APPENDIX C Hot Spot Overview

APPENDIX C1
Fellgate

C1 FELLGATE

1 DESCRIPTION OF AREA

The Fellgate area is located east of the A194 Leam Lane and approximately 600m west of the A19. It is bounded by the metro line running through Fellgate metro station to the north and the A184 Newcastle Road to the south. Durham Drive encircles the residential estate area which is accessed from the A194 or Fellgate Avenue, off Hedworth Lane to the east. The area is predominantly residential with several schools and associated playing fields, and some commercial properties.

Monkton Burn is located to the east, approximately 250m from the closest properties, and Calfclose Burn is located to the west, approximately 60m from properties. The location of the watercourses are shown in Figure C1. South of Fellgate the area is agricultural as shown in Photographs 3 and 4. From the north eastern corner of the estate at approximately 20mAOD, the land rises south west to the A194, to over 40mAOD. The topography of the area is shown in Figure C2.

Northumbrian Water sewers in the area are separate surface and foul sewer sewers. There is a drain from the fields (photograph 3) which enters a 450mm culvert under Durham Drive (photograph 4). The culvert is believed to follow the line of a former drainage ditch prior to the estate being built.

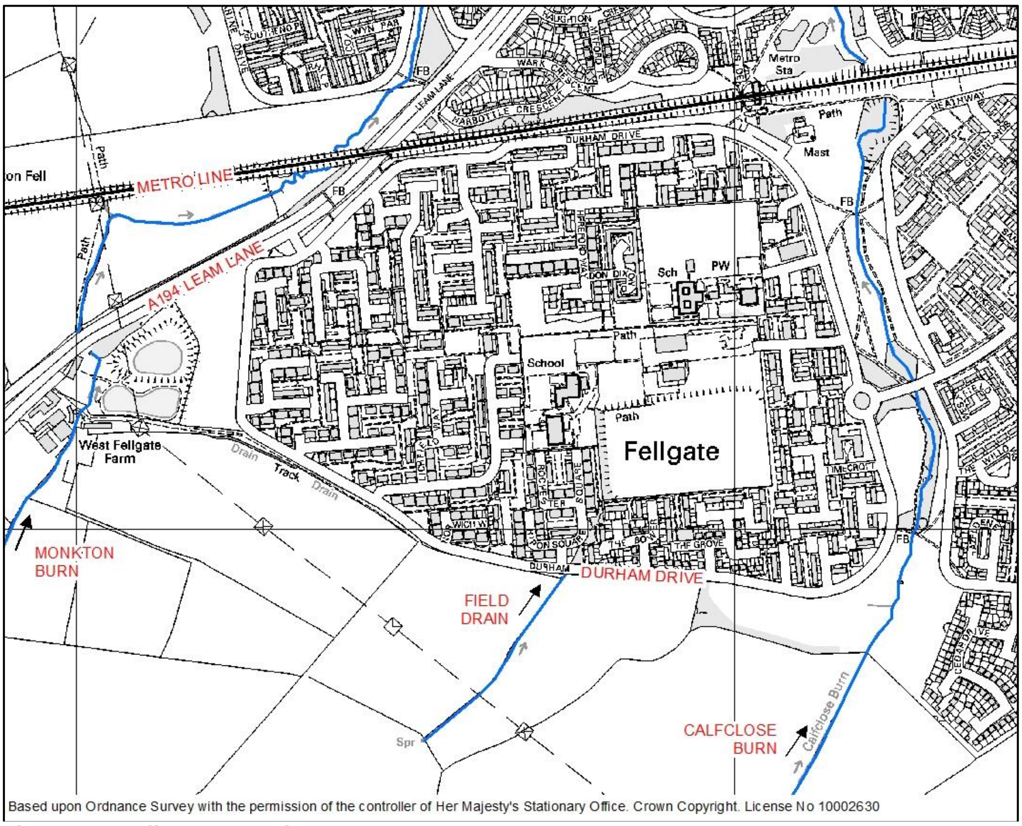

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Figure C1 Fellgate Overview

Photograph 1: Agricultural fields to south of Fellgate

Photograph 2: Agricultural fields to south of Fellgate

Photograph 3: Field drain from field flowing north

Photograph 4: Durham Drive, looking east low point in road

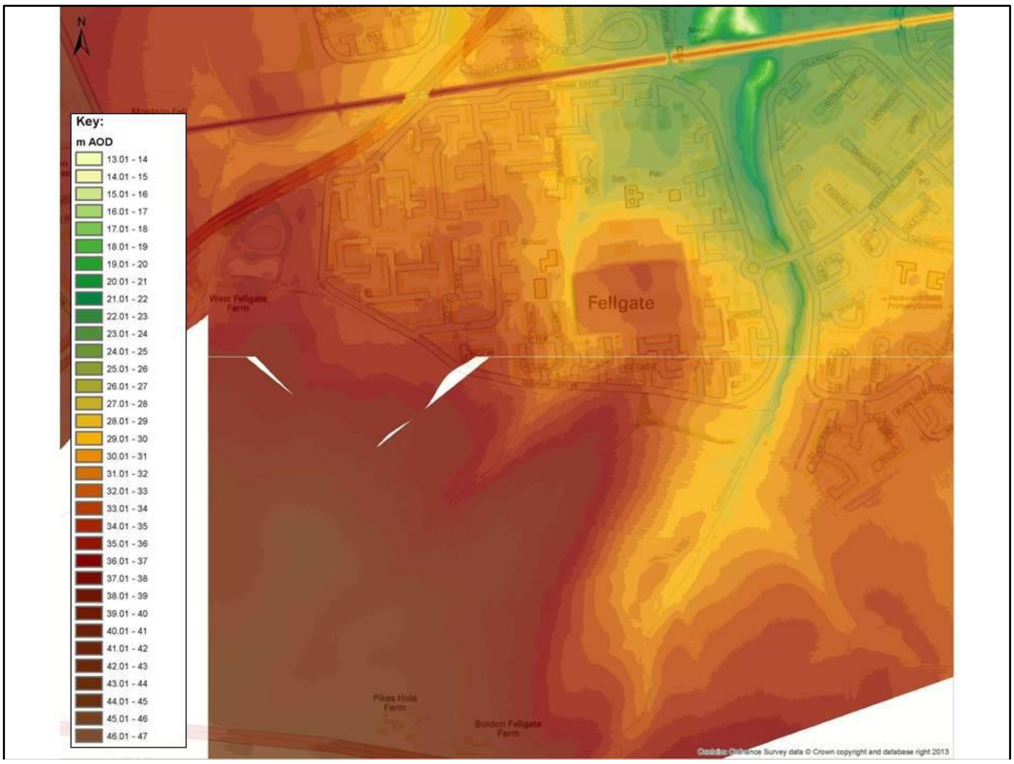

Figure C2 Local topography of Fellgate

2 DEVELOPMENT PLANS AND OPPORTUNIITIES

Review of the Strategic Housing Land Availability Assessment (SHLAA)[1] highlighted areas within the Fellgate estate as being potentially developable. These sites are highlighted in red in Figure C3. The two areas identified as 'potentially developable' sites cover approximately 3 hectares in total.

The largest potentially developable site is within an area of existing flood risk; which will need to be considered before development is taken forwards. Any options considered in Section 6 may reduce flood risk to this site and enable a site with lower flood risk to be taken forward to development. The site is also within an area which contributes to flood risk (from surface water runoff) as discussed further in Section 5. Development on this site would need to ensure it does not contribute to the existing flood risk issues.

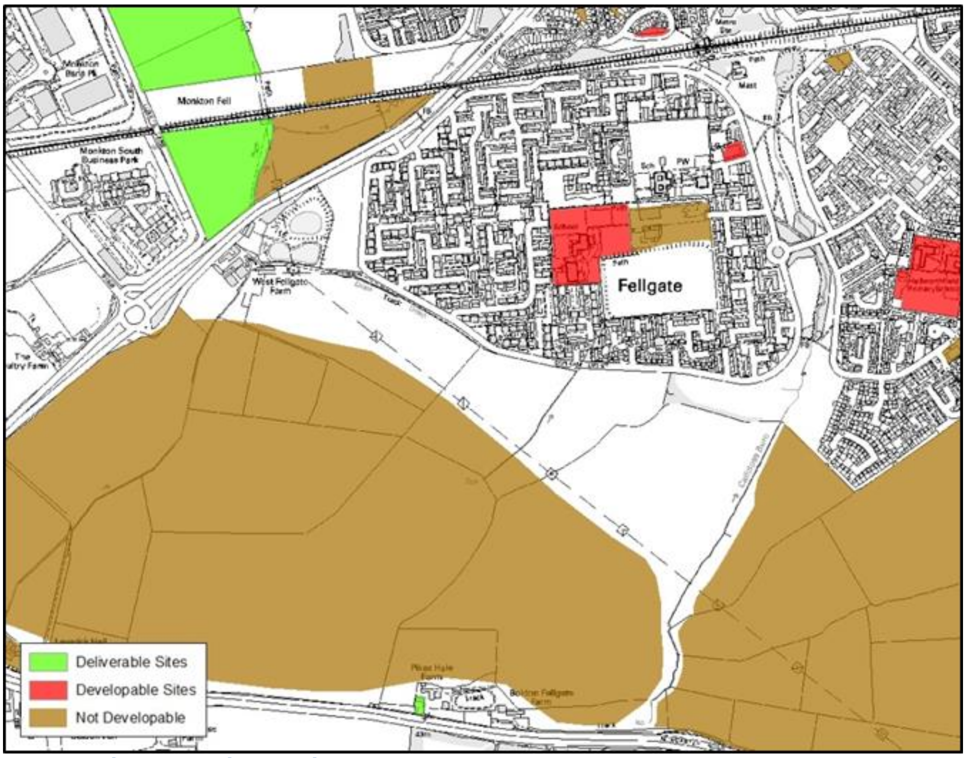

Figure C3 Development Plan Review

3 ENVIRONMENTAL DESIGNATIONS AND OTHER POSSIBLE CONSTRAINTS

A desk-based high level screening of environmental information was carried out to identify any initial issues which could potentially influence option selection and assessment for this site. The information within the National Receptor Database, including international and national designated areas and listed buildings was screened. The screened data did not highlight any significant environmental receptors within the Fellgate area. A search of Magic[2] identified small pockets of Deciduous Woodland BAP (Biodiversity Action Plan) priority habitat east of the estate; north of the roundabout from Durham Drive to Fellgate Avenue and north west of the estate beyond the A194 Leam Lane and the metro line.

[1] South Tyneside Council (2011) Strategic Housing and Land Availability Assessment
[2] Magic (2013) Defra receptor database; www.magic.defra.gov.uk

Review of British Geology maps[3] identifies the superficial deposits of the Fellgate area as clay. The bedrock is Pennine Middle Coal Measures Formation; predominantly sandstone with some mudstone, siltstone, sandstone classification across eastern sections and the southern western corner of the estate.

4 DETAILED MODEL RESULTS

Figure C4 shows the predicted surface water flooding extent for a 1% annual exceedance probability (AEP) (1 in 100) event in a Do Nothing scenario. This is a hypothetical scenario which is assessed to allow the benefits of the options considered to be compared against. For Fellgate, the Do Nothing scenario assumes that the culvert under Durham Drive from the field is blocked and that all NWL assets remain operational. The number of properties at risk in the Do Nothing scenario compared to the existing situation (culvert operational) was very similar, suggesting the culvert is ineffective in significant rainfall events. The numbers of property at risk in the Do Nothing scenario for a range of rainfall events is shown in Table C1. The effects of climate change on the levels of flood risk are shown in Table C2. The modelling note in Appendix A includes the methodology for the detailed modelling.

Table C1 Properties at risk in the Do Nothing Scenario

Location	Total properties at risk* in each rainfall event			
	3.33% AEP (1 in 30)	1.33% AEP (1 in 75)	1% AEP (1 in 100)	0.5% AEP (1 in 200)
Residential	10	31	41	60
Commercial	0	0	0	1
Total	**10**	**31**	**41**	**61**

*Properties have been counted as being at risk when flood depths adjacent to the property are above the assumed property threshold of 150mm.

Table C2 Total Properties at risk in Do Nothing with Climate Change Flows

Rainfall event							
3.33% +CC AEP (1 in 30+cc)		1.33% + CC AEP (1 in 75+cc)		1% + CC AEP (1 in 100+cc)		0.5% + CC AEP (1 in 200+cc)	
No. at risk	Increase	No. at risk	Increase	No. at risk	Increase	No. at risk	Increase
24	+14	32	+1	60	+19	105	+44

[3] British Geology Survey (2013) Geology Maps; http://www.bgs.ac.uk

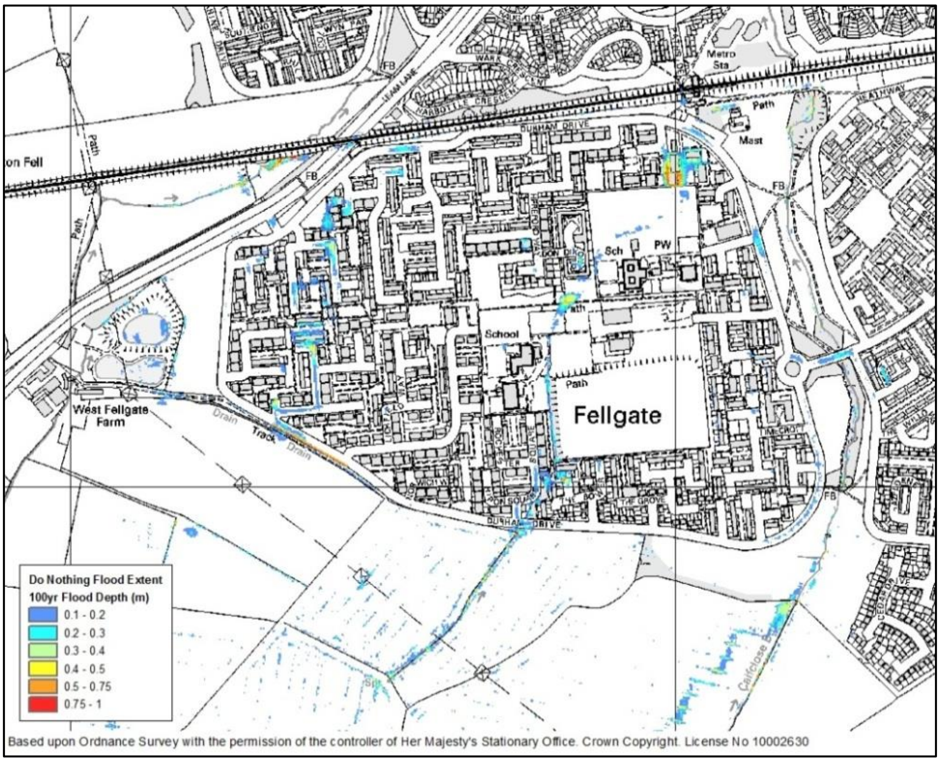

Figure C4 Do Nothing 1% AEP event

5 FLOOD MECHANISM ASSESSMENT

The detailed modelling was analysed, and in addition to site visits and the review of initial data, the following conclusions and detail on flood mechanisms can be drawn:

- Several areas of the estate were affected by the June 2012 rainfall event.
- Sandbags were noted during the site visit in April 2013, supporting the reports of historical flooding to the area.
- Surface water runoff from the fields to the south of the area follows two main flow routes into the Fellgate area: east of Oxford Way and at Lichfield Way.
- At Oxford Way the flow route (eastern flow route) is located between Oxford Way and The Bower. Flood waters flow towards the south eastern corner of the playfield and along the back of Rochester Square (photograph 5), to the west of Fellgate primary school. The flows then head north easterly across Don Dixon Drive (photograph 6) and the northern school field to The Hollows and Wellway.
- The flow route at Lichfield Way (western flow route) focuses around Leicester Way, flowing northerly across the western side of the estate.
- The source of flooding in the east is surface water runoff from the agricultural fields; the storm and foul sewers east of Fellgate primary school are also overwhelmed in the smallest flood event modelled (3.33% AEP).
- Some of the foul sewer network has been assessed as becoming overwhelmed during storm events, which may suggest misconnections from the surface water system into the foul system.

Photograph 5: Flow path through Fellgate

Photograph 6: Edge of flow path through Fellgate

6 SURFACE WATER MANAGEMENT OPTIONS

6.1 Long List of Options

A long list of measures was screened initially to identify potential suitable measures to reduce surface water flooding at Fellgate. Table C3 shows the screening process of measures considered. The measures which were considered viable were used to create options which could potentially reduce the surface water flooding.

Table C3 Long list of measures

	Mitigation Measure	Initial Screening	Technically Feasible?
Source	Green roofs	Potentially as a part measure implemented on schools in the eastern area	Some Potential
	Soakaways	May provide some attenuation of flows, although infiltration into surrounding field already limited	No
	Swales	Could be used along field perimeter, although volumes are quite large, would be classed as storage. Could potentially be used within housing estate to contain direct overland flows, although space restriction likely to limit the size of rainfall event which can be mitigated	Some Potential
	Permeable Paving	Could be installed in housing area although unlikely to achieve sufficient reduction in flow	Some Potential
	Attenuation/Storage	Space available in fields to create storage and attenuate flows prior to continuing into storm system	Yes
	Rainwater Harvesting	Could be installed in housing area although unlikely to achieve sufficient reduction in flow	Some Potential
Pathway	Increase drainage/sewer capacity	Sewer capacity in eastern area does reduce through estate	Yes
	Separation of foul and surface water sewers	Storm and foul systems already separate within area	No
	Improved maintenance regimes	Assumed all existing networks are in good working order	No
	Managing overland flows	Some flows could be potentially diverted away from houses to river in east. Additional opportunity to control flows above ground	Yes
	Land management practices	Changes, such as re-directing field ploughing, could achieve some slowing of flow and increase permeability of land, although difficult to measure	Some Potential

	Mitigation Measure	Initial Screening	Technically Feasible?
Receptor	Improved Weather warning	Unlikely to be effective for small fast-reacting catchment. Needs rainfall storm forecasting; which can change rapidly and be difficult to predict. Would need to be implemented at a wider scale; either nationally or in combination with other councils in area	No
	Planning policies	Measure to be taken forward at council wide level	No
	Permanent/Temporary defences	Likely to divert water elsewhere	No
	Social Change, education and awareness	Through action impact could be decreased although risk not reduced and difficult for public to take action without warning	No
	Improved resilience and resistance measures	Properties at risk could be fitted with resilience measures	Yes

6.2 Short List of Options

The measures considered viable in Table C3 were taken forward to create options which could have the potential to reduce surface water flooding. The options were then assessed against specific criteria to consider which to specifically assess in greater detail using the hydraulic model. The criteria used are discussed in Section 4.2 of the main SWMP report. The score assigned to each criteria per option ranged between -2 (Severe negative outcome/Impact) to +2 (High positive outcome). The assessment is shown in Table C4.

Table C4 Short list of options

	Option Description	Economic		Technical		Site Specific Objectives		Social Impact		Environmental		Sustainability		Overall
	Weighting		**30**		**20**		**20**		**10**		**10**		**10**	**100**
A	**Do Nothing**	0	0	0	0	-2	-40	-2	-20	-2	-20	-2	-20	-100
B	**Do Existing; operation of existing assets**	0	0	0	0	-2	-40	-2	-20	-1	-10	-1	-10	-80
C	**Store/attenuate flows in field in east and west**	-1	-30	2	40	1	20	1	10	1	10	2	20	70
D	**Storage on west in field and permeable paving (playgrounds) and ponds within housing area in eastern area**	-2	-60	-1	-20	1	20	-1	-10	1	10	1	10	-50
E	**Diversion of surface water runoff from field to watercourse**	-1	-30	2	40	1	20	1	10	1	10	2	20	70
F	**Increase storm capacity in sewer network and store attenuate/flows in western area**	-2	-60	-1	-20	1	20	0	0	1	10	1	10	-40
G	**Increase all storm water capacities**	-2	-60	-1	-20	1	20	0	0	0	0	1	10	-50
H	**Resilience/Resistance measures - Individual Property Protection**	-1	-30	1	20	1	20	-1	-10	0	0	1	10	10

Option G was considered one of the most expensive options at this early stage and was not taken forward to modelling. Individual property protection (Option H) was not taken forward as options to reduce flood risk through dealing directly with the source of flooding or flood pathways were considered in further detail first.

In summary the following options were taken forward to modelling and assessed in greater detail. The detail of the options is included in Section 6.3.

- Do Nothing (block the field drain culvert)
- Option 1 - Do Existing – operation of existing assets
- Option 2 – Divert surface water flows from the field to the watercourse
- Option 3 – Store surface water flows from the field, install new upsized storm sewer on in eastern area and small storage area on school field.

Once Option 2 had been modelled it was evident that flood risk could potentially be reduced further through options which included mitigation measures within the estate, this influenced the chose of the third option which was taken forward to modelling.

6.3 Option Modelling

Option modelling was carried out to consider the benefits provided by dealing with the surface water flows at source (Option 2). This highlighted the residual risk and additional modelling (Option 3) was used to assess the scale of measures required within the estate in order to reduce the level of flood risk further, particularly to the properties in The Hollows area of the estate.

6.3.1 Option 2 - Divert surface water flows from the field to the nearest watercourse

Option 2 components and the residual flood risk is shown in Figure C5. The option consisted of a drainage channel along the edge of the field to the south of the Fellgate estate. The drainage channel started from the south west corner of the estate and flowed east to discharge into the Calfclose Burn. The maximum volume collected in a 0.5% AEP (1 in 200) event was approximately 7200m^3. As the ground level rises in the middle of the field south of the estate, consideration was made to channel the eastern flows to Calfclose Burn and the western flows to Monkton Burn. However on review of the DTM the ground rises prior to meeting Monkton Burn in the west, the overall channel would also have to be longer to ensure collection of all surface water runoff from the field and divert flows to the separate watercourses. Therefore all flows were directed to the eastern watercourse; Calfclose Burn.

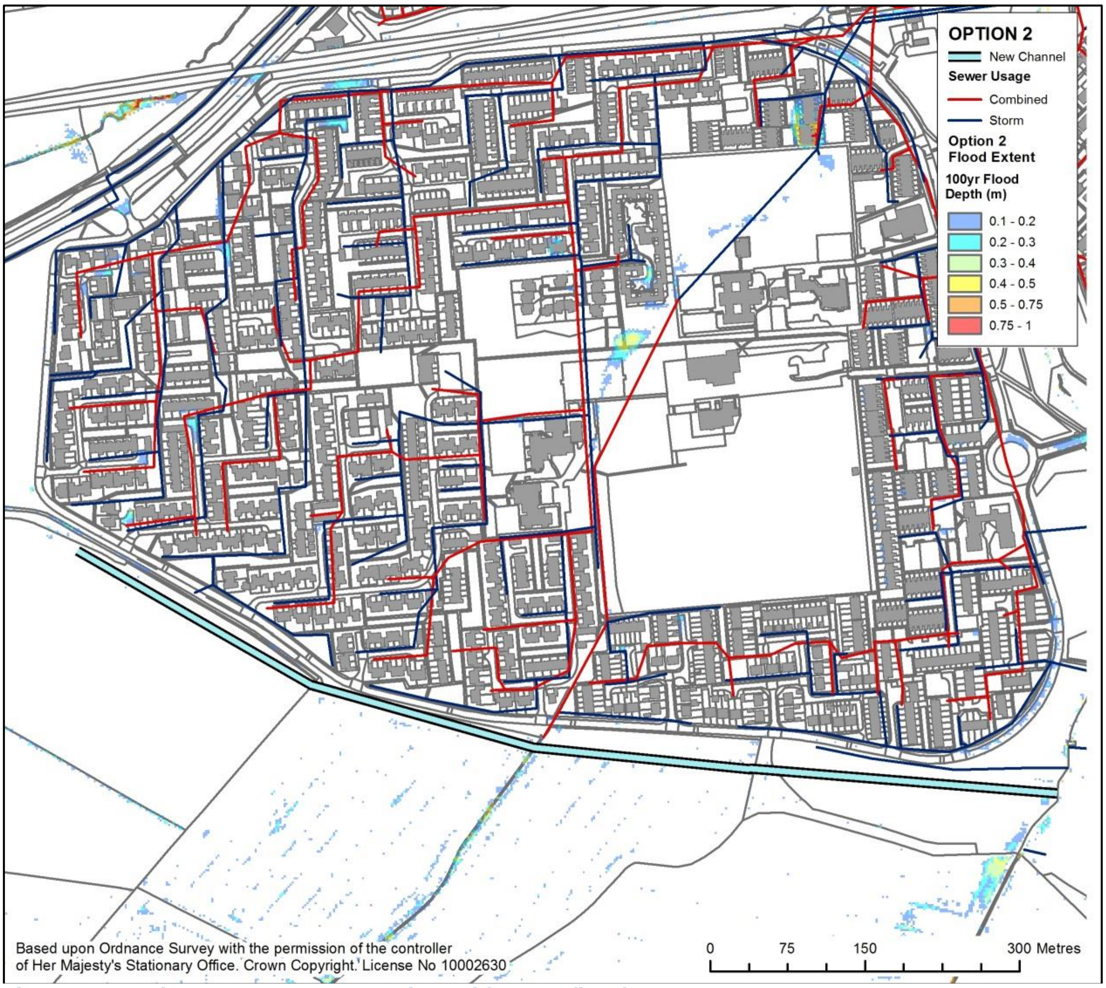

Figure C5 Option 2 components and resulting 1% flood extent

Directing the surface water runoff from the field straight to the watercourse significantly reduced the flooding issues on the western side of the estate. In the east of the estate there is less pressure on the NWL assets which the field drain connects into, however this only reduced the flooding slightly. The capacity of the receiving Calfclose Burn is considered to have sufficient capacity to receive the flows at this point, although further work would need to be carried out to ensure flood risk was not being increased downstream through implementation of the option.

6.3.2 Option 3 – Store surface water flows from the field, install new upsized storm sewer in eastern area and small storage area on playing field

The components of Option 3 are shown in Figure C6, along with the residual flood risk. The option consists of a drainage channel along the edge of the field to the south of the estate. The drainage channel funnels surface water flows from the field to the inlet of the culvert under Durham Drive. The surface water flows are retained at this location behind a new embankment, with a reduced size of inlet pipe to control flows into the culvert and reduce pressure on the assets downstream. The stored water at this location is estimated to take approximately 9 hours to discharge after a 0.5% AEP (1 in 200) 240 minute event.

Within the housing estate a new storm water sewer and manhole was installed to divert flows which pond north east of the sports pitch and allow them to discharge straight into

Calfclose Burn. The new sewer conveys 12,500m^3 of flow into the watercourse in a 0.5% AEP (1 in 200) event. The capacity of Calfclose Burn is considered to have sufficient capacity to receive the flows and also not cause the discharging flows from the sewer system to be locked up to the modelled 0.5% AEP (1 in 200) event. Further work would be carried out to ensure this through the design development.

In the corner of the north eastern playing field a bund was constructed to capture additional surface water runoff from the playing field prior to it affecting properties. The maximum depth of water stored by the bund in a 0.5% AEP (1 in 200) event was approximately 0.45m. Additional drainage in the corner of the playing field was also installed to discharge the stored water into the existing storm water culvert, resulting in the culvert discharging approximately 1,250m^3 to the watercourse north east of Fellgate for a 0.5% AEP (1 in 200) event.

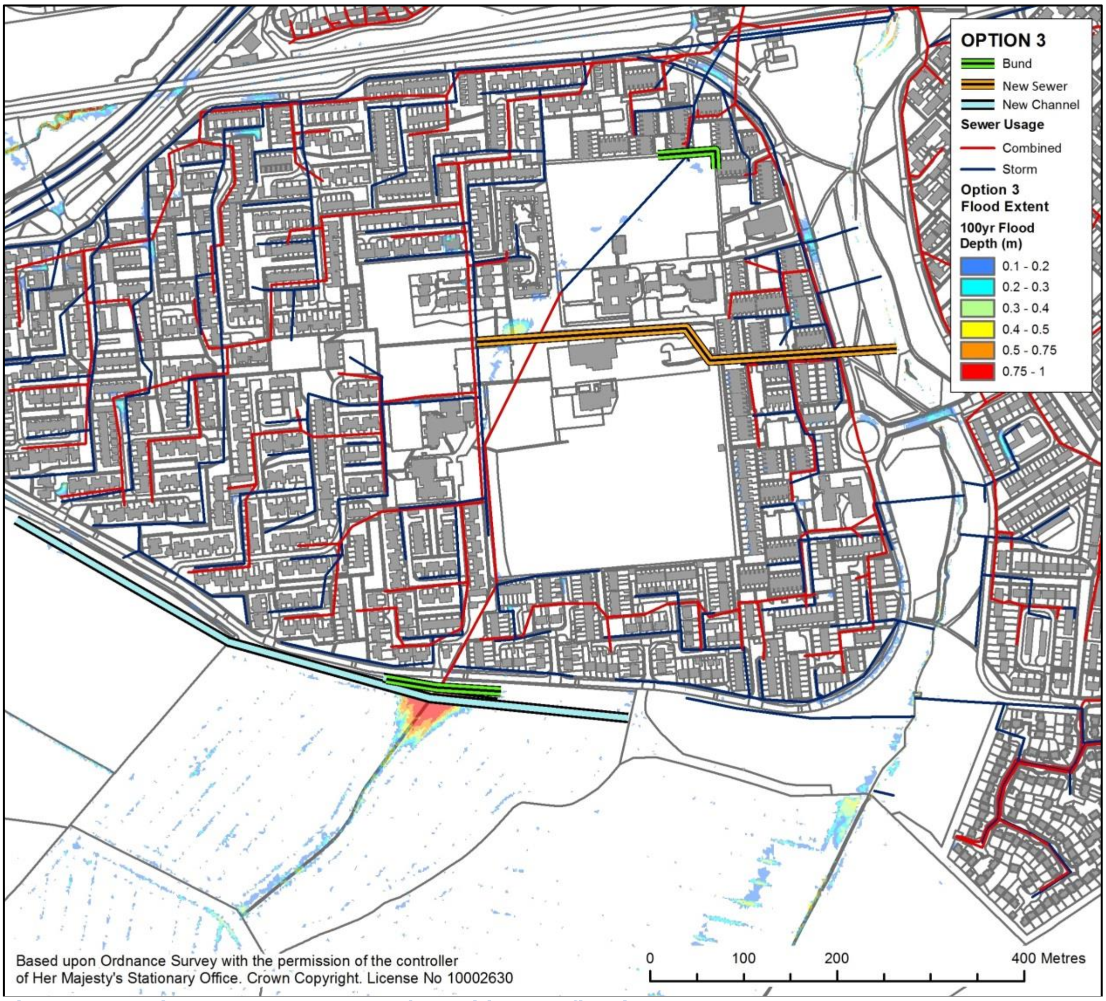

Figure C6 Option 3 components and resulting 1% flood extent

Option 3 reduced both the flooding from the western area of the estate and the additional flooding in the east at The Hollows.

The residual flood risk from the options is included in Table C5, with the reduction in flood risk (compared to the Do Nothing scenario) included in Table 6 Reduction in properties for modelled options (compared to Do Nothing).

Table C5 Properties at risk in the options

	Option 1 – Do Existing				Option 2 – Divert surface water flows from the field				Option 3 – Store surface water flows from the field, install new upsized storm sewer			
	3.33%	1.33%	1%	0.5%	3.33%	1.33%	1%	0.5%	3.33%	1.33%	1%	0.5%
Res	10	30	40	60	4	10	15	22	8	12	11	25
Com	0	0	0	1	0	0	0	1	0	0	0	0
Total	10	30	40	61	4	10	15	23	8	12	11	25

Table 6 **Reduction in properties for modelled options (compared to Do Nothing)**

	Option 1 – Do Existing				Option 2 – Divert surface water flows from the field				Option 3 – Store surface water flows from the field, install new upsized storm sewer			
	3.33%	1.33%	1%	0.5%	3.33%	1.33%	1%	0.5%	3.33%	1.33%	1%	0.5%
Res	0	1	1	0	6	21	26	38	2	19	30	35
Com	0	0	0	0	0	0	0	0	0	0	0	1
Total	0	1	1	0	6	21	26	38	2	19	30	36

Table C5 and Table 6 Reduction in properties for modelled options (compared to Do Nothing) show option 3 had greater impact on reducing the properties at flood risk in the 1% AEP event, although not during all flood probabilities assessed. This could be due to the limitations in the method of extracting flood depths at individual property points as discussed in Section 3.7 of the main report as the residual flood extent from Option 3 is clearly reduced. The property numbers are indicative and the level of flood reduction would be verified through development of the option.

6.4 Costs and Benefits

The costs and benefits of the modelled options were assessed using the modelled outputs; these are shown in Table C7.

Table C7 Option Costs and Benefits

	Do Nothing (£k)	Option 1 – Do Existing (£k)	Option 2 – Divert surface water run flows (£k)	Option 3 – Store flows and upsize sewer (£k)
Construction Costs	-	£0	£966	£1,668
Whole Life Costs		£83	£1,155	£1,859
Optimism Bias (60%)		£50	£693	£1,115
Total PV Costs		£133	£1,848	£2,975
Damages	£3,131	£3,026	£2,053	£2,052
Benefits	-	£104	£1,078	£1,079
BCR		0.79	0.58	0.36

Option 3 has the greatest potential to reduce flood risk across the area through further refinement and modelling. The minor increase in calculated benefits from Option 2 is likely to be due to limitation in the method of extracting water levels from the model for a large area (see main report). To estimate the potential benefits of a refined Option 3 (3b) the lowest modelled water levels from Option 2 and 3 were taken to assess the potential benefits and Flood and Coastal Risk Management (FCRM GiA) funding. These are summarised in Table C5, the benefits only increase slightly, however it shows the potential FCRM GiA funding potentially available if flood risk across the whole area was significantly reduced.

Fellgate has deprivation indices[4] of 22997 and 16381 across the area; these class it as being within a 60% least deprived area in England which is included in the calculation of the potential FCRM GiA funding.

Table C8 Refined option 3 economic assessment

	Refined Option 3b (£K)
PV Damages (£k)	£2,042k
PV Benefits (£k)	£1,083k
BCR	0.36
Potential FCRM GiA funding	£113k

Table C8 highlights that the FCRM GiA potentially available is insufficient to fund the large-scale scheme considered within the modelling. Such a scheme is therefore only likely to progress with sufficient additional funding from other sources. This is an initial indication of the level of funding which may be available if flood risk across the area was reduced. Further refinement of the options could potentially reduce residual risk. The value of FCRM GiA would be subject to further detailed investigation of the proposals and would be assessed in relation to other flooding schemes at a national level.

6.5 Recommended Actions

The assessment of the Fellgate area has provided the following conclusions to take forward to the action plan:

- To manage flood risk in the short term, small scale options should be reviewed such as maintenance of the culverts, sewers and field drains and associated trash screens to ensure the capacity of the system can be fully utilised when required. However the benefits of small scale options would be less as the number of properties is significantly less in smaller events.
- To significantly reduce the risk of surface water flooding across Fellgate in the long term, for lower probability events, with greater impacts, a combination of measures is required. The options considered achieve this reduction in flood risk but are not considered to be economically viable at the present time.
- Further assessment of the options to reduce flooding on the eastern side of the estate is recommended. This would balance the size of a new culvert with a small storage area within the playing field.
- The current preferred option to reduce flooding across the estate would cost significantly more than the FCRM GiA that is available. Further consideration of funding, including from alternative sources, should be carried out prior to detailed assessment.
- The diversion channel which reduces the flood risk most significantly could be implemented first when funding is available and other measures could be installed later to address the residual risks.

[4] Office for National Statistics (2010); Indices of Multiple Deprivation (IMD)

- Individual property protection could be considered alongside local measures to reduce surface water runoff within the estate. This may include consideration of correcting misconnections into the foul sewer and managing surface water at a localised level, including the promotion of water butts.

APPENDIX C2
Cleadon Lea Overview

C2 CLEADON LEA

1 DESCRIPTION OF AREA

Cleadon Lea refers to an area located between Boldon Lane and the A1018 Shields Road, within the south eastern area of South Tyneside. The area is predominantly residential with a primary school to the east. The local topography of the area is shown in Figure 2. The lowest area of Cleadon Lea is in the south west of the estate at approximately 21mAOD; the land rises north east towards the A1018 South Shields Road to over 40mAOD. Agricultural land is located to the north, beyond the built up area.

The existing housing estate was built in the 1990's on a reclaimed site of a former pond. The natural topography of the land results in surface water from the fields to the north, draining to the lower lying southern boundary. The Cleadon Lea residential area has a separate storm and foul sewer network. A combined storm sewer flows east to west through the fields north of Cleadon Lea from a farm and several residential buildings, adjacent to South Shields Road. North-west of the Cleadon Lea residential area the main combined sewer flows south down Burdon Road.

Following drainage issues and flooding after construction of the housing estate, a drainage channel and inlet pipe was installed to store and transfer surface water runoff to the sewer system. The housing developer is understood to have paid Northumbrian water a commuted sum tor the initial connection to the drainage network. An upgrade of the inlet pipe size was then approved in 2000. The existing drainage channel is located on the edge of the field to the north of the properties (photograph 4). This takes surface water runoff to a 300mm storm sewer, the inlet is shown in photograph 3. Minor changes have occurred in the past to mitigate the surface water flood risk that has been highlighted by local residents. The locations of the assets to reduce flood risk are shown in Figure C1.

The flooding across Cleadon Lea is predominantly due to the surface water runoff from the agricultural fields to the north flowing to lower lying areas in the estate. The existing assets are believed to be insufficient to deal with significant rainfall events and the sewers become overwhelmed by the surface water runoff entering the network.

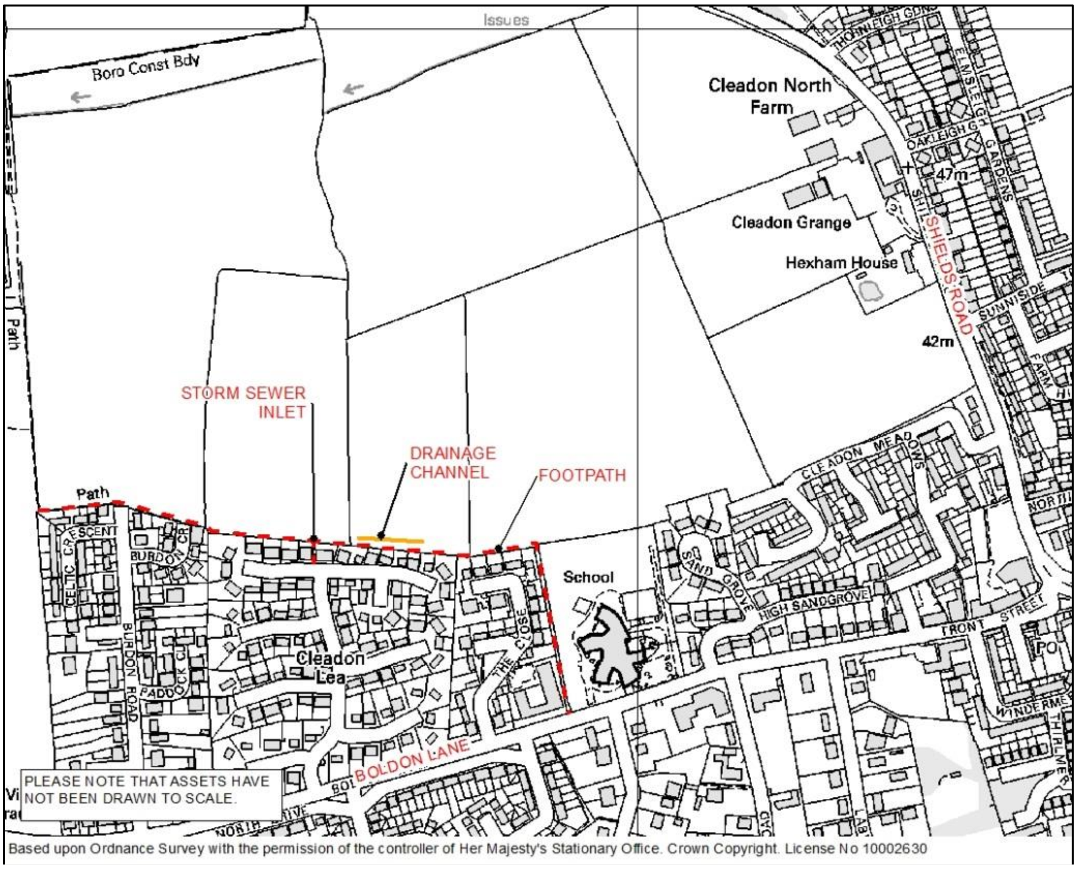

Figure C1 Cleadon Lea Overview

Photograph 1: Fields to north east

Photograph 2:Cleadon Lea estate

Photograph 3: Inlet to NWL storm sewer north of the estate

Photograph 4: Existing defence asset to manage surface water runoff

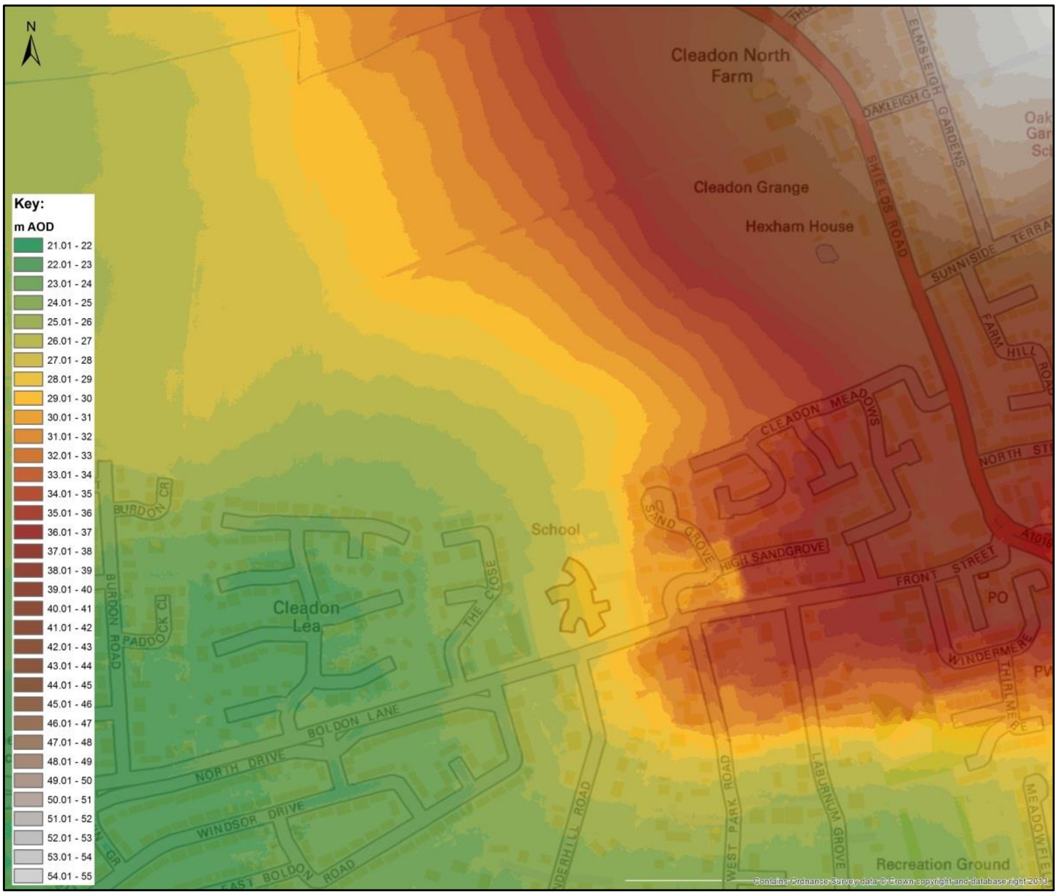

Figure C2 Local topography of the Cleadon area.

2 DEVELOPMENT PLANS AND OPPORTUNIITIES

Review of South Tyneside's Strategic Housing Land Availability Assessment (SHLAA)[1] highlighted areas north of Cleadon Lea that had been considered for development. The SHLAA sites closest to Cleadon Lea are highlighted in Figure C3, the majority of the sites were not assessed as being developable at the time.

If these sites were ever re-considered for development, in the future, it would essential to ensure that any development would not contribute to and increase the surface water runoff which currently impacts Cleadon Lea. The drainage of any future development would be assessed during the development control process.

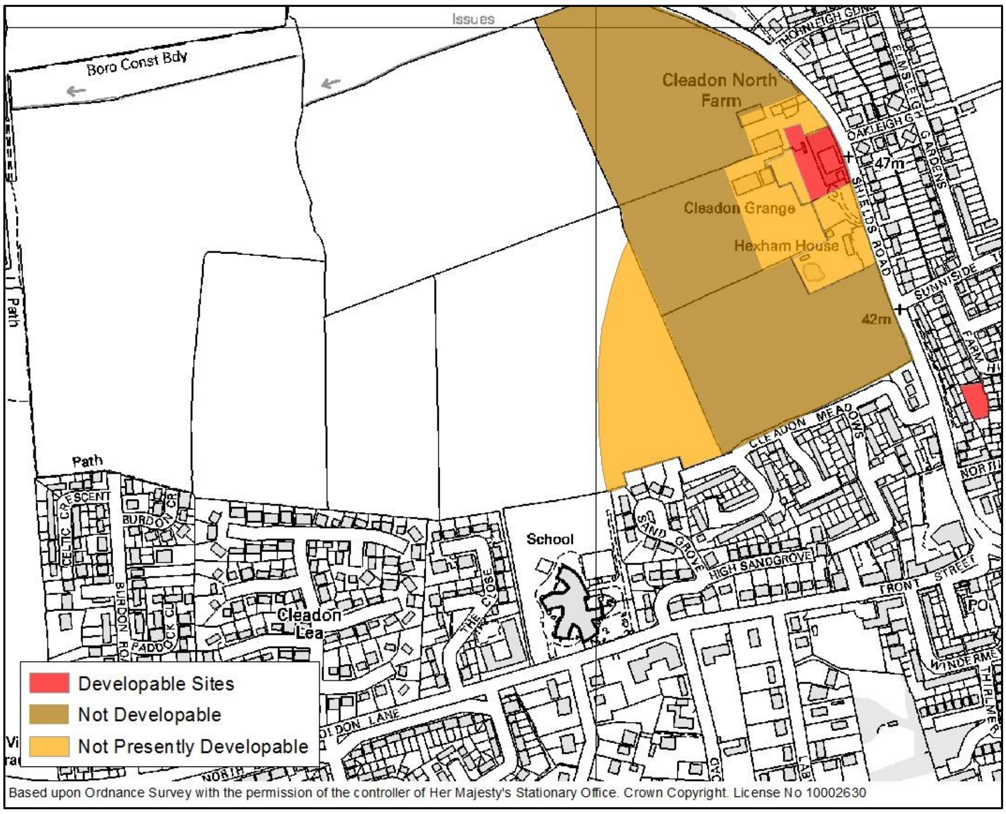

Figure C3 Development Plan Review

3 ENVIRONMENTAL DESIGNATIONS AND OTHER POSSIBLE CONSTRAINTS

A desk-based high level screening of environmental information was carried out to identify any initial issues which could potentially influence the option selection and assessment for this site. The information within the National Receptor Database was screened which includes international and national designated areas and listed buildings. The screened data did not highlight any significant environmental receptors within the Cleadon Lea area. A search of Magic[2] identified a small area of Deciduous Woodland BAP (Biodiversity Action Plan) priority habitat and Lowland Meadows BAP priority habitat north west of the Cleadon Lea estate.

[1] South Tyneside Council (2011)Strategic Housing and Land Availability Assessment
[2] Magic (2013) Defra receptor database; www.magic.defra.gov.uk

Review of British Geology maps[3] identifies the superficial deposits of Cleadon Lea and the area immediately north as clay. The bedrock across Cleadon Lea and to the north is identified as Pennine middle coal measures; mudstone, siltstone and sandstone. East of Cleadon Lea the bedrock is Yellow Sands Formation; sandstone and Roker Formation; Dolostone.

4 DETAILED MODEL RESULTS

Figure C4 shows the predicted surface water flooding extent for a 1% annual exceedance probability (AEP) (1 in 100) event in a Do Nothing scenario. This is a hypothetical scenario which is assessed to allow the benefits of the options considered to be compared against. For Cleadon Lea the Do Nothing scenario assumes the connection to the NWL storm sewer in the field is blocked and there are breaches along the existing bund which currently exists along the back of the estate at the edge of the field. The numbers of properties at risk in the Do Nothing scenario compared to the existing scenario were very similar. The numbers of property at risk in the Do Nothing scenario for a range of rainfall events is shown in Table C1. The effects of climate change on the levels of flood risk are shown in Table C2. The modelling note in Appendix A includes the methodology for the detailed modelling.

Table C1 Properties at risk in Do Nothing

Location	Total properties at risk in each rainfall event			
	3.33% AEP (1 in 30)	1.33% AEP (1 in 75)	1% AEP (1 in 100)	0.5% AEP (1 in 200)
Residential	18	28	28	35
Commercial	0	0	0	0
Total	**18**	**28**	**28**	**35**

*Properties have been counted as being at risk when flood depths adjacent to the property are above the assumed property threshold of 150mm.

Table C2 Total number of properties at risk in Do Nothing with Climate Change Flows

Rainfall event							
3.33% +CC AEP (1 in 30+cc)		1.33% + CC AEP (1 in 75+cc)		1% + CC AEP (1 in 100+cc)		0.5% + CC AEP (1 in 200+cc)	
No. at risk	Increase	No. at risk	Increase	No. at risk	Increase	No. at risk	Increase
34	**+16**	43	**+15**	45	**+17**	50	**+15**

[3] British Geology Survey (2013) Geology Maps; http://www.bgs.ac.uk

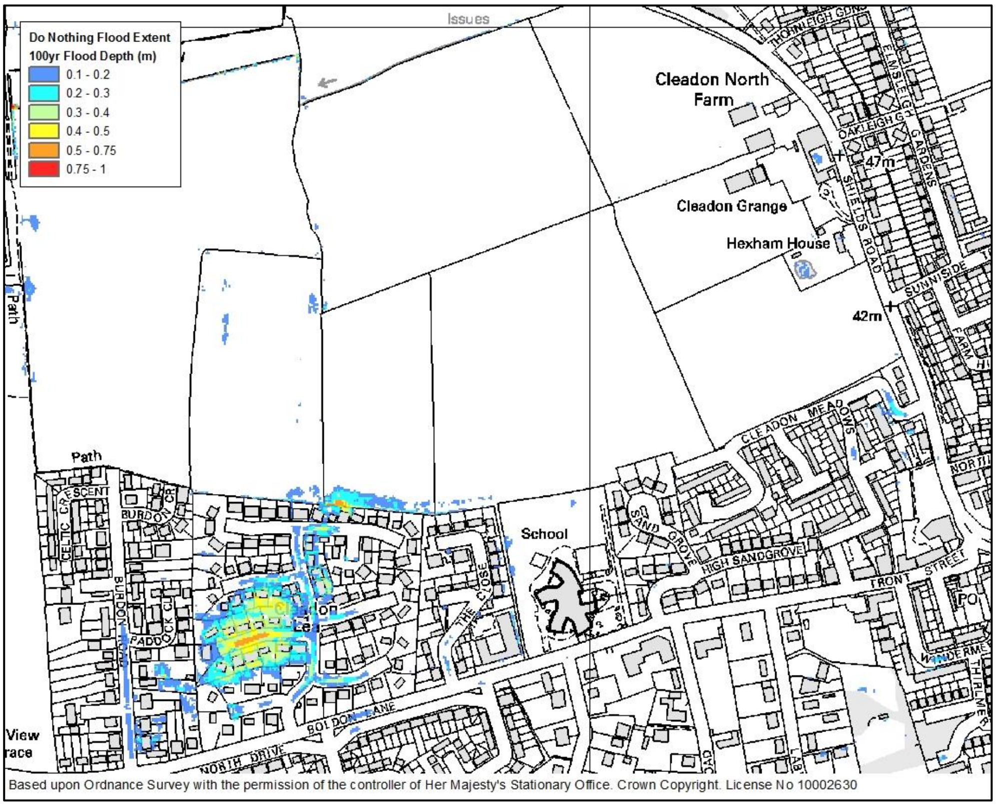

Figure C4 Do Nothing 1% AEP event

5 FLOOD MECHANISM ASSESSMENT

The detailed modelling was analysed, and in addition to site visits and the review of initial data, the following conclusions and detail on flood mechanisms can be drawn:

- Surface water runoff from directly north and north-east collects at the northern boundary of the residential properties on Cleadon Lea and spills into the residential area.
- The flow route is through gardens and properties; photograph 5 shows the back of the estate where it flows from the field. These properties are located to the east of the pedestrian access route to the field which also forms the flow route. (photograph 6).
- The surface water flows in a south westerly direction, reaching greater depths in the south west area of the estate.
- The storm sewer running through the estate is overwhelmed by the surface water runoff from the agricultural fields; contributing to significant flooding.
- With the existing flood risk mitigation structures in place, properties are at risk in a 3.33% AEP (1 in 30) event (the smallest rainfall event modelled).
- Evidence of sand bags from the site visit during April 2013 supported the historic occurrences of flooding to the area.
- Previous initial investigation was carried out into the issues at this location[4]; the modelling within the SWMP provides further evidence and detail on the flood mechanisms.

[4] Royal Haskoning (2011) Cleadon Lea Drainage Study

- The original pipe connection from the field to the storm sewer was understood to be 150mm, recent data suggested this was historically upgraded to a 300mm culvert, however the modelling demonstrated this upgrade has little benefit as the storm sewer is already at capacity during the storm events modelled (the highest annual exceedance probability event modelled was the 3.33% event)

Photograph 5: Back of properties; flow route from field

Photograph 6: Flow route into the residential area

6 SURFACE WATER MANAGEMENT OPTIONS

6.1 Long List of Options

A long list of measures was screened initially to identify potential suitable measures to reduce surface water flooding at Cleadon Lea.
Table C3 shows the screening process of measures considered. The measures which were considered viable were used to create options which could potentially reduce the surface water flooding.

Table C3 Long list of measures

	Mitigation Measure	Initial Screening	Technically Feasible?
Source	Green roofs	Not considered appropriate for existing properties and would not mitigate field runoff into this hot spot	No
	Soakaways	May provide some attenuation of flows, although infiltration into surrounding field already limited, likely to be due to clay ground conditions	Some Potential
	Swales	Could be used along field perimeter, although may be classed as storage due to size required. Could be used along roads for overland conveyance channels	Some Potential
	Permeable Paving	Would require large changes to a lot of smaller property extents and would not deal with surface water runoff from field	No
	Attenuation/Storage	Could use available space in field	Yes
	Rainwater Harvesting	Would not deal with surface water runoff issue from field	No
Pathway	Increase drainage/sewer capacity	Combined sewer to north of Cleadon Lea (running east-west) could be increased and include suitable inlets, whilst the storm network around the property would also need to capture surface water runoff. NWL would need to agree to accept the surface water flows into their system	Some Potential
	Separation of foul and surface water sewers	CSOs to north could be separated, however separate systems already in south areas	Some Potential

	Mitigation Measure	Initial Screening	Technically Feasible?
	Improved maintenance regimes	Assumed all existing networks are in good working order	No
	Managing overland flows	Flows from surface water runoff could be diverted away from residential area, although not to a river (over 1.5km away)	Some Potential
	Land management practices	Changes, such as re-directing field ploughing, could achieve some slowing of flow and increase permeability of land, although difficult to measure.	Yes
Receptor	Improved weather warning	Small, localised catchment therefore unlikely to be effective.Would need to be implemented at a wider scale; either nationally or in combination with other councils in area	No
	Planning policies	Measure to be taken forward at council wide level	No
	Permanent/Temporary defences	Likely to divert water elsewhere	No
	Social Change, education and awareness	Through action impact could be decreased although risk not reduced and difficult for public to take action without warning	No
	Improved resilience and resistance measures	Properties at risk could be fitted with resilience measures	Yes

6.2 Short List of Options

The measures considered viable in
Table C3 were taken forward to create options which could have the potential to reduce surface water flooding. The options were then assessed against specific criteria to consider which to specifically assess in greater detail using the hydraulic model. The criteria used are discussed in Section 4.2 of the main SWMP report. The score assigned to each criteria per option ranged between -2 (Severe negative outcome/Impact) to +2 (High positive outcome). The assessment is shown in Table C4.

Table C4 Short List of options

No.	Option Description	Economic		Technical		Site Specific Objectives		Social Impact		Environmental		Sustainability		Overall
	Weighting		**30**		**20**		**20**		**10**		**10**		**10**	**100**
A	**Do Nothing**	0	0	0	0	-2	-40	-2	-20	-2	-20	-2	-20	-100
B	**Do Existing; operation of existing assets**	0	0	0	0	-2	-40	-2	-20	-1	-10	-1	-10	-80
C	**Store/attenuate flows in field**	-1	-30	2	40	2	40	1	10	1	10	2	20	90
D	**Divert surface water flows to enter the storm sewer elsewhere**	-2	-60	1	20	2	40	1	10	1	10	1	10	30
E	**Implement localised land management practices; field drains, horizontal ploughing practices**	-1	-30	1	20	0	0	1	10	1	10	2	20	30
F	**Increase all storm water capacities**	-2	-60	-1	-20	1	20	0	0	0	0	1	10	-50
G	**Resilience/Resistance measures - Individual Property Protection**	-1	-30	1	20	1	20	-1	-10	0	0	1	10	10

Option E (Localised land management practices) was not considered likely to achieve flood risk reduction for the larger rainfall events and therefore modelling was not progressed. Option F (Increased storm water sewer capacity) was considered one of the most expensive options and was not taken forward to modelling. Individual property protection (Option G) was not taken forward further as options to reduce flood risk through dealing directly with the source of flooding or flood pathways were considered in further detail first.

In summary the following options were taken forward to modelling and assessed in greater detail. The detail of the options is included in Section 6.3.

- Do Nothing (block the culvert from the field drain, remove embankment)
- Option 1 – Do Existing – operation of existing assets
- Option 2 – Store/attenuate flows in field (using existing model)
- Option 3 – Store/attenuate flows in field and remove infiltration from sewer

Once Option 2 had been modelled it became evident there was an opportunity to create a smaller storage area and therefore an additional option from those in Table C3 was considered most appropriate to assess through modelling (Option 3).

6.3 Option Modelling

Option modelling was carried out to consider the benefits provided by storing the surface water runoff at source (Option 2 and 3) and any residual risk.

6.3.1 Option 2 – Store/attenuate flows in northern field (using existing model)

Option 2 was modelled by constructing an embankment along the southern boundary of the field. The storm sewer connection was disconnected to reduce the storm sewer being overwhelmed. An active control mechanism could be fixed to the storm water connection allowing the storage area to discharge into the storm sewers once a rainfall event has passed and there is sufficient capacity to take the surface water. The embankment was oversized in the model to collect all the runoff from the field, this then provided information on the size of embankment required and consider any potential residual flood risk. Storing all the field runoff ensures the storm water sewer is not overwhelmed and no residual flood risk (Figure C5) across the area was shown for the flood events modelled.

Using the existing Northumbrian Water model the model outputs concluded 21,250m^3 of water would need to be stored for a 0.5% AEP (1 in 200) event, with maximum depths of stored water at approximately 1.8m. Changes to the Reservoirs Act are expected in the near future which would reduce the statutory threshold to 10,000m^3 from 25,000 m^3 and bring this storage area option under regulation. However further analysis of the model identified a dummy area within the model which was thought to have been included in the original sewer model to represent infiltration into the combined sewer to the north across the field. It could either have been used to assist with calibration in higher probability events modelled by NWL, which now in the events being assessed in this study potentially leads to an over prediction of flows. Alternatively an issue with the sewer leaking may have been identified when the model was built. These additional flows contribute to the storage area and potentially result in it being modelled larger than would be required in reality.

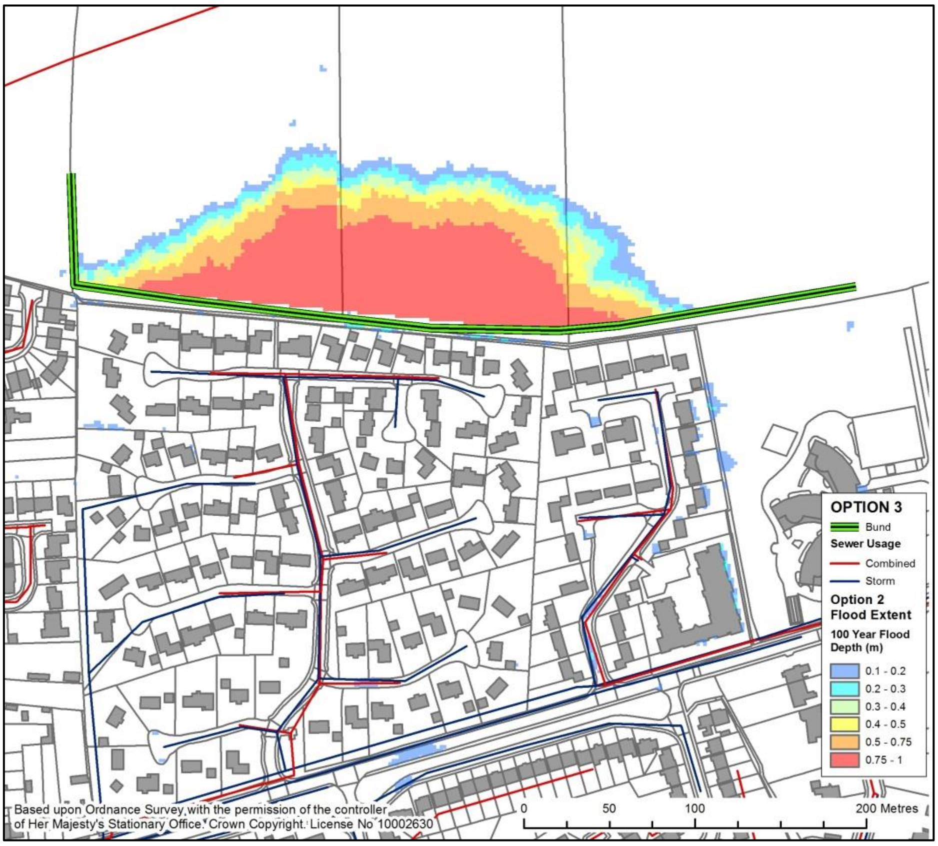

Figure C5 Option 2 and resulting 1% flood extent

6.3.2 Option 3 – Store/attenuate flows in northern field and remove infiltration from sewer

Option 3 consists of storage within the field through the construction of an embankment in the same location as Option 2. The dummy area in Option 2 was removed, reducing the volume of flows contributing to the storm events modelled. To ensure the reduction of infiltrating flows from the sewer, the sewer to the north could be lined along the required section. Option 3 and the residual flood risk is shown in Figure . The storm sewer connection was disconnected to reduce the storm sewer being overwhelmed. An active control mechanism could be fixed to the storm water connection allowing the storage area to discharge into the storm sewers once a rainfall event has passed and there is sufficient capacity to take the surface water.

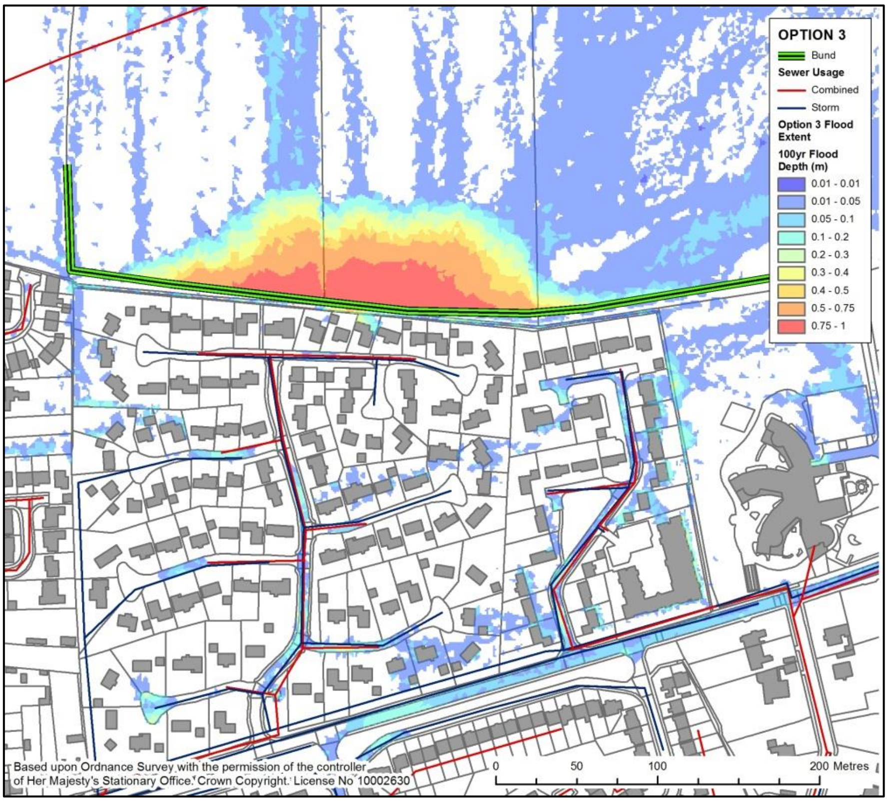

Figure C6 Option 3 and resulting 1% flood extent

The volume of water stored was 7,130m^3 for a 0.5% AEP (1 in 200) event with maximum depths stored water at approximately 1.1m, which is below the threshold to be classed as a reservoir. There is minimal residual risk from surface water in Cleadon Lea when storing all field runoff during a storm event as the storm sewer is no longer overwhelmed by the field runoff. CCTV of the northern sewer would confirm whether the lining of the sewer is required. Alternatively the dummy area may have been included to assist in calibration of the model in smaller events, however when considering low probability storm events this is expected to result in overestimation of flows.

The residual flood risk from the options is included in Table C5, with the reduction in flood risk (compared to the Do Nothing scenario) included in

Table C6.

Table C5 Properties at risk in options

	Option 1 – Do Existing				Option 2 – Store/attenuate flows in field (using existing model)				Option 3 – Store/attenuate flows in field and remove infiltration from sewer			
	3.33%	1.33%	1%	0.5%	3.33%	1.33%	1%	0.5%	3.33%	1.33%	1%	0.5%
Res	18	26	28	35	0	0	0	1	0	0	0	1
Com	0	0	0	0	0	0	0	0	0	0	0	0
Total	18	26	28	35	0	0	0	1	0	0	0	1

Table C6 Reduction in properties for modelled options (compared to Do Nothing)

	Option 1 – Do Existing				Option 2 – Store/attenuate flows in field (using existing model)				Option 3 – Store/attenuate flows in field and remove infiltration from sewer			
	3.33%	1.33%	1%	3.33%	1.33%	1%	3.33%	1.33%	1%	3.33%	1.33%	200
Res	0	2	0	0	18	28	28	34	18	28	28	34
Com	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	2	0	0	18	28	28	34	18	28	28	34

Table C5 and Table C6 show both options reduced the risk across the Cleadon Lea significantly. In the Do Existing option the modelling suggests the existing assets provide very little benefit to reducing the number of properties at flood risk.

6.4 Costs and Benefits

The costs and benefits of the modelled options were assessed using the modelled outputs; these are shown in Table C7. The volumes for an embankment to provide protection for a 0.5% AEP (1 in 200) event were assessed and costed. For a lower (higher probability) standard embankment the residual damages from overtopping in larger events need to be understood to carry out a more detailed benefit assessment.

Table C7 Option Costs and Benefits

	Do Nothing (£k)	Option 1 – Do Existing (£k)	Option 2 – Store/attenuate flows in field (using existing model) (£k)	Option 3 – Store/attenuate flows in field and remove infiltration from sewer (£)
Construction Costs	-	-	£857	£759
Whole life maintenance costs		£140	£949	£834
Optimism Bias (60%)		£84	£569	£501
Total PV Costs		£224	£1,518	£1,335
Damages	£3,221	£3,171	£512	£533
Benefits		£50	£2,709	£2,688
BCR		0.22	1.78	2.01

Cleadon Lea has a deprivation rank of 30,698[5] which places it within the 60% least deprived areas within the UK which is included in the calculation of the potential Flood and Coastal Risk Management (FCRM GiA) funding. With the benefits Option 3 is shown to provide and reduction in properties at risk across the risk bands it is estimated the FCRM GiA funding may be approximately £218k. This would be subject to further detailed investigation of the proposals and would be assessed in relation to other flooding schemes at a national level. This is an initial indication of the level of funding which may be available, additional funding sources will need to be obtained to progress any improvements. The risk bands within the FCRM GiA funding calculator could be used to assist in development of the option and assessing the level of protection to be provided by the flood storage area

[5] Office for National Statistics (2010); Indices of Multiple Deprivation (IMD)

6.5 Recommended Actions

The assessment of the Cleadon Lea area has provided the following conclusions to take forward to the action plan:

- To significantly reduce the risk of surface water flooding within the area a storage area could be created.
- Discussions with NWL and potentially CCTV surveys could be carried out to confirm whether the combined sewer to the north of the estate would need to be lined as part of the works to reduce flood risk.
- As there is no watercourse nearby, a control system at the entrance to the existing storm sewer could be installed. This would allow flows to discharge into the storm sewer at a controlled rate following a rainfall event when there is sufficient capacity in the network.
- The storage area could potentially provide additional environmental and amenity benefits.
- An embankment at lower cost could potentially be constructed; however this would provide a lower standard of protection to flooding from surface water. Further assessment of this option is required to refine and confirm the design standard of the storage area and the associated residual risks in larger rainfall and successive events.

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APPENDIX C3
Sunderland Road Overview

C3 CLEADON SUNDERLAND ROAD

1 DESCRIPTION OF AREA

Cleadon Sunderland Road refers to an area in the south-east of South Tyneside, on the east side of Cleadon. The area being assessed covers the junction between Whitburn Road and Woodland Road, across the fields to the north of Cleadon Lane, to the north east of central Cleadon. Sunderland Road (A1018) runs north to south through the middle of the area. To the east of Cleadon there is a significant area of agricultural land. An overview of the area is shown in Figure C1.

The topography of the area rises from the lower parts in the south-west of the area at approximately 17mAOD towards the higher ground at over 60mAOD in the north-east across the agricultural land. The area is predominantly residential with some commercial buildings. The topography of the area is shown in Figure .

The Cleadon Sunderland Road area is primarily served by a combined sewer network with additional storm sewers along some roads. Flooding in the area is predominantly caused by surface water runoff from the fields to the north east (photograph 1) flowing to the lower lying areas around Whitburn Road in the south east. The surface water runoff from the fields also contributes to the sewer system being overwhelmed.

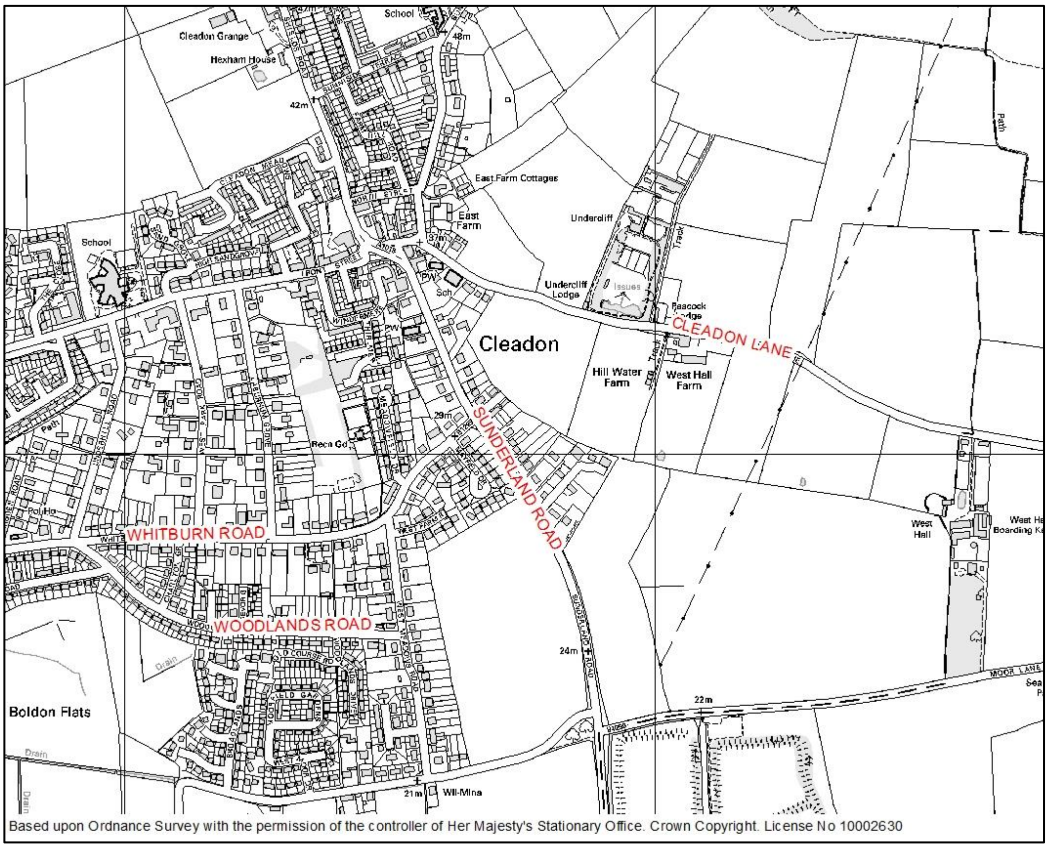

Figure C1 Cleadon Sunderland Road Overview

Photograph 1: Fields north-east of Sunderland Road

Photograph 2: South down Sunderland Road

Photograph 3: West down Whitburn Road

Photograph 4: Field east of Sunderland Road

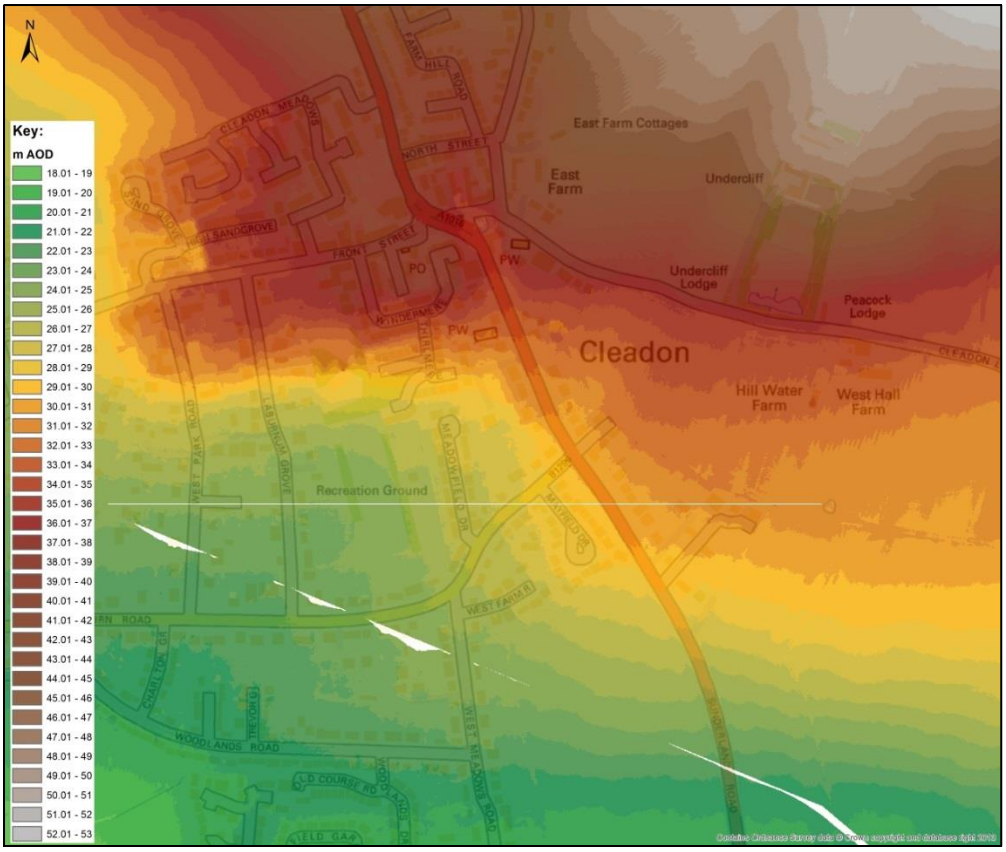

Figure C2 Local topography of Cleadon Sunderland Road

2 DEVELOPMENT PLANS AND OPPORTUNIITIES

Review of the Strategic Housing Land Availability Assessment (SHLAA)[1] highlighted several areas within the Cleadon Sunderland Road study that had been considered for development. The majority of areas had been classed as not developable in the short or medium term. The sites considered in the SHLAA close to Cleadon Sunderland Road are highlighted in Figure .

If these sites were considered for development again in the future it would essential to ensure that any development would not contribute to and increase the surface water runoff which currently impacts the area. The options considered to reduce flood risk could potentially reduce the current risk of flooding to some of the sites. The drainage of any future development would need to be assessed during the development control process.

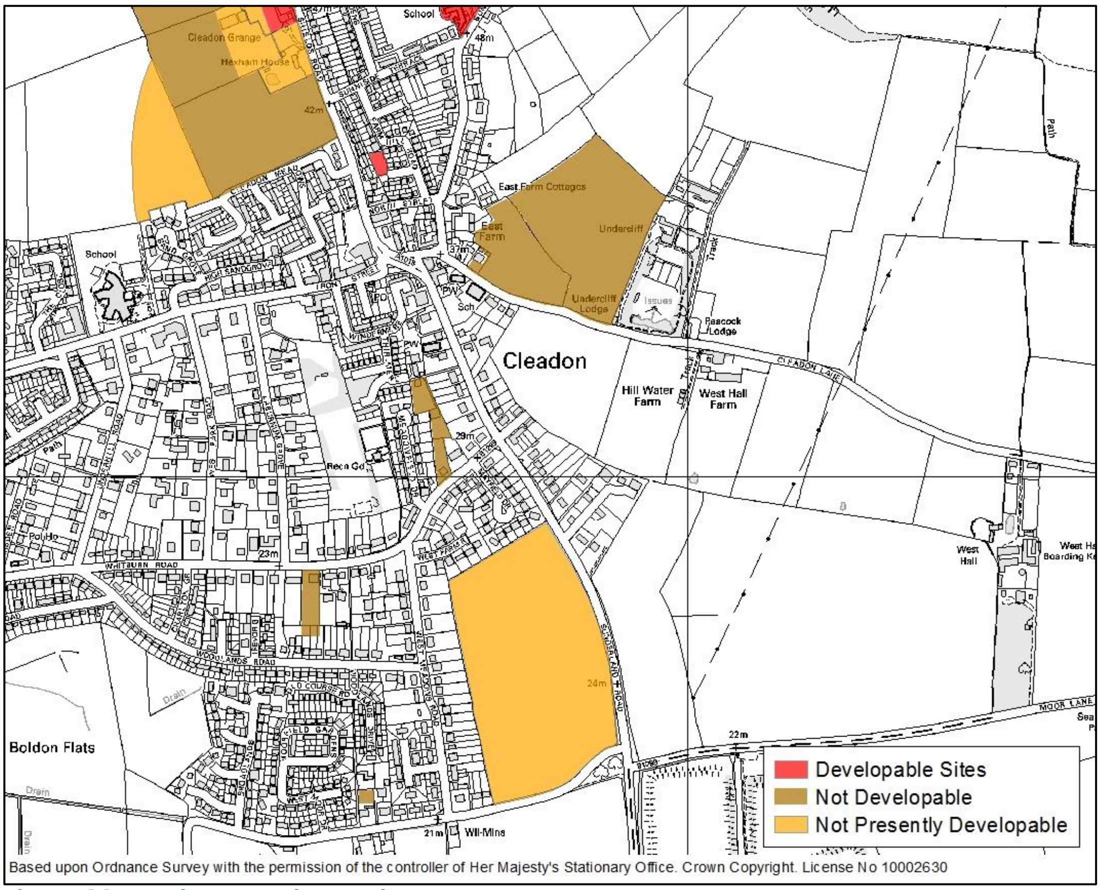

Figure C3 Development Plan Review

[1] South Tyneside Council (2011) Strategic Housing and Land Availability Assessment

3 ENVIRONMENTAL DESIGNATIONS AND OTHER POSSIBLE CONSTRAINTS

A desk-based high level screening of environmental information was carried out to identify initial issues which may influence the options selection and assessment. Information within the National Receptor Database, including international and national designated areas and listed buildings, was screened. The screened data highlighted a Site of Special Scientific Interest (SSSI) located to the south west of Cleadon (Figure C4). A search of Magic[2] identified areas of Deciduous Woodland BAP (Biodiversity Action Plan) priority habitat across the area, and Traditional Orchard BAP to the north east. There are also numerous listed buildings, mainly north of the Whitburn Road/Sunderland Road junction.

Review of British Geology maps[3] identifies the superficial deposits of Cleadon are predominantly clay, with the area north of Cleadon Lane identified as Till; Diamicton. The bedrock to the east of Sunderland Road is identified as Roker Formation; Dolostone, with Raisby Formation; Dolostone and Sandstone to the west.

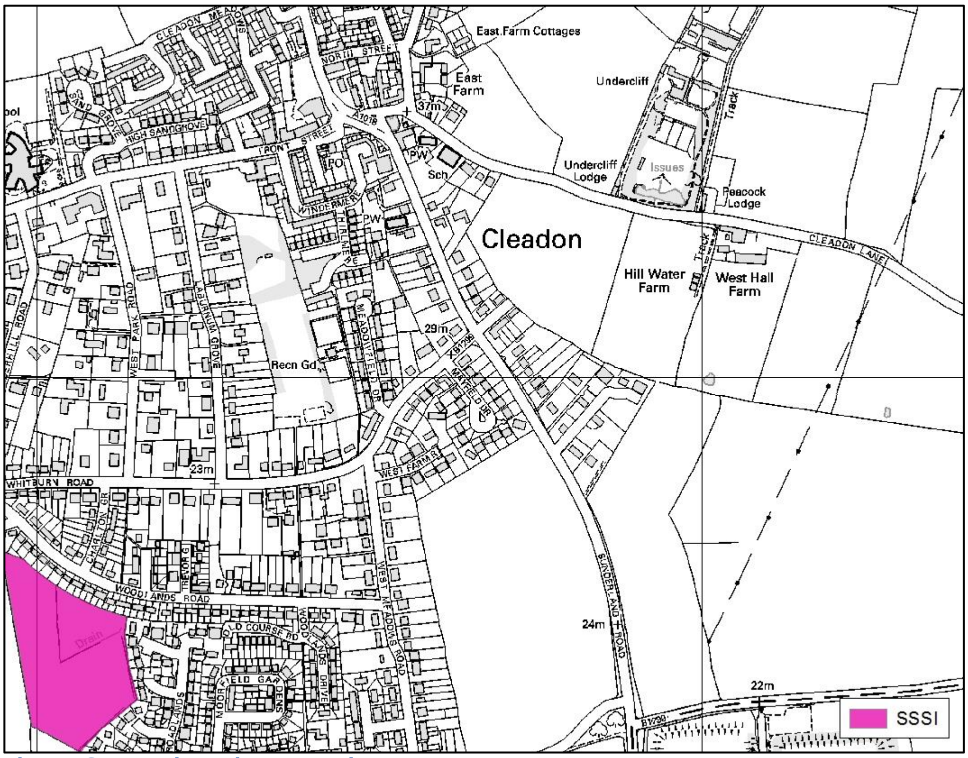

Figure C4 Local Environmental Receptors

4 DETAILED MODEL RESULTS

Figure C5 shows the predicted surface water flooding extent for a 1% annual exceedance probability (AEP) (1 in 100) event in a Do Nothing scenario. This is a hypothetical scenario which is assessed to allow the benefits of the options considered to be compared against.

[2] Magic (2013) Defra receptor database; www.magic.defra.gov.uk
[3] British Geology Survey (2013) Geology Maps; http://www.bgs.ac.uk

For Cleadon Sunderland Road, the Do Nothing scenario assumes no water can enter the surface water drainage system through the road gullies. The number of properties at risk in the Do Nothing scenario compared to the existing scenario was slightly increased in the smaller, higher probability events (below 1% AEP (1 in 100) events). The numbers of property at risk in the Do Nothing scenario for a range of rainfall events is shown in Table C1. The effects of climate change on the levels of flood risk are shown in Table C2. The modelling note in Appendix A includes the methodology for the detailed modelling.

Table C1 Properties at risk in Do Nothing

Location	Total properties at risk in each rainfall event			
	3.33% AEP (1 in 30)	1.33% AEP (1 in 75)	1% AEP (1 in 100)	0.5% AEP (1 in 200)
Residential	16	21	26	33
Commercial	2	2	2	4
Total	18	23	28	37

*Properties have been counted as being at risk when flood depths adjacent to the property are above the assumed property threshold of 150mm.

Table C2 Total number of properties at risk in Do Nothing with Climate Change Flows

Rainfall event							
3.33% +CC AEP (1 in 30+cc)		1.33% + CC AEP (1 in 75+cc)		1% + CC AEP (1 in 100+cc)		0.5% + CC AEP (1 in 200+cc)	
No. at risk	Increase	No. at risk	Increase	No. at risk	Increase	No. at risk	Increase
22	**+4**	35	**+12**	37	**+9**	56	**+19**

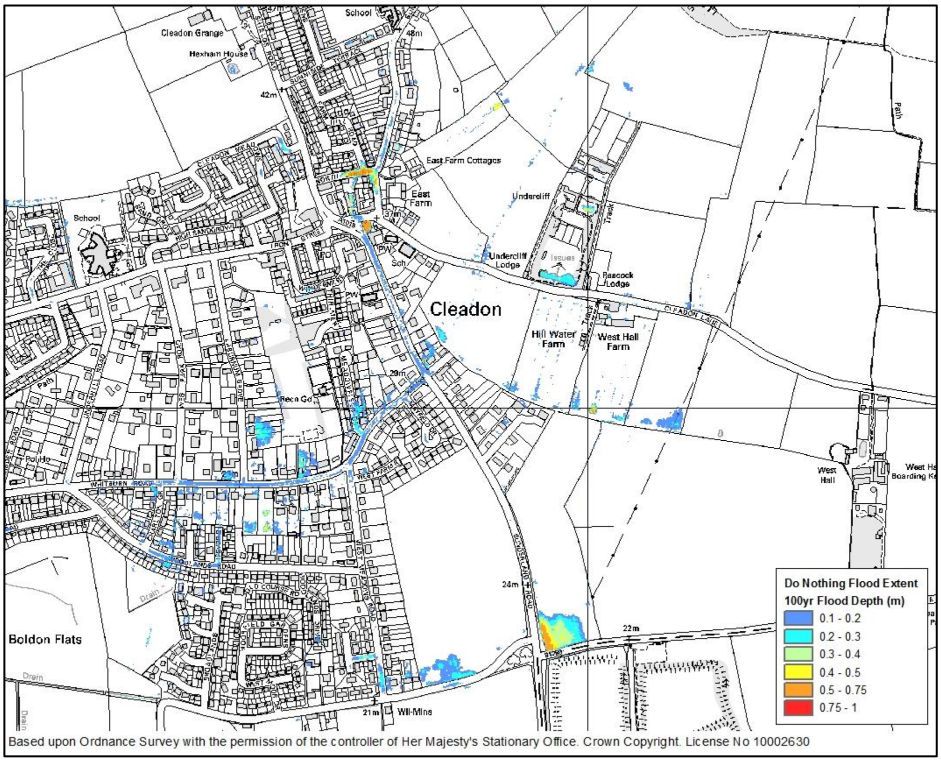

Figure C5 Do Nothing 1% AEP event

5 FLOOD MECHANISM ASSESSMENT

The detailed modelling was analysed, and in addition to site visits and the review of initial data, the following conclusions and detail on flood mechanisms can be drawn:

- Although no records of historic events were provided, the council were aware there had been flooding issues in the past.
- Surface water runoff comes from the north-east across the agricultural fields, crossing Cleadon Lane.
- In the northern area of Cleadon there are additional surface water flow routes impacting areas around Sunniside Lane.
- The surface water flows from the north of the area flow down Sunderland Road and combine with additional surface water runoff from the road; the flows then go west along Whitburn Road and affect low-lying areas in the south-west of Cleadon.
- The combined sewers along Sunderland Road and Whitburn Road are overwhelmed by the surface water runoff and this contributes to the flood risk during the modelled rainfall events (≤3.33% AEP events).
- There are surface water flows which come from the fields to the south east but have little effect on property; however these collect in the corner of the field at the Moor Lane/Sunderland Road junction and can reach significant depths.

6 SURFACE WATER MANAGEMENT OPTIONS

6.1 Long List of Options

A long list of measures was screened initially to identify potential suitable measures to reduce surface water flooding at Cleadon Sunderland Road. Table C3 shows the screening process of measures considered. The measures which were considered viable were used to create options which may reduce the surface water flooding.

Table C3 Long list of measures

	Mitigation Measure	Initial Screening	Technically Feasible?
Source	Green roofs	Not considered appropriate for existing properties	No
	Soakaways	May provide some attenuation to reduce flows into the drainage network, although would need to be used in combination with additional option to mitigate surface water runoff from field	Some Potential
	Swales	Could be used along field perimeter, although may be classed as storage due to size required. Could be used along roads for controlled overland conveyance of flood flows	Some Potential
	Permeable Paving	Would require large changes to a lot of smaller property extents	No
	Attenuation/Storage	Could potentially use available space in field to create storage area	Yes
	Rainwater Harvesting	Could be installed in housing area although would need to be used in combination with option to deal with surface water runoff from field	Some Potential
Pathway	Increase drainage/sewer capacity	Would also need to capture runoff	Yes
	Separation of foul and surface water sewers	Combined and storm sewers exist in some locations, storm sewers could be added in some areas	Some Potential

	Mitigation Measure	Initial Screening	Technically Feasible?
	Improved maintenance regimes	Assumed all existing networks are in good working order	No
	Managing overland flows	Flows from surface water runoff could be diverted away from residential areas, although not to a river. No river nearby (closest over 2.5km)	Yes
	Land management practices	Changes, such as re-directing field ploughing, could achieve some slowing of flow and increase permeability of land, although difficult to measure	Some Potential
Receptor	Improved weather warning	Small, localised catchment therefore unlikely to be effective. Would need to be implemented at a wider scale; either nationally or in combination with other councils in area	No
	Planning policies	Measure to be taken forward at council wide level	No
	Permanent/Temporary defences	Likely to divert water elsewhere	No
	Social Change, education and awareness	Through action impact could be decreased although risk not reduced and difficult for public to take action without warning	No
	Improved resilience and resistance measures	Properties at risk could be fitted with resilience measures	Yes

6.2 Short List of Options

The measures considered viable in Table C3 were taken forward to create options which could have the potential to reduce surface water flooding. The options were then assessed against specific criteria to identify which should be considered in greater detail using the hydraulic model. The assessment criteria used are discussed in Section 4.2 of the main SWMP report. The score assigned to each criteria per option ranged between -2 (Severe negative outcome/Impact) to +2 (High positive outcome). The assessment is shown in Table C5.

Table C4 Short List of options

No.	Option Description	Economic		Technical		Site Specific Objectives		Social Impact		Environmental		Sustainability		Overall
	Weighting		**30**		**20**		**20**		**10**		**10**		**10**	**100**
A	**Do Nothing**	0	0	0	0	-2	-40	-2	-20	-2	-20	-2	-20	-100
B	**Do Existing; operation of existing assets (road gullies)**	0	0	0	0	-2	-40	-2	-20	-1	-10	-1	-10	-80
C	**Store/attenuate majority of surface water**	-1	-30	1	20	1	20	1	10	1	10	2	20	50
D	**Store/attenuate main surface water runoff source and divert to storm sewer**	-2	-60	1	20	1	20	1	10	1	10	1	10	10
E	**Increase all storm water and sewer capacities**	-2	-60	-1	-20	2	40	0	0	0	0	1	10	-30

No.	Option Description	Economic		Technical		Site Specific Objectives		Social Impact		Environmental		Sustainability		Overall
	Weighting		**30**		**20**		**20**		**10**		**10**		**10**	**100**
F	**Resilience/Resistance measures - Individual Property Protection**	-1	-30	1	20	1	20	-1	-	0	0	1	10	10

Significant lengths of sewer would need to be upgraded to increase capacities; therefore Option E was considered expensive and was not taken forward to modelling. Individual property protection (Option F); was not taken forward further as options to reduce flood risk through dealing directly with the source of flooding or flood pathways were considered in further detail first.

In summary the following options were taken forward to modelling and assessed in greater detail. The detail of the options is included in Section 6.3.

- Do Nothing (blockage of existing gullies)
- Option 1 - Do Existing – gullies operational
- Option 2 – Store water from surface water flow routes (4 storage areas)
- Option 3 – Store water from main surface water flow route

6.3 Option Modelling

Option modelling was carried out to consider the benefits and residual risk of the options.

6.3.1 Option 2 - Store water from surface water flow routes (4 storage areas)

This option included four separate embankments to create storage areas in order capture the main surface water flows from the fields which were considered to contribute to flooding. The embankments were oversized in the model to collect maximum volumes of runoff from the field and provide information on the sizes of storage required and consider any potential residual risk.

The option 2 components and residual risk is shown in Figure C1 Option 2 components and residual risk
The four areas required embankments between the heights of 1.2m to 2.6m and lengths between 135m to 275m for a 0.5% AEP (1 in 200) event. The area where the storage was modelled was identified from geological data as being underlain by clay. Therefore it is unlikely the water would rapidly infiltrate after a rainfall event; it will therefore have to be disposed of via alternative measures. This could potentially require diversion into the highway drain once the peak flows have passed and there is capacity in the sewer network. The flows in the highway drain ultimately drain to Howden sewage treatment works where there are potential capacity issues, this would need further consideration before progressing this option further.

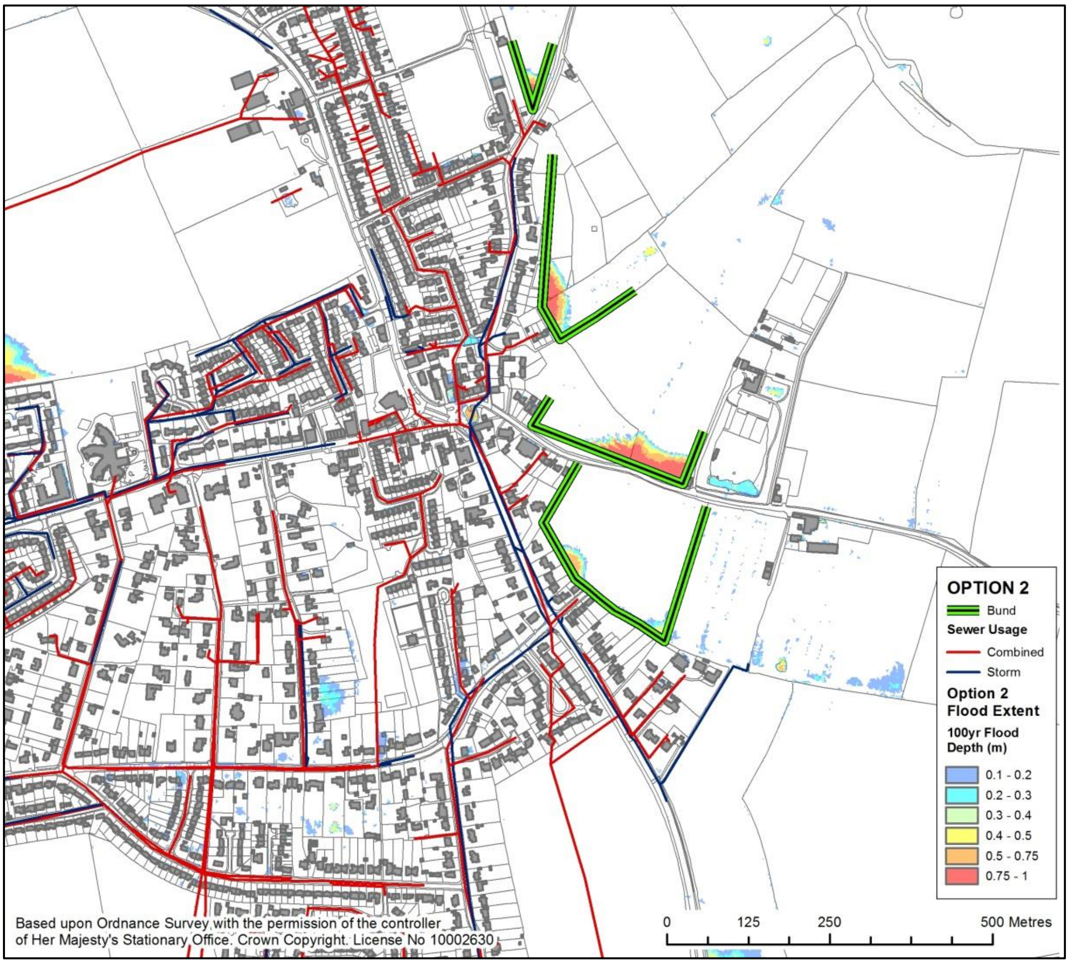

Figure C1 Option 2 components and residual risk

The model output demonstrates the residual flood risks from local surface water. The option reduces the flood extents and depths, but does not remove all flood risk in the area. The flood depths on Sunderland Road and Whitburn Road are reduced in addition to a reduction in the flood extents south of Whitburn Road. The reduction in number of properties at risk of flooding is shown in Table C6, below.

6.3.2 Option 3 - Store water from main surface water flow route

Option 3 assessed the potential for reducing flood risk by dealing only with the largest source of surface water runoff. A storage area was created in the field east of Whitburn Road East cul-de-sac. The runoff from the fields at this location was stored through the construction of an oversized embankment in the model to collect the maximum volume of runoff, this then provided information on the size of emabnkment required to create the storage. The option included discharge of the stored water into a highway drain further south of Cleadon. This was modelled through the construction of a new length of connecting sewer to the south eastern corner of the storage area. A channel along the edge of the storage embankment was created to convey flows to the 225mm pipe inlet. A historic watercourse runs on the southern boundary of No.23 Sunderland Road and into a public sewer, this connection point can be considered with the development of the option if taken forward. The size of pipe limited the flows to reduce the effects on the existing sewer network where there are understood to be existing capacity issues at the sewage treatment works in which the sewers utilmately flow to. Dsicussions with NWL would be required prior to progressing this option. The option 3 components and residual risk is shown in Figure .

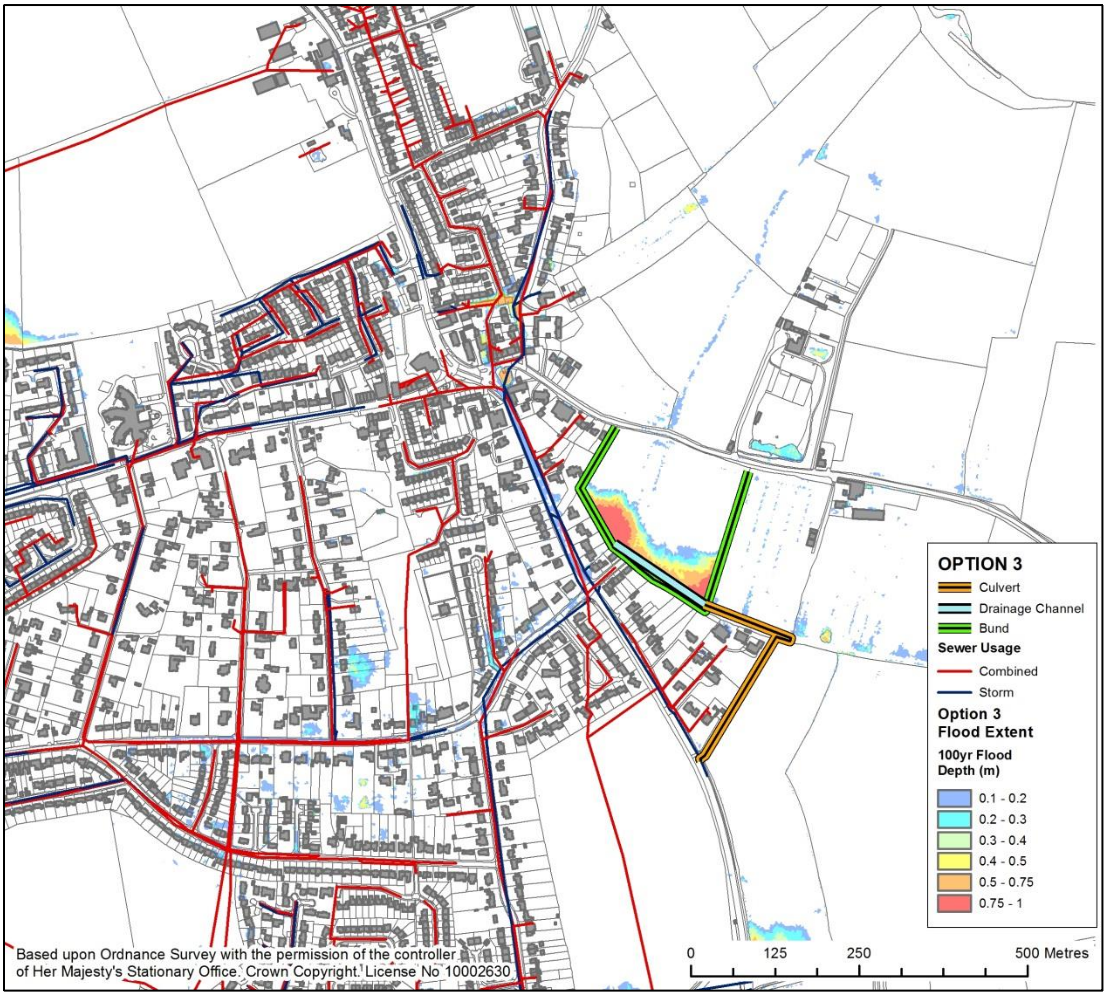

Figure C7 Option 3 components and residual risk

The option reduces the flood depths along either side of Whitburn Road, although not as greatly as Option 2. Flooding to the north of Cleadon remains and contributes flows to Sunderland Road.

A sensitivity run was carried out on Option 3, which included additional gullies (3 gullies modelled for every existing 1). However this had little effect on reducing flood risk further in the area.

The residual flood risk from the options is included in Table C5, with the reduction in flood risk (compared to the Do Nothing scenario) included in Table C6.

Table C5 Properties at risk in options

	Option 1 – Do Existing				Option 2 – Store water from surface water flow routes (4 storage areas)				Option 3 – Store water from main surface water flow route			
	3.33%	1.33%	1%	0.5%	3.33%	1.33%	1%	0.5%	3.33%	1.33%	1%	0.5%
Res	13	18	24	34	3	7	7	11	9	11	14	22
Com	2	2	2	2	0	1	1	2	2	2	2	1
Total	15	20	26	36	3	8	8	13	11	13	16	23

Table C6 Reduction in properties for modelled options (compared to Do Nothing)

	Option 1 – Do Existing				Option 2 – Store water from surface water flow routes (4 storage areas)				Option 3 – Store water from main surface water flow route			
	3.33%	1.33%	1%	3.33%	1.33%	1%	3.33%	1.33%	1%	3.33%	1.33%	1%
Res	3	3	2	-1	13	14	19	22	7	10	12	11
Com	0	0	0	2	2	1	1	2	0	0	0	3
Total	3	3	2	1	15	15	20	24	7	10	12	14

Table C5 and Table C6 show both options reduced the risk across the Cleadon Sunderland Road area, with Option 2 having the greatest reduction. In the Do Existing option the modelling suggests the existing road gullies provide some reduction in flooding, although to very few properties. The modelling results indicate there is one more property at risk in the Existing scenario compared to the Do Nothing, however this could be due to the limitations in the method of extracting flood depths at individual property points as discussed in Section 3.7 of the main report.

6.4 Costs and Benefits

The costs and benefits of the options were assessed using the model outputs; these are shown in Table C7 . Cost estimates for options were based on embankment works to store flows from a 0.5% AEP (1 in 200) event. For a lower (higher probability) standard embankment there would be residual damages from overtopping in larger events. Further modelling would have to be carried out to understand these residual damages for a detailed benefit assessment to be carried out. As a result the costs for a 0.5% AEP embankment have been costed as the benefits from this standard can be more accurately estimated.

Table C7 Option Costs and Benefits

	Do Nothing (£k)	Option 1 – Do Existing (£k)	Option 2 – Store water from all surface water sources (£k)	Option 3 – Store main surface water flows (£k)
Construction Costs	-	£0	£1,233	£706
Whole life maintenance costs	-	£36	£1,424	£814
Optimism Bias (60%)		£21	£854	£488
Total PV Costs		**£57**	**£2,278**	**£1,303**
Damages	£3,374	£3,207	£2,066	£2,872
Benefits		£168	£1,308	£502
BCR	-	**2.93**	**0.57**	**0.39**

The Cleadon Sunderland Road area has deprivation rankings of 30,245[4] and 30,231, which classifies the area as being within the 60% least deprived areas of England, a factor which is included in the calculation of potential Flood and Coastal Risk Management (FCRM GiA) funding. With the benefits provided by Option 2; reducing all surface water runoff from the fields, it is estimated the maximum FCRM GiA funding potentially available may be approximately £112k. This would be subject to further detailed investigation of the proposals and would be assessed in relation to other flooding schemes at a national level. As shown this is significantly less than the estimated costs of the options assessed and further consideration is therefore required in order to identify additional sources of funding. A cost beneficial scheme also needs to be sought prior to funding applications for FCRM GiA being made. If an option was considered which did not reduce the flood risk as greatly as option 2, the potential FCRM GiA funding would decrease. The risk bands within the FCRM GiA funding calculator could be used to assist in development of the options further.

6.5 Recommended Actions

The assessment of the Cleadon Sunderland Road has provided the following conclusions to take forward to the action plan:

- Flood risk from surface water runoff can be reduced by providing storage areas in the fields to the north east of Cleadon.
- To reduce residual flood risk across the area more significant works, potentially including upgrade of the sewer capacity, would be required.
- Embankments at lower cost could potentially be constructed; however this would provide a lower standard of protection to flooding from surface water. Further assessment of this option is required to refine and confirm the design standard of storage areas constructed and the associated residual risks in larger rainfall and successive events.
- The preferred option of reducing flooding across the estate would cost significantly more than flood defence grant available, further consideration of funding should be carried out prior to detailed assessment.
- There are several surface water flow routes into the Cleadon Sunderland Road area, requiring multiple storage areas to fully address ths flood risk. The amount of funding available may therefore dictate the level of storage which could be implemented.
- The storage areas could potentially provide additional environmental and amenity benefits.
- Further assessment of this area and engagement with NWL is required, to discuss residual risk from insufficient sewer capacities, connection of potential storage areas into the sewers and the capacity issues at the sewage treatment work. This will allow options to be refined and the most appropriate option for this area to be confirmed.

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[4] Office for National Statistics (2010); Indices of Multiple Deprivation (IMD)

APPENDIX C4
Lindisfarne Roundabout

C4 LINDISFARNE

1 DESCRIPTION OF AREA

The Lindisfarne study area refers to a zone around the A19/A194 junction (Lindisfarne Roundabout); and the roundabout of the A194/A1300 John Reid Road as shown in Figure C1 Lindisfarne Overview. The A194 Leam Lane runs east to west through the area, with the A19 running north to south and passing over the A194 at Lindisfarne Roundabout. A primary school is located south-east of Lindisfarne Roundabout, whilst residential properties are located across the area. To the north west of the roundabout is King Georges Park. The majority of properties are on either side of Leam Lane, to the east of the A19, located above the level of the road.

The sewers in the area are predominantly combined sewers serving the properties; whilst there are additional storm sewers down either side of Leam Lane and north up the A19 providing highway drainage.

The roundabouts are located within areas of lower lying land (approximately 13mAOD at Lindisfarne roundabout) which then rises towards the south east to the Brockley Whins area at approximately 30mAOD. The local topography of the area is shown in Figure C2. Surface water runoff flows into the low lying areas, particularly at Lindisfarne Roundabout, causing flooding which affects the strategic transport route across South Tyneside. This has been experienced historically, and most recently during significant rainfall events in 2012.

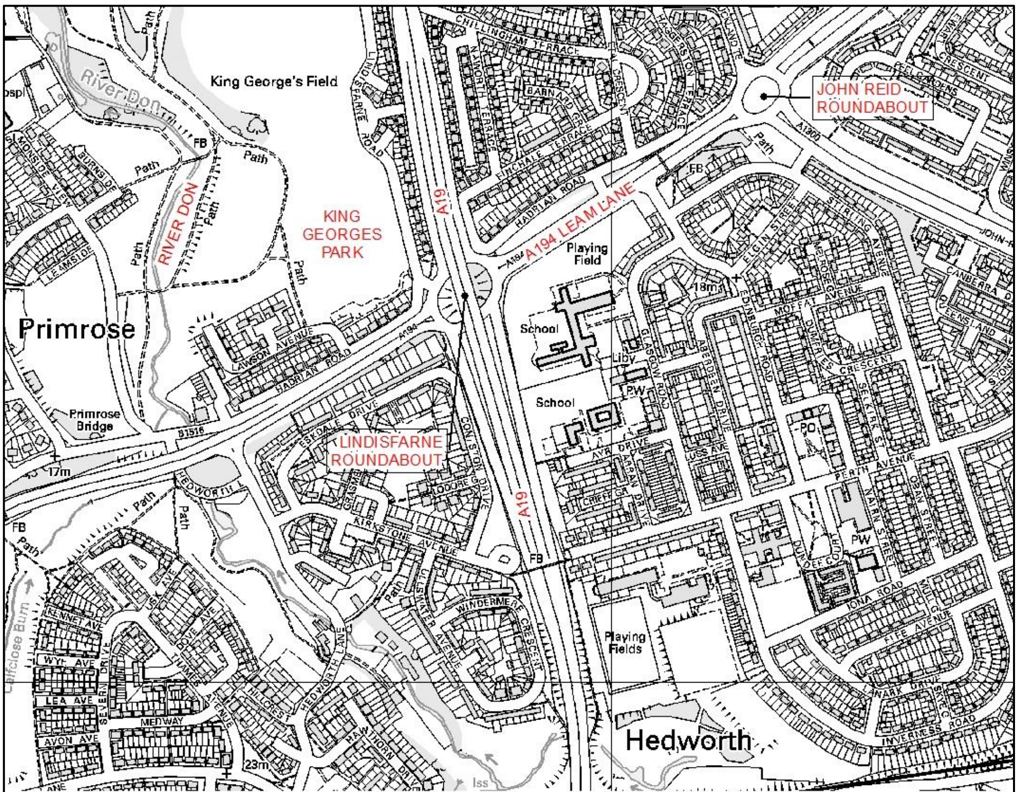


Figure C1 Lindisfarne Overview

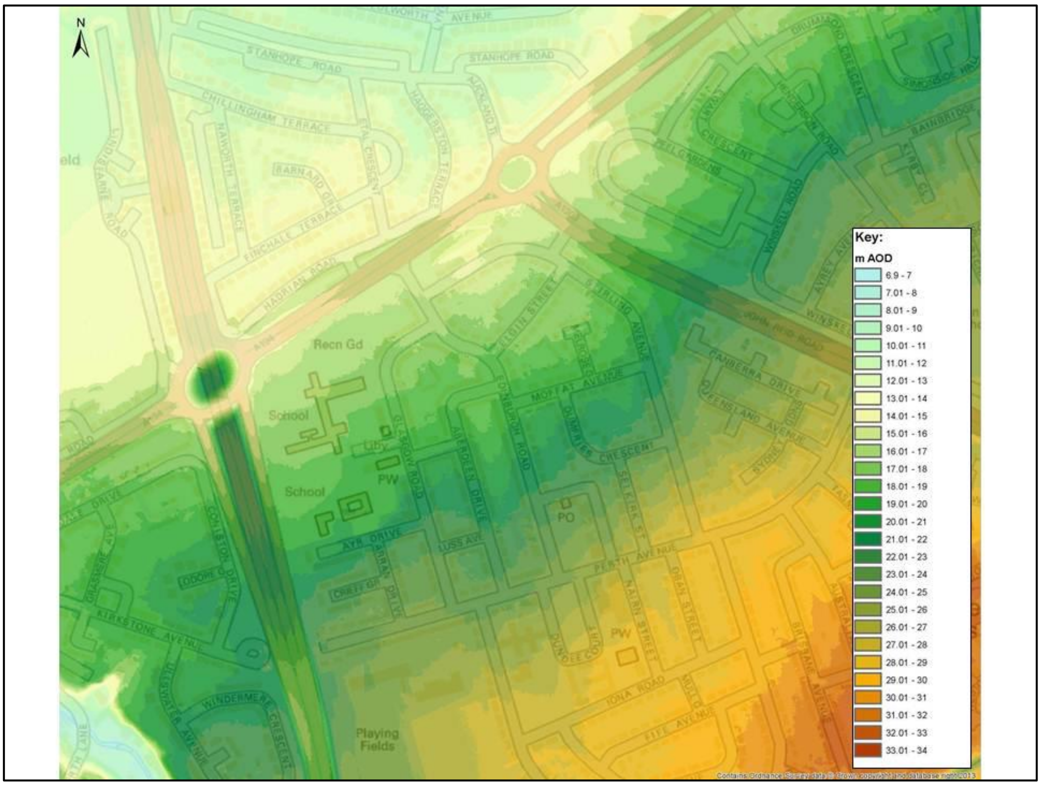


Figure C2 Local topography of the Lindisfarne area.

The Lidar shown in Figure C2 shows the A19 north of the A194 is not recognised correctly; the northern section of the A19 is not within the DTM. When carrying out detailed modelling of the area, adjustments to the model were made accordingly to ensure the A19 was represented correctly.

2 DEVELOPMENT PLANS AND OPPORTUNIITIES

Review of the Strategic Housing Land Availability Assessment (SHLAA)[1] highlighted several areas within the Lindisfarne area as being potentially developable. The potentially developable sites are highlighted in red in Figure C3; the potentially developable sites cover approximately 3.5ha in total.

The impact that the potentially developable areas have on the existing sewer system, which is already at capacity, needs to be considered carefully by the developer to ensure there is no increase in flood risk compared to the existing situation. The drainage of any future development would be assessed during the development control process.

[1] South Tyneside Council (2011)Strategic Housing and Land Availability Assessment

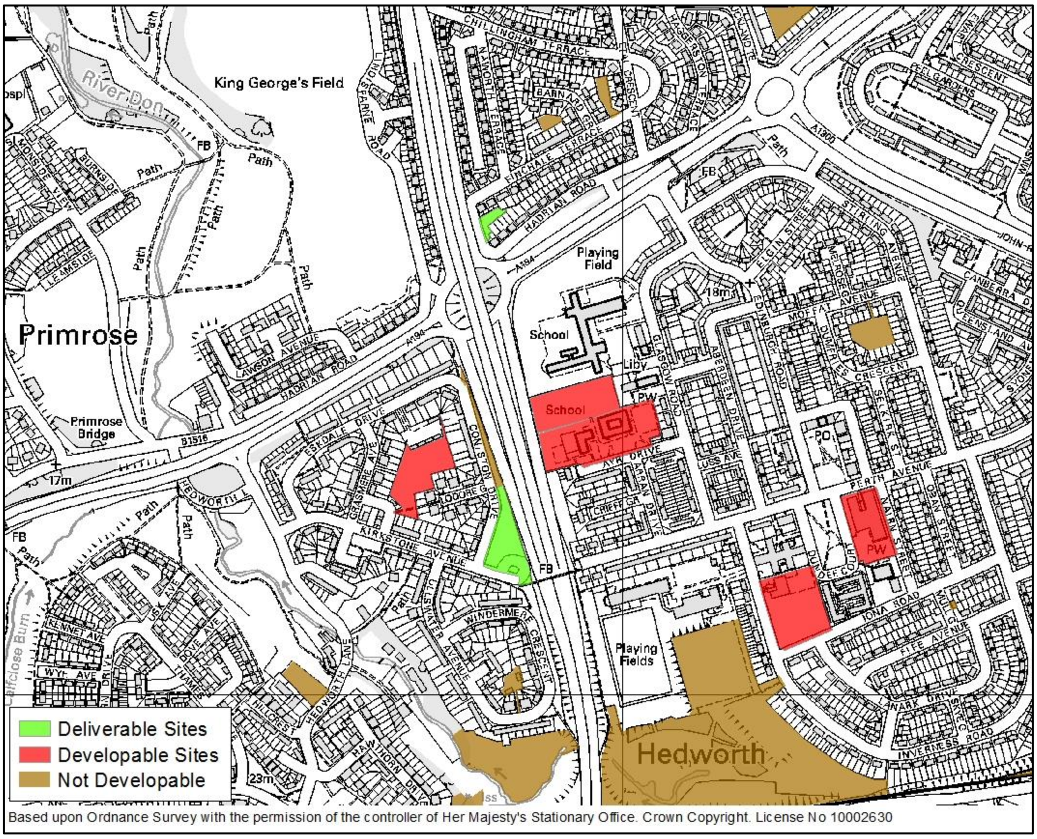


Figure C3 Development Plan Review

3 ENVIRONMENTAL DESIGNATIONS AND OTHER POSSIBLE CONSTRAINTS

A desk-based high level screening of environmental information was carried out to identify any initial issues which could potentially influence the optioneering. Information within the National Receptor Database, including international and national designated areas and listed buildings, was screened. The screened data highlighted Local Nature Reserves in the area; the closest located to the north east within King Georges Park. The location is shown in Figure C4. A search of Magic[2] identified a small area of Deciduous Woodland BAP (Biodiversity Action Plan) priority habitat within King Georges Park.

Review of British Geology maps[3] identifies the superficial deposits of the Lindisfarne area are predominantly clay, except the area at Lindisfarne roundabout which is highlighted as being a combination of Clay and Silt and Diamicton. The bedrock is a mixture of Pennine Middle Coal Measures Formation; sandstone and mudstone, siltstone, sandstone classifications.

[2] Magic (2013) Defra receptor database; www.magic.defra.gov.uk
[3] British Geology Survey (2013) Geology Maps; http://www.bgs.ac.uk

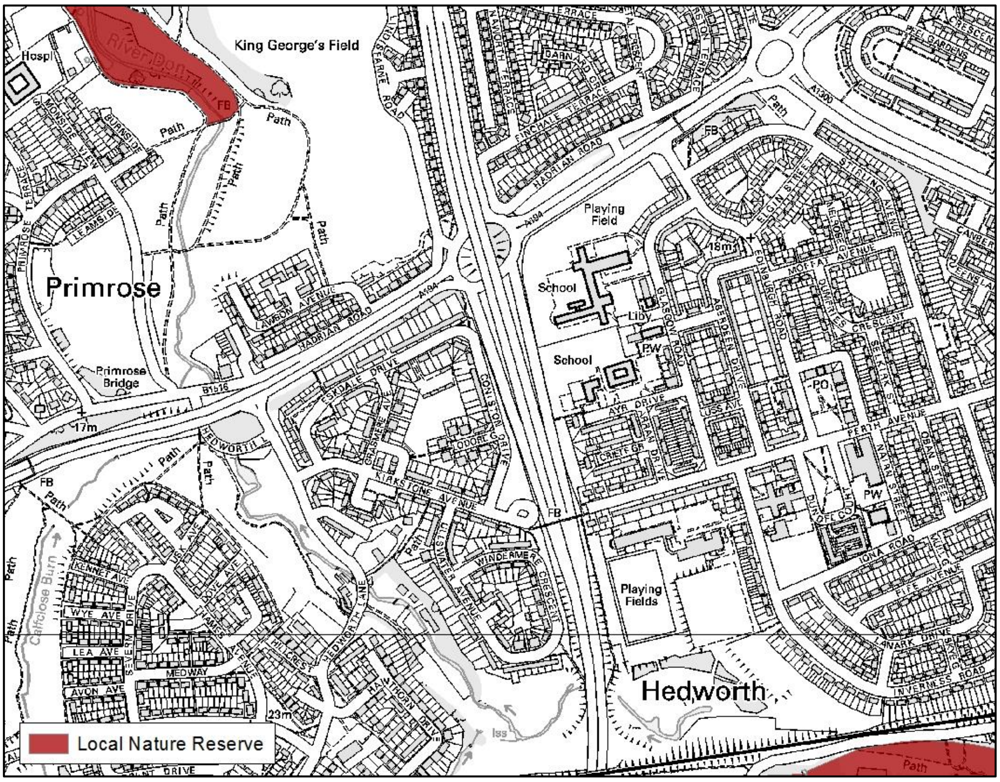


Figure C4 Local Environmental Receptors

4 DETAILED MODEL RESULTS

Figure C5 shows the predicted surface water flooding extent for a 1% annual exceedance probability (AEP) (1 in 100) event in a Do Nothing scenario. This is a hypothetical scenario which is assessed to allow the benefits of the options considered to be compared against.

For the Lindisfarne area the Do Nothing scenario assumed no water can enter the surface water drainage system through the road gullies. The numbers of property at risk in the Do Nothing scenario for a range of rainfall events is shown in Table C1. The effects of climate change on the levels of flood risk are shown in Table C2. The modelling note in Appendix A includes the methodology for the detailed modelling.

The area was particularly chosen as it is a strategic transport route across South Tyneside and therefore the road flooding is of concern. During a 3.33% AEP rainfall event (1 in 30) approximately 240m of the A194 roundabout and adjoining slip roads are affected by depths of water greater than 0.1m, with maximum depths up to 0.5m. The duration of flooding is 2 hours 20 minutes, with depths over 0.3m for approximately 1 hour 50 minutes. In a 1% AEP event, approximately 315m of road is estimated to be affected by flooding greater than 0.1m, with depths up to 0.7m. The duration of flooding is nearly 3 hours, with depths over 0.3m for approximately 2 hours.

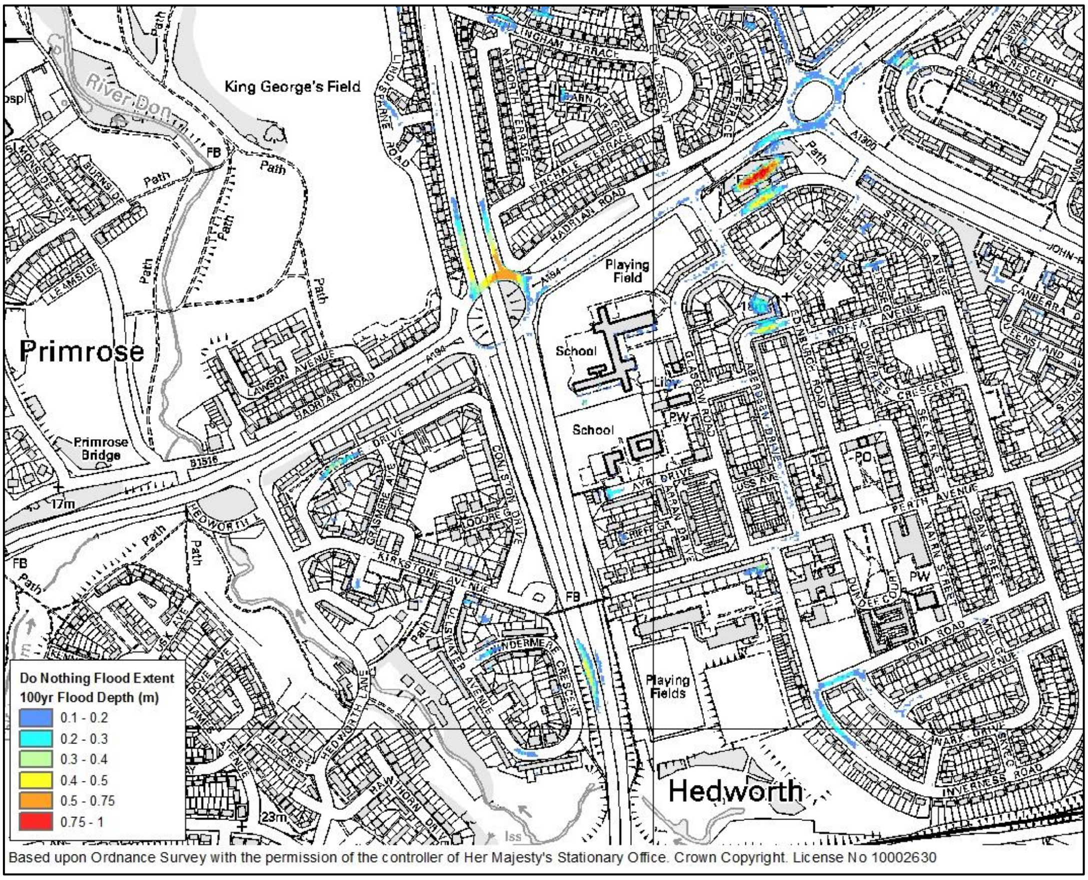


Figure C5 Do Nothing 1% AEP

Table C1 Properties at risk in Do Nothing

Location	**Total properties at risk in each rainfall event**			
	3.33% AEP (1 in 30)	**1.33% AEP (1 in 75)**	**1% AEP (1 in 100)**	**0.5% AEP (1 in 200)**
Residential	14	17	18	34
Commercial	0	0	0	0
Total	14	17	18	34

*Properties have been counted as being at risk when flood depths adjacent to the property are above the assumed property threshold of 150mm.

Table C2 Total number of properties at risk in Do Nothing with Climate Change Flows

Rainfall event							
3.33% +CC AEP (1 in 30+cc)		**1.33% + CC AEP (1 in 75+cc)**		**1% + CC AEP (1 in 100+cc)**		**0.5% + CC AEP (1 in 200+cc)**	
No. at risk	Increase	No. at risk	Increase	No. at risk	Increase	No. at risk	Increase
18	**+4**	32	**+15**	36	**+18**	39	**+5**

5 FLOOD MECHANISM ASSESSMENT

The detailed modelling was analysed, and in addition to site visits and the review of initial data, the following conclusions and detail on flood mechanisms can be drawn:

- The main areas of flood risk are around the Lindisfarne Roundabout and to properties south of Leam Lane, with some additional flooding of the roundabout further east at John Reid Road.
- Flooding is caused by a combination of surface water not being able to enter the sewers and the surcharge of several combined and storm water/highway drains which occurred in the smallest flood event modelled: a 3.33% AEP event..
- The discharge of the combined sewers and highway drains occurs at the main flooding locations; Lindisfarne roundabout and properties south of Leam Lane.
- Leam Lane conveys the flows from the sewers to the low lying areas at the roundabouts.
- Flooding incidents at the Lindisfarne Roundabout were recorded in 2013 with further historical records prior to this.

6 SURFACE WATER MANAGEMENT OPTIONS

6.1 Long List of Options

A long list of measures was screened initially to identify potential suitable measures to reduce surface water flooding at Lindisfarne area. Table C3 shows the screening process of measures considered.

Table C3 Long list of measures

	Mitigation Measure	Initial Screening	Technically Feasible?
Source	Green roofs	Not considered appropriate for existing properties	No
	Soakaways	May provide some attenuation to reduce flows into the drainage network, although unlikely to be sufficient as a sole measure or be sufficient for larger events	Some Potential
	Swales	Potentially along road sides and within roundabout	Yes
	Permeable Paving	Would require large changes to a lot of smaller property extents to reduce water entering drainage network so not considered feasible	No
	Attenuation/Storage	Could use roundabout, road verges or parkland to north west if used in combination with managing/diverting flows	Yes
	Rainwater Harvesting	Majority of flooding at Lindisfarne roundabout coming from storm water network draining road so little benefit	No
Pathway	Increase drainage/sewer capacity	Increasing capacity of both the combined sewer and highway drainage could reduce flooding	Yes
	Separation of foul and surface water sewers	Foul could be separated at housing area, although highway flooding would still be an issue.	No
	Improved maintenance regimes	Assumed all existing networks are in good working order	No
	Managing overland flows	Flows from surface water runoff could be diverted away from roundabout, river fairly close (approx 400m in parkland to north-west), although ground levels may need to be altered in the park and consideration made to capturing the flows before flooding occurs at the roundabout	Yes

	Mitigation Measure	Initial Screening	Technically Feasible?
	Land management practices	Mostly urban surroundings, little green space to implement and have significant reduction of surface water flows	No
Receptor	Improved Weather warning	Would need to be implemented at a wider scale; either nationally or in combination with other councils in area	No
	Planning policies	Measure to be taken forward at council wide level	No
	Permanent/Temporary defences	Not possible whilst keeping road operational	No
	Social Change, education and awareness	During rainfall events the road could be operated differently - keeping road users out of the area expected to flood	Some Potential
	Improved resilience and resistance measures	Road infrastructure mainly at risk	No

6.2 Short List of Options

The measures considered viable in Table C3 were taken forward to create options which could have the potential to reduce surface water flooding. The options were then assessed against specific criteria to consider which to specifically assess in greater detail using the hydraulic model. The criteria used are discussed in Section 4.2 of the main SWMP report. The score assigned to each criteria per option ranged between -2 (Severe negative outcome/Impact) to +2 (High positive outcome). The assessment is shown in Table C4.

Table C4 Short List of options

No.	Option Description	Economic		Technical		Site Specific Objectives		Social Impact		Environmental		Sustainability		Overall
	Weighting		**30**		**20**		**20**		**10**		**10**		**10**	**100**
A	**Do Nothing**	0	0	0	0	-2	-40	-2	-20	-2	-20	-2	-20	-100
B	**Do Existing; operation of existing assets (road gullies)**	0	0	0	0	-2	-40	-2	-20	-1	-10	-1	-10	-80
C	**Storage for the main sources of surface water across the roundabouts**	-1	-30	1	20	1	20	1	10	0	0	1	10	30
D	**Divert flows from Lindisfarne roundabout to watercourse**	-2	-60	1	20	1	20	1	10	1	10	1	10	10
E	**Localised swales**	1	30	2	40	-1	-20	0	0	1	10	1	10	70
F	**Increase storm water capacities**	-2	-60	1	20	2	40	-2	-20	0	0	-1	-10	-30
G	**Underground/ offline storage**	-2	-60	1	20	2	40	0	0	0	0	0	0	0

There was considered insufficient room at Lindisfarne roundabout to construct localised swales (Option E) to deal with the volume of flooding in the larger storm events. Offline storage was not modelled due to high construction costs. An additional option was considered and modelled in an attempt to find a lower cost solution to reduce flood risk in smaller, higher probability flood events. This additional option included a combination of Option C and Option F (Option 3 below).

In summary the following options were taken forward to modelling and assessed in greater detail. The detail of the options is included in Section 6.3.

- Do Nothing (blockage of existing road gullies)
- Option 1 - Do Existing – road gullies operating
- Option 2 – Capture runoff from main areas of flooding (Lindisfarne and John Reid roundabout and properties)
- Option 3 – Store water in John Reid roundabout and upgrade highway drain near Lindsfarne Roundabout.
- Option 4 – Divert surface water flows to watercourse

6.3 Option Modelling

Option modelling was carried out to provide further detail on the flood mechanisms and consider the benefits and residual risk of the options.

6.3.1 Option 2 – Capture runoff from main areas of flooding

Detailed modelling of option 2 was carried out to investigate/examine flows; capturing major flooding from the manholes to identify the potential storage volumes which would be required to manage the flooding. However the most significant flows are from surcharge of the highway sewer at the Lindisfarne roundabout where there are significant challenges in capturing the flows. There are limited opportunities to store the flows from the sewer in this area due to insufficient space in the local area. There are limitations in excavating the A19 roundabout due to potential impact on the A19 embankment, local services and loss of trees which provide screening to residential properties. The residual flood extent is shown in Figure C6; this is from the surface water which has not been able to enter the highway drains.

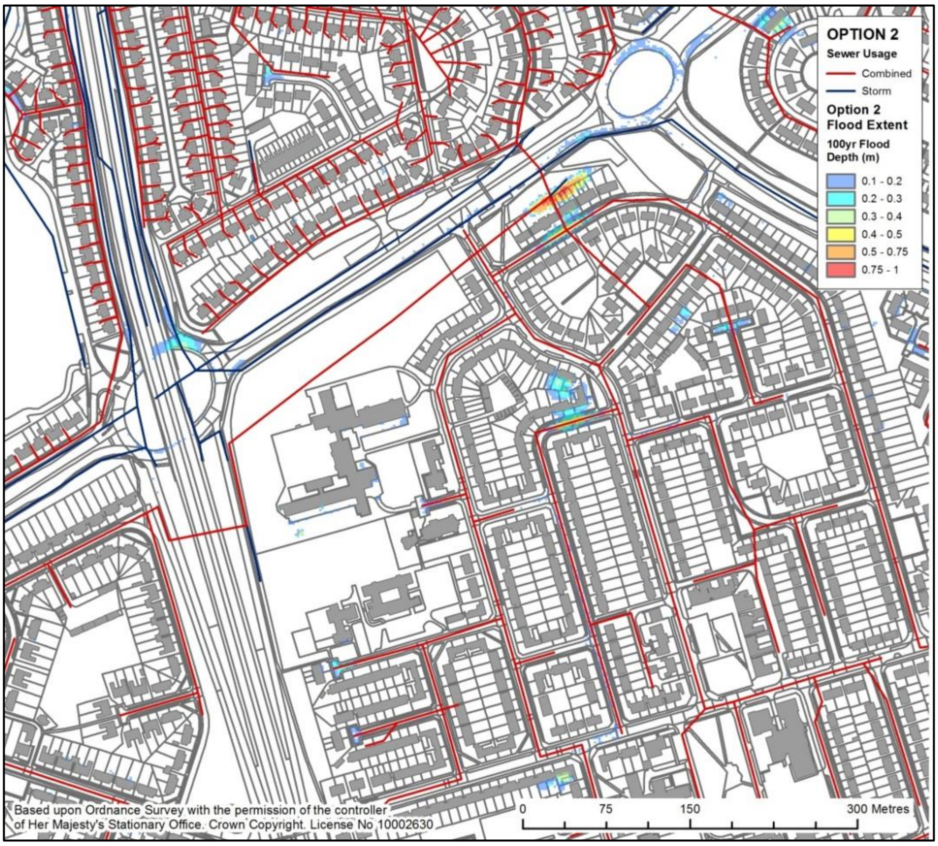


Figure C6 Option 2 1% AEP extent

The Option 2 modelling provided the following information which can be used when considering other options; such as offline storage.

- To reduce flooding at Lindisfarne Roundabout (only considering the main discharge at this location) it is estimated approximately 700-800m^3 of storage would be required for a 3.33% AEP (1 in 30) event, and approximately 3,000m^3 for a 0.5% (1 in 200) event.
- The flood water around the properties (south of Leam Lane/east of Edinburgh Road) would require approximately 3,000m^3 for a 3.33% AEP (1 in 30) event, and 6,000-7,000m^3 for a 0.5% (1 in 200) event.
- The eastern roundabout, (John Reid Road), sits in the middle of several flow paths; approximately 3,100m^3 of flows were captured during a 0.5% (1 in 200) event.

6.3.2 Option 3 – Store water in eastern roundabout and upgrade highway drain

The aim of the works in Option 3 was to consider measures which could be implemented to reduce flood risk in smaller, higher probability rainfall events. The option involved the upgrade of the highway drain further north of Lindisfarne roundabout to reduce the surcharge and additional works at the eastern roundabout to store the surface water runoff. Within the eastern roundabout the ground levels were lowered and new gullies with non-return valves connected to store water in the roundabout without the flows backing up onto the road. New drainage was also installed to allow the stored water to empty into the highway drain. The option components and residual risk for a 3.33% AEP (1 in 30) event is shown in Figure C7.

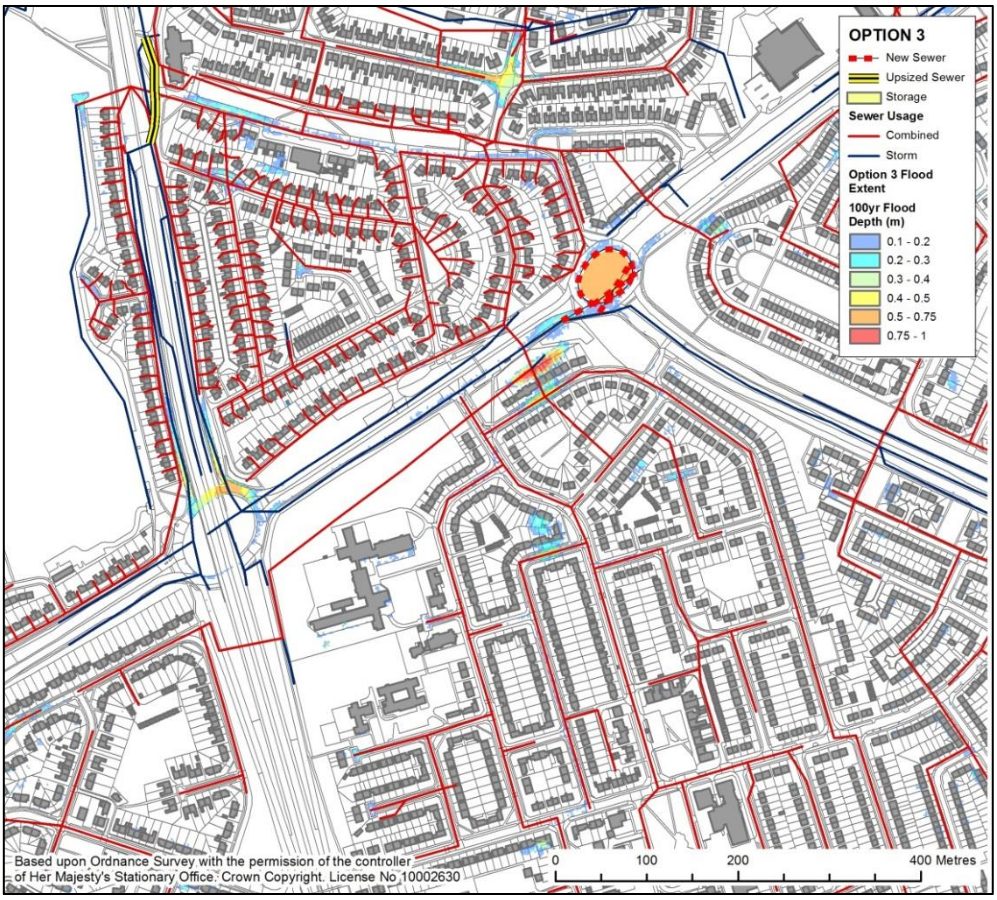


Figure C7 Option 3 3.33% AEP event

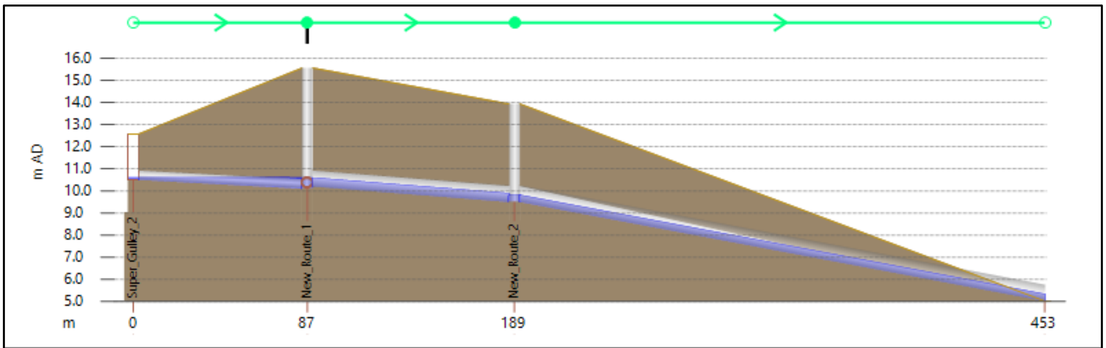
The modelling found the surcharge in the northern highway drain was removed through upgrading the capacity further north. The risk associated with the lack of downstream capacity was removed; however the option had minor benefit in reducing flood depths at the roundabout. The residual flooding is due to the lack of cover at manholes due to shallow depths of the highway drains at the roundabout.

6.3.3 Option 4 – Divert flows to watercourse

Option 4 involved capturing the surface water flows at the Lindisfarne Roundabout and diverting them to the River Don in the north east within King Georges Park. Capturing the flows, potential underground services and the impacts on the highway route during construction make the option a challenge to implement; further development of the option will be required working with the Highways team.

The local topography also means that significant volumes of excavation would be required to implement the option. A piped and open channel option for the diversion were assessed. An open channel would allow the channel to a greater range of flows, however there would be significant loss of the park to achieve the required profiles for the drainage channel.

As a result the piped option was modelled in greater detail at this stage; 5 large gullies on the roundabout take the surface water flows to the watercourse through a 750mm pipe. The profile of the pipe from the roundabout to the watercourses is shown in Figure C8. A piped diversion channel would be limited to dealing with design flows, further development would need to assess potential siltation problems and rodent issues due to infrequent use.



Link	Super_Gulley_2.1	New_Route_1.1	New_Route_2.1
width (mm)	450	750	750
us inv (m AD)	10.500	10.200	9.500
ds inv (m AD)	10.100	9.500	5.020

Node	-	New_Route_1	New_Route_2	New_Outfall

Figure C8 Option 4 profile

The modelled option dealt with flows up to the 1.33% AEP (1 in 75) event, although a residual peak depth of 0.14m remained for a short period. The residual flooding is shown in Figure C9. The works involved in this option do not deal with the flood risk to the properties in the east and flooding at John Reid Roundabout.

The effects on levels within the River Don as a result of the diversion of flows were assessed through comparison to the existing modelled river levels. The comparison was made for the greatest rainfall event modelled; the 0.5% AEP (1 in 200) event. There was a negligible effect, with no additional properties at risk due to the extra flows within the watercourse.

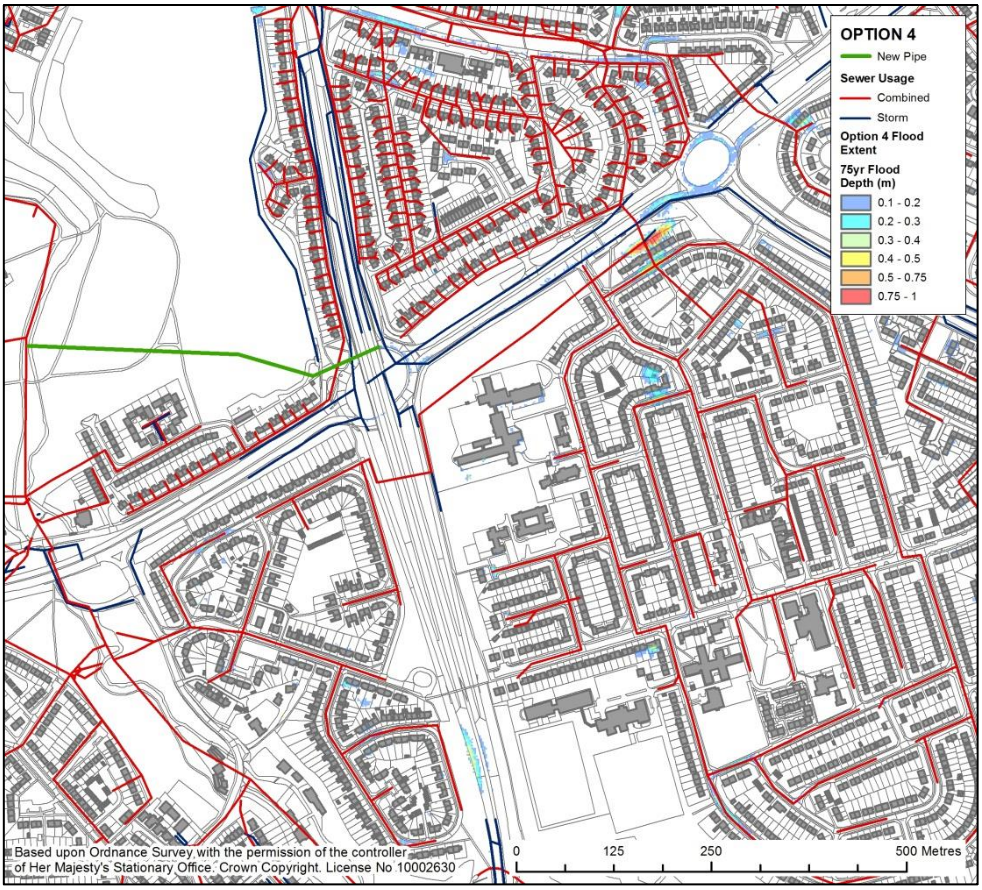


Figure C9 Option 4 1.33% AEP event *River flooding has not be shown in this figure

6.4 Costs and Benefits

As no clearly viable options within the scope of the SWMP were recognised, no detailed costs and benefits have been completed. Option 4 has the most potential, although needs further development. The option has been estimated to have a whole life cost of approximately £1.3 million; this includes maintenance costs, £764k construction costs plus optimism bias. Further development of the option would have to be carried out to develop the option and refine the costs.

To reduce the flooding at Lindisfarne roundabout offline storage could potentially be progressed with a pumped return that could fill when the sewers surcharge significantly. As an estimate this could potentially cost £2 million and therefore it is recommended that a range of options at different scales are considered in greater detail prior to progressing such option.

It should be noted that there are very few residential properties at risk across the area. The properties at risk are east of the Lindisfarne roundabout and are likely to require additional measures to supplement options considered to reduce flooding at Lindisfarne roundabout. Therefore if options are implemented only to reduce flooding at Lindisfarne roundabout, the economic appraisal of these options to apply for Flood and Coastal Erosion Risk Management Grang in Aid (FCERM GiA) would rely on there being sufficient benefits solely from a reduction in traffic delays. Under current guidance it is considered unlikely that sufficient economic benefits could be defined based on traffic delays alone.

6.5 Recommended Actions

The assessment of the Lindisfarne area has provided the following conclusions to take forward to the action plan:

- There are several sources of flooding across the area which interact, predominantly from surface water runoff from the highways, discharge of the highway/storm and combined sewers near Lindisfarne Roundabout and the properties south of Leam Lane.
- The ground levels around Lindisfarne roundabout are generally higher than the roundabout itself. This limits the viability of storage options in the area due to the volume of excavation which would be required, the impact on adjacent structures (A19 flyover), potential buried services and the loss of trees that currently screen the adjacent properties from the highway.
- Further detailed assessment of this area is required to assess a greater range of options at different scales.
- The outputs of the options should be discussed with the council highways team to assist in developing the most appropriate long-term solution.
- It is understood plans are in place to improve traffic management in the area. These and any future highway alteration plans should consider the surface water management issues and how any improvements can be incorporated into the highway works.
- Through consultation with stakeholders, including local resilience forums, mitigation measures could be implemented to reduce the impact the flooding has on the important transport route during intense storm events. This could include traffic management measures, including the consideration of diversion routes and the use of matrix signs to warn road users of restrictions.

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APPENDIX C5
New Market Walk

C5 NEWMARKET WALK

1 DESCRIPTION OF AREA

Newmarket Walk refers to an area that is located north west of the junction of Chichester Road (B1298) and Imeary Street; north to Derby Terrace. The metro line runs north-south along the western edge of the area; a brick wall separates the railway embankment from the properties in Newmarket Walk. Victoria Road runs underneath the metro line. To the north of the area the metro continues on a viaduct at a raised level. The area is predominantly residential with pedestrian-only areas in its centre, around Newmarket Walk. Main roads (A194, A1018) are primarily around the edge of the area. An overview of the area is shown in Figure C1.

The ground on each side of the elevated metro line is at approximately 9mAOD. To the east of Westoe Road and south of Chichester Road the level increases to over 20mAOD. The topography of the area is shown in Figure C2.

Flooding is caused by surface water flows collecting in the low lying land between the metro and Newmarket Walk. The Newmarket Walk area is predominantly served by a combined sewer network with several additional storm sewers which become overwhelmed during a 3.33% AEP (the smallest event modelled) and lower probability rainfall events.

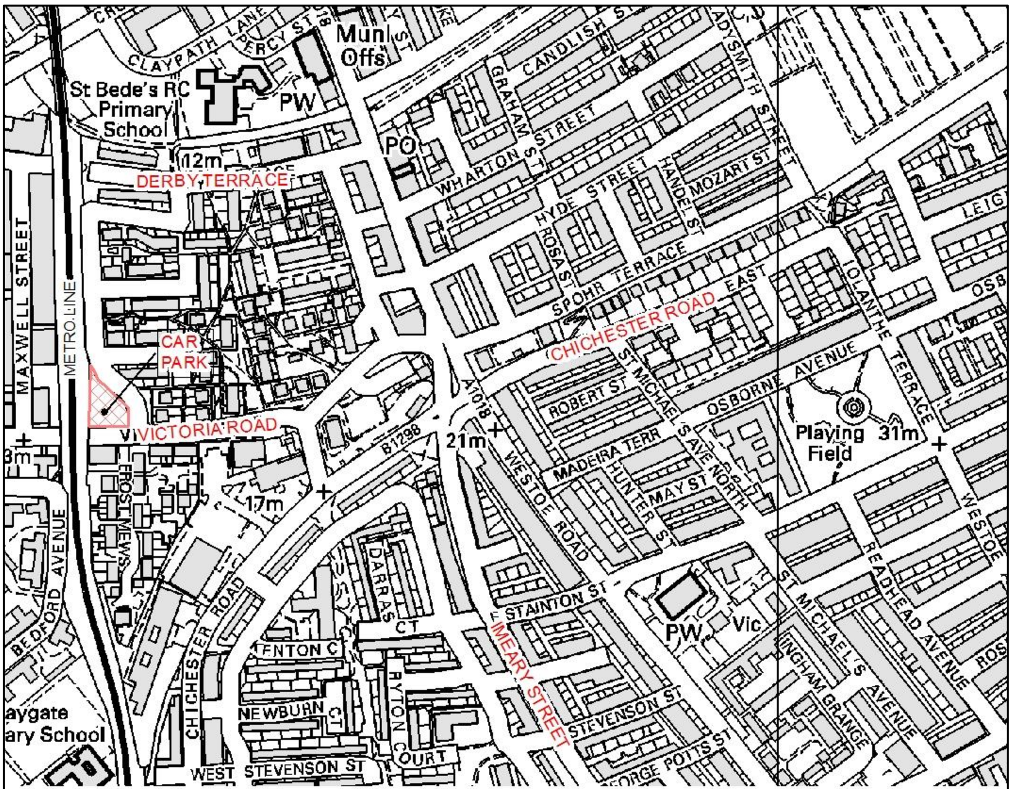

Figure C1Newmarket Walk Overview

Photograph 1: Car park on north side of Victoria Road, next to metro line (metro embankment in background)

Photograph 2:East up Victoria Road from car park

Photograph 3: Properties adjacent to the railway line

Photograph 4: Area of initial ponding of surface water

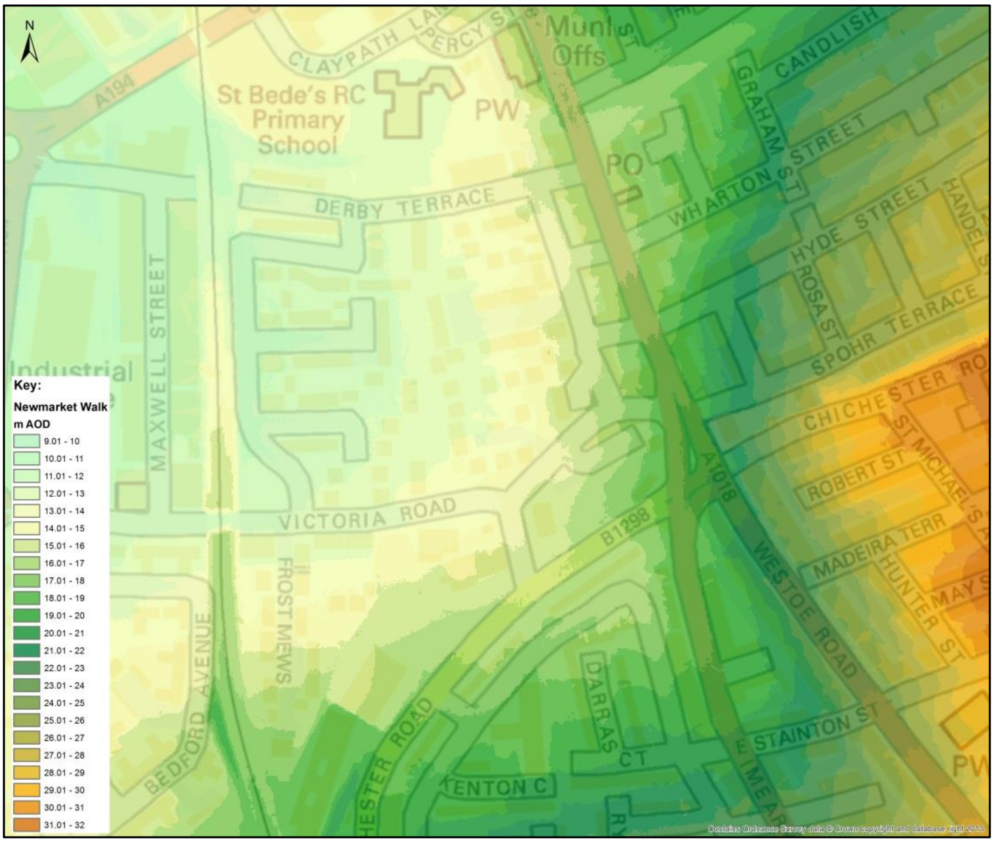

Figure C2 Local topography of the New Market walk area.

2 DEVELOPMENT PLANS AND OPPORTUNIITIES

Review of the Strategic Housing Land Availability Assessment (SHLAA)[1] highlighted two potential development areas within the Newmarket Walk area. These areas are highlighted in Figure C3. In the finalised development allocations, one area was considered as being not developable, the other as potentially developable. The potentially developable site is not considered as being at risk from surface water flooding itself. However when the site is developed it will be essential to ensure the development does not contribute additional surface water to the surrounding area and increase flood risk elsewhere. The drainage of any future development would be assessed during the development control process.

[1] South Tyneside Council (2011)Strategic Housing and Land Availability Assessment

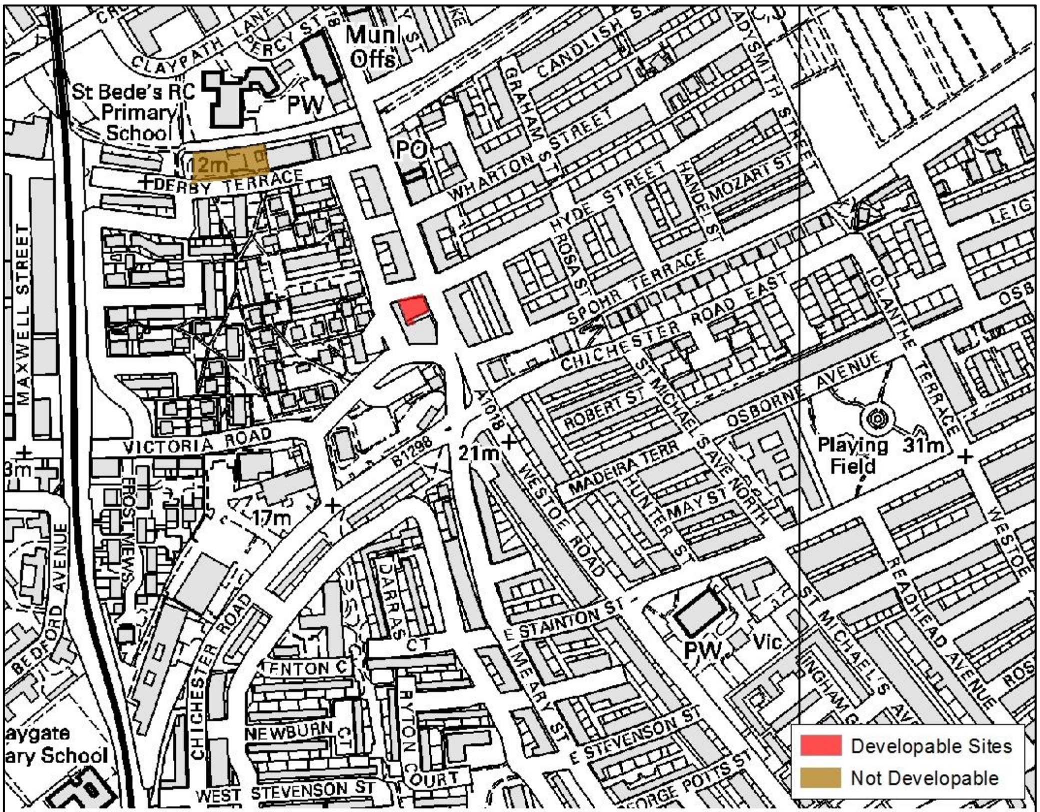

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Figure C3 Development Plan Review

3 ENVIRONMENTAL DESIGNATIONS AND OTHER POSSIBLE CONSTRAINTS

A desk-based high level screening of environmental information was carried out to identify any initial issues which could potentially influence the selection and assessment of options for reducing flood risk in this area. Information within the National Receptor Database including international and national designated areas and listed buildings was screened. The screened data did not highlight any significant environmental receptors within the Newmarket Walk area.

Review of British Geology maps[2] identifies the superficial deposits of the Newmarket Walk area are predominantly clay and silt with Diamicton Till in the southern area across Chichester Road The bedrock is the Pennine Middle Coal Measures Formation; predominantly a mudstone, siltstone and sandstone classification across the northern area with sandstone across the south area.

4 DETAILED MODEL RESULTS

Figure C4 shows the predicted surface water flooding extent for a 1% annual exceedance probability (AEP) (1 in 100) event in a Do Nothing scenario. This is a hypothetical scenario which is assessed to allow the benefits of the options considered to be compared against. The Do Nothing scenario at Newmarket Walk assumes no water can enter the surface water drainage system through the road gullies. The

[2] British Geology Survey (2013) Geology Maps; http://www.bgs.ac.uk

section of railings north of the wall running adjacent to the metro was included in the model.

The number of properties at risk in the Do Nothing scenario indicated by the modelling is very similar to the number of properties known to be at risk in the existing situation. The number of properties at risk in the Do Nothing scenario for a range of events is shown in Table C1. Although access to upper level flats would be affected by surface water flooding there would be no depth damages and therefore these properties are not included in the property count. The effects of climate change on the levels of flood risk are shown in Table C2. The modelling note in Appendix A includes the methodology for the detailed modelling.

Table C1 Properties at risk in the Do Nothing scenario

Location	**Total properties at risk in each rainfall event**			
	3.33% AEP (1 in 30)	**1.33% AEP (1 in 75)**	**1% AEP (1 in 100)**	**0.5% AEP (1 in 200)**
Residential	67	85	85	94
Commercial	3	4	4	5
Total	70	89	89	99

*Properties have been counted as being at risk when flood depths at the property are above the assumed property threshold of 150mm.

Table C2 Total number of properties at risk in Do Nothing with Climate Change Flows

Rainfall event							
3.33% +CC AEP (1 in 30+cc)		**1.33% + CC AEP (1 in 75+cc)**		**1% + CC AEP (1 in 100+cc)**		**0.5% + CC AEP (1 in 200+cc)**	
No. at risk	Increase	No. at risk	Increase	No. at risk	Increase	No. at risk	Increase
91	**+21**	104	**+15**	113	**+24**	119	**+20**

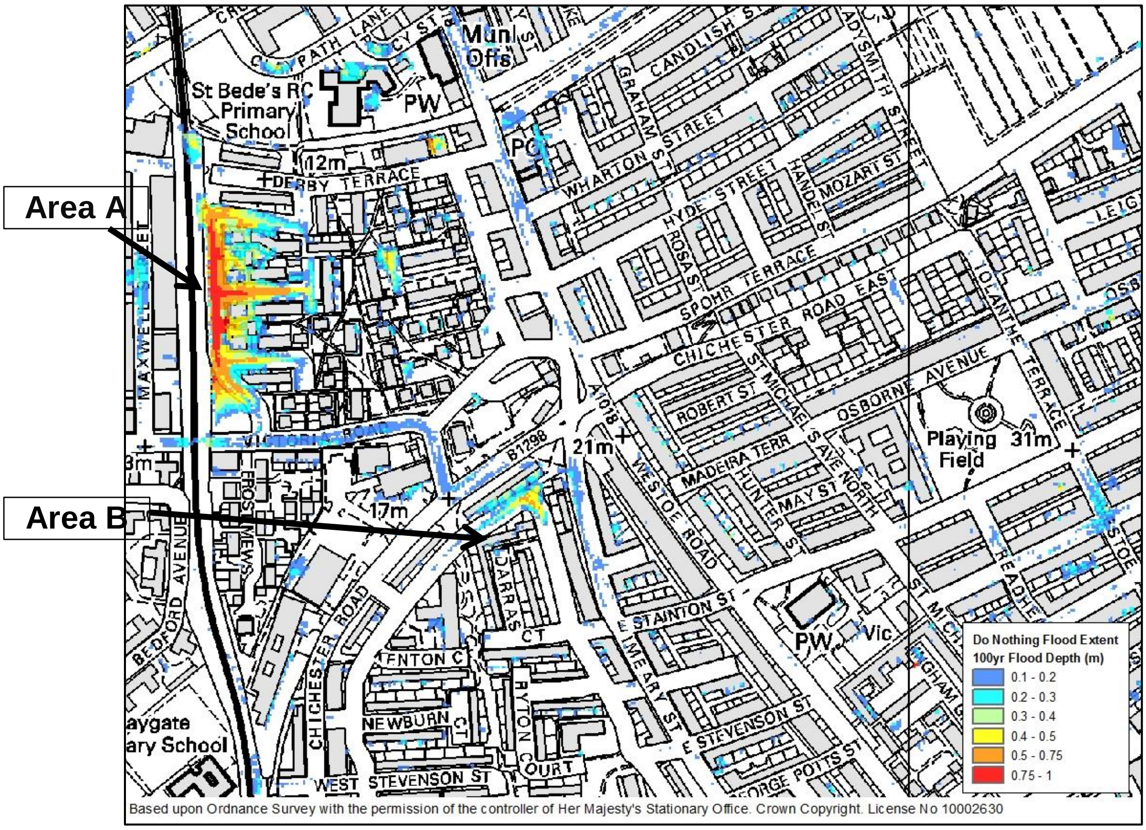

Figure C4 Do Nothing 1% AEP event

5 FLOOD MECHANISM ASSESSMENT

The detailed modelling was analysed, and in addition to site visits and the review of initial data, the following conclusions and detail on flood mechanisms can be drawn:

- There are no historical records of properties flooding in the area.
- The modelled flooding with more significant depths is focused within two areas; water storing along the edge of the wall parallel with the metro line and backing up east to the properties on Newmarket Walk (Area A), the second area (Area B) of significant risk is located in an area south of Chichester Road, near Darras Court.
- The area of flooding along the railway embankment is caused by surface water flows collecting against the wall parallel to the railway line.
- The area of flooding to the south of Chichester road is linked to an additional highway drain which connects into a combined sewer, The system is overwhelmed in the smallest flood event modelled (3.33% AEP) with flooding experienced during a 3.33% AEP event and lower probability events.

6 SURFACE WATER MANAGEMENT OPTIONS

6.1 Long List of Options

A long list of measures was screened initially to identify potential suitable measures to reduce surface water flooding at the Newmarket Walk area; at both Darras Court and Newmarket Walk. Table C3 shows the screening process of measures considered. The measures which were considered viable were used to create options which could potentially reduce the surface water flooding.

Table C3 Long list of measures

	Mitigation Measure	Initial Screening	Technically Feasible?
Source	Green roofs	Not considered appropriate for existing properties	No
	Soakaways	May provide some attenuation of flows to reduce flows in drainage network, although majority of runoff is directly from roads. Due to the potential of clay in the area the success of soakaways will be limited	Some Potential
	Swales	Could be used between the properties and the metro, though may be classed as storage due to size required. May be good space for inclusion of swales, particularly around Newmarket Walk	Some Potential
	Permeable Paving	Would require large changes to a lot of smaller property extents	No
	Attenuation/Storage	Could potentially use between the metro and houses; and car park	Yes
	Rainwater Harvesting	Could be installed in housing area although would have to be used in combination with option to deal with surface water runoff from roads	Some Potential
Pathway	Increase drainage/sewer capacity	Would also need gulley improvements to collect runoff	Yes
	Separation of foul and surface water sewers	Additional storm sewers already added to many areas	No
	Improved maintenance regimes	Assumed all existing networks are in good working order	No
	Managing overland flows	Flows come through residential area and pond between properties and metro. No river nearby to divert flows to (600m to nearest watercourse; River Tyne, across residential areas)	No
	Land management practices	Mainly urban area, little opportunity to implement land management practices to attenuate flows	No
Receptor	Improved weather warning	Catchment for urban runoff catchment is small and localised therefore unlikely to be effective. Would need to be implemented at a wider scale; either nationally or in combination with other councils in area	No
	Planning policies	Measure to be taken forward at council wide level	No
	Permanent/Temporary defences	Defences around blocks of buildings could reduce risk, although access problems likely and water could put pressure on wall adjacent to railway if allowed to pond against it	No
	Social Change, education and awareness	Through action impact could be decreased although risk not reduced and difficult for public to take action without warning	No
	Improved resilience and resistance measures	Properties at risk could be fitted with resilience measures, such as flood doors	Yes

6.2 Short List of Options

The measures considered viable in Table C3 were taken forward to create options which could have the potential to reduce surface water flooding. The options were then assessed against specific criteria to consider which to specifically assess in greater detail using the hydraulic model. The criteria used are discussed in Section 4.2 of the main SWMP report. The score assigned to each criteria per option ranged between -2 (Severe negative outcome/Impact) to +2 (High positive outcome). The assessment is shown in Table C4.

Table C4 Short List of options

No.	Option Description	Economic		Technical		Site Specific Objectives		Social Impact		Environmental		Sustainability		Overall
	Weighting		**30**		**20**		**20**		**10**		**10**		**10**	**100**
A	**Do Nothing**	0	0	0	0	-2	-40	-2	-20	-2	-20	-2	-20	-100
B	**Do Existing; operation of existing assets (road gullies)**	0	0	0	0	-2	-40	-2	-20	-1	-10	-1	-10	-80
C	**Store surface water flows within the localised area**	-1	-30	1	20	1	20	1	10	1	10	2	20	50
D	**Increase all storm water and sewer capacities**	-2	-60	1	20	2	40	0	0	0	0	1	10	10
E	**Resilience/Resistance measures - Individual Property Protection**	-1	-30	1	20	1	20	-1	-10	0	0	1	10	10

Individual property protection (Option E); a flood mitigation option was not taken forward to modelling, options to directly reduce flood risk were considered primarily. In summary the following options were taken forward to modelling and assessed in greater detail. Detail of the options is summarised in 6.3.

- Do Nothing (blockage of existing road gullies)
- Option 1 - Do Existing – road gullies operating
- Option 2 – Localised storage and upgrading of a sewer section
- Option 3 – Increase sewer capacities

6.3 Option Modelling

Option modelling was carried out to consider the benefits provided by each option and the residual risk.

6.3.1 Option 2 – Localised storage and upgrading of a sewer section

This option consisted of a combination of measures to reduce flooding across the area. Firstly small localised storage areas were created between the metro and the properties at Newmarket Walk. Wide areas of concrete along the road were replaced with grassed areas and lowered to a maximum of 1.5m below road level to provide the storage. Through creating the storage area in Figure C5, approximately 600m^2 of local area was used. Additional road drains were connected to outfalls into the storage areas, the water would potentially infiltrate following the rainfall event, although ground investigation would be required.

To reduce flood risk at the additional area (Darras Court), upsizing of a length of combined sewer to 525mm was included as shown in Figure C5, In addition extra road drainage (including a larger than standard gulley and 300mm connection) to get the flows into the connecting storm sewer were implemented[3]. Localised landscaping of the area east of the properties on the edge of Darras Court would also be required to create a small bund to divert flows.

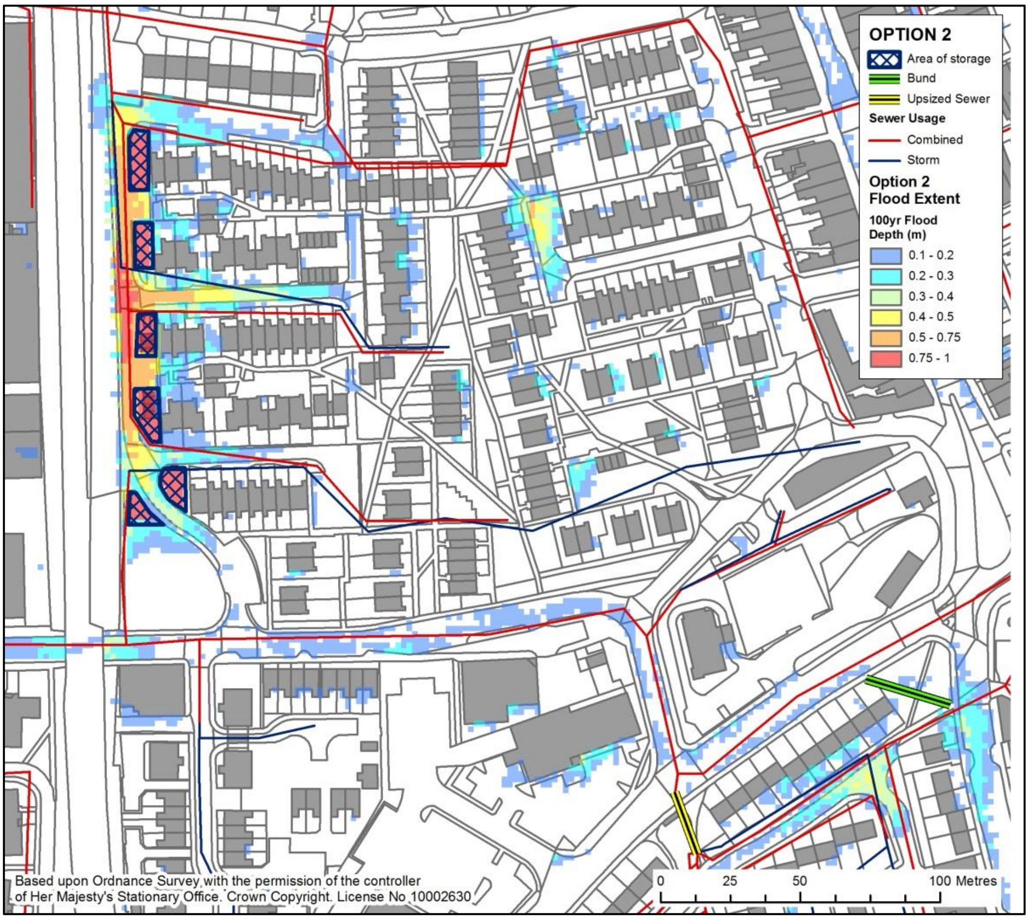

Figure C5 Option 2 and resulting 1% flood event

The model output demonstrates the residual flood risks from local surface water. The surface water depths around the properties at Newmarket walk are significantly reduced by creating additional storage in the areas where the water naturally flows to.

Table C5 and Table C6 show the option reduced the number of properties at significant risk by 13 properties compared to the Do Nothing situation. It also reduced the number of properties at risk in the higher probability events (up to 1% AEP). Table C5 suggests

[3] Following the modelling NWL indicated the upsized sewer was already 900mm diameter, which would reduce the surcharge further and allow more flow into the sewer; improving conveyance. However the flooding issue is linked to surface water from the roads and therefore even with this size pipe, the additional gullies would be required in the area to get the surface water into the system.

a significant number of properties remain at risk; however the properties affected by greater depths of flooding were reduced.

6.3.2 Option 3 – Increase sewer capacities

The option consisted of upsizing the combined sewers and public storm sewer along Newmarket Walk and placing a new sewer under the railway line viaduct. The measures near Darras Court were as included in option 2; upsizing a length of combined sewer with additional road drainage to get flows into the connecting storm sewer[3]. The option components and residual risk are shown in Figure C6.

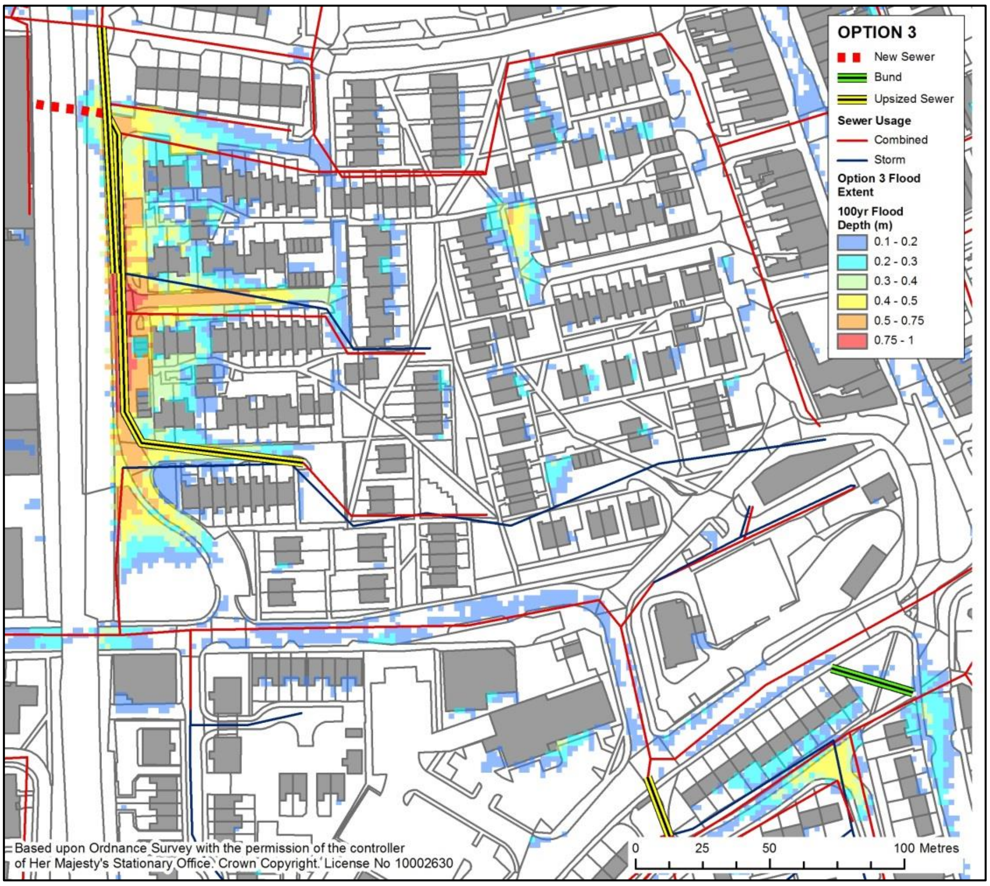

Figure C6 Option 3 and resulting 1% flood event

The residual risk is greater than with Option 2, there is significant depth remaining around the properties at Newmarket Walk. The residual risk around the properties at Darras Court is the same as Option 2 as the options implemented in the model are identical.

Table C5 and Table C6 show option 3 had no additional affect in reducing the overall number of properties at flood risk across the area compared to the existing situation with the gullies operating; however the properties affected by greater depths of flooding were reduced.

The residual flood risk from the options is included in Table C5 with the reduction in flood risk (compared to the Do Nothing scenario) included in Table C6.

Table C5 Properties at risk in options

	Option 1 – Do Existing				Option 2 – Localised storage and upgrading of a sewer section				Option 3 – Increase sewer capacities			
	3.33%	1.33%	1%	3.33%	3.33%	1.33%	1%	3.33%	3.33%	1.33%	1%	3.33%
Res	59	69	80	90	58	68	76	90	62	81	87	99
Com	2	4	4	5	1	2	1	3	1	3	3	3
Total	61	73	84	95	59	70	77	93	63	84	90	102

Table C6 Reduction in properties for modelled options (compared to Do Nothing)

	Option 1 – Do Existing				Option 2 – Do Something				Option 3 – Do Something			
	3.33%	1.33%	1%	3.33%	3.33%	1.33%	1%	3.33%	3.33%	1.33%	1%	3.33%
Res	8	16	5	4	9	17	9	4	5	4	-2	-5
Com	1	0	0	0	2	2	3	2	2	1	1	2
Total	9	16	5	4	11	19	12	6	7	5	-1	-3

Table C5 and Table C6 suggests Option 2 only has a minor improvement in decreasing flood risk than Option 1; the existing scenario. The benefits calculated in Section 6.4 for Option 2 are greater which shows although the flood risk has not been completely mitigated; the depths of flooding have been reduced in Option 2. The damages and numbers at risk show there is potential for further refinement to reduce the impacts of surface water flooding.

6.4 Costs and Benefits

The costs and benefits of the modelled options were assessed using the modelled outputs; these are shown in Table C7. Following indications by NWL that the sewer at Darras Court was upsized, the construction costs were updated to reflect remove this element from the options costs.

Table C7 Option Costs and Benefits

	Do Nothing (£k)	Option 1 – Do Existing (£k)	Option 2 – Store water (£k)	Option 3 – Upsize sewers (£k)
Construction Costs	-	£0	£554	£556
Whole life Costs	-	£30	£573	£568
Optimism Bias (60%)	-	£18	£344	£341
Total PV Costs	-	**£48**	**£917**	**£908**
Damages	£21,336	£20,650	£17,690	£18,170
Benefits	-	£686	£3,646	£3,166
BCR	-	**14.29**	**3.98**	**3.49**

The Newmarket Walk area has a deprivation ranking of 2,893[4] and 6,338 (out of 32,482), it is classed as being in a 20% most deprived area within England which is included in the calculation of the potential Flood and Coastal Risk Management Grant in Aid (FCRM GiA) funding. With the benefits Option 2 is assessed to provide and reduction in properties at risk across the risk bands it is estimated the FCRM GiA funding may potentially be approximately £227k. This would be subject to further detailed investigation of the proposals and would be assessed in relation to other flooding schemes at a national level. This is insufficient to entirely fund the required improvement schemes to reduce surface water risk, additional funding sources will need to be obtained to progress any improvements. The risk bands within the FCRM GiA funding calculator could be used to assist in development of the options further and assess which level of protection provided by an option is preferable.

6.5 Recommended Actions

The assessment of Newmarket Walk has provided the following conclusions to take forward to the action plan:

- To reduce the risk of surface water flooding at Newmarket Walk several localised storage areas could potentially be created. An initial assessment has identified approximately 900m^3 could be created.
- The localised storage areas could potentially improve the local landscaping, through the creation of more green space,
- Further consideration would need to be balance the depth of the grassed areas to create storage whilst not having any Health and Safety concerns and improving the local landscape.
- Further assessment of Option 2 to reduce flooding at Newmarket Walk is recommended.
- Consultation with residents would be essential to get their buy in to progress and development of the options.
- Individual property protection measures should be considered to potentially provide a quick win solution to the properties at greatest risk across the area.
- Local measures to reduce surface water runoff across the whole area should be considered, this could include promotion of water butts.
- Measures such as increased road gullies could be implemented to reduce flood risk at Darras Court; this would need further engagement with NWL as this would add additional flows to their sewer network. The work in this location could be carried out in conjunction with Newmarket walk or separately.

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[4] Office for National Statistics (2010); Indices of Multiple Deprivation (IMD)

considered unlikely that sufficient economic benefits could be defined based on traffic delays alone.

6.5 Recommended Actions

The assessment of the Lindisfarne area has provided the following conclusions to take forward to the action plan:

- There are several sources of flooding across the area which interact, predominantly from surface water runoff from the highways, discharge of the highway/storm and combined sewers near Lindisfarne Roundabout and the properties south of Leam Lane.
- The ground levels around Lindisfarne roundabout are generally higher than the roundabout itself. This limits the viability of storage options in the area due to the volume of excavation which would be required, the impact on adjacent structures (A19 flyover), potential buried services and the loss of trees that currently screen the adjacent properties from the highway.
- Further detailed assessment of this area is required to assess a greater range of options at different scales.
- The outputs of the options should be discussed with the council highways team to assist in developing the most appropriate long-term solution.
- It is understood plans are in place to improve traffic management in the area. These and any future highway alteration plans should consider the surface water management issues and how any improvements can be incorporated into the highway works.
- Through consultation with stakeholders, including local resilience forums, mitigation measures could be implemented to reduce the impact the flooding has on the important transport route during intense storm events. This could include traffic management measures, including the consideration of diversion routes and the use of matrix signs to warn road users of restrictions.

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APPENDIX C6
King George

C6 KING GEORGE

1 DESCRIPTION OF AREA

King George refers to an area in the east of South Tyneside, located west of Harton cemetery and east of the allotments. King George Road (A1018) runs north-south through the area. The area is predominantly residential with properties aligning either side of King George Road. An overview of the area is shown in Figure C1.

The ground levels fall from the A1300 in the south east of the site at over approximately 40mAOD, in a north westerly direction. The King George area is at approximately 18mAOD. The topography of the area is shown in Figure C2.

The area of potential flood risk is predominantly located across King George Road around Holmfield Avenue. The area is served by a combined sewer network with several additional storm sewers which become overwhelmed during a rainfall event.

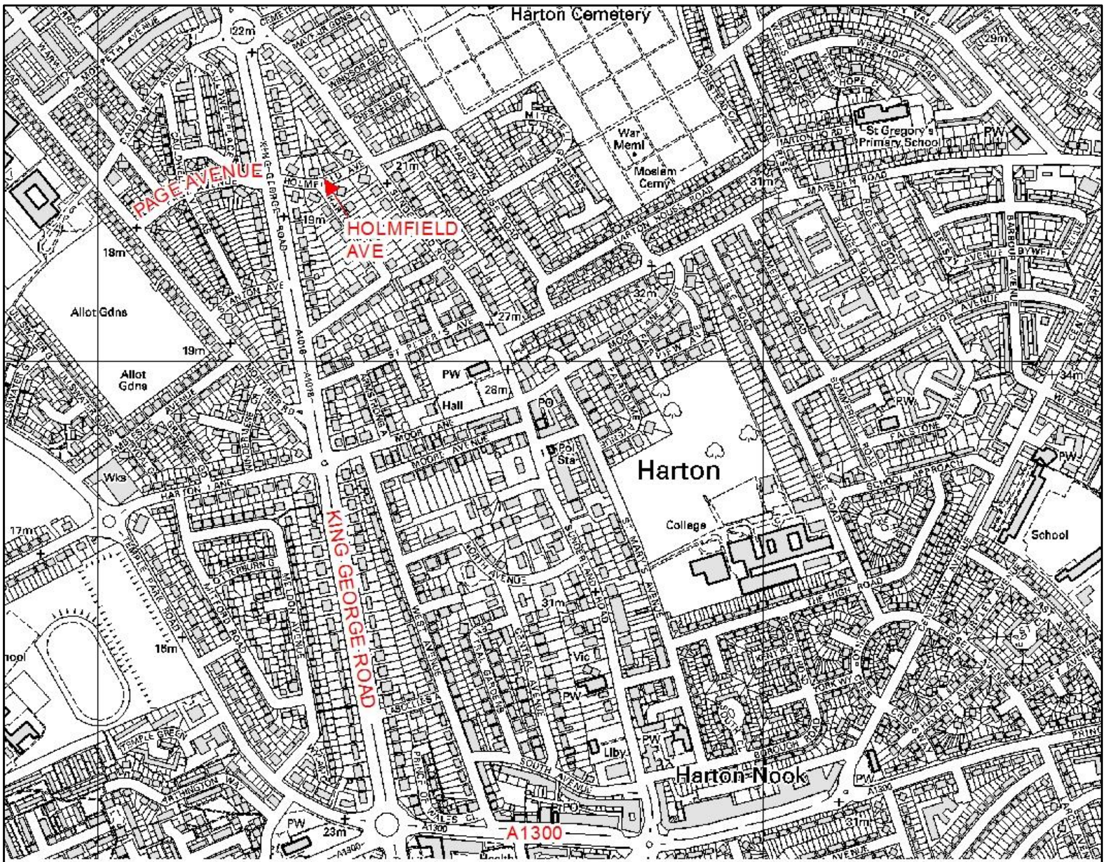

Figure C1 King George Overview

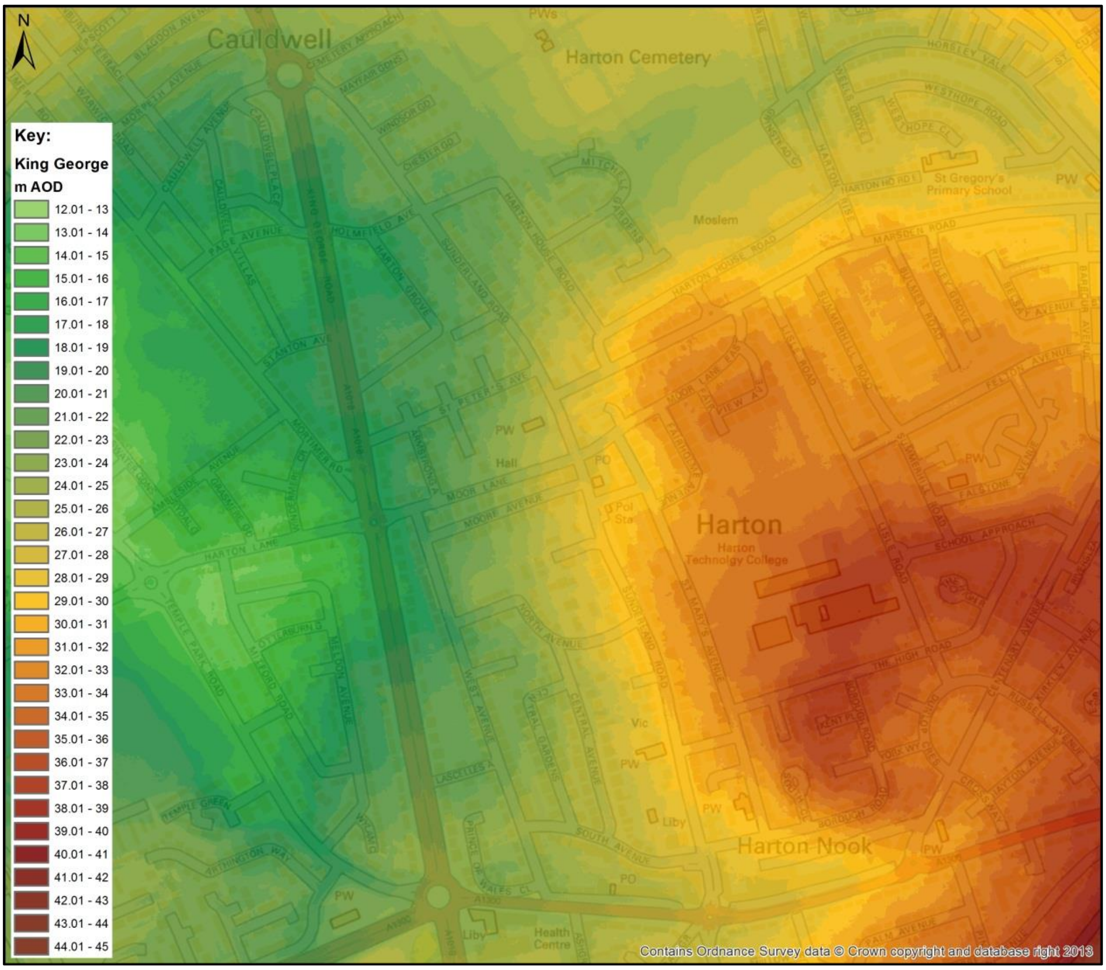

Figure C2 Local topography of the New Market walk area.

2 DEVELOPMENT PLANS AND OPPORTUNIITIES

Review of the Strategic Housing Land Availability Assessment (SHLAA)[1] highlighted no sites within the immediate area with some sites further south. These areas are highlighted in Figure C3. When the developable sites are progressed for development, it will be essential to ensure the development does not contribute additional surface water to the surrounding area and increase flood risk elsewhere. The drainage of any future development would be assessed during the development control process.

[1] South Tyneside Council (2011)Strategic Housing and Land Availability Assessment

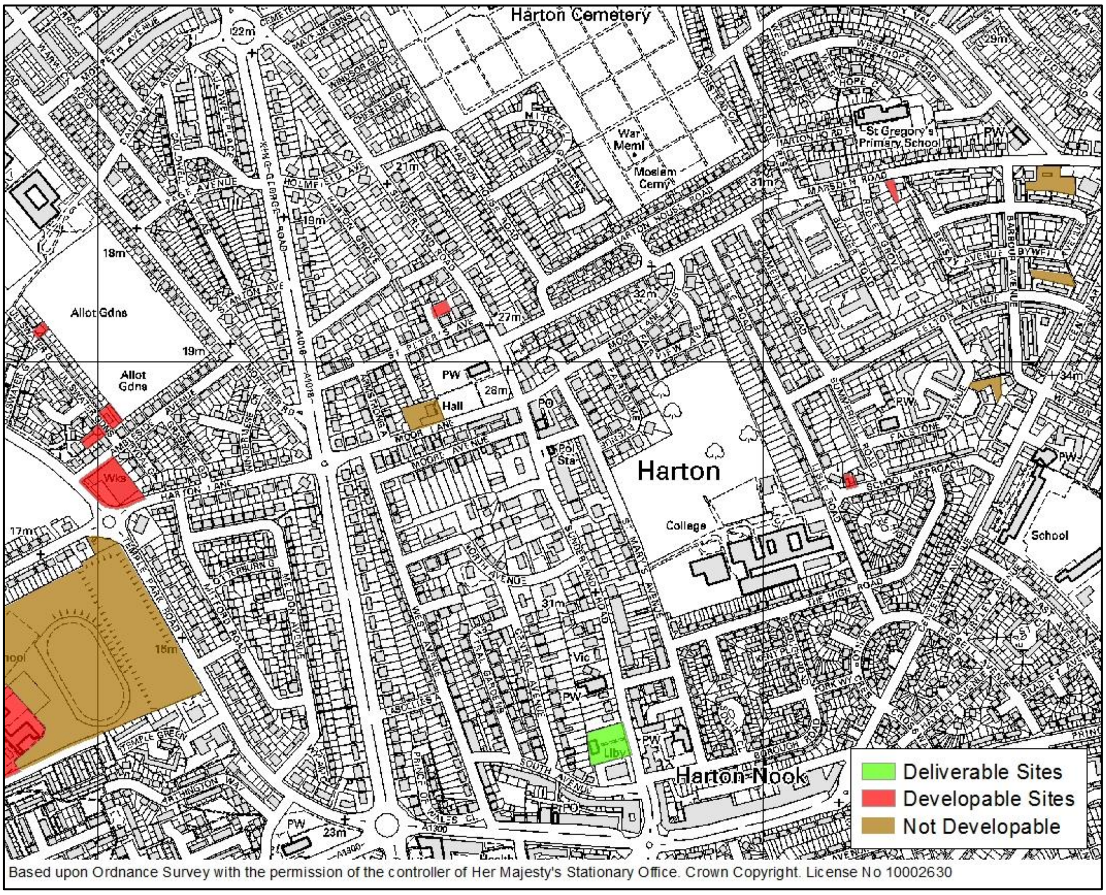

Figure C3 Development Plan Review

3 ENVIRONMENTAL DESIGNATIONS AND OTHER POSSIBLE CONSTRAINTS

A desk-based high level screening of environmental information was carried out to identify any initial issues which could potentially influence the selection and assessment of options for reducing flood risk in this area. Information within the National Receptor Database including international and national designated areas and listed buildings was screened. The screened data did not highlight any significant environmental receptors within the King George area. A search of Magic[2] identified a small area of Deciduous Woodland BAP (Biodiversity Action Plan located at the north western corner of the Harton cemetery and several listed buildings.

Review of British Geology maps[3] identifies the superficial deposits of the King George area are Pelaw Clay on the western side and Diamicton Till to the east of Sunderland Road and north of Page Avenue. The bedrock is the Grindstone Post Member – Sandstone.

[2] Magic (2013) Defra receptor database; www.magic.defra.gov.uk
[3] British Geology Survey (2013) Geology Maps; http://www.bgs.ac.uk

4 DETAILED MODEL RESULTS

Figure C4 shows the predicted surface water flooding extent for a 1% annual exceedance probability (AEP) (1 in 100) event in an existing scenario. The number of properties at risk in the existing scenario for a range of events is shown in Table C1. The effects of climate change on the levels of flood risk are shown in Table C2. The modelling note in Appendix A includes the methodology for the detailed modelling.

Table C1 Properties at risk in the existing scenario

Location	Total properties at risk in each rainfall event			
	3.33% AEP (1 in 30)	1.33% AEP (1 in 75)	1% AEP (1 in 100)	0.5% AEP (1 in 200)
Residential	2	4	4	12
Commercial	0	0	0	0
Total	2	4	4	12

*Properties have been counted as being at risk when flood depths at the property are above the assumed property threshold of 150mm.

Table C2 Total number of properties at risk in existing with Climate Change Flows

Rainfall event							
3.33% +CC AEP (1 in 30+cc)		1.33% + CC AEP (1 in 75+cc)		1% + CC AEP (1 in 100+cc)		0.5% + CC AEP (1 in 200+cc)	
No. at risk	Increase	No. at risk	Increase	No. at risk	Increase	No. at risk	Increase
4	**+2**	5	**+1**	13	**+9**	19	**+7**

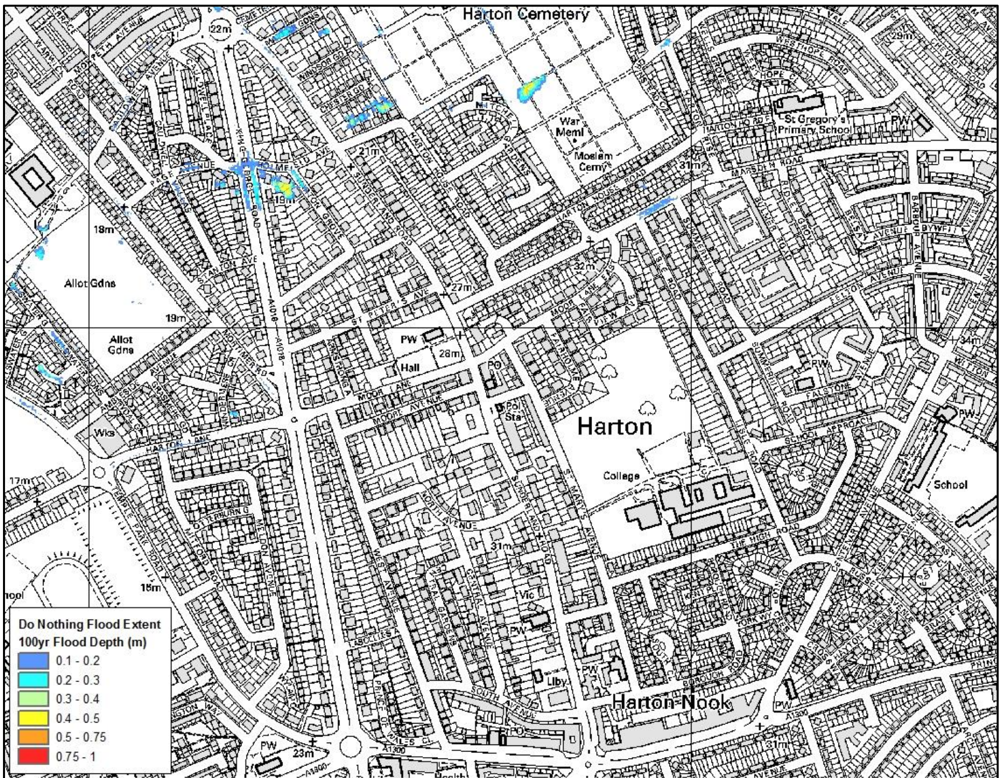

Figure C4 Do Existing 1% AEP event

5 FLOOD MECHANISM ASSESSMENT

The detailed modelling was analysed, the following conclusions and detail on flood mechanisms can be drawn:

- The flooding is due to surcharge of the combined sewer system at Page Avenue, Holmfield Avenue and King George Road.
- Surface water flows from the cemetery cause some minor surface water flooding on Chester Gardens.
- Following detailed modelling, only a limited number of properties were considered to be at risk of flooding.
- Maximum surface water flooding volume was estimated to be approximately $2250m^3$.

6 SURFACE WATER MANAGEMENT OPTIONS

6.1 Long List of Options

A long list of measures was screened initially to identify potential suitable measures to reduce surface water flooding at the King George area. Table C3 shows the screening process of measures considered. The measures which were considered viable were used to create options which could potentially reduce the surface water flooding.

Table C3 Long list of measures

	Mitigation Measure	Initial Screening	Technically Feasible?
Source	Green roofs	Not considered appropriate for existing properties and wouldn't deal with mitigate problem in this hot spot	No
	Soakaways	May provide some attenuation of flows to reduce flows in drainage network, although unlikely for volume required.	No
	Swales	Space along road edge and middle of reservation to create swales	Yes
	Permeable Paving	Would require large changes to a lot of smaller property extents to reduce water entering CSO	No
	Attenuation/Storage	Could attenuate in green areas along road an in reservation	Yes
	Rainwater Harvesting	Could reduce water entering CSO	Some Potential
Pathway	Increase drainage/sewer capacity	Increase CSO to cope with mitigate flows	Yes
	Separation of foul and surface water sewers	CSO's exist, these could be separated to increase capacity for foul system	Yes
	Improved maintenance regimes	Assumed all existing networks are in good working order	No
	Managing overland flows	Flows from surface water run off when it has left the sewer could be diverted away from residential area, although not to a river	Yes
	Land management practices	Mainly urban area, little opportunity to implement land management practices to attenuate flows	No

	Mitigation Measure	Initial Screening	Technically Feasible?
Receptor	Improved Weather warning	Would need to be implemented at a wider scale; either nationally or in combination with other councils in area	No
	Planning policy's	Measure to be taken forward at council wide level	No
	Permanent/Temporary defences	Likely to push water elsewhere.	No
	Social Change, education and awareness	Through action impact could be decreased although risk not reduced and difficult for public to take action without warning	No
	Improved resilience and resistance measures	Properties at risk could be fitted with resilience measures	Yes

6.2 Conclusion

Following discussion of the detailed modelling outputs with the partners the decision was made not to develop the option assessment further within the SWMP. The flood risk is predominantly due to the capacity of the sewer system and Northumbrian Water confirmed this area is something they are currently assessing.