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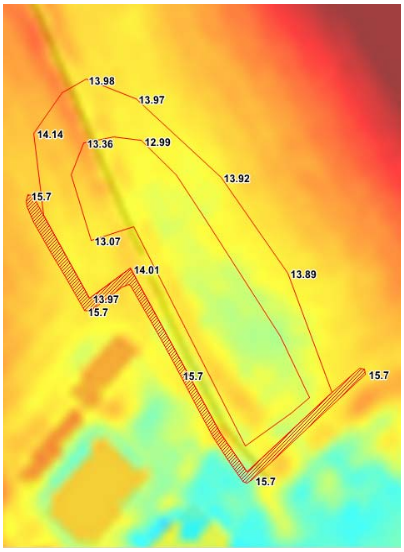
Norwich Urban Area Local Flood Mitigation Options Assessment

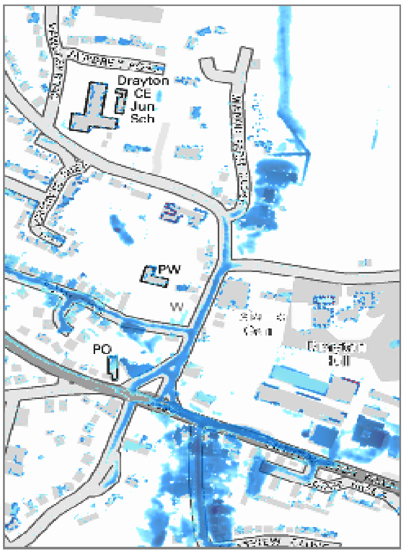
Prepared for:
Norfolk County Council

FINAL

UNITED KINGDOM & IRELAND

Norfolk County Council





REVISION SCHEDULE

Rev	Date	Details	Prepared by	Reviewed by	Approved by
1	June 2014	DRAFT For Client Comment	Danielle Skilton Flood Risk Consultant Stephanie Wood Assistant Engineer Martha Newman Graduate Engineer	Sarah Kelly Principal Consultant	Elizabeth Gent Principal Consultant
2	July 2014	Final Report for Issue	Martha Newman Graduate Engineer	Elizabeth Gent Principal Consultant	Elizabeth Gent Principal Consultant
3	November 2014	Final	Elizabeth Gent Principal Consultant	Elizabeth Gent Principal Consultant	Elizabeth Gent Principal Consultant

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1 INTRODUCTION

1.1 Project Background

The Norwich Urban Area has been identified as being at high risk to surface water flooding. As a result, Norfolk County Council (NCC) received early action funding to deliver the Norwich Urban Area Surface Water Management Plan (SWMP)[1]. The SWMP assessed the surface water flood risk across the whole contiguous urban area of the City and surrounding settlements. Completed in November 2011, the Norwich Urban Area SWMP has now achieved NCC cabinet sign off.

Broad-scale surface water modelling completed for the SWMP identified three areas to be at greatest risk of surface water flooding across the Norwich Urban Area. These were delineated as Critical Drainage Areas (CDAs). A number of surface water mitigation options were identified for each CDA, with the intention that they would be carried forward to NCC's Flood & Coastal Erosion Flood Risk Management Grant in Aid application (FCRM GiA). However, to inform the FCRM GiA applications further work focusing on the costs and benefits of the potential flood mitigation options is required.

1.2 Project Aims and Work Areas

The overall aim of the project is to provide a review of the mitigation options presented within the Norwich SWMP and include additional cost - benefit detail to enable the submission of the FCRM GiA applications.

To achieve this aim the project has been split into three work areas:

- Work Area 1: A review of the CDA extents to include the upstream catchments to create new 'Critical Drainage Catchments' (CDCs). Following the creation of the CDCs, re-calculation of the number of properties at risk of surface water flooding within each area. This work area comprised of the following sub-tasks:
    - Collection of the most up-to-date topographic data;
    - Use of Geographic Information Systems (GIS) to revise the CDA extents;
    - Review and update of the Norwich SWMP broad scale baseline surface water modelling;
    - Development of detailed surface water models for the CDC areas;
    - Calculation of the number of properties at risk of surface water flooding; and,
    - Mapping of baseline model results.
- Work Area 2: Re-consideration of the suitability of the Norwich SWMP options through further assessment of the potential cost - benefits of the mitigation options. This work area comprised of the following sub-tasks:
    - Review of the Norwich SWMP mitigation options against the updated baseline surface water modelling results;
    - Site walkover with NCC on the 20th of February 2014 to verify the updated baseline modelling, examine the potential feasibility of mitigation options and identify additional options to be considered;
    - Schematisation of the preferred flood mitigation options into the baseline surface water modelling;

[1] URS Scott Wilson (2011) *'Norwich Surface Water Management Plan',* URS: Scott Wilson: Basingstoke.

- Running of the detailed surface water models for each of the CDCs including the preferred flood mitigation options;
- Calculation of the number of properties at risk of surface water flooding when the preferred flood mitigation options are included; and,
- Mapping of the modelled options results alongside analysis of changes in flood depth.

- Work Area 3: Further assessment of the financial implications (residential / commercial / utilities and infrastructure) of surface water flooding within the CDCs to inform future FCRM GiA applications. This Work Area comprised of the following sub-tasks:
  - Estimation of costs for the preferred flood mitigation option;
  - Estimation of the potential residential and commercial damages (benefits) for each of the flood mitigation options;
  - Carrying out a cost - benefit analysis for each of the options; and,
  - Determining a Partnership Funding Score using the Environment Agency's Partnership Funding Calculator[2].

[2] Environment Agency's *'Partnership Funding Calculator',* available at https://www.gov.uk/government/publications/fcrm-partnership-funding-calculator accessed 23rd May 2014.

2 CRITICAL DRAINAGE CATCHMENTS AND BASELINE MODEL REVIEW

2.1 Norwich Wide Modelling

As part of the SWMP a broad-scale direct rainfall model covering the Norwich Urban Area was constructed.

The Norwich-wide model has been revised as part of this study to provide updated information on surface water flood risk across the Norwich Urban Area. This model has been updated to make use of Light Detecting and Ranging Data (LiDAR) and Ordnance Survey (OS) MasterMap data produced since the completion of the SWMP in 2011. In addition, the model was run with revised losses of 7mm/hr to the sewer network. The application of a uniform loss to the sewer network across the Norwich Urban Area forms one of the greatest assumptions within the modelling.

The updated modelling has been used to inform inputs into the detailed CDC models. Appendix B provides further information on how this model has been developed.

2.2 Revision of Critical Drainage Area (CDA) Extents

Using the latest LiDAR, the CDA extents identified as part of the SWMP have been reviewed to include the upper catchments. The inclusion of the upper catchments provides a more comprehensive model and baseline and means that there is more scope to manage surface water flooding at its source rather than focusing on where the problems become more apparent i.e. in the urban areas. These have been redefined as Critical Drainage Catchments (CDCs).

The CDCs have been defined using the 'Spatial Analyst' add-on tool in ESRI ArcGIS which completes the following steps:

1. Identify the location of "streams" by analysing flow direction across the LiDAR;
2. Locate the downstream points of these streams; and,
3. Use the watershed tool to determine the catchment associated with downstream points.

This methodology delineated a number of CDC areas across Norwich. The three CDC areas examined within this study are shown within Figure A1 in Appendix A. These remain the CDCs with the greatest flood risk and are as follows:

1. CDC1 – Drayton;
2. CDC2 – Catton Grove & Sewell; and,
3. CDC3 – Nelson & Town Close.

2.3 Detailed Modelling Methodology

TUFLOW modelling software has been used to develop three detailed direct rainfall hydraulic models for the CDCs of Drayton, Catton Grove & Sewell and Nelson & Town Close. These detailed models have been developed from the baseline Norwich Wide model. As part of the detailed modelling, the following enhancements have been made:

- Model extents reviewed and updated based on the hydrological catchment area;
- Use of catchment specific rainfall profiles;
- Increased resolution (smaller grid size) to gain additional detail in spatial representation of ground levels and features;

- Review and modification of the topographic data to incorporate features such as bridges and underpasses;
- Inclusion of revised building threshold levels and definition of road structures; and,
- Inclusion of a specific rate of loss of 7 mm/hr to the Anglian Water sewer network.

The detailed modelling provides an enhanced baseline representation of surface water flooding across the CDCs. For example, modification of the local topography through the inclusion of area-specific building thresholds, reduced road levels to represent kerbs and the addition of topographic features such as bridges and underpasses, has refined the local topography to better represent the overland flow paths.

Following the updates to the models, the baseline simulation was run to produce revised flood depth and hazard outputs for each of the CDCs. Each of the CDC models has been run for the following rainfall return periods:

- 3.3% Annual Exceedance Probability (AEP) (1 in 30 year);
- 1.33% AEP (1 in 75 year);
- 1% AEP (1 in 100 year);
- 1% AEP (1 in 100 year) including the effects of climate change; and,
- 0.5% AEP (1 in 200 year).

The modelling outputs are shown in Appendix C to E.

A complete list of Baseline and Option model runs can be viewed in Tables 2.3 and 3.3 respectively, in the Model Build Report (Appendix B), along with further details of the modifications and assumptions made to the CDC models.

2.4 Summary of model updates

Table 2-1 summarises the differences and revisions made to the models.

Table 2-1: Summary of model updates

	SWMP Modelling	Norwich Wide Modelling	Detailed CDC Modelling
Model Grid size (m)	5	5	2
Building Threshold (m)	0.25	0.1	0.1
Reduction in road level (m)	Not applied	0.125	0.125
LiDAR data (date flow)	1m & 2m (Feb 2010)	2m (February 2011)	2m (February 2011)
Mastermap date created	July 2009	December 2013	December 2013
Loss to the sewer network (mm/hr)	11	7	7

2.4.1 Model Limitations

Although the model has been greatly refined from the Norwich SWMP, there are still a number of limitations and assumptions that should be noted.

The model is not integrated with the Anglian Water sewer network, so continuous losses across the catchments have been assumed. Sensitivity analysis has shown that surface water flooding within the CDC areas is very sensitive to the loss to the sewer network in some places. Likewise, there is no account of potential surcharging of sewers across the catchment where they may reach capacity.

The threshold levels applied to the buildings has been set to 0.1 m; this is considered to be a representative estimate based on observations in a site walkover of the threshold levels across the CDCs, however in some instances this may be an underestimation. Due to the methodology adopted to determine the building threshold levels, there are a number of instances where buildings are below ground (predominantly on larger buildings on a steep slope). As a result, there is a tendency for water to accumulate within the building footprint. It is recommended that where properties are highlighted to potentially be at risk of surface water flooding, a site examination is undertaken to determine the true susceptibility to surface water flooding.

It should be noted that the mapping of the model results only shows the predicted likelihood of surface water flooding for defined areas. Due to the coarse nature of the source data used, the maps are not detailed enough to define risk for individual addresses. Individual properties therefore may not always face the same probability of flooding as the areas that surround them.

There may also be particular occasions when flooding has occurred in the past that does not match the predicted patterns shown on these maps. The maps reflect all the suitable and relevant data provided and have been produced using expert knowledge to create conclusions that are as reliable as possible. It is essential that users of these maps understand the complexity of the data and modelling utilised in their production and is also aware of the associated limitations and uncertainties in the mapping. The maps are not intended to be used in isolation.

2.5 Baseline Modelling Results

The inclusion of more detailed spatial representation of ground levels within the CDC has reduced the number of properties that are at risk in the baseline condition when compared to the strategic scale modelling results taken from the Norwich SWMP. This is due in part to the use of updated LiDAR as well as the detailed model having a finer representation of ground levels and structures which influence the movement of overland flow. This means that the detailed CDC model redefines flow paths (particularly along residential roads) and hence routes surface water more accurately.

2.5.1 CDC1 – Drayton

The baseline flood depth and hazard maps are presented in Appendix C Figures C1.1 to C2.5.

The baseline modelling shows there to be three predominant overland flow paths across the CDC, one draining from the northwest, one the north and the other the northeast. The flow paths originate from surface water runoff from agricultural land and generally follow the natural topography of the land. The flow paths converge at the junction of School Road and Drayton High Road before flowing along Low Road towards the River Wensum in the south.

The flow paths across the CDC are defined predominantly by the topography of the land; however, the presence of road and building structures also has an influence on flow. The channel within the roads has the tendency to cause surface water to follow the path of the road, whereas buildings act as obstructions, causing water to pond outside the building and flow around the building.

The maximum flood depths (1.3m for the 1% AEP (1 in 100 year) event) in this CDC are modelled to be in the Drayton Hall Mobile Home Park. There is also significant flooding along part of George Drive, Low Road, Drayton Grove and Marriot Chase.

2.5.2 CDC2 – Catton Grove

The baseline flood depth and hazard maps are presented in Appendix D Figures D1.1 to D2.5.

The Catton Grove CDC area is defined by a predominant flow path flowing from Old Catton in the north to the River Wensum in the south. In addition there are a number of lateral flow paths from the west and east, such as from the Sprowston area, Mousehold Heath and Upper Hellesdon.

The flows paths are again predominantly influenced by the topography of the area; however there are a number of more obvious occasions where the channel of the road has influenced the flow of water such as Angel Road and Heath Road. Additionally, there are instances where surface water is restricted by the embankment of a raised road, such as the flow from Old Catton reaching Chartwell Road.

The areas of greatest flood depths are predicted to occur in Tanager Close, Long Row, to the north of Albany Road and the paddock at Old Catton. The flood depths here are a result of local topographic low points that result in the accumulation of overland flow.

2.5.3 CDC3 – Nelson & Town Close

The baseline flood depth and hazard maps are presented in Appendix E Figures E1.1 to E2.5.

The Nelson & Town Close CDC area has a dominant flow path that flows from the south east to the north. There are a number of lateral inflows from the west of the CDC that join the main flow path as it flows towards the north. The topography of the CDC is defined by a number of relatively steep valleys that slope towards the shallow gradient of the floodplain.

Within the CDC, the greatest area of surface water flooding is predicted to occur within the area between Park Lane and West Parade. Water accumulates in this area as it is along the main flow path channel. The presence of the slightly elevated Earlham Road acts as an embankment, causing water to accumulate behind the road.

Additionally to this, the modelling also indicates substantial depths of surface water flooding to occur at Gladstone Road (and adjacent roads), Doris Road (and adjacent Roads) and Ely Street and Heigham Street to the south.

There are a number of roads that act as main flow paths, channeling surface water across the area. These include Jessop Road, Earlham Road and Unthank Road which channel water in an easterly direction.

2.6 Flooded Property Counts

The number of properties at risk for each return period has been calculated across the three CDCs. Details of the property type have been inferred from the Environment Agency's National Receptor Database (NRD).

Property counts have been completed for the following rainfall return periods which correlate to the FCRM GiA categories of 'significant', 'moderate' and 'low' flood risk and will be used to inform the cost-benefit analysis. These return periods also allow for comparison with the modelled option property counts (as described later in Section 3.9):

- 3.3% AEP (1 in 30 year – Significant Risk);
- 1% AEP (1 in 100 year) – Moderate Risk; and,
- 0.5% AEP (1 in 200 year) – Low Risk.

To provide greater confidence that the properties would actually flood under each of the return periods and to overcome the various assumptions and limitations within the modelling (as described in Section 2.4.1), property counts have been completed for all property centre points flooding to a depth of 0.1m or greater.

The flooded property counts for each of the CDCs are provided in Table 2-2. In order to inform the detail of the cost - benefit assessment, counts have been completed for residential and non-residential buildings.

As part of the cost – benefit assessment, residential buildings have been further classified based on their location within areas (Lower Layer Super Output Areas) ranked within the Indices of Multiple Deprivation. These are classified as being ‘less deprived’, ‘mid deprived’ or ‘most deprived’. It should be noted that the deprivation classification has an impact on the partnership funding score.

Non-residential properties include all other buildings including commercial buildings, shops, hospitals and schools amongst others.

The property counts are considerably higher than the original counts completed as part of the SWMP. This is likely to be due to a number of reasons including the reduced building threshold levels and the larger coverage of the CDC boundaries.

Table 2-2: Baseline Property Counts

Annual Exceedance Probability (AEP)	Property Type	Property Count (all flooded properties at 0.1m depth or greater)		
		CDC1 - Drayton	CDC2 – Catton Grove	CDC3 – Nelson and Town Close
3.3% AEP (1 in 30 year) Significant Risk	Residential	260	2,169	1,727
	Non -Residential	94	321	290
	TOTAL	**354**	**2,490**	**2,017**
1% AEP (1 in 100 year) Moderate Risk	Residential	422	3,219	2,426
	Non -Residential	126	545	414
	TOTAL	**548**	**3764**	**2,840**
0.5% AEP (1 in 200 year) Low Risk	Residential	548	3,946	2,948
	Non -Residential	158	679	514
	TOTAL	**706**	**4,625**	**3,462**

3 OPTIONS REVIEW AND APPRAISAL

3.1 Introduction

The Norwich SWMP identified a number of flood mitigation options that were considered to help alleviate flood risk from surface water flooding within defined CDAs in the Norwich Urban Area. As part of this study these options have been reviewed and the options appraisal revisited using the results from the updated CDC baseline surface water modelling.

3.2 Options Appraisal Methodology

A number of options were identified for consideration within each of the CDCs as part of the SWMP. These were identified following the source-pathway-receptor conceptual model.

The source-pathway-receptor model describes the conceptual mechanism of flooding. For flooding to occur, there must be a source of flooding, a receptor to flooding, and a pathway linking the two. The identification of possible flood alleviation options has been based around this concept, as described below.

- **Source** – source options aim to reduce the rate and volume of surface water runoff through infiltration or storage, hence reducing the impact on the local drainage network.
- **Pathway** – pathway options seek to manage the overland (and underground) flow pathways of water in the urban environment.
- **Receptor** – receptor options intend to reduce the impact of flooding to those that are affected (people, properties and the environment).

The options considered include both structural and non-structural measures. Structural options have been defined in the Defra SWMP Guidance[3] as those which require fixed or permanent assets to mitigate flood risk. Non-structural measures are defined as those which may not involve fixed or permanent assets, but contribute to the reduction of flood risk through influencing behaviour.

To refine the large number of potential measures into a short-list the criteria presented in Defra's SWMP Guidance[3] has been utilised. These criteria score each of the options based on 'technical', 'economic', 'social', 'environmental' and 'objectives'. The full options assessment table for each of the CDCs is included in Appendix F.

The short-listed options for each of the CDC's are described in the following paragraphs. To establish the potential benefits of the flood mitigation options the short-listed options for each CDC were included in the baseline surface water modelling. To incorporate the options it has been necessary to make some indicative sizings based on review of the topography, geology and engineering judgement. These would need to be refined as part of outline design.

3.3 CDC1 - Drayton

At this stage the costs of each option have not been included in the appraisal, except in high-level terms of scoring the economic impact (negative or positive cost benefit) for the options assessment table (Appendix F). This is to ensure that the costs of the options do not bias the appraisal process. The costs of each of the preferred options have been determined as part of the cost - benefit assessment, included in Section 4.

3.3.1 SWMP Preferred Options

The Norwich SWMP analysed a number of options for CDC1 with the preferred options being:

[3] Defra (2010) *Surface Water Management Plan Technical Guidance',* Defra: London.

- Installation of borehole soakaways;
- Agricultural land management;
- Four flood storage areas across Drayton in the following locations: in the west of Drayton, north of Manor Farm Close, Pond Lane and on land to the east of George Drive;
- Increased watercourse conveyance for the ditch located in the western part of Drayton; and,
- Alternative flow route for the ditch located in the west of Drayton by utilising the public surface water sewer in Marriott Way.

In addition to the options identified within the SWMP, an option for an infiltration trench, located along the northern and eastern boundaries of the Drayton Hall Mobile Home Park has also been identified.

A full list of the options and assessment of these is provided in Appendix F.

3.3.2 Discounted SWMP Options

A number of the SWMP options have been discounted as they are not considered to be feasible following a review of the updated baseline surface water modelling and further investigation of the local conditions such as flooding mechanisms, geology, topography and sewerage infrastructure. These include:

- Borehole soakaways: Approximate groundwater levels across Norwich and the surrounding areas shows that in Drayton, the groundwater is typically between 5m to and 10m below ground level. In addition to this, the ground beneath Drayton is classified as a Principal Aquifer[4] by the Environment Agency[5]. Therefore, borehole soakaways are not deemed feasible in this area due to the potential risk of contaminating the groundwater.
- The flood storage adjacent to Pond Lane: This has been discounted as the area available for storage is small, thus the impact this would have on the alleviation of flood risk would be minimal.
- The flood bund proposed east of George Drive: This has been discounted as the topography of the area does not lend itself to flood storage without excessive excavation work.
- Increased watercourse conveyance: Increasing the conveyance of this ditch in west Drayton would 'speed up' the flow of water, in turn putting the properties downstream of the ditch at greater risk of flooding. Weirs could be used to reduce the rate of flow, however, the increase in capacity that would be provided by clearing the ditch and installing weirs would have minimal impact on alleviating the flood risk downstream of the ditch.
- Alternative flow route: Diverting flows from the ditch west of Drayton to the surface water sewer in Marriott Way was proposed in the Norwich SWMP. Since reviewing the topography of this area and the level of the sewer in Marriott Way, it appears that the sewer is too high to enable a sufficient gravity connection from the ditch. Flows from the ditch would likely need to be pumped to the sewer.

[4] Principal aquifers typically have a high fracture permeability that can provide a high level of water storage that can support water supply and/or river base flow on a strategic scale.

[5] Environment Agency Groundwater Maps. available online at http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683.0&y=355134.0&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=groundwater [Accessed on 06/01/2014]

3.3.3 CDC1 Preferred Options

Following discussions with the SWMP Steering Group the following preferred options were considered for further assessment:

- Option CDC1-1: A flood storage area on land north of Manor Farm Close, adjacent to Pond Lane and on land to the east of George Drive has scored highly in the options appraisal. As the land is allocated for development, the developer will be required to install attenuation features with capacity for a 1% AEP (1 in 100 year) event with climate change event under planning policy. Therefore funding through the SWMP Steering Group would not need to be sought. As this option does not need to seek funding this has not been considered further in the study, however the SWMP Steering Group should ensure liaison with the developers and planning team to ensure appropriate measures are incorporated into the sites design.

- Option CDC1-2: A Flood Storage Area (FSA) could be located in the agricultural land located north-west of Drayton Grove, with an approximate volume of 1,500m^3. This would act to intercept flows from a large part of the western extent of the catchment.

- Option CDC1-3: An infiltration swale could be located on the eastern and northern boundaries of Drayton Hall Mobile Home Park. In accordance with the SuDS Manual (CIRIA C697) the following assumptions have been made as part of this study:

  - The infiltration swale would have a total length of 300m;
  - The base will be approximately 1m wide;
  - The crest of the swale will be approximately 9m wide; and,
  - An infiltration rate of 1x10^{-5} m/s has been assumed.

  It should be noted, that the feasibility of this option is dependent on an investigation into the permeability of the ground beneath Drayton.

- Option CDC1-4: Agricultural Land management is a potential quick win option that could be implemented through communication and education. Measures include increasing tree coverage and ploughing land in a perpendicular direction to the contours of the land. As this option is predominantly a non-structural scheme, with no capital costs, it has not been considered further within this study. The SWMP Steering Group should seek to undertake this option as part of their current communication and engagement activities.

3.4 CDC2 – Catton Grove and Sewell

3.4.1 SWMP Preferred Options

The Norwich SWMP analysed a number of options for CDC2 with the preferred options being:

- Retro-fit SuDS;
- Installation of borehole soakaways; and,
- A flood storage area in Catton Park, to the north of the CDC; and,
- A flood storage area within the grounds of Angel Road Junior School.

In addition to the options identified within the SWMP, the following options have also been identified:

- A swale adjacent to Ives Road;

- Underground storage at Sleaford Green; and,
- Underground storage at Lawson Road.

A full list of the options and assessment of these is provided in Appendix F.

3.4.2 Discounted SWMP Options

Borehole soakaways have been discounted as, following further investigation, it was found that this option is not viable as the groundwater beneath CDC2 is typically between 0 m to 5 m below ground level. In addition to this, the ground beneath Norwich is classified as a Principal Aquifer by the Environment Agency. Therefore, borehole soakaways are not deemed feasible in this area due to the potential risk of contaminating the groundwater.

3.4.3 CDC2 Preferred Options

Following discussions with the SWMP Steering Group the following preferred options were considered for further assessment:

- Option CDC2-1: Flood storage area in Catton Park – This flood attenuation basin could be located in the south of Catton Park, adjacent to Oak Lane. The flood attenuation area will have an approximate volume of 1,500 m^3.
- Option CDC2-2: Swale at Ives Road – An attenuation swale could be incorporated into the green space adjacent to Ives Road. The following assumptions have been made as part of this study:
    - The swale would have a total length of 400 m;
    - The base will be approximately 1m wide; and,
    - The crest of the swale will be approximately 9m wide.
- Option CDC2 - 3, 4, 5 & 8: Retrofit SuDS – Small, residential scale attenuation SuDS such as water butts and tanked permeable paving have been identified as suitable for a number of residential properties located in Oak Lane, Pembrey Close, Ardney Rise, Tanager Close, Waterloo Road, Temple Road, Albany Road, Heath Road, Shipstone Road, Clarke Road, Guernsey Road, Stacy Road and Magpie Road and Catton Grove Road. All of these roads are affected by the flood flow pathways across this CDC. This option has not been investigated further within this CDC, but is considered within CDC3 as described in Section 3.5 below.
- Option CDC2-6: Flood storage at Sleaford Green – A series of geocellular storage crates could be incorporated into the green spaces of Sleaford Green. The following assumptions have been made as part of this study:
    - The geocellular storage crates will have a combined plan area of 400 m^2;
    - They will be 0.8 m deep; and,
    - The combined rate of discharge will be restricted to 10 l/s.
- Option CDC2-7: Flood storage area at Angel Road Junior School – A flood attenuation feature in the form of underground storage, such as geocellular storage crates or permeable paving, has been assumed for this area. The following assumptions have been made as part of this study:
    - The surface water storage feature will have an approximate volume of 1,000 m^3; and,
    - A maximum discharge rate of 5 l/s has been assumed.

- Option CDC2-9: Flood storage area between Lawson Road and Denmark Road – The space between these two roads has a number of large car parking areas. These areas could incorporate a storage tank with a combined approximate volume of 1,250 m^3. A total discharge rate of 20 l/s has been assumed.

3.5 CDC3 – Nelson and Town Close

3.5.1 SWMP Preferred options

The Norwich SWMP analysed a number of options for CDC3 with the preferred options being:

- Retrofit SuDS;
- Installation of borehole soakaways; and,
- A flood storage area in Eagle Park which is located south of Newmarket Street.

3.5.2 Discounted options

A number of the SWMP options have been discounted as they are not considered to be feasible following a review of the updated baseline surface water modelling and further investigation of the local conditions such as flooding mechanisms, geology, topography and sewerage infrastructure. These include:

- Borehole soakaways have been discounted as, on closer inspection, it was found that this option is not viable as the groundwater beneath CDC3 is typically between 0m to 5m below ground level. In addition to this, the ground beneath Norwich is classified as a Principal Aquifer by the Environment Agency. Therefore, borehole soakaways are not deemed feasible in this area due to the potential risk of contaminating the groundwater.
- Recent improvements to play facilities at Eagle Park have included small scale flood mitigation measures . There is little potential for the creation of additional storage at the park to provide further alleviation of flood risk to CDC3. Therefore, this option is not considered further.

Due to the highly urban nature of CDC3 no larger schemes, such as flood storage areas, have been identified as there is insufficient space to accommodate such options.

3.5.3 CDC3 Preferred Options

Following discussions with the SWMP Steering Group the only preferred options for further assessment within CDC3 are:

- Option CDC3-1: Retrofit SuDS have been identified as the only a feasible option to model. Small, residential scale attenuation SuDS such as water butts and tanked permeable paving have been identified as suitable for the majority of properties within the CDC.
- Option CDC3-2: Property level flood protection has been identified as a potential option for properties at significant risk of flooding. This could be implemented through a range of resistance and resilience measures. It should be noted that this option is not exclusive to CDC3 and has been examined in this instance to assess the suitability.

3.6 Norwich Wide Options

In addition to the specific options outlined above, there are a number of preferred options which scored highly within each of the CDCs. These could therefore be considered for future implementation across the whole Norwich Urban area. These include:

- Property level flood protection, including resilience and resistance measures, could be implemented across buildings identified as being at risk of surface water flooding;
- Community resilience, through working with flood groups and other community groups to raise awareness and develop community flood plans; and,
- Retrofit SuDS at property level, either small scale attenuation measures such as water butts or infiltration SuDS.

It should be noted that the improved maintenance regimes, property level protection and community resilience options have not been taken forward to be modelled as the benefit from any one of these will be local to the building or cannot be quantified.

Property level protection is however considered as an alternative option for CDC3, and has been examined within the cost-benefit analysis.

3.7 Options Modelling Methodology

Following the completion of the options appraisal, the preferred options have been incorporated into the detailed baseline CDC models. This has been undertaken to establish the potential benefit, in terms of reduction in flood depth that each option could offer for a range of return period events.

Table 3-1 details the options taken forward to be modelled as these were shown to demonstrate a high level of feasibility.

As described in section 2.5, the options models have been run for the following rainfall return periods which correlate to the FCRM GiA categories of ‘significant’, ‘moderate’ and ‘low’ flood risk and will be used to inform the cost-benefit analysis:

- 3.3% AEP (1 in 30 year – Significant Risk);
- 1% AEP (1 in 100 year) – Moderate Risk; and,
- 0.5% AEP (1 in 200 year) – Low Risk.

Further details on how the options have been represented are included in the Model Build Report (Appendix B).

Table 3-1: Preferred Options Modelled

CDC	Potential Flood Mitigation Option Reference and Description
CDC1 - Drayton	CDC1-2 – Flood storage area to the north-west of Drayton
	CDC1-3 – Infiltration swale in the east of Drayton
CDC2 – Catton Grove and Sewell	CDC2-1 – Flood storage area to the north of Oak Lane in Old Catton
	CDC2-2 – Swale alongside Ives Road
	CDC2-6 – Underground storage in the green spaces in Sleaford Green
	CDC2-7 – Underground storage in the playground of Angel Road Junior School
	CDC2-9 – Underground storage between Lawson Road and Denmark Road
CDC3 – Nelson and Town Close	CDC3-1 – Retrofit water butts and SuDS storage options

3.8 Options Modelling Results

3.8.1 CDC1 – Drayton

The flood storage area to the west of the CDC and the infiltration trench to the east have been represented through the alteration of the elevation of the land. The infiltration trench has additionally been assigned an increased infiltration rate of $1x10^{-5}$ m/s. The location of these options can be seen in Figure C3.0 in Appendix C.

Figures C3.1 – C3.3 (Appendix C) illustrate the flood depths across the CDC with the incorporation of these options as well as the depth difference between the baseline scenario and the modelled option scenario.

The infiltration trench modelled functions to intercept the overland flow path flowing from the north east to south west. The capacity of the trench could potentially be increased, through the development of a bund on the downstream end, to allow for a greater volume of water to be retained within the trench. Little ponding is observed as the high infiltration rates allows for a more rapid loss of water.

The resulting effect of the infiltration trench in the flooding hotspot at Drayton Hall Mobile Home Park is minimal. There is shown to be a reduction of approximately 9 mm in flood depth across the flood hotspot area (approximately 0.17 ha) for the 3.3% AEP event. The reduction in flood depth is less with the larger return period events. This indicates that the capacity of the trench would need to be considerably larger to accommodate volumes of runoff necessary to further reduce the flood depths. In addition, intercepting the flow from the south will have added benefit. There is no effect on flood depths downstream of the infiltration trench.

The flood storage area intercepts overland flow from the catchment to the west. Within the modelled scenario, the flood storage fills to a depth of 1.7 m in the 0.5% AEP event. In all scenarios, surface water spills from the storage area around the bunds at the north and east. The depth difference map shows that the flood storage area has a positive benefit on reducing the flood depth along the flow path to the south. The benefit on reducing flood depth is greatest just downstream of the storage area for the 3.3% AEP event.

3.8.2 CDC2 – Catton Grove

The options scenario for CDC2 looked at a suite of measures which have been implemented across the CDC area. The location of these options can be seen in Figure D3.0 in Appendix D.

Figure D3.1 – D3.3 illustrates the flood depths across the CDC with the incorporation of these options as well as the depth difference between the baseline scenario and the modelled option scenario.

The storage basin at Oak Lane in Old Catton and the swale within the green space along Ives Road has been represented through the modification of the model topography to provide the required storage volumes.

The storage tank options at Sleaford Green, Angel Road Junior School and Lawson Road have been represented through the development of a 1D network. This works to drain all the water from the roof areas of the selected buildings, to a storage node of a specified capacity, before water is then discharged at a given rate. In order to model this scenario, the building footprints were raised to 1.5 m to ensure that no overland flow would drain to the storage tank areas. This has had an additional impact of causing the buildings to act as barriers to the flow (see Figure 3-1). *Therefore caution should be used when looking at the results downstream,, as it is unclear how much of the reduced flood depths downstream are as a result of the flood storage tank or the ‘barrier to flow’ created by the raised building footprints.*

The flood storage basin in Oak Lane has been increased in capacity and, as a result, water depth of up to 2 m is modelled to be retained for the 1% AEP event. This has had an effect on the downstream area, with up to a 15 mm reduction in flood depths around the properties to the east of Oak Lane.

The swale adjacent to Ives Road has resulted in a reduction in the flood depths up to 0.5 km downstream of the swale. The greatest benefit (up to 50 mm) is seen adjacent to the swale. There is a reduction of approximately 10 mm up to 0.5 km from the swale.

The storage tanks at Sleaford Green have been modelled to show greater flooding locally to the buildings, based on the impact of raising the building threshold and intercepting the flow. There is however a benefit (50 mm reduction) to the flood depths downstream of the area. There is minimal wider benefit beyond the Sleaford Green area.

The storage tank at Angel Road Junior School has had a very significant effect – this may largely be due to the up-stand of the buildings intercepting flows. The result is up to 1.2 m of water accumulating in the playground area of the school. This has also increased the flood risk upstream of the school (as seen in Figure 3-1 this may be due to how the storage tank is represented in the model). The impact on the downstream area is however greater with a reduction in flood depths up to 1.2 km downstream. Flood depths have decreased by 10 mm – 150mm. In order to prevent the upstream area being at greater risk of flooding, the storage tank size could be increased to provide a greater capacity. The volume of water held within the area is approximately 11,500 m^3 for the 1% AEP event. C*aution should be used when looking at the results downstream of the School, as it is unclear how much of the reduced flood depths are as a result of the flood storage tank or the 'barrier to flow' created by the raised building footprints in the model.*

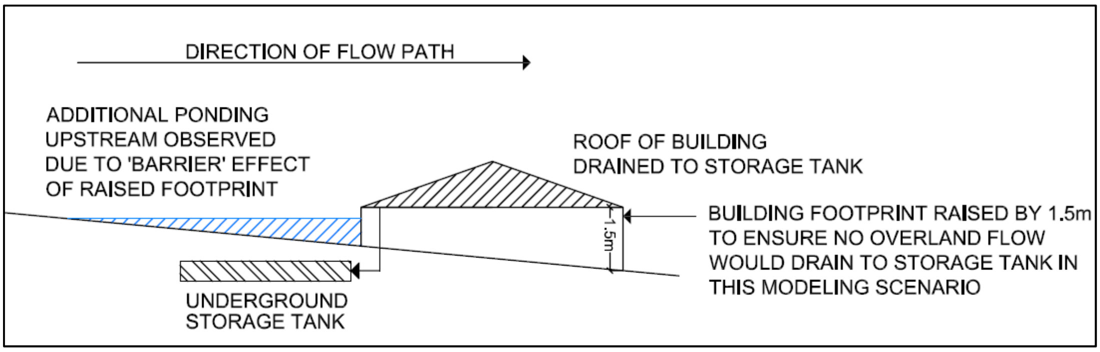


Figure 3-1: Ponding upstream of Angel Road School

The storage tanks at Lawson Road have had a slight negative effect as a result of the option implementation. This is largely based on the higher building up-stand causing water to accumulate behind the buildings (as per Figure 3-1). There is a knock on effect within the area upstream of this where flood depths at Layson Drive are reduced. This may be a result of the change in the flow path just downstream or as a result of the raised building footprint in the model as outlined in Figure 3-1. C*aution should be used when looking at the results around the School, as it is unclear how much of the change in flood depths are as a result of the flood storage tank or the 'barrier to flow' created by the raised building footprints in the model.*

3.8.3 CDC3 – Nelson & Town Close

The retrofitting of SuDS options using water butts has been incorporated into a small section of the CDC. This has been done to see the relative impact that the implementation on SuDS can have on the wider area. 1,070 properties around the Gladstone Road area have been modelled as these are considered to be representative of the property types of the CDC. Figure E3.0 in Appendix E shows the location of where this has been implemented in the model.

It was assumed that each property would have, as a minimum, 0.4 m^3 of storage of rainfall through the provision of water butts (this is equivalent to two standard 240l water butts). These would therefore collect the first 0.4 m^3 of runoff from the roof areas before filling and spilling to the drainage network.

The average roof area in this area is equal to 52 m^2. The equivalent rainfall depth for 0.4m^3 equates to 7.7 mm across the roof area. Therefore, within the model, it has been assumed that the first 7.7 mm of rainfall is "lost". This method assumes that the water butts are empty to start with and that all the water from the roof would drain to the water butts.

Figure E3.1 – E3.3 illustrates the flood depths across the CDC with the incorporation of these options as well as the depth difference between the baseline scenario and the modelled option scenario.

It can be seen that this option has a notable effect on the flood depths within the residential area as well as further downstream. The benefit area extends across an area up to 500m away from the area of option implementation. The area with the greatest flood depth reduction is that around the flood hotspot area to the north of Gladstone Road and Heigham Road, West End Street and Dereham Road. This option requires effective communication to property owners regarding the use of water from the water butts to ensure they are emptied regularly and therefore would have capacity for rainfall storage or they are designed to be self-draining (with further investigation under this option to ensure there is no risk to foundations through subsidence).

For this CDC, property level protection is considered a preferred option. It should be noted that this has not been modelled as property level protection only provides benefit to the individual property. In the following cost – benefit analysis, the implementation of this measure will assume property level protection is applied to all properties within the CDC area that are at risk from flooding in the 3.3% AEP event.

3.9 Flooded Property Counts Post-Options Implementation

The property counts (across each CDC area), following the incorporation of the preferred options, are included in Tables 3-2, 3-4 and 3-6. Tables 3-3, 3-5 and 3-7 summarise the difference between the baseline property counts (as detailed in Table 2-2) and option property counts, i.e. the numbers of properties that are predicted to 'benefit' and no longer flood due to the implementation of the flood mitigation options. Where property level protection has been proposed it was assumed that a 1 in 30 year standard of protection was met.

Property counts were completed for the entire CDC areas for CDC1 and CDC3 as the options were examined independently. For CDC2, as the options were modelled simultaneously, a different approach was taken in order to quantify the benefit for each of the options. A 'benefit area' was identified for each option, based on the area in which flood depth was reduced as a result of the measure implemented. Therefore, within Tables 3-4 and Table 3-5 the counts area based on the benefit area downstream, rather than the entire CDC.

Table 3-2: CDC1 Modelled Option - Flooded Property Counts Post-Scheme

Annual Exceedance Probability (AEP)	Property Count (all flooded properties at 0.1m depth or greater)					
	Baseline		Option CDC1 – 2 Flood Storage Area NW Drayton		Option CDC1 – 3 Infiltration Swale East Drayton	
	Res.*	Non-Res.**	Res.	Non-Res.	Res.	Non-Res.
3.3% AEP (1 in 30 year)	260	94	259	95	256	94

Annual Exceedance Probability (AEP)	Property Count (all flooded properties at 0.1m depth or greater)					
	Baseline		Option CDC1 – 2 Flood Storage Area NW Drayton		Option CDC1 – 3 Infiltration Swale East Drayton	
	Res.*	Non-Res.**	Res.	Non-Res.	Res.	Non-Res.
1% AEP (1 in 100 year)	422	126	422	126	422	125
0.5% AEP (1 in 200 year)	548	158	547	156	546	158

* Res. Residential property (Res.)
** Non-Residential (Non Res.)

Table 3-3: CDC1 Difference in Flooded Property Counts Between Baseline and Option Scenarios

Annual Exceedance Probability (AEP)	Property Count (all flooded properties at 0.1m depth or greater)			
	Option CDC1 – 2 Flood Storage area NW Drayton		Option CDC1 – 3 Infiltration Swale East Drayton	
	Res.	Non-Res.	Res.	Non-Res.
3.3% AEP (1 in 30 year)	-1	+1	-4	0
1% AEP (1 in 100 year)	0	0	0	-1
0.5% AEP (1 in 200 year)	-1	-2	-2	0

Table 3-4: CDC2 Modelled Option - Flooded Property Counts Baseline & Post-Scheme

(a) Baseline

Annual Exceedance Probability (AEP)	Property Count (all flooded properties at 0.1m depth or greater)									
	CDC2 - 1 FSA* (Oak Lane)		CDC 2 - 2 Swale (Ives Road)		CDC2 - 6 FSA (Sleaford Green)		CDC 2 - 7 FSA (Angel Road)		CDC 2 - 9 FSA (Lawson Road)	
	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.
3.3% AEP (1 in 30 year)	12	0	168	29	96	6	259	38	14	4
1% AEP (1 in 100 year)	14	0	207	38	139	6	473	150	24	7
0.5% AEP (1 in 200 year)	18	0	258	42	167	6	574	190	29	9

* Flood Storage Area (FSA)

(b) Post-Scheme

Annual Exceedance Probability (AEP)	Property Count (all flooded properties at 0.1m depth or greater)									
	CDC2 - 1 FSA (Oak Lane)		CDC 2 - 2 Swale (Ives Road)		CDC2 - 6 FSA (Sleaford Green)		CDC 2 - 7 FSA (Angel Road)		CDC 2 - 9 FSA (Lawson Road)	
	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.
3.3% AEP (1 in 30 year)	12	0	166	28	92	6	170	33	14	3
1% AEP (1 in 100 year)	13	0	205	38	126	6	441	140	19	4
0.5% AEP (1 in 200 year)	17	0	257	41	144	6	562	186	24	6

Table 3-5: CDC2 Difference in Flooded Property Counts between Baseline and Option Scenarios

Annual Exceedance Probability (AEP)	Property Count (all flooded properties at 0.1m depth or greater)									
	CDC2 - 1 FSA (Oak Lane)		CDC 2 - 2 Swale (Ives Road)		CDC2 - 6 FSA (Sleaford Green)		CDC 2 - 7 FSA (Angel Road)		CDC 2 - 9 FSA (Lawson Road)	
	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.
3.3% AEP (1 in 30 year)	0	0	-2	-1	-4	0	-89	-5	0	-1
1% AEP (1 in 100 year)	-1	0	-2	0	-13	0	-32	-10	-5	-3
0.5% AEP (1 in 200 year)	-1	0	-1	-1	-23	0	-12	-4	-5	-3

Table 3-6: CDC3 Modelled Option - Flooded Property Counts Post-Scheme

Annual Exceedance Probability (AEP)	Property Count (all flooded properties at 0.1m depth or greater)					
	Baseline		CDC3 - 1 Attenuation SuDS		CDC3 - 2 Property Level Protection (3.3% AEP)	
	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.
3.3% AEP (1 in 30 year)	1,727	290	1,665	285	0	290
1% AEP (1 in 100 year)	2,426	414	2,360	409	2,426	414
0.5% AEP (1 in 200 year)	2,948	514	2,852	505	2,948	514

Table 3-7: CDC3 Difference in Flooded Property Counts Between Baseline and Option Scenarios

Annual Exceedance Probability (AEP)	Property Count (all flooded properties at 0.1m depth or greater)			
	CDC3 - 1 Attenuation SuDS		CDC3 - 2 Property Level Protection (3.3% AEP)	
	Res.	Non-Res.	Res.	Non-Res.
3.3% AEP (1 in 30 year)	-62	-5	-1727	0
1% AEP (1 in 100 year)	-66	-5	0	0
0.5% AEP (1 in 200 year)	-96	-9	0	0

3.10 Summary of Options Review and Appraisal

The options assessment highlighted a range of options for each of the CDC areas that could be implemented to help with managing the surface water flood risk. A selection of these were incorporated into the detailed baseline modelling to determine their potential benefit.

A high level assessment of the number of properties removed from flooding at each of the return periods has been undertaken. In summary:

- CDC1 - Option CDC1-3, an infiltration swale at East Drayton provides the greatest benefit of the options modelled, however a minimal number of properties benefit.
- CDC2 - Option CDC2-7 flood storage at Angel Road School provides the greatest benefit of the options modelled.
- CDC3 - CDC3-2 Property Level Protection provides the greatest benefit, removing 1727 properties from flooding within the 3.3% AEP event.

4 COST BENEFIT ANALYSIS

4.1 Introduction

Cost benefit analysis is a systematic approach that has been developed to select the most appropriate option through valuing the potential benefits against its lifetime costs.

As part of this study a high-level cost benefit assessment has been carried out. Additionally, as the schemes are likely to be seeking funding through FCRM GiA the Partnership Funding Score, as determined though the Environment Agency's Partnership Funding Calculator, has been assessed.

4.2 Cost - Benefit Analysis Methodology

The cost-benefit assessment of each of the preferred mitigation measures has been carried out in accordance with the Environment Agency's Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG)[6], and the Multi-Coloured Manual (MCM)[7].

The Partnership Funding Rapid Assessment tool, developed by URS, has been used to provide an Overview Appraisal of scheme benefits and the predicted Environment Agency Partnership Funding Score (see Section 4.2.1). The Tool has been developed by URS to provide a high-level assessment of the economic benefits of flood mitigation options based on a range of parameters including the number of properties flooding pre- and post-mitigation and the cost of the proposed scheme. The tool is developed in accordance with the Environment Agency's Partnership Funding Calculator and completes the calculator as part of the assessment to determine the Raw and Adjusted Partnership Score for each mitigation option.

To calculate the potential benefits of each flood mitigation measure, the Partnership Funding Rapid Assessment Tool applies the MCM Weighted Annual Average Damage approach. This approach uses the flooded property counts estimated in the hydraulic modelling for the 3.3% AEP (1 in 30 year), 1% AEP (1 in 100 year) and 0.5% AEP (1 in 200 year) rainfall events, as requested by the Client. Flooded property counts for the return periods in between these are interpolated. The flooded property counts are then used to determine the value of damage due to flooding that the CDC may be subjected to over the lifetime of the scheme, a value which is then used to represent the financial 'benefit' that will be gained as a result of the implemented flood mitigation measure. The return periods used within the Partnership Funding Calculator are 5% AEP (1 in 20 year), 1.3% AEP (1 in 75 year) and 1% AEP which are considered a 'Very Significant' risk, a 'Significant' risk and a 'Moderate' risk, respectively. Therefore the results displayed within the PF Calculator will be different to those displayed within the tables in section 3.9, which are showing property counts for different return periods.

The lifetime costs of the potential flood mitigation schemes have been estimated based on SPONS 2014[8]. The costs include design and construction costs but exclude legal

[6] Environment Agency. (2010). *Flood and Coastal Erosion Risk Management appraisal guidance*. Bristol: Environment Agency

[7] Defra. (2005). *The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques*. London: Middlesex University Press.

[8] AECOM. (2014). *SPON'S Civil Engineering and Highway Works Price Book* 28th Edition. CRC Press.

costs, site surveys, maintenance[9], inflation from May 2014, Value Added Tax (VAT), allowance for unknown ground conditions and costs associated with wayleaves and third party issues. At this early stage a number of assumptions have been made in each of the cost estimates, for example, the assumption that there is no contaminated land. In line with FCERM-AG a 60% optimism bias or contingency has been added to the costs to reflect the level of uncertainty in the costings at this high-level assessment stage.

Where property level flood protection (PLP) has been selected as a preferred option, it is assumed that a cost of £5000 per property will be incurred, based on the JBA Consulting Evaluation of Defra Property Level Flood Protection study[10] and includes an individual property survey, the implementation of protection measures and administration.

The following generic assumptions have been applied to the cost benefit analysis:

- Property counts for depth of flooding greater than 0.1m at the centre point of the property;
- Potential benefits of the options are measured using a count of the properties which could benefit from a reduction in flood risk;
- All non-residential properties have been classed as commercial for the purposes of the cost - benefit assessment;
- The commercial footprint has been based on the MCM mean of 418m^2;
- All mitigation measures will have a 100 year design life;
- The cost-benefit analysis has been derived over a 100 year time period;
- The post-scheme property counts were based on the assumption that properties would only be at risk of flooding above the standard of protection offered by the scheme;
- Where Property Level Protection is employed, protection up to a 1 in 30 year flood event is assumed;
- There are no environmental benefits (water-dependent habitat or intertidal habitat created or protected river improved); and,
- No additional funding from external sources has been included.

4.2.1 Partnership Funding Calculator

Following completion of the cost-benefit analysis the Partnership Funding Calculator has been populated for each of the potential flood mitigation schemes. The Partnership Funding Calculator is an Excel spreadsheet which can be downloaded from the Environment Agency website[11].

[9] It is assumed that maintenance of flood storage areas and infiltration swales would fall under NCC's or Norwich City Council's normal maintenance regime for parkland areas and therefore the maintenance cost for the schemes has been included as nil. It is also assumed that maintenance of property level flood protection would be carried out by the home owner, and again has been included as nil.

[10] JBA Consulting . (2012). Evaluation of the Defra Property-level Flood Protection Scheme: 25918.

[11] Environment Agency's *'Partnership Funding Calculator',* available at https://www.gov.uk/government/publications/fcrm-partnership-funding-calculator accessed 23rd May 2014.

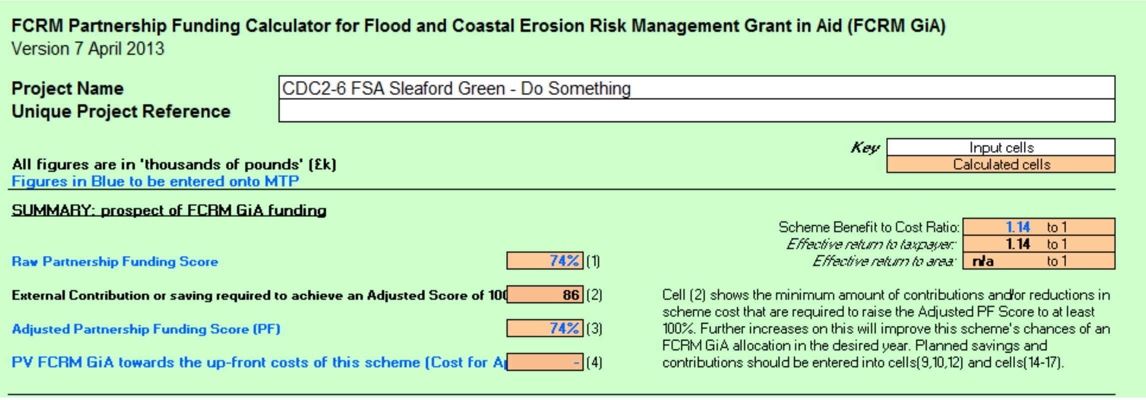
The inputs to the calculator are set out below, with the key inputs for this study are highlighted bold:

- **Number of households in different flood risk bands 'Before' and 'After' the investment, split by three levels of deprivation (Outcome Measure 2);**
- **Present Value benefits;**
- **Present Value costs of appraisal, construction and total (i.e. including maintenance and allowances for reasonably foreseeable risks);**
- Duration of benefits;
- Funding contributions (if appropriate);
- Hectares of water dependent habitat being created (Outcome Measure 4a);
- Hectares of new intertidal habitat created (Outcome Measure 4b); and,
- Kilometres of protected river protected (Outcome Measure 4c).

The spreadsheet calculates the maximum amount of FCRM GiA available to a project, together with the level of necessary contributions. These calculations are based on the value attached to each outcome and £1 of benefit being delivered, the costs involved in achieving them, and the duration that benefits are expected to last for. The basic principle is that national budgets will pay for a share of the benefits achieved when outcomes are delivered. Further information on FCRM GiA funding is included in Section 4.4.

The main outputs of the Partnership Funding Calculator are presented in the summary at the top of the sheet (shown in Figure 4-1).

Figure 4-1: Screenshot of 'Summary' Section Partnership Funding Calculator



The main outputs contained in the summary section are:

- Raw Partnership Funding (PF) Score - this value is used to determine the proportion (%) of costs that can be justified against national budgets.
- External Contribution or saving required to achieve an adjusted score of 100% - this value (£k) is the contribution that is required from other sources of funding (see Section 4.4) to achieve a 100% PF Score. Alternatively, a reduction in costs to that value could be sought but it would need to yield the same benefit.

- Adjusted Partnership Funding Score – if external contributions are made available for a scheme the 'Raw PF Score' is then adjusted to be the Adjusted PF Score. The Adjusted PF Score must exceed 100% before FCRM GiA is allocated and a project can proceed.

- PV FCRM GiA towards the up-front costs of this scheme (Cost for Approval) – The amount of contribution or funding forthcoming from FCRM GiA for the upfront costs for the scheme only, i.e. costs for appraisal, design and construction.

- Scheme Benefit to Cost Ratio – this is the cost - benefit ratio for the scheme based on the present value whole life costs and outcomes the project delivers over the duration of the benefits period. This must be above 1 for the scheme to be taken forward.

Further information on the Partnership Funding Calculator is provided in the Environment Agency's guidance document '*Estimating outcome measure contributions and using the FCRM GiA funding calculator for flood and coastal erosion risk management projects*'[12].

4.3 Cost - Benefit Analysis Results and Discussion

A cost-benefit analysis using the URS Partnership Funding Rapid Assessment Tool has been undertaken for each of the preferred options in the CDCs. The inputs and results for each of the CDCs are presented in the following paragraphs and the associated Partnership Funding Calculator Spreadsheets are included in Appendix G.

4.3.1 CDC1 - Drayton

Table 4-1 sets out the information used to complete the cost-benefit analysis of the proposed mitigation schemes within CDC1. Table 4-2 presents the results for the cost - benefit analysis.

Table 4-1: CDC1 Cost - Benefit Analysis Input Data

Scheme	Design Life (Years)	Average House Price (£)	Commercial Footprint (m²)	Present Value Damages (£k)	Standard of Protection	Scheme Costs		
						PV Scheme Cost (£k)	Total Maintenance Cost (PV, £k)	Total Whole Life Cost (PV, £k)
CDC1-2 Flood Storage Area to the north west	100	£195,335	418	£32,179	100	£379	-	£379
CDC1-3 Infiltration Swale to the east	100	£195,335	418	£32,179	100	£97	-	£97

[12] Estimating outcome measure contributions and using the FCRM GiA funding calculator for flood and coastal erosion risk management projects, February 2014, Environment Agency. http://cdn.environment-agency.gov.uk/LIT_9142_dd8bbe.pdf

Table 4-2: CDC1 Cost - Benefit Results

Scheme	Benefits (PV, £k)	Costs (PV, £k)	Benefit Cost Ratio	Raw Partnership Funding Score (%)
CDC1-2 Flood Storage Area to the north west	£626	£379	2.8	10%
CDC1-3 Infiltration Swale to the east	£45	£97	0.5	9%

The flood storage area (CDC1-2) and infiltration swale (CDC1-3) proposed for the Drayton catchment (CDC1) did not receive a high partnership funding score and therefore are not likely to gain funding. This is principally due to the property counts not reducing significantly post scheme. This is also partly due to each of the residential properties that fall within CDC1 being categorized as 'less deprived', as the partnership funding calculation is weighted to favour properties that are considered as 'most deprived' for funding purposes.

4.3.2 CDC2 – Catton Grove and Sewell

Table 4-3 sets out the information used to complete the cost-benefit analysis of the proposed mitigation schemes within CDC2. Table 4-4 presents the results for the cost - benefit analysis.

Table 4-3: CDC2 Cost - Benefit Analysis Input Data

Scheme	Design Life (Years)	Average House Price (£)	Commercial Footprint (m²)	Present Value Damages (£k)	Standard of Protection	Scheme Costs		
						PV Scheme Cost (£k)	Total Maintenance Cost (PV, £k)	Total Whole Life Cost (PV, £k)
CDC2-1 Flood Storage Area (Oak Lane)	100	£165,672	418	£364	100	£299	-	£299
CDC2-2 Swale (Ives Road)	100	£147,626	418	£10,862	100	£169	-	£169
CDC2-6 Flood Storage Area (Sleaford Green)	100	£120,966	418	£4,197	100	£331	-	£331
CDC2-7 Flood Storage Area (Angel Road)	100	£127,234	418	£36,998	100	£1,440	-	£1,440
CDC2-9 Flood Storage Area (Lawson Road)	100	£122,042	418	£1,682	100	£567	-	£567

Table 4-4: CDC2 Cost - Benefit Results

Scheme	Benefits (PV, £k)	Costs (PV, £k)	Benefit Cost Ratio	Raw Partnership Funding Score (%)
CDC2-1 Flood Storage Area (Oak Lane)	£20	£299	0.1	2%
CDC2-2 Swale (Ives Road)	£150	£169	0.9	11%
CDC2-6 Flood Storage Area (Sleaford Green)	£461	£331	1.4	74%
CDC2-7 Flood Storage Area (Angel Road)	£1,258	£1,440	0.9	11%
CDC2-9 Flood Storage Area (Lawson Road)	£400	£567	0.7	12%

The Partnership Funding Scores for preferred options CDC2-1, 2, 7 and 9 are low and therefore are unlikely to gain FCRM GiA funding without contributions from other funding sources. Option CDC2-6 in Sleaford Green has the highest score of 74% however is still not high enough to be considered for funding without external contributions or savings. A contribution of £86,000 would be required to achieve the 100% PF Score and take the project forward for further consideration.

4.3.3 CDC3 – Nelson and Town Close

Table 4-5 sets out the information used to complete the cost-benefit analysis of the proposed mitigation schemes within CDC3. Table 4-6 presents the results for the cost - benefit analysis.

Table 4-5: CDC3 Cost - Benefit Analysis Input Data

Scheme	Design Life (Years)	Average House Price (£)	Commercial Footprint (m²)	Present Value Damages (£k)	Standard of Protection	Scheme Costs		
						PV Scheme Cost (£k)	Total Maintenance Cost (PV, £k)	Total Whole Life Cost (PV, £k)
CDC3-1 Attenuation SuDS	100	£200,336	418	£136,117	100	£524	-	£524
CDC3-2 Property Level Flood Protection (3.3% AEP)	100	£200,336	418	£136,117	30	£8,635	-	£8,635

Table 4-6: CDC3 Cost - Benefit Results

Scheme	Benefits (PV, £k)	Costs (PV, £k)	Benefit Cost Ratio	Raw Partnership Funding Score (%)
CDC3-1 Attenuation SuDS	£3,413	£525	6.5	114%
CDC3-2 Property Level Flood Protection (3.3% AEP)	£49,526	£8,635	5.7	115%

Both of the preferred options in this CDC have a Partnership Funding Score of greater than 100% and therefore it is considered they both have potential business case to be considered for funding. The Property Level Flood Protection (CDC3-2) has achieved a Raw Partnership Funding Score of 115% and therefore more likely to be considered as a priority target. It is thought that the higher scores in this CDC are due to there being more 'mid-deprived' and 'most-deprived' properties that would potentially benefit from a flood mitigation scheme.

4.4 Sources of Funding

In the main, flood risk management projects are funded by a combination of the following funding streams:

- National funding – Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GiA),
- Regional funding – Local Levy, and
- Local / other funding contributions.

The mechanism for attracting the national (FCRM GiA) and regional (Local Levy) funding gives priority to the protection of residential properties.

Flood and Coastal Risk Management Grant in Aid (FCRM GiA) is the capital budget set aside by central government for flood defence projects across England. Following consultation during 2011, Defra introduced a new approach to the funding of flood risk management capital projects. This approach was termed the 'Flood and Coastal Resilience Partnership Funding' approach. The Partnership Funding Approach is governed by the Environment Agency and represents a key source of funding for flood alleviation measures proposed by Lead Local Flood Authorities and Internal Drainage Boards.

The Environment Agency's Partnership Funding (PF) Calculator is used to determine the amount of FCRM GiA that a project is eligible for. The Adjusted Outcome Measure Score needs to exceed 100% before a project can proceed and FCRM GiA awarded. Where there is a shortfall, contributions from internal or external sources will be required to reach the 100% funding level, before the scheme can progress. All schemes that are estimated to achieve over the 100% threshold are submitted to the Environment Agency for inclusion on their Medium Term Plan and the schemes are then prioritised. The funding of an individual scheme that achieves over 100% will vary each year depending on the number of schemes that are being considered and the total amount of money that is available to fund schemes across the country.

4.4.1 Other Sources of Funding and Contribution

In order to maximise the benefits of the new approach to funding of flood risk management capital projects, NCC should work closely with partnering organisations and other bodies to attract alternative sources of funding. It is important to note that the likelihood of securing FCRM GiA can significantly increase when other sources of funding are secured.

Given the potential shortfall in funding for some of the preferred options, other ‘external contributions’ are likely to be required so that the scheme achieves the necessary PF Score. In taking forward flood risk management schemes for the Norwich Urban Area, NCC will need to consider securing funding from alternative sources, including other flood risk management authorities, stakeholders and private beneficiaries. Table 4.7 presents other potential sources of funding.

Table 4-7: Potential Sources of Flooding

Potential Sources of Funding	Description	Administered By:
Local Levy	A levy on local authorities within the boundary of each Regional Flood and Coastal Committee (RFCC). The Local Levy is used to support, with the approval of the committee, flood risk management projects that are not considered to be national priorities and hence do not attract full national funding through the FCRM GiA. The Local Levy allows locally important projects to go ahead to reduce the risk of flooding within each committee’s area.	Environment Agency through Anglian RFCC
Private Contributions	Voluntary, but funding from beneficiaries of projects could make contributions from national funding viable. Contributions could be financial or “in kind” e.g. land, volunteer labour.	NCC (as LLFA) and Norwich City Council
Water Company Investment	Investment heavily regulated by Ofwat but opportunities for contributions to area-wide projects which help to address sewer under-capacity problems.	Anglian Water Services
Community Infrastructure Levy (CIL)	The Community Infrastructure Levy (CIL) came into force during April 2010 and allows Local Authorities in England and Wales to raise funds from developers undertaking new building projects within their area of governance. Such funds can be used to provide infrastructure that will be necessary to mitigate the effects of the development, including flood defences. Any larger scale developments proposed in the local area that could affect drainage and flood patterns in the CDA could provide an opportunity for the CIL to be used.	Norwich City Council
Section 106 Agreements	Section 106 agreements (Town and Country Planning Act 1990) are a mechanism designed to make a development proposal acceptable in planning terms, through the site specific mitigation of impacts from a development. The use of Section 106 generated funds for the development of flood alleviation measures within the CDA would depend on the location of proposed developments in flood prone areas.	Norwich City Council
Local Residents / Businesses	Community engagement can be a very effective means of raising awareness of flood risks and management activities in local areas, and promoting a sense of ‘helping communities to help themselves’ can result in contributions from private sources, such as local residents and businesses.	Norwich City Council
Local Flood Risk Management Partners	Local Flood Risk Management Partners, or Risk Management Authorities, could also be engaged. For example Anglian Water Services manage much of the drainage system in the CDCs and therefore could be a potential source of funding if the scheme offers mutual benefits.	NCC (as LLFA)
SAB Income	Application and inspection fees from developers in support of the approval and inspection of new development related SuDS.	NCC (as LLFA)

Potential Sources of Funding	Description	Administered By:
Council Tax	A “ring-fenced” provision within the annual council tax for the specific purpose of addressing Flood Risk Management.	Norwich City Council
Business Rates Supplements	Agreement from local businesses to raise rates for specified purposes.	Norwich City Council
Council Capital Funding	The Councils infrastructure programme prioritising capital improvement projects. NCC’s programme has included funding for drainage capacity improvements for a number of years which is targeted at the highway drainage systems, but could include a flood scheme, if benefits can be identified.	NCC and Norwich City Council
Council Revenue Funding	NCC has a number of revenue streams to support technical and admin processes and to maintain council infrastructure. Existing revenue budgets include Highway Drainage Maintenance, Highway Gully Maintenance, Watercourse Maintenance and funding for the Flood Management Team discharging the LLFA duty for the Council.	NCC and Norwich City Council
Other	There are a multitude of alternative funding sources available depending on the type of activity or scheme being proposed. For example, this could include delivery of Water Framework Directive (WFD) objectives, and will be dependent on the scheme seeking funding.	Various

4.4.2 Maintenance Costs

On-going maintenance and operation costs will need to be secured or funded by NCC, or a suitable mechanism put in place with the asset owners or maintainers; they will not be funded through FCRM GiA.

For the purposes of this study it has been assumed that maintenance of flood storage areas and infiltration swales would fall under NCC’s or Norwich City Council’s normal maintenance regime for parkland areas and therefore the maintenance cost for the schemes has not been included. It is also assumed that maintenance of property level flood protection would be carried out by the home owner, and again has not been included.

It is recommended that NCC take opportunities created during scheme development to secure funding of the future on-going costs.

5 SUMMARY

This report comprises the surface water flood mitigation options assessment for the Norwich Urban Area.

As part of the assessment the CDA areas of Drayton, Catton Grove & Sewell and Nelson & Town Close have been redefined as CDCs. The CDC areas have been delineated to include the upper extent of the drainage catchment. The CDC area therefore represents the extent of the area that contributes to the surface water flooding. This reclassification encourages the consideration of flood mitigation options at the sources of the flooding.

The feasibility of a range of potential surface water management options was assessed. The following options were considered to be feasible and were taken forward for further assessment:

- CDC1 – Drayton
    - CDC1-2: Flood storage area north west of Drayton Grove
    - CDC1-3: Infiltration swale north east of Drayton Hall Mobile Home Park
- CDC2 – Catton Grove & Sewell
    - CDC2-1: Flood storage to the north of Oak Lane
    - CDC2-2: Swale alongside Ives Road
    - CDC2-6: Underground storage within Sleaford Green
    - CDC2-7: Underground storage within the playground of Angel Road Junior School
    - CDC2-9: Underground storage between Lawson Road and Denmark Road
- CDC 3 – Nelson & Town Close
    - CDC3-1: Retrofitting waterbutts and other small scale SuDS
    - CDC3-2: Property level protection (this was not modelled, however the results of the baseline modelling enabled this option to be assessed within the cost – benefit analysis)

A high level assessment of the number of properties removed from flooding at each of the return periods has been undertaken. In summary:

- CDC1 - Option CDC1-3 an infiltration swale in north east Drayton provides the greatest benefit of the options modelled, however a minimal number of properties benefit.
- CDC2 - Option CDC2-7 flood storage at Angel Road School provides the greatest benefit of the options modelled.
- CDC3 - CDC3-2 Property Level Protection provides the greatest benefit, removing 1727 properties from flooding within the 3.3% AEP event.

The results of the cost - benefit assessment show that of the options investigated, property level protection and SuDS retrofit would currently score highly enough to be likely to be considered as a priority target for FCRM GiA funding. For the other options investigated, if partial funding from other sources were to become available, then the resulting partnership funding score may achieve the required value for consideration.

The CDC3 flood mitigation measures of attenuation SuDS in the form of water butts or property level protection are options that could be applied across the wider Norwich Urban Area. The modeling and cost benefit assessments show that these measures provide the greatest benefit in terms of reduction in flood risk to the immediate area (and in the case of water butts the downstream areas). To reduce the implication of funding these measures for the whole of Norwich, which would be significant, the measures could be rolled out gradually and prioritised in areas of greatest need.

This study has highlighted a number of options which could be implemented across the Norwich Urban Area. Each of the options modelled has a notable benefit to the local flood risk. The wide scale implementation of retrofit SuDS systems, along with larger capital schemes, could cumulatively result in wide scale benefit. The impact of this is shown within the benefit created by SuDS implementation within CDC3 – Nelson & Town Close, where small scale implementation at each property provided a notable benefit to the flood hotspot downstream.