Hepscott Flood Risk Study

Hepscott FRS

Northumberland County Council

July 2011
Draft Report
9W1520

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1 INTRODUCTION

Heavy rainfall over the Northumberland village of Hepscott has led to a number of significant flood events in the last decade. The most recent occurred in September 2008 which affected a number of properties and led to over £200,000 in property damage. Most flooding originated from the Hepscott Burn and its tributary the Red House Burn, when flows in these tightly constrained watercourses overtopped their banks. In some areas, this lack of flow capacity is exacerbated by restrictive structures across the watercourse including bridges and culverts.

A previous review of the flooding problems at Hepscott was undertaken for the Environment Agency following the September 2008 flood event to determine the causes and financial impacts of the residential flooding, as well as present a number of potential flood management options. Consequently, and following subsequent local pressure, the Environment Agency constructed a number of small scale management schemes with the intention of reducing future flood impacts. Prior to this report, the effectiveness of the Environment Agency works were unknown as the schemes were largely implemented without formal hydraulic assessments being completed and no formal monitoring had taken place.

Northumberland County Council has now taken a lead role in progressing the approach to future flood management at Hepscott. At this first stage, Royal Haskoning has been commissioned by Northumberland County Council to provide a flood risk study for the village to determine the primary mechanisms of flooding, report on the current assets in the catchment, provide an assessment of the effectiveness of the Environment Agency schemes, and identify further appropriate solutions that might be implemented to manage and reduce flood risk in the future. This report presents the findings and conclusions from this study.

As part of the study, an inspection of all major channel structures was carried out and delivered to the Council in December 2010. This asset report is provided in Appendix A.

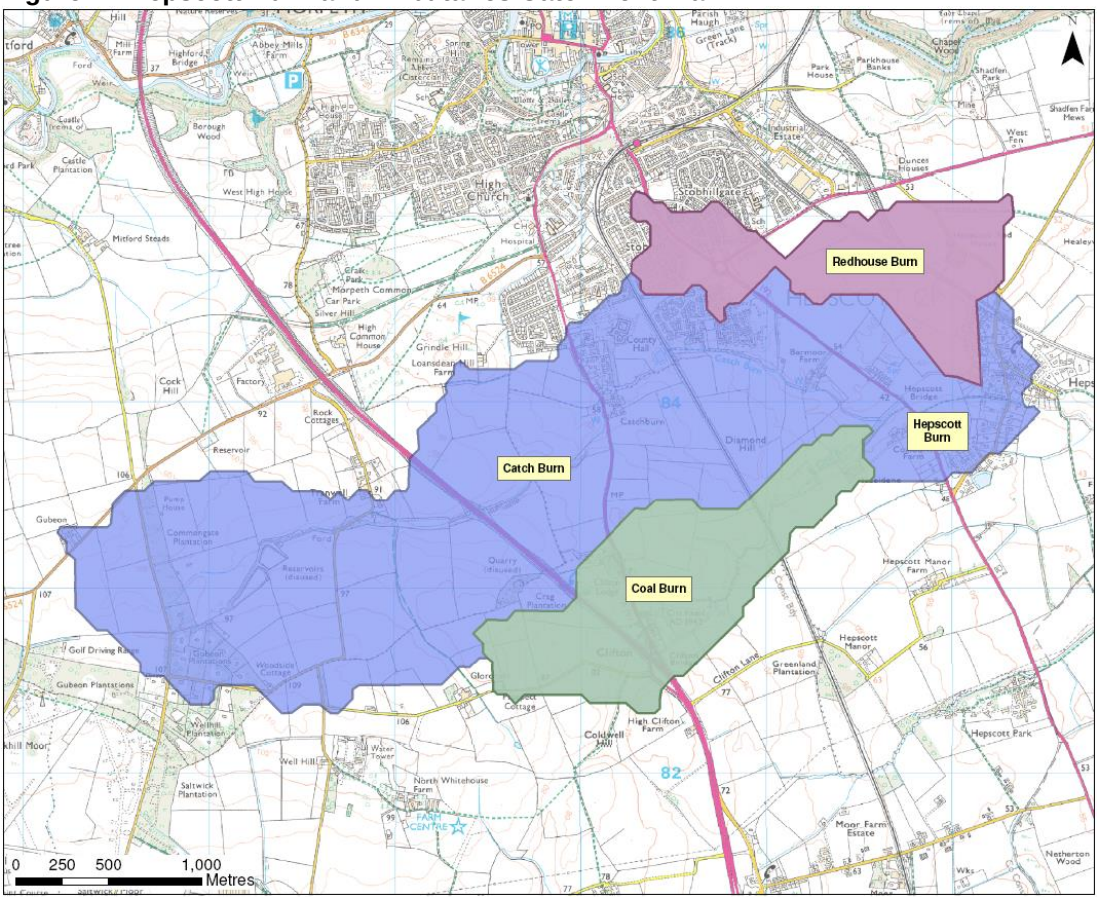
2 BACKGROUND

2.1 Catchment Description

Hepscott is a small rural village approximately 2km south east of Morpeth in Northumberland. The primary watercourse which flows through the village is the Hepscott Burn, and is classified as an Ordinary Watercourse. The Hepscott Burn drains a catchment area of approximately 8.1km^2, incorporating 3 tributaries which converge just upstream of the village (Catch Burn, Coal Burn, and Red House Burn). The catchment area is dominated by agricultural land which slopes on a shallow gradient towards the east. The only exceptions to this are the small built up areas at Hepscott and a small proportion of the upper catchment which incorporates the southern extent of Morpeth and adjoining residential housing estates.

Figure 1 provides an overview of the Hepscott Burn catchment and the four watercourses in question. The following sections provide greater detail of each of these watercourses and further details of the structures are provided in Appendix A.

Figure 1 - Hepscott Burn and Tributaries Catchment Plan



2.1.1 Coal Burn

The source of the Coal Burn is located near to Clifton Lodge, approximately 2.5km south west of Hepscott between the A197 and the A1. The watercourse drains an area of approximately 1.3km^2 as it flows east across farmland around the foot of Diamond Hill. The only notable infrastructure along the Coal Burn is the local Blyth & Tyne rail line, where the watercourse is culverted for a stretch of approximately 40m. The condition of this culvert is unknown. There are currently no formal flood defences on the Coal Burn and no residential or commercial properties which could become flooded. For this reason, the Coal Burn does not cause much concern and is not considered in great detail within the study.

2.1.2 Catch Burn

The Catch Burn begins at a site of disused reservoirs approximately 4km west of Hepscott, with a secondary input from the Silvington Burn. The Burn has a steep-sided channel as it flows across Tranwell Farm and west across farmland before passing beneath the A1 through a long culvert section. Downstream of the A1, the watercourse flows through a very steep sided channel before passing under the A197 road bridge where the watercourse turns a sharp 90° right bend. Beyond the A197 the watercourse flows between a number of residential properties near Southgate Wood and across the grounds of the Northumberland County Council offices, into a storage pond before passing through a culvert under the main railway line. Downstream of the railway the Catch Burn flows to the south of the residential estate at Crookham Grove and through Barmoor Farm to the confluence with the Coal Burn where the two watercourses form the Hepscott Burn.

2.1.3 Red House Burn

The source of this tributary is located in what are reportedly disused mine workings approximately 2.5km north-west of Hepscott. The Red House Burn flows initially west to east along side the North East Main Line railway embankment across farmland at Red House Farm.

The watercourse then turns to the south, and is culverted underneath the railway line approximately 100m east of the farm house. Downstream of the railway line the watercourse flows in a short, narrow open channel section for approximately 5m before entering a longer culverted section underneath The Orchard residential development.

The railway embankment culvert is in very good condition having recently been re-lined by Network Rail (February – March 2011). However, the condition of the residential culvert is reportedly poor. The inlet to this culvert is very restricted (approx 200 X 200mm), and there is significant risk of it becoming overwhelmed by high-flow events.

Having passed underneath The Orchard housing development, the watercourse emerges on the western perimeter of The Orchard in a stretch of open watercourse. This reach is approximately 0.6m deep and 1m wide, and stretches for approximately 200m before entering the final culvert beneath crofts Park. Prior to entering the Crofts Park culvert, the watercourse is crossed by a small bridge with a short 300mm diameter

culvert. This culvert was almost completely blocked with silt and debris at the time of our site visit and is therefore extremely ineffective.

The Crofts Park culvert is of circular concrete construction with a 300mm diameter and 250m in length. It is reportedly in poor condition, although CCTV survey data was not available to confirm this.

The Crofts Park culvert passes beneath the housing estate before its outfall into the main Hepscott Burn to the south of Crofts Park.

2.1.4 Hepscott Burn

From the confluence of the Coal and Catch Burns, the Hepscott Burn flows across approximately 400m of farmland before entering Hepscott village, where it is joined by the Red House Burn tributary from the north (left bank) at Crofts Park.

Hepscott Burn continues to the rear of a number of residential properties upstream of the main road which runs through Hepscott village. The road crosses the river over a composite bridge with a steel and concrete deck and brick parapets. The bridge is approximately 5m wide, provides a two-lane carriageway, and has parapets approximately 1.2m high. The bridge is a constriction to the channel in both width and height, but appears to be in good structural condition.

Downstream of the road bridge, there is a stone and concrete weir within the channel. The original purpose of this weir is currently not confirmed, though the adjacent resident is reluctant to have the weir removed as he believes it adds historical value to his property. The weir constricts the width of the channel considerably, resulting in a cross-sectional area loss of approximately 50% at normal levels, and also results in raising water levels upstream of the weir at low flows.

A 4m long single carriageway road crossing sited immediately downstream of the weir provides vehicular access to two residential properties. The watercourse originally passed beneath this crossing through twin 600mm circular culverts which caused a significant restriction to the channel. In an attempt to reduce this restriction, the Environment Agency has replaced these culverts with a single, precast oval culvert which has significantly increased culvert capacity.

Downstream of the residential crossing, a farm access track crosses the burn via a masonry arch bridge. The bridge culvert is narrower than the natural width of the channel at approximately 1.4m, but also of substantial height (approximately 1.8m). Due to the steep and deeply incised nature of the channel at this location, it is not considered to cause a substantial restriction to the flow of the burn. Structurally, the bridge appears in acceptable condition, though there is some damage to both parapets with some sections missing. These have been highlighted with orange fencing.

2.2 History of Flooding

Many parts of the North East suffered severe flooding following heavy rainfall during September 2008. At Hepscott, fluvial flooding during this event resulted in inundation of

four residential properties at The Orchard, Crofts Park and homes adjacent to the Hepscott Burn.

At The Orchard, flows in the Red House Burn exceeded the capacity of the small culvert, leading to overland flooding into properties to the north of the estate. Environment Agency records suggest that No.14 The Orchard was flooded to a depth of 750mm, resulting in significant damage.

The capacity of the Red House culvert at Crofts Park was also exceeded during this event, leading to overland flooding through the housing estate, along its pre-culverted route. Flows from this culvert, combined with high flows in the Hepscott Burn are believed to have resulted in flood depths of approximately 1m at Nos. 6 and 9 Crofts Park.

Downstream, Little Bridge House located close to the weir was also flooded to a depth of 100mm. The owner of this property has subsequently invested heavily in a masonry wall around the property perimeter to provide individual property protection.

Data supplied by the Hepscott Flood Action Group suggest that a total of 11 properties were directly affected by flooding during the September 2008 event and that a further 17 were affected by flooding to gardens and garages.

2.3 Previous Studies

2.3.1 North East Flooded Communities Review (August 2009)

In 2009 Arup undertook a review of the Hepscott Burn as a part of the Environment Agency's assessment of the September 2008 flood event. Included in this review was an assessment of the mechanisms of the flood event, and an initial estimate of the economic damages incurred.

In the absence of flow data for the Hepscott Burn, the review utilised data from the nearby River Blyth to estimate that the September 2008 flood was between a 1 in 100 (1% Annual Exceedance Probability (AEP)) and a 1 in 200 (0.5% AEP). The mechanisms for flooding are identified as follows:

- Storage capacity of catchment being exceeded during flood conditions.
- The Hepscott Burn exceeding its channel capacity.
- The Red House Burn exceeding its culvert capacity at The Orchard and Crofts Park due to the fast response time of the catchment and undersized culverts.

Flooding in September 2008 was concluded to have cost £281,582. This figure takes into account residential flooding reported by the Environment Agency and the Hepscott Flood Action Group.

The report concluded that upstream storage is the preferred flood alleviation method. This review was undertaken before the Environment Agency implemented small scale flood management schemes, and as such the effects of their works are not considered. A cost-benefit analysis concludes that work on the Red House Burn would provide the greatest potential benefits.

3 PROBLEM

The current flooding problems at Hepscott appear to be a result of insufficient channel and culvert capacities on the Red House and Hepscott Burns. This issue can be attributed in part to constrictions in the Hepscott Burn due to housing development and old, under sized-culverts. However, the fast response time of the upper catchment also produces high flows in all three watercourses, placing further pressure on the downstream channel.

From assessment of the previous flooding and discussions with relevant stakeholders, it is apparent that flood issues with the greatest impacts are situated in three main locations:

- The culvert entrance at the northern extent of The Orchard;
- The culvert entrance at Croft's Park;
- The Hepscott Burn through the village, from upstream of the road bridge to the residential access crossing at Little Bridge House.

This assessment of fluvial flooding issues at Hepscott is based on site and desk-based investigations and consultation with the Environment Agency. It is not known whether schemes implemented following the September 2008 event have resolved these issues, as their behaviour during high-flow events has not been monitored.

3.1 The Orchard Culvert Entrance

The culvert at this location is fed from two separate sources – the Red House Burn and a surface water field drain which drains the farmland to the south of the railway line. During the site visits, both sources exhibited significant flows. During times of high rainfall, the watercourse responds quickly and combines with the field drain to produce flows greater than the capacity of the culvert.

The culvert capacity is compromised by suspected blockages and deformations which have resulted from a lack of maintenance. Whilst no CCTV surveys have been undertaken, it is accepted that the condition of the culvert has deteriorated badly. It is understood that the owner of the property located closest to the culvert entrance has been served notice to have that section of the culvert repaired, although it is unclear if this work has been carried out.

Once the culvert is exceeded, there is very limited surrounding land which can be inundated without resulting in flooding to residential property. In flood conditions this area becomes quickly inundated, and floodwaters overflow into the rear gardens of properties at The Orchard.

Figure 2 - Orchard Culvert Entrance

3.2 Crofts Park Culvert Entrance

The culvert beneath Crofts Park is a circular concrete culvert of approximately 250mm diameter. It is fed from the stretch of open watercourse which flows along the rear boundaries of properties at The Orchard and it outfalls directly into the Hepscott Burn. The total length of culvert is approximately 250m. During high flow events the culvert is rapidly surcharged due to its limited capacity. Its initial inadequate capacity is further limited by the poor condition, and as a result residential flooding was seen at this location in September 2008. When the culvert capacity is exceeded and unable to discharge the input from the open watercourse, water levels at the entrance rise until they meet ground level. At this point the relief of the land naturally slopes easterly towards the Hepscott Burn and water from the tributary is able to flow into the garden of the residential property at the culvert entrance and through Crofts Park, leading to residential flooding.

Figure 3 - Crofts Park Culvert entrance

3.3 Hepscott Burn through Hepscott Village

Several structures in the Hepscott Burn channel cause constriction to high flows and exacerbate the effects of flooding, causing raised water levels, and consequently increased flood extents.

The road bridge for the main road through Hepscott forms a significant channel constriction at times of high flows (**Figure 4**). The brick parapets are impermeable, and as a result excess flow is diverted around the bridge, causing flooding on the road and into the grounds of surrounding properties.

Downstream, the concrete and stone weir in the river channel forms a second point of constriction (**Figure 5**). Here the channel cross-sectional area is greatly reduced (around 50% at normal flow levels), and as a result flow backs up behind the structure causing increased water levels upstream. It is believed that the presence of the weir worsens the effects of flooding at the road bridge due to backing up water levels upstream, as well as causing flooding in the immediate vicinity. The weir serves no practical purpose in the channel, and therefore causes a constriction without any benefit.

Immediately following the weir is a residential access crossing with a twin circular culvert. The central dividing wall between the two circular culverts is a restriction in the channel, and the two culverts only have a limited capacity, which may be exceeded in very high flows. In a similar fashion to the weir, the reduced cross sectional area at this location in the channel raises river levels upstream.

In summary, the Hepscott Burn is constricted in the centre of the village, and flooding occurs due to the construction of properties within close proximity to the channel. Flooding is exacerbated by constrictions caused by in-channel structures which increase upstream water levels resulting in flooding in the area between Crofts Park, upstream of the road bridge, and the residential crossing.

Downstream of the twin culvert residential crossing, the channel widens slightly as it flows towards the farm access crossing. This increased width provides increased capacity which is considered adequate. Support for this assessment is illustrated by the lack of flooding in this location during the September 2008 event. As a result, it is apparent that flooding in Hepscott Village caused by the reduced channel capacity caused by in-channel constrictions, rather than inadequate channel size.

Figure 4 - Road Bridge over Hepscott Burn

Figure 5 - Weir structure in watercourse

4 ENVIRONMENT AGENCY WORKS TO DATE

Following recent flooding events and near misses, the Environment Agency Local Levy team has installed a number of small-scale flood alleviation measures in an attempt to reduce the impact of future high order events. Details of each of these measures is provided in the following sections.

4.1 Catch Burn

4.1.1 Tranwell Farm Storage Pond

The Environment Agency has constructed a small flow control structure and flood storage pond on the Catch Burn at Tranwell Farm (**Figure 6 & Figure 7**) in an attempt to control water levels during high-flow events. This combined defence consists of an in-channel flow control structure constructed from plastic sheet piles with timber bracing, and a small storage pond formed by the construction of an earth embankment with a pipe outfall.

The sheet pile control structure has an orifice at the channel invert to allow low flows to pass through. However, during higher order events, flood waters backup behind the weir and spill out of channel into the flood storage pond which has been constructed along the left bank, contained by an approximately 1m high, clay cored embankment. The stored water slowly returns to the channel via a 450mm diameter pipe outfall.

It was confirmed by the Environment Agency that no as-built drawings were supplied by the contractor on completion. The structure was intended as a low design structure, and as yet is unproven and untested. Royal Haskoning is concerned that there are safety issues in the event of failure during a flood event, which could result in a flood wave propagating down the watercourse if the weir were to fail.

Figure 6 - Tranwell Farm weir structure

Figure 7 - Tranwell Flood Storage Area

4.1.2 Timber Dams

Halfway between the A1 culvert and A197, the Environment Agency has placed a series of timber dams along a 150m stretch of the watercourse in an attempt to attenuate flows by creating partial blockages and turbulence in the channel (**Figure 8**). The timber logs have been driven into the right bank using an excavator and then staked in place on the left bank with another vertical timber.

In total, seven dams have been constructed along the 150m stretch of the burn, and in places smaller debris is gathering to provide further constriction to the channel. The effectiveness of the defences is unclear as they were observed at low flow, when they do not constrict the flows. The build up of smaller debris does however indicate that they are functioning in providing an obstacle. However, it was noted that some of the timber logs have been placed at a significant height above the channel, and it is questionable whether these sections will have any effect on even high-flow events.

Figure 8 - Timber Dams on Catch Burn

This is a second attempt to install such timber dams at this location using larger timber sections, as the original dams were washed away in a previous high flow event.

4.1.3 Northumberland County Council Storage Pond

The storage pond on the grounds of the Northumberland County Council offices was originally filled from the Catch Burn by means of a small weir in the watercourse which allowed a double culvert inlet to divert flow into the storage pond. During high-flow events the weir structure was exceeded and the storage pond bypassed via an overflow channel.

The Environment Agency has adjusted the levels of flow and storage at the pond by raising the level of the inlet weir and installing an additional three culvert inlet to allow increased flows into the pond (**Figure 9**).

With an increased input into the pond, the Environment Agency has ensured higher potential storage by adding a 200mm high steel plate to the top of the existing concrete outfall weir. This plate increases the storage level in the pond by 200mm (approx 1,800m^3).

During extreme events, when the inflow to the storage pond is exceeded, the additional flows will enter into the bypass channel as previously.

Figure 9 - Various features of Northumberland County Council Storage Pond

Northumberland CC Storage Pond

Original storage pond inlet (Right) with new Environment Agency triple pipe inlet (Left)

New Environment Agency stop board at pond outfall to increase storage in pond

Stepped outfall from storage pond

4.2 Red House Burn

4.2.1 Red House Farm Storage Pond

This scheme involved the construction of a small in-channel flow control bund across the watercourse immediately downstream of the farm track crossing at Red House Farm (**Figure 10**). The structure allows low flows to pass through, with higher flows forced to back-up behind the structure. The increased water levels in the channel allow water to flow though a series of overflow pipes which have been installed to spill water into an existing off-line storage pond.

The outflow from this first storage pond is controlled by a stone weir which passes flows though a narrow channel into a second flood storage area. This second pond was

constructed by the Environment Agency from a long, clay cored embankment along the left bank of the watercourse, tying into higher ground to the north.

Flows discharge from this storage pond through a 600mm plastic pipe outfall through the embankment. The outfall pipe has a timber stop board installed on to its invert to restrict flows through the pipe and retain some water in the pond at all times to maintain a small area for aquatic habitat.

At the time of inspection the first storage pond appeared to have significantly more capacity than utilised. Silt and vegetation levels are currently unknown, but are thought to be high, and the outfall is set relatively low, which reduces the potential storage volume. That said, it is understood that the Environment Agency were keen not to significantly increase the storage volume in case of failure and potential maintenance costs associated with the revised 2010 Reservoirs Act.

During our site inspection, significant cracking in the upper surface of the Environment Agency embankment was noted. This is likely due to swelling of the embankment clay and should be investigated as a matter of urgency.

The effectiveness of this pond combination is unclear; however the landowner has reported that he has not seen the storage pond operating at full capacity to date.

Figure 10 - Red House Farm Storage Pond

Red house Farm Storage Pond

In channel flow control bund down stream of farm access track

Environment Agency embankment and outfall into Red House Burn

Environment Agency embankment and storage area

Cracking in upper surface of embankment

4.2.2 The Orchard Storage Pond and Bypass Channel

Downstream of the railway culvert, the Environment Agency has constructed a second storage area on the Red House Burn to further attenuate flows and reduce the risk of flooding to the residents of The Orchard. This defence consists of a levelled storage area with a 1m high clay embankment which runs along the rear of the residential properties and ties into high ground the east and at the railway embankment, thus preventing flow from entering the rear of these properties as has occurred during previous events. A 300mm pipe acts as an outfall from the storage area, which runs for approximately 5m before connecting into a 600mm pipe which has been laid across the field. This 600mm pipe bypasses the Red House Burn and outfalls directly into the Hepscott Burn approximately 200m upstream of the Red House Burn Outfall and Crofts Park.

In addition to the outfall pipe, an over-flow weir has been constructed to prevent water levels in the pond getting too high and over topping in to the residential gardens to the

east. This spill way is located over the outfall pipe, and a second small embankment focuses any over topped flows down the 600mm pipe into which the initial flows outfall.

When the inlet to The Orchard culvert is exceeded, excess flood water now becomes ponded behind the embankment instead of flowing into the residential properties at the Orchard. Flows then exit the pond through the outlet or over the spill way and are discharge through the 600mm pipe across the field into the Hepscott Burn.

Figure 11 - EA Bund & Bypass Pipe at The Orchard

Environment Agency embankment and Outfall

Secondary embankment and connection with larger 600mm bypass pipe

5 MODELLING OF ENVIRONMENT AGENCY LOCAL LEVY SCHEMES

5.1 Aim of Modelling

A 1D hydraulic model of the Catch Burn, Red House Burn, and Hepscott Burn has been constructed using ISIS river modelling software. The aim of this modelling was to assess the hydraulic benefits that are provided by the Environment Agency's recent flood alleviation measures and access the magnitude of residential flood risk. By investigating two separate scenarios of the watercourse (Existing and Pre-Scheme); we have been able to assess the direct impact that the additional storage and attenuation measures have had at specific locations within the catchment.

Please note that our assessment of the standard of Protection provided by the Environment Agency schemes is based only on their hydraulic performance, and does not make any assumptions about their structural stability or integrity. Further details of their structural condition can be found in Appendix A.

All model results and schematics are provided in Appendix B.

5.2 Modelling Methodology

The 1D hydraulic model was constructed using river channel cross sections surveyed by Academy Geomatics in February 2011. Care was taken during the design of the survey to ensure that all major channel structures were surveyed thoroughly to ensure their accurate representation within the model. The details of each of the Environment Agency flood alleviation schemes were included in the model (weirs, storage areas, timber dams).

5.2.1 Catchment Hydrology

Due to the lack of available flow or rainfall data, the FEH (Flood Estimation Handbook) Rainfall Runoff method was used to generate the model inflow hydrographs. With the aim of this modelling to establish an indicative level of understanding relating to the effectiveness of the Environment Agency flood defence works, this method was considered the most appropriate method to define inflows to the watercourses.

Once the Existing model had been completed, a second model was constructed in which the Environment Agency works were removed, thus representing the nature of the catchment prior to the installation of the works (Pre-Schemes model).

Both models were run using the same 5, 20, and 100 years inflow hydrographs.

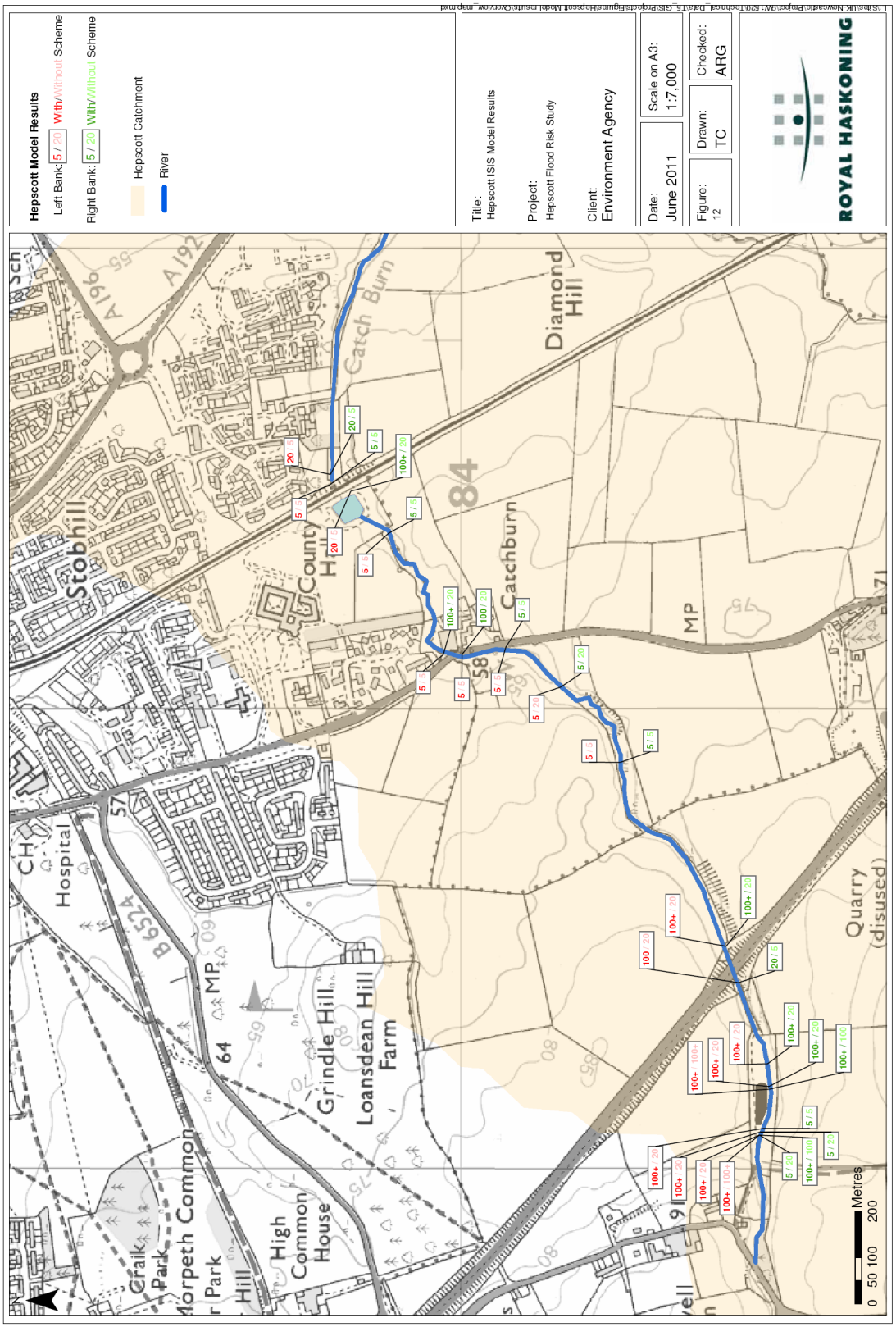
By comparing water levels in these two models, we have been able to establish:

- Indicative standards of protection for various locations along each watercourse, and
- The relative improvement in protection provided by the works implemented by the Environment Agency Local Levy Team.

5.3 Modelling Results

Figures 12 and **13** provide indicative standards of protection for key flood risk areas within the catchment as indicated by the Existing and Pre-Schemes model scenarios. It is clearly evident from these modelling results that there has been a clear improvement in the standard of protection as a result of the recently installed Environment Agency schemes. In the Pre-Schemes model, the majority of the key flood risk areas in the catchment have a standard of protection of between 5 and 20 years. However, the Existing model results show that the majority of these areas will now only flood at a 100 year event or greater.

In summary, it appears that the schemes which have been installed by the Environment Agency are effective at reducing the risk of flooding in and around Hepscott. However, there are a number of key areas that will still suffer flooding at lower return period events. Details of these areas are provided in the following sections.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Right Bank: 5 / 20 With/Without Scheme
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River
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Project: Hepscott Flood Risk Study
Client: Environment Agency
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Catch Burn
Diamond Hill
Catchburn
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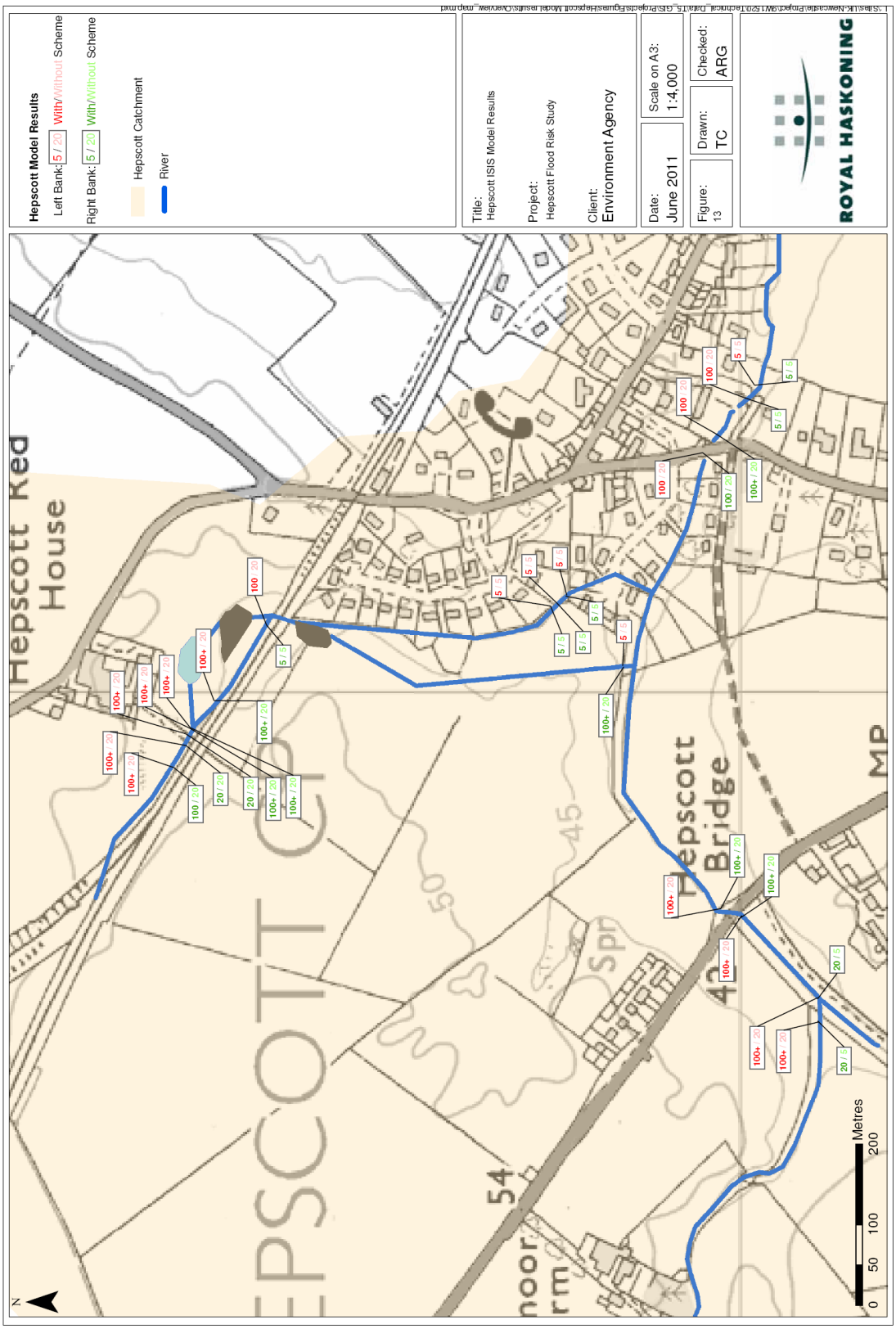
Hepscott Model Results
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Client: Environment Agency
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Checked: ARG
ROYAL HASKONING
Hepscott Red House
Hepscott Bridge
Metres
0 50 100 200
N

5.3.1 Key Areas of Interest

Red House Burn

As shown on **Figure 13**, the installation of the overflow pipes into the Red House Farm Ponds has reduced the level of backing up in this part of the upper catchment, resulting in lower water levels in the channel adjacent to the rail crossing and farm track. However, although we see a reduction in water levels at this location, the model clearly demonstrates that large quantities of flood water overtop the flow control weir and bypass the storage ponds (approximately 80%). It appears that the effectiveness of this scheme is limited by the capacity of the pipes which feed the storage pond.

Opportunity: Increase size of the inflow pipe to the storage pond to increase capacity and better utilise the storage potential.

Downstream of the Railway Culvert, the installation of the storage embankment and bypass culvert appears to have been successful at preventing flooding to the rear of properties at The Orchard. The Pre-Schemes model shows that overtopping of The Orchard culvert would previously occur even at the 5 year return period event and the risk of impacts to downstream properties increases significantly with events of increasing magnitude. However, the Existing model results show that the new embankment will not be over topped even from a 100 year return period event. The design of the embankment allows overtopping into the bypass culvert which occurs during the 5 year event and greater. This discharges directly into the Hepscott Burn therefore lowering levels in the storage pond and reducing the risk of over topping.

However, although The Orchard storage pond is sufficient for preventing flooding to properties at The Orchard, the storage arrangement does not limit the flows which still enter the original Orchard Culvert. In fact, the higher water level resulting from the storage of water in the pond increases forward flows though the original culvert due to an increase in hydraulic head at the inlet of the culvert, causing greater amounts of water to flow through the culvert than would have previously occurred. Consequently, flows through the open channel section along the rear of these properties is higher than previously, with an increase of 35L/s for a 1 in 20 year event, and thus still results in the entrance to the Crofts Park culvert becoming overwhelmed. Modelling results show that the rate of flooding at this culvert will be approximately 195L/s for the 5 year event and 237L/s for the 100 year event. This is an increase from the previous flooding rates of 191L/s and 206L/s, an increase of approximately 2% and 15% consecutively.

Opportunity: Install a weir plate at the culvert entrance to reduce flows entering The Orchard culvert.

Catch Burn

Unfortunately, the greatest reduction in water levels is seen in the least inhabited region of the catchment, and although there is improvement, the improvement is not to the same degree in the more populated areas.

The Pre-Scheme and Existing models have shown that the recent Environment Agency installations have gone some way to reducing water levels on the Catch Burn. The greatest effect of the schemes are seen in the upper catchment closest to the storage pond at Tranwell Farm. Here channel capacities have been improved from overtopping at the 20 year event, to overtopping at the 100 year event. The same is also true for the culvert under the A1 which should now no longer become surcharged prior to the 100 year event.

The Pre-Scheme model shows that overtopping of the channel banks previously occurred at the bridge under the A197 from 5 year (left bank) and 20 year (right bank) return period events. Due to the low level of the left bank, the standard of this bank is not improved by the upstream storage and woody dams, as overtopping from the 5 year event still occurs but only floods adjacent fields and has no impact on the road. However, flooding on the right bank at this location is reduced, with flooding occurring during the 100 year event rather than the 20 year, thus impacts to the A197 are reduced.

Further downstream at the Northumberland County Council pond, the addition of 3 extra inlet pipes to increase flows through the pond and increasing of the height of the over flow weir, appears to have done very little to reduce the flows bypassing the pond. Although the model does show some reduction in the amount of bypassing, and consequently, an increase in flow through the pond, the model still shows that up to 75% of the flows during a 100 year return period event will flow over the weir and bypass the pond.

The minor works that have been introduced on the Catch Burn do appear to have resulted in an overall improvement in the standard of protection, and this improvement could be considered significant in places, especially on the Hepscott Burn through Hepscott village itself.

The Hepscott Burn

The primary area of concern within Hepscott is located immediately upstream and downstream of the main road bridge in Hepscott Village near Crofts Park. The Pre-Scheme model shows that the channel upstream of the bridge is likely to be at risk from flooding from the 20 year return period event. However, the with scheme model shows that this section improves to only become over topped by the 100 year return period event.

Similarly downstream of the bridge, the main channel has an improved standard from 20 years to 100 years. However, there is a small section immediately upstream and downstream of the residential access bridge where standards remain at 5 years. This is due to a low channel bank and backing up at the bridge entrance, but is not considered a risk to property flooding.

5.3.2 Modelling Summary

As stated above, the modelling of the Hepscott Catchment and Environment Agency Schemes has highlighted that there is a general improvement in the standard of protection throughout the catchment as a direct result of the works carried out by the

Environment Agency. This modelling has also aided in the identification in of a number of minor issues with these schemes which are resulting in them not fulfilling their potential, or causing minor increases in flood risk. These issues are addressed in the following Options Identification section.

6 ECONOMIC BENEFITS OF FLOOD PROTECTION

An assessment of the likely economic benefits of flood protection has been carried out using the Benefits of Flood and Coastal Risk Management (MCM) weighted Annual Average Damage approach. The number of properties at risk has been established for each of the key flood risk areas based on site investigations, documented past events and hydraulic modelling. Having established the number of properties at risk, the results of the hydraulic modelling have been used to assign each of these properties with a Standard of Protection (SoP). This SoP is then used to estimate the Average Annual Damage (AAD) which will be incurred at each of the properties. For this high level assessment, and the absence of detailed flood water depth and property type information, the MCM Weighted Annual Average Damage (WAAD) has then been used to estimate potential maximum damages. This annual damage per property has then been multiplied over the length of the appraisal period to estimate the total economic benefits of any potential scheme. At this stage, these have been discounted to provide Present Value (PV) benefits following the guidance of the Treasury Green Book.

The damages for two appraisal periods have been calculated to provide Northumberland Council with the most flexible level of information. A 25 year period has been applied to assess the benefits of the recently installed Environment Agency schemes, as this is considered an appropriate design life for these structures.

A 100 year appraisal period has also been calculated to provide an understanding of the maximum benefits that could be expected for any improved capital scheme in Hepscott.

Table 1 below illustrates that the Environment Agency schemes already provide significant economic benefits to the residents of Hepscott. Based on these calculations, the scheme is expected to provide over **£725,000** in benefits over its life time, and if maintained for 100 years, the benefits will exceed £1.2m.

Due to these existing benefits, the total additional benefits which can be achieved from reducing the residual flood damages, over and above that which is currently in place is limited. Over the next 25 years, the total benefits which can be achieved from any further flood defence improvements are £359,979. This value increases to £613,900 over 100 years.

Due to this relatively small value of potential economic benefits available, the type and scale of engineering options that are likely to gain Flood Defence Grant in Aid (FDGiA) funding are limited.

The following section provides a summary of the types of future options which could be implemented to provide further improved flood risk management for Hepscott. Due to the limited economic benefits, the likelihood of achieving benefit cost ratios high enough to gain government funding is low. It is likely that contributions from third party sources (e.g. Flood Action Group, Council, Local Levy) will need to be sought if additional defences are to be installed.

Table 1 – Maximum Potential Benefits of Flood Protection in Hepscott Catchment

		Onset of Flooding		Maximum 25 Year Scheme Benefits			Maximum 100 Year Scheme Benefits		
Location	**No. Properties @ Risk**	**Before Scheme**	**After Scheme**	**Before Scheme**	**After Scheme**	**Benefits of scheme**	**Before Scheme**	**After Scheme**	**Benefits of scheme**
A197 Left Bank	4	5	5	£217,890	£217,890	£0	£371,584	£371,584	£0
A197 Right Bank	2	20	100	£35,755	£2,762	£32,993	£60,975	£4,710	£56,265
			Subtotal	*£253,644*	*£220,652*	*£32,993*	*£432,559*	*£376,294*	*£56,265*
The Orchard	9	5	100	£490,252	£12,429	£477,822	£836,063	£21,197	£814,866
			Subtotal	*£490,252*	*£12,429*	*£477,822*	*£836,063*	*£21,197*	*£814,866*
Crofts Park Culvert	2	5	5	£108,945	£108,945	£0	£185,792	£185,792	£0
			Subtotal	*£108,945*	*£108,945*	*£0*	*£185,792*	*£185,792*	*£0*
Upstream Hepscott Bridge	9	20	100	£160,896	£12,429	£148,466	£274,388	£21,197	£253,191
			Subtotal	*£160,896*	*£12,429*	*£148,466*	*£274,388*	*£21,197*	*£253,191*
Downstream Hepscott Bridge	4	20	100	£71,509	£5,524	£65,985	£121,950	£9,421	£112,529
			Subtotal	*£71,509*	*£5,524*	*£65,985*	*£121,950*	*£9,421*	*£112,529*
			Total Benefit	**£1,085,245**	**£359,979**	**£725,266**	**£1,850,751**	**£613,900**	**£1,236,851**

7 SCHEME OPTIONS

Following a thorough review of the previous flood event reports, site visits, and hydraulic modelling of the Environment Agency schemes, we have identified a number of engineering options which could be implemented to reduce the impact of future flooding events in Hepscott and the wider catchment. A full cost benefit analysis has not been carried out; however, the selection of low cost options has been based on the likely limited funding that could be available based on the simplified approach to benefits described previously in Chapter 6. Due to the limited amount of potential benefits, it is unlikely that any of the proposed schemes will attract the required level of FDGiA funding without significant third party contributions.

Indicative cost estimates have been derived for each of the presented options based on our previous knowledge and experience of similar schemes and construction work in other locations. The costs provided are intended as an indication rather than a final amount, due to the presence of significant design assumptions. As a result they are intended as outline costs for the purposes of analysis and comparison. Each of the options would require thorough site investigation before being taken forward and detailed costs should be calculated once this process has been completed.

7.1 Option 1: Improve inflow to the Red House Burn Storage Pond

As has been illustrated by the hydraulic modelling of the Red House Burn storage ponds, the majority of flood flows, even for low order events such as a 5 year return period event, overtop the in-channel control structure, and bypass the storage ponds. This bypassing results in the storage areas not being used to their full potential and could go some way to explaining why the landowner has yet to see them full to capacity, despite their relatively limited volume.

The topographic survey of the channel and storage inlet pipes for the Red House Storage pond found that the outlet of the pipe which feeds the storage is 50mm higher than its inlet. Coupled with the small inlet pipe sizes, this has shown that the utilisation of the flood storage area is limited by the capacity of the inflow pipes.

By re-laying the inlet pipes to the storage pond at an appropriate gradient, and potentially installing additional or larger pipes, it would be possible to increase the utilisation of the pond, increasing flood attenuation in the upper catchment and reduce flows downstream, with the aim of reducing peak flows along the Red Ouse Burn and at the confluence with the Hepscott Burn.

The indicative cost for improvements to the Red House Storage Inlet is in the region of £20,000.

7.2 Option 2: Remove culverts at The Orchard and Crofts Park

The primary causes of flooding on the Red House Burn originate from The Orchard and Crofts Park culverts. As previously discussed, the flooding at The Orchard has been effectively alleviated by the construction of the Environment Agency's embankment and diversion culvert. However, as a result of the higher water levels in the storage area,

minor increases in peak flows are able to pass though The Orchard culvert, leading to marginally higher flood levels at the Crofts Park culvert.

Considering its route beneath a number of residential properties, the cost of upgrading the Crofts Park culvert to a level which can adequately discharge the increased flows is likely to be prohibitive and it therefore not recommended.

A more cost effective option would be to seal off the inlet to the Orchard culvert, forcing the entire flows from the Red House Burn to flow through the storage pond and bypass culvert on a continual basis.

Such an approach will slightly reduce the storage potential and attenuating properties of the scheme, but will permanently remove the risk of flooding to Crofts Park from the Red House Burn.

However, such an option would need to be considered carefully, as this would mean the diversion and culverting of over 200m of open watercourse which could have a significant environmental constraints and is against Environment Agency protocols.

The indicative cost for improvements to the Orchard and Crofts Perk culverts are in the region of £60,000. This includes a small allowance of the installation of a weir plate at The Orchard culver inlet, and the replacement of both culverts with a internal sleeve. This cost is likely to increase if the culverts are found to be at significant depth or excavation / jacking is required.

7.3 Option 3: Expand Storage Volume at Northumberland County Council Offices

As has been highlighted by the current hydraulic modelling, the storage pond at Northumberland County Council suffers similar problems to those at the Red House storage ponds, in that although some attenuation is provided, the majority of flood flows still bypass the pond due to the inlet arrangement at its inflow.

With this option we propose to improve the effectiveness of this storage in two ways:
1) Improving the inlet to allow greater flows into the pond would reduce the volume that bypasses the storage.
2) increase the actual storage volume of the pond by adjusting the level of the outfall.

1) At present, flows enter via a series of pipes from a stilling basin upstream of the main pond. When the capacity of these pipes is exceeded, excess water weirs over the edge of the stilling basin into a bypass channel which flows around the pond and back into the main channel.

By excavating an over flow channel between the stilling basin and pond, the inflow capacity to the pond can be significantly increased, whilst removing the current pipes which in turn will remove the need for their future maintenance. Such a scheme would require excavation of the current footpath around the pond and the installation of a short foot bridge (Approx. 5m). This is unlikely to be cost prohibitive and could further improve the aesthetic amenity of the council gardens.

2) Improvement of the pond inlet alone will not improve the effectiveness of the pond, as this will simply result in higher water levels flowing over the pond outlet. To improve the flood alleviation potential of the scheme, it will be necessary to increase the available flood storage volume.

At present, the water level in the pond is maintained at a relatively high level as a result of the level of the stone weir outlet. By installing an outlet pipe from the pond at a lower level through the existing stone weir, it will be possible to considerably lower the water level in the pond, allowing greater volumes to be stored during higher order events.

Such an option is likely to disrupt the aquatic habitat present in the pond, so a full consultation with the Environment Agency FRB team will be required at an early stage if such an option is to be considered further.

An alternative arrangement could be to further increase the sill level of the outlet, although further investigations will be required to check the existing bank levels to ensure that the banks of the pond do not over top causing flooding to the council pond.

The indicative cost for improvements to the Northumberland County Council pond are likely to be in the region of £30,000, which would include the replacement of the inlet culvert with larger pipes of a excavated channel and foot bridge, and works at the pond outlet. A contingency of an additional £20,000 may be required for additional works to raise local banks heights around the pond inlet if necessary.

7.4 Option 4: Construct Flood Storage on the Coal Burn at Hazeldene

The Environment Agency has previously identified an area of farmland adjacent to the Hazeldene as being potentially suitable for flood storage. Access to the site has not yet been achieved due to difficulties with the landowner, but desk studies of the topography confirm that the land could be suitable.

There are two potential locations for water storage within close proximity, and this option considers that either one of the locations could be utilised, or a combination of the two. The first location is an existing area of vegetated land around the current river channel which is left as set-aside between two areas of utilised agricultural land. The watercourse appears to take two paths around a central island from Ordnance Survey mapping, though studies of aerial photography do not provide confirmation due to the presence of vegetation.

It is proposed that a storage pond is constructed by excavation at this point, either by removing the central island, or widening the channel. The maximum potential area could be up to $50m^2$ square, allowing significant storage in the region of 2,500 – $4,000m^3$.

The second location is approximately 200m downstream, where the relief of the land provides an opportunity to construct an embankment across the watercourse and create a small storage area upstream. An embankment of approximately 50m to 100m across the channel at this location would allow water to accumulate for approximately 150m

upstream. The location of the proposed embankment is surrounded by the same arable farmland, but water would be stored inside of the set-aside river channel.

It is possible to either utilise potential storage at one or both of the locations, however an important consideration is the limiting capacity before such a structure would need to be listed as a reservoir, increasing maintenance costs. Following the provisional changes detailed in the Flood and Water Management Act 2010, the maximum capacity of flood storage at this location would be 10,000m³ before registration would be necessary. This would apply for either one structure or both structures in conjunction, due to their proximity.

The indicative cost for the construction of this additional storage is difficult to estimate without the exact dimensions of the required embankment and knowledge of site conditions and access. It is likely that the costs of such a scheme would be similar to those for the existing Environment Agency storage areas, depending upon the level of design that the council would require. If a similar level of design to the Environment Agency schemes is required, then an estimate of approximately £60,000 is considered appropriate.

7.5 Option 5: Construct Flood Storage on the Catch Burn

The location on the Catch Burn where the Environment Agency has constructed timber dams could potentially be used for a larger-scale flood storage scheme.

The relief of the channel provides the potential for a small, water-retaining embankment to be constructed to provide a barrier for floodwaters. Any such embankment would only be required to have a length of ~20m, and would create a small, deep storage area capable of holding significant volumes of flood water.

The steep sides of the channel indicate some evidence of industrial activity and it was mentioned during site visits to the area that there has previously been used as a spoil tip. Therefore a ground investigation would be required to investigate the possibility of encountering contaminated land.

Potential storage at this location would allow control of the flow of the Catch Burn and an increased response time for the catchment, partly alleviating downstream issues. Implementation of this option would require removal of the EA timber dams in the channel, as large debris in the channel would have the potential to damage a water-retaining embankment and compromise strength.

There is very little infrastructure in the area surrounding the proposed embankment location, with the majority used for animal grazing. At times of normal flow the area would not be greatly affected, and the land could still be used for current purpose. In times of higher flow, with water retained in a small proportion of the site, much of the land would remain unaffected; though with deep water access control would be required.

As above, an indicative cost for the construction of this additional storage is difficult to estimate without the exact dimensions of the required embankment and knowledge of site conditions and access. It is likely that the costs of such a scheme would be similar to those for the existing Environment Agency storage

areas, depending upon the level of design that the council would require. If a similar level of design to the Environment Agency schemes is required, then an estimate of approximately £60,000 - £200,000 is considered appropriate.

In such cases, consideration of the 2010 Reservoirs Act will be required as flood storage areas in excess of 10,000m^3 will require considerably greater levels of design which ill make such potential schemes much more expensive.

7.6 Option 6: Flood Warning

Considering the low level of benefits that are likely to be achieved by a flood alleviation scheme for Hepscott, the most cost effective approach may be the installation of a flood warning service rather than any hard engineering solutions.

With the installation of relatively inexpensive rain gauges within the upper catchment, and an understanding f the catchment response to rainfall, it could be possible to provide a flood warning service to the affected properties in Hepscott.

Through discussions with the Environment Agency flood warning team, it is unlikely that the Environment Agency will be able to provide or maintain a flood warning system due to the capacity of their current system. However, this should not prevent the council installing a standalone, independent system of its own. Such a system could be installed for very little cost and maintained by the council, or possibly more appropriately, by members of the Hepscott flood action group, who would be well positioned to spread the message of a warning.

The indicative cost for the installation of a flood warning system is likely to be in the region of £10 – 15,000 for the purchase and installation of equipment, plus £10,000 for the completion of a flood warning study which will be required to ensure that the system is set up to provide the best possible results.

7.7 Option 7: Individual Property Protection

Although a flood warning system does not reduce the impact of flooding, in conjunction with individual property protection such as airbrick covers and demountable flood gates, such a system could provide a more suitable level of protection than any large scale engineering projects.

7.8 Additional Recommendations

7.8.1 Removal of Weir on Hepscott Burn

As discussed the weir don stream of the main road in Hepscott provides no function yet causes a significant restriction to flow. The council may wish to discuss the removal of this weir with the land owner. This could involve the complete removal of the weir or the removal of the stop boards.

The indicative cost for the removal of this weir is approximately £5,000.

7.8.2 Repair Cracking in Red House embankment

As discussed above, significant cracking has been identified in the crest of the embankment at the Red House Farm. The cause of this cracking is unknown and thus the exact nature of the problem is difficult to ascertain, thus making a cost estimate for this work difficult.

The indicative cost for the repair of the embankment is likely to be in the region of £20,000 – 40,000.

7.8.3 Investing in Maintenance of Environment Agency Schemes

At present, and from the outcomes of the hydraulic modelling, it appears that the schemes implemented by the Environment Agency have been very successful in reducing the risk of flooding at Hepscott. Although the actual performance of these structures is as yet untested, there is the potential that they could provide significant improvement to flood management to the catchment. Rather than investing in additional flood management schemes, the council may instead wish to invest the in maintenance or improvement of these structures to make them into more permanent features.

As yet, the performance of the schemes is not known so it is not possible to provide any indicative cost for the future maintenance of the structures.

7.9 Summary of Proposed Options

A combination of any of the Options outlined above could be implemented to provide improved flood management and reduce flood risk to the residents of Hepscott.

Reduction of flood risk on the Red House Burn could be obtained with small-scale, relatively economical, adjustments to the watercourse and existing defences installed by the Environment Agency, such as **Options 1 & 2.**

Flood problems on the Hepscott Burn are generally a consequence of the constricted capacity of the Burn as it passes through the centre of the village, and the short response time of the catchment to rainfall events. **Option 3** provides an opportunity to increase the capacity of the storage at the Northumberland County Council pond, whilst **Options 4 and 5** concentrate on providing additional storage throughout the catchment.

Recognising the current economic situation within the UK and the limited availability of funds for flood management projects, **Options 6** and **7** provide low cost options which could build upon and compliment the small scale works already undertaken by the Environment Agency.

8 CONCLUSIONS AND RECOMMENDATIONS

Following a number of significant flood events at Hepscott in Northumberland including the September 2008 event, and the installation of a series of small scale flood management measures by the Environment Agency Local Levy Team, Northumberland County Council commissioned Royal Haskoning to carryout a Flood Risk Study for the catchment.

Through a review of previous reports, site visits, discussions with third parties, and hydraulic modelling of the main watercourses in the catchment, it has been confirmed that the key flood risk areas are located on the Red House Burn and Hepscott Burn immediately upstream and downstream of the Hepscott Bridge, and that there is no other areas of significant risk to property from flooding within the catchment.

Hydraulic modelling has shown that prior to the installation of the Environment Agency schemes, the standard of protection at these locations was as low as 1 in 5 years. However, the schemes implemented by the Environment Agency appear to have been very successful in improving the local standard of protection and reducing future risk with many of these areas now having a standard of protection up to 100 years.

As with all flood management schemes, there still remains some level of residual risk. However, with the improvement in the standard of protection to as much as 1 in 100 in some locations, the residual risks are relatively low. As such, the economic benefits which could be gained from any additional flood management works are low, and it is unlikely that such minor flood damages will attract any significant Flood Defence Grant in Aid (FDGiA) funding unless significant third party contributions are secured.

A number of small scale options have been proposed which will build on the works already completed by the Environment Agency. These include the installation of a stop board at the entrance to The Orchard culvert to reduce flows through this orifice when the water levels in the storage area cause the culvert to surcharge. Additionally, the installation of pressure transducers at key locations around the catchment would allow the Council to set up and monitor their own flood warning system which will work independently from those run by the Environment Agency.