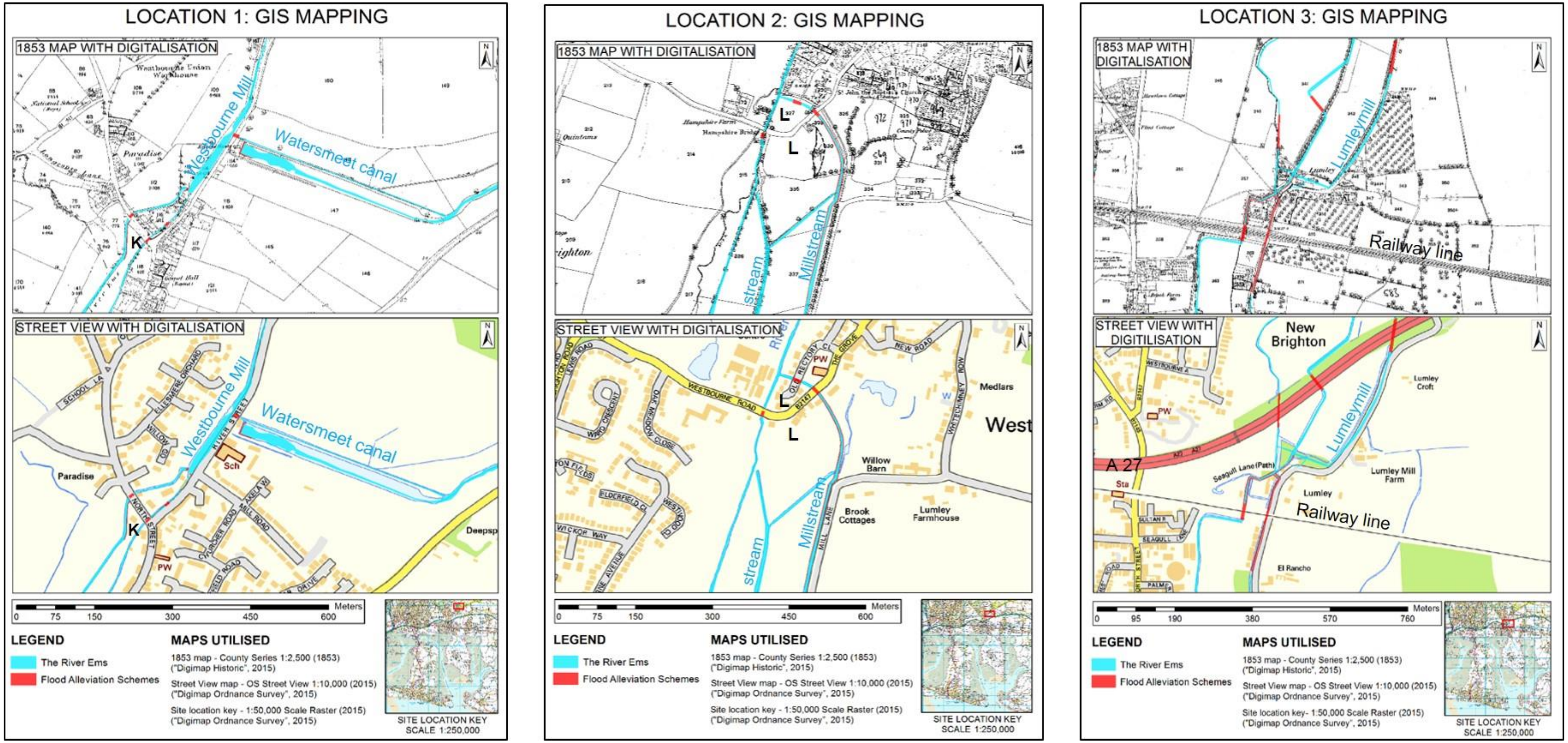


Figure 5: GIS assessment FPS at site location 4 to 6

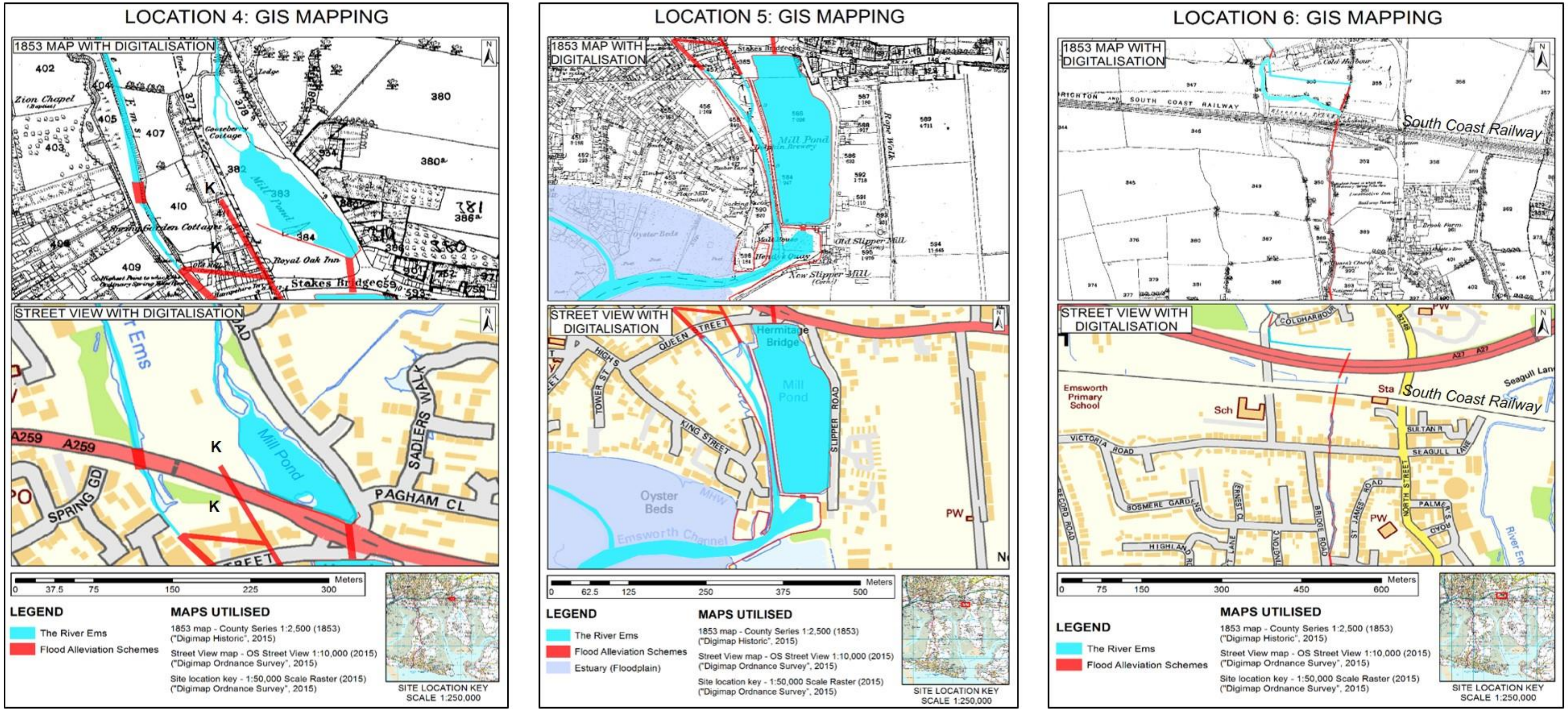
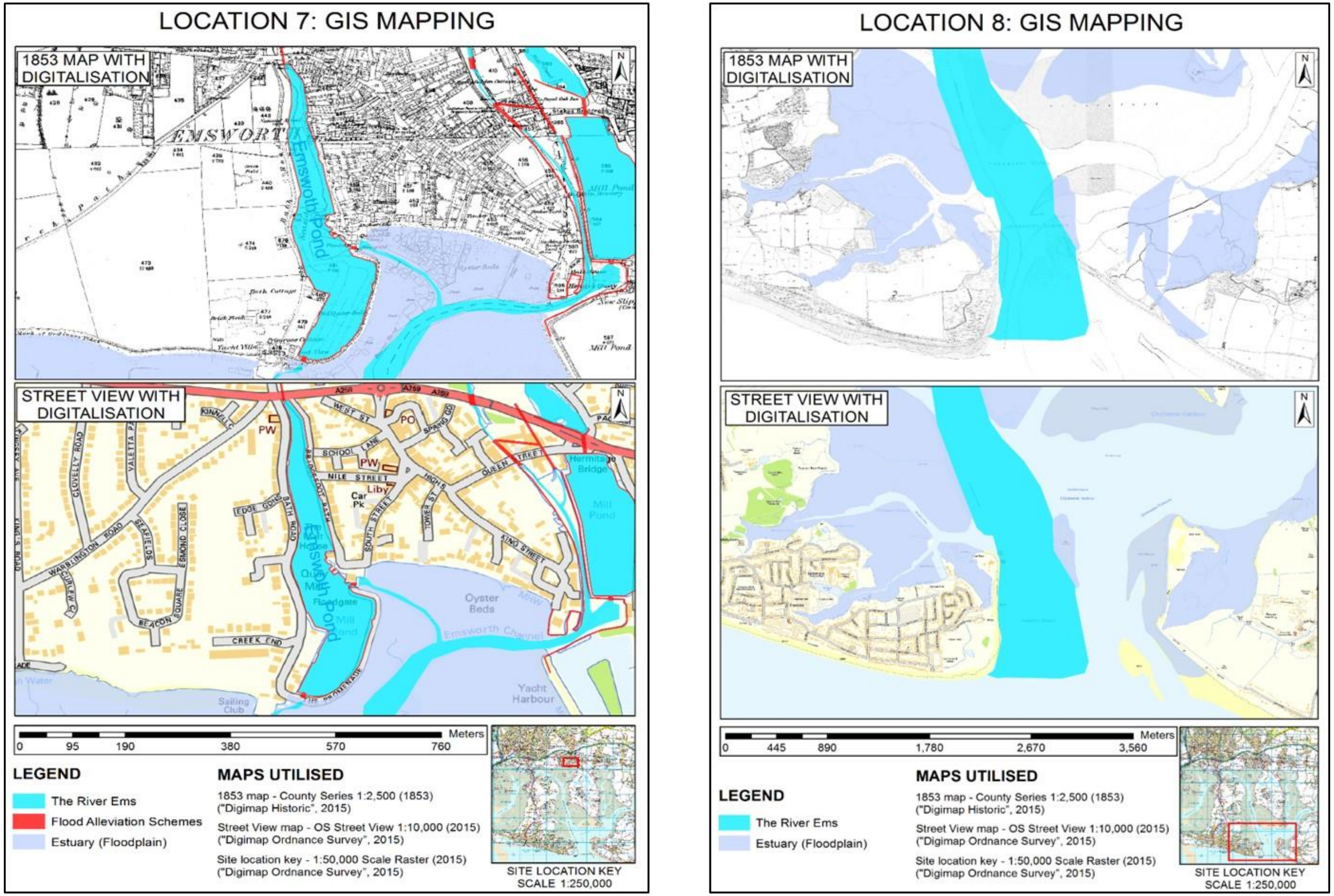


Figure 6: GIS assessment FPS at site location 7 and 8



MAPS UTILISED

1853 map - County Series 1:2,500 (1853) ("Digimap Historic", 2015)

Street View map - OS Street View 1:10,000 (2015) ("Digimap Ordnance Survey", 2015)

Site location key - 1:50,000 Scale Raster (2015) ("Digimap Ordnance Survey", 2015)

Figure 5 location 4, reveals a significant change in the size of Mill Pond between 1853 and 2016. Firstly, the construction of the main road, the A259, has pushed the pond backwards, hence the embankment, which is situated on the south side of the pond was built to protect the road. The area between the two channels (K) previously had more development however this has been removed. This could be due to increased flood risk as a result of the concretisation of the river channel. On Figure 5 location 5, there has not been a substantial change within the channel between the historic and current-day maps. Figure 5 location 6, shows that the channel has been diverted and forced to turn earlier due to the construction of the A27. The river was already culverted for the railway embankment in 1853, therefore with the construction of the A27, it was logical to move the river so as to avoid culverting it beneath the railway embankment again.

Figure 6, location 7, shows that the Millpond in its current state provides more storage capacity than that of the pond in 1853. Figure 6 location 8 shows the entrance/exit of Chichester Harbour. This is important as this is the point where the channel meets the sea where the river load is deposited.

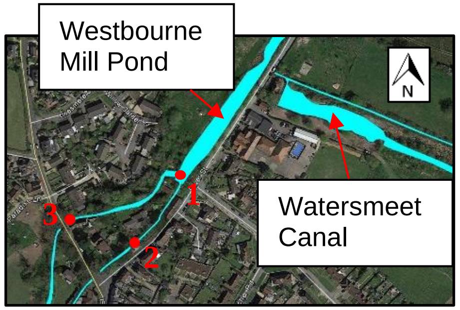
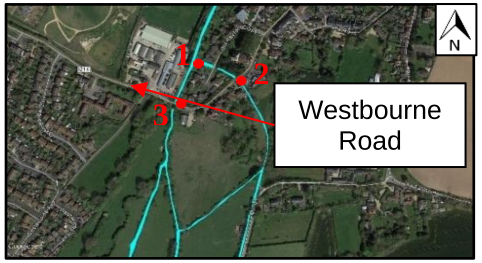
The result from the GIS assessment clearly revealed that the entire middle course of the Ems has been disorientated by human development and FPS built over the years. The comparison of the past and the present state of the Ems River on the two maps show the changes and human interventions on the River channel. These interventions seem to offer protection at the specific section and aggravate the flood risk downstream. This problem has led to the construction of series of FPS at different section over the years to an extent that the river channel has been dissected into different streams, ponds and canals and completely reduce to concrete gutters in many sections. This has ruined the natural process of the middle course of the Ems and its ecology. Yet, the flood risk in the area is rated very high and there is the demand for more FPS to reduce the risk (UK Environment Agency, 2015).

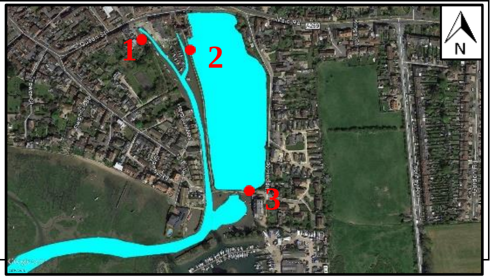
3.2 Field survey outcomes

Field observation and data gathered were syntheses into site proformas. The site proforma presents a snapshot of each location sampled and what was identified on-site. The Proformas (Table 2) aims to develop an understanding of the effect of FPS on the river ecology particularly, the sampled locations and also assess the positive and negative effects of the FPS.

4 Discussion

The paper has established that all-natural rivers flood (Bell, 2007; Álvarez, 2011; Task Committee on Hydrology", 2013) and the ecosystem services offered by rivers have attracted humans settlement and developments to river floodplains and estuaries. Settlements and developments in rivers floodplains and estuaries are most likely to suffer flooding or be at risk of flooding, thereby requiring FPS to protect life and properties. Traditionally, FPS has been site-specific, hard engineering solutions such as embankments, floodwalls, channelization, sluice gates and dams. However, research has shown that the hard-engineering FPS are not sustainable, as they tend to stabilise the river channel, reduce flood risk at the specific site, but reduce percolation at the site, increase the volume of floodwater downstream, effect negatively on the river ecology, and aggravate the flood risk downstream (Johnson and Priest, 2008; Wong et al. 2015). Catchment wide schemes and softer engineering approach have evolved as a potentially sustainable solution to managing flood risk. These include flood storage (online and offline) and dredging.

Sample Location & Description	Positive impact of FPS	Negative Impact of FPS	Satellite View of Locations (SVL)
Location 1: Watersmeet Canal joins the main river, which converges into one large channel, known as Westbourne Mill Pond, where this in-channel pond splits in two, marked on SVL 1 a sluice gate is in place at the opening of the northerly channel and a weir at the southerly one. These two channels continue downstream where they eventually meet again to form one channel.	The ability to reduce the flow downstream of a channel can prevent or reduce the severity of flooding, therefore, the sluice gate is providing protection to people and properties. The culverting of the river, to allow the bridges to be built, provides access routes through this area.	Channelization of the river is unnatural and it reduces the aesthetics and the ecology of the river. It reduces erosion and therefore sediment transport is also affected. The use of a sluice gate can provide more storage of water by manipulating flows, however, in this case, the gate is operated by the landowner and therefore the gate could be used incorrectly to ensure the landowner does not get flooded. This will have an impact further downstream which could cause flooding, due to increase flow rates.	 Digitalised satellite view of Location 1.
Location 2: The river flows in a South-Westerly direction until it reaches point 1, where a sluice gate is located. At points 2 & 3 the millstream is briefly culverted for a road to pass over. Downstream of point 2 the millstream is channelized. The main river channel between points 1 and 3 is impounded by an embankment on the right-hand bank whilst thick vegetation on the left-hand bank.	The ability to reduce the flow downstream of a channel can prevent or reduce the severity of flooding, therefore, the sluice gate is providing protection to people and properties. The culverting of the river, to allow the bridges to be built, provides access routes through this area.	Channelization of the river is unnatural and it reduces the aesthetics and the ecology of the river. It reduces erosion and therefore sediment transport is also affected. The use of a sluice gate can provide more storage of water by manipulating flows, however, similar to location 1, the gate is operated by the landowner and therefore inappropriate application of the gate is possible that could have the same effect as location 1.	 Digitalised satellite view of Location 2.
Location 3: A network of channels come together to form the main river seen in SVL3.	The ability to reduce the flow downstream of a channel can prevent or	The gate is controlled by the landowner, this could cause a conflict of interest, in that the person operating	

They converge at point 1, where the river is briefly one channel before separating into two, with one channel having a sluice gate. Both channels continue downstream where they are culverted through the railway embankment, the eastern channel continues down to point 2.	reduce the severity of flooding, and therefore the sluice gate is providing protection to people and properties. There is also an economic saving due to this protection.	the sluice gate should be controlling the flows in order to provide as much protection for everyone. However, if the landowner may control the gate for personal protection, which may cause increased flows downstream and possibly flooding for the properties in that area, especially due to the channelization of the stream and the small bridges along this part of the river.	
Location 4: The two channels at this site are directly linked to the two channels in location 3. The channel to the West is the main river. There is a spill weir located further upstream of point 1. Downstream of point 1 is the road A259. The channel to the east is open and forms online storage as Peter Pond. The pond has heavy vegetation, with an embankment parallel to the road.	Peter Pond provides a habitat for wildlife. The inclusion of the spill weir, which allows the area between the channels to flood decreases the chances of flooding occurring in areas that will affect people.	Peter Pond has very little Flow and therefore will not be able to carry sediment which would usually be transferred further downstream. The build-up of sediment can also have a negative impact on aquatic life. The bridges restrict the river to certain channel size and therefore during times of flood if not maintained could cause a bottleneck effect not allowing water to escape downstream and concurrently build up upstream.	 Digitalised satellite view of Location
Location 5: The channels that emerge on the west are both formed from the western channel in location 4. The two channels points 1 & 2 converge to form one channel, which is subject to tidal surges and therefore protection	The Slipper Mill Pond (point 3) attracts different forms of wildlife. In times of flood, the pond can provide storage for flood water. The use of the sluice gate allows	There was clearly a build-up of sediment in the Slipper Mill Pond this is due to the very little flow that passes through the pond. This can be problematic for a number of reasons. It can affect aquatic habitats causing the species to move or die. It could	 Digitalised satellite view of location 5.

has been provided with an embankment on one side including gabions, and a wall protecting the opposite bank.	more water flow downstream and therefore relieves water build-up upstream of the sluice gate.	also raise the bed level of the Pond and therefore reduce the channel storage of water. The sediment is also not carried downstream and therefore landforms may be lost through erosion.	
Location 6: This location is divided into two areas. Area 1 contains a single channel which is culverted at a number of locations. Area 2 has channels culverted at two locations, once under Victoria Road and again further downstream. This section of the river, in area 2, is channelized.	It has reduced the size of the river which allows more space for the development of buildings and infrastructure.	With the river channelized so heavily, it is no longer a natural river, as it does not allow any erosion and therefore no morphology of the river is available and it has also taken away any aesthetics the river could provide. The river is also culverted for longer lengths of this section, this further decreases ecological development	 Digitalised satellite view of location 6
Location 7: Emsworth Mill Pond has two exits points, one located at point 3 which is a weir allowing water to exit and enter during high tide. The second is a sluice gate which can be opened and closed, shown at point 2.	Storage of fluvial water which might have caused flooding in the pond and allow the water to exit slowly through the weir, reduce flooding. Brent goose uses the pond as habitat.	The Emsworth Mill Pond had a clear build-up of sediment in the pond this is due to the very little flow that passes through the pond. This can affect aquatic habitats causing the species to move or die. It could also raise the bed level of the Pond and thus reduce the channel storage of water. It could affect sediment supply downstream.	 Digitalised satellite view of location 7

Table 2: samples side description, FPS and impact assessment

The case study (River Ems) has highlighted the major effects of FPS on rivers. It has clearly demonstrated how FPS affect both physical processes (Figure 4 to 6), the environmental conditions and ecological value of rivers (Figure 7 to 9).

The results have shown that the River Ems has been heavy squeezing and disorientated as a result of human development and associated FPS. In fact, many sections of the middle course of River Ems has been reducing to concrete gutters and channels. These have consequently reduced the ecosystem services of Ems (see site proformas in Figure 7 to 9). The effects of the various FPS are felt throughout the middle and the lower course of the River system. In general, these FPS have been implemented upon the river to reduce flood risk, but they have failed to succeed since the recent flood risk assessment in the area is still rated high (UK environmental Agency 2015). The river has been reduced to nothing in places as well as restricted by culverts and channelization and that has destroyed the most habitat at the middle course of the river. Many of those schemes (Mill Ponds and Canals) were perhaps introduced a long time ago (before 1853), where a human understanding of the potential environmental/ecological effects was possibly minimal, and humans ability to control and manipulate rivers for development might have been highly celebrated. However, the situation is different today, our knowledge on the environmental and ecological benefit of river systems, water bodies and associated physical processes have improved significantly. Based upon this knowledge the UK government, for instance, has made a commitment to ensure that the present land-use policy seeks where possible to reduce, and certainly not to add to, the overall level of flood risk. The strategy to achieve this commitment was to “allow space for water” so that the government can manage the adverse consequences for people and the economy that can result from flooding and coastal erosion while achieving environmental and social benefits from river systems and water bodies (Defra 2004; Fitton et al. 2016).

It is obvious from the case study that human developments were at war with the river systems. The policy of “give water space” was not observed and that resulted in the construction of different FPS. These FPS did not only reduce flooding, erosion, percolation and river ecology but also they intercept the river sediment due to channel concretisation. What effect does the sediment deposition in the ponds having downstream? Naturally, the river carries sediment filled with rich nutrients throughout the watercourse to its floodplains and estuaries, where the sediment load is usually deposited. The sediment does not only form marshland to serve as habitat but also the accompanying nutrients provide food for shellfish and other species that live or spawn in estuaries. Many FPS including ponds and canals that intercept sediment load upstream tend to cause a shortage of sediment downstream and the erosion of floodplain and marshlands and reduce the supply of nutrient to estuaries. It could also cause tidal and wave erosion at the coast as the coastal system adjust to compensate for the loss of sediment supply from the river (Chichester Harbour Conservancy 2004).

The effects of FPS on the physical river system can be very clear in places and less so in others. First, the obvious physical effect is the interferences of the fluvial processes (erosion, transportation and deposition) and the actual FPS itself, which affect the aesthetic view. Figures 4 to 9 clearly show that in some area the Ems is either lost completely or reduced to small gutters. When FPS is implemented the river regime can be altered and therefore some of the fluvial processes cannot occur thereby effectively transforming the river from its original regime. It is important to conduct a detailed investigation into river rehabilitation as a possible solution to restoring back rivers to their original regime by removing the outdated FPS, which restrict the river as a way of reducing present flood risk.

Some FPS could have potentially positive effects, for instance, flood storage in the form of ponds and dams provide a thriving habitat for different species, however, this could be temporary due to the potential effects on water quality. The pond could encourage a concentration of pollutants, which could cause death or migration of aquatic life. Furthermore, the reduction of erosion and sediment transport downstream as a result of FPS may cause significant erosion and loss of nutrients at the floodplain and the estuary of a river. This may result in loss of habitats to aquatic life, waterfowls and migratory birds. Offline flood storage, which is only used during flooding events to remove flood waters away from the river seems to be one of the sustainable FPS, which needs serious consideration. The offline flood storage act as a floodplain and thus implies working with the river in a natural sense. It provides habitat and the water stored could be allowed to return to the river downstream after the flood event.

5 Conclusion

Rivers have been studied since the early settlements were developed. A wealth of knowledge on rivers now exists and our understanding continues to progress. This paper has investigated the effect of flood protection schemes have on rivers. We found that many rivers worldwide have been considerably affected by FPS. Some of the effects were immediate reductions in river channel width or changing the shape of the river, and some were long term effects, which has effect on different parts of the river system, such as the loss of habitat, reduction of nutrient, lack of sediment being deposited at the river estuary due to upstream FPS. The results have shown that many types of FPS are used to reduce flood risk, some of which possess minor positive effects. However, all forms of hard-engineering FPS have been shown to have a negative effect on rivers in one way or the other. It is clear, therefore, that a balance between, constructing the FPS for human benefit and protecting the fluvial system for the benefit of the environment, must be met.

In general, experts agree that the natural environment of rivers needs to be given more protection and the use of catchment-wide schemes could be one way of achieving this. However, the public is not rallying behind the catchment-wide schemes. This is due to the esoteric explanation of the policy and the frustration, and confusion caused by climate change and associated recent flooding that has increased the demand for site-specific FPS by the public. In conclusion, policy needs to be clear and realistic, engaging local communities to provide sufficient and acceptable protection, whilst having an as little negative effect on the river systems as possible.

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