A46 Newark Bypass

TR010065/7.40

7.40 Hydraulic Modelling Technical Note

APFP Regulation 5(2)(a)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

Volume 6

November 2024

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

A46 Newark Bypass

Development Consent Order 202[x]

7.40 HYDRAULIC MODELLING TECHNICAL NOTE

Regulation Number:	Regulation 5(2)(a)
Planning Inspectorate Scheme Reference	TR010065
Application Document Reference	TR010065/7.40
Author:	A46 Newark Bypass Project Team, National Highways

Version	Date	Status of Version
Rev 1	November 2024	Deadline 3 Submission

Contents

Figures

Tables

Executive Summary

This technical note provides information regarding additional hydraulic modelling and analysis carried out to supplement the details provided in Chapter 6.3 Environmental Statement - Appendix 13.2 Flood Risk Assessment (APP-177). The technical note also provides details to support the responses to the Relevant Representations from the Environment Agency, specifically discussing the issues raised in EAFR-001, EAFR-002, EAFR-007 and EAFR-009.

In assessment of fluvial flood risk impacts to and from the Scheme, the Scheme FRA (APP-177) considers that fluvial flood risk impacts in the 1% AEP plus climate change event from the Mitigated Scheme to sensitive receptors are negligible, in accordance with Design Manual for Roads and Bridges guidance. This technical note aims to improve the understanding of the flood risk impacts at receptors resulting from the Scheme, for the 1% AEP plus climate change event and also for the modelled lower magnitude events. Many of these impacts are very small in magnitude, with changes in flood depths in the hydraulic model results of the order of a few millimetres.

Sources of uncertainty in the hydraulic modelling results are discussed, noting that model uncertainties occur for all models and have a potential magnitude that is comparable to or greater than the very small changes in flood depth assessed in this technical note.

Within this technical note, model results are presented and discussed for the baseline and Scheme (permanent works) scenarios, and the return period events assessed for the Scheme. All presented impacts to receptors in the 1% AEP plus climate change event are negligible. This is discussed further in Section 3.5.

Sensitivity testing has been undertaken at Windmill Viaduct for the 1%AEP plus climate change event. This sensitivity testing reduces the number of more vulnerable receptors that are impacted by the Scheme. Sensitivity tests discussed in this technical note are additional to, and independent of, any sensitivity testing discussed in Appendix A of the FRA (APP-177).

Following sensitivity testing, impacts to receptors have been reassessed. The average impact from the Mitigated Scheme is an increase of 6mm south of Cattle Market roundabout on top of an average baseline flood depth of 965mm, with no change in flood hazard classification.

The conclusions of the FRA (APP-177) and the significance of effect for fluvial flood risk presented within Chapter 13 Road Drainage and the Water Environment (APP-057), are unchanged by the additional sensitivity testing results presented within this technical note. All increases in flood levels presented for the design event are “negligible” as the increase in depth is less than 10mm, in accordance with Design Manual for Roads and Bridges guidance and are therefore considered acceptable by the Applicant.

1. Introduction

1.1 Background

1.1.1 The proposed A46 Newark Bypass Scheme (hereafter referenced as the 'Scheme') comprises the development of a stretch of the A46 between Farndon Junction and Winthorpe Junction. The Scheme aims to upgrade an existing single carriageway road in Newark-on-Trent to a dual carriageway.

1.1.2 The Scheme requires the construction of a new carriageway that will be located alongside the existing carriageway. These associated works will require new junctions and features such as utilities, drainages, public rights of way and accesses, which will include environmental mitigation work.

1.1.3 As a part of the A46 Newark Bypass DCO application submission, the Applicant has assessed the potential changes to flood risk due to the Scheme, to enable mitigation measures to be prepared as part of the Scheme design that comply with National Planning Policy Framework requirements. This assessment is presented in Chapter 6.3 Environmental Statement - Appendix 13.2 Flood Risk Assessment (APP-177) (hereafter referenced as the 'Scheme FRA').

1.1.4 This technical note provides details to support the responses to the Relevant Representations from the Environment Agency, specifically discussing the issues raised in EAFR-001, EAFR-002, EAFR-007 and EAFR-009. Section 1.4 outlines how the sections of this technical note relate to the specific Relevant Representations.

1.1.5 In assessment of fluvial flood risk impacts to and from the Scheme, the Scheme FRA (APP-177) considers that fluvial flood risk impacts in the 1% AEP plus climate change event (the design event) from the Mitigated Scheme to sensitive receptors are "negligible", in accordance with Design Manual for Roads and Bridges (DMRB) LA 113[1] and LA 104[2] guidance. Additional hydraulic modelling and analysis has been undertaken to help to respond to the Relevant Representations and therefore to supplement the details provided in the Scheme FRA. This additional modelling and analysis consisted of targeted sensitivity tests, using the hydraulic model to improve the understanding of flood risk impacts at specific receptors for specific events.

1.1.6 An additional technical note has been issued on the Floodplain Compensation Areas (7.41) alongside this note, which provides further detail on the design and assessment of the floodplain compensation areas that form part of the Scheme.

[1] National Highways (2019) DMRB LA 113 – Road drainage and the water environment, Revision 1 [online] available at: LA 113 - Road drainage and the water environment (standardsforhighways.co.uk). LA 113 - Road drainage and the water environment (standardsforhighways.co.uk);

[2] National Highways (2020) DMRB LA 014 – Environmental assessment and monitoring, Revision 1 [online] available at: LA 104 - Environmental assessment and monitoring (standardsforhighways.co.uk). LA 104 - Environmental assessment and monitoring

1.2 List of terms used

1.2.1 The following terms are used throughout this technical note and are defined here for ease of reference:

- Original model – this was the hydraulic model developed and used to support the Scheme FRA (APP-177).
- Sensitivity tests – these are tests that have been undertaken using the original model as a base. The tests involve the enforcement of features in the model at specific locations to provide greater understanding of the modelled flood risk for the 1% AEP plus climate change event.
- Baseline scenario – this is the scenario representing the river and floodplain under the existing 'baseline' conditions prior to the development of the Scheme. Sensitivity tests have been undertaken on both baseline and Scheme scenarios in the hydraulic model in order to produce comparable results for the 1% AEP plus climate change event. Therefore, the baseline scenario reflects the model enforcements made in the sensitivity tests and consequently differs from the original model.
- Mitigated Scheme – this term was used in the Scheme FRA (APP-177) to refer to the representation of the Scheme in the hydraulic model that includes the mitigation measures that are part of the DCO application. In sensitivity tests for the 1% AEP plus climate change event, comparisons are made between the Mitigated Scheme and the baseline, both of which have the same local model enforcements, unless noted otherwise.
- Enforced/enforcements – these terms have been used throughout this technical note to refer to the model amendments, including ground features and structures, made as part of the sensitivity testing for the 1% AEP plus climate change event. The sensitivity tests are discussed in further detail in Section 3.
- Receptor vulnerability – the Scheme FRA (APP-177) considers receptor sensitivity according to the DMRB guidelines. These broadly align with flood risk vulnerability classifications provided in Annex 3 of the National Planning Policy Framework (NPPF)[3]. For this technical note, receptor vulnerability is expressed according to the NPPF classifications which are: Essential Infrastructure, Highly Vulnerable, More Vulnerable, Less Vulnerable and Water Compatible.
- Flood hazard – this term is used throughout the technical note to describe the potential risk to receptors. The hydraulic model outputs flood hazard classifications which align with those described in the Environment Agency "Flood Risks to People"[4] documentation. Modelled peak velocities and depths

---

[3] National Planning Policy Framework - Annex 3: Flood risk vulnerability classification - Guidance - GOV.UK (www.gov.uk)

[4] Environment Agency (2006) Flood Risks to People, available at: https://assets.publishing.service.gov.uk/media/602bbc768fa8f50383c41f80/Flood_risks_to_people_-_Phase_2_The_flood_risks_to_people_methodology_technical_report.pdf

are used to classify areas of flooding as Low, Moderate, Significant or Extreme degree of hazard.

1.3 Use of the National Receptor Database in the assessment of potential flood risk impacts

1.3.1 The Environment Agency National Receptor Database (NRD)[5] classifies receptors according to Multi-Coloured Manual (MCM) codes[6], class codes and class descriptions. The NRD contains point location information on properties such as their address and the type of property use. The NRD does not provide information about non-property-based receptors such as transport networks and environmental designations.

1.3.2 Due to licensing restrictions, the NRD is not widely accessible to the public as it relies on Ordnance Survey data, which is subject to restrictions regarding its release as open data. However, summary information derived from the NRD is included in various Environment Agency publications and reports. Therefore, both this technical note and the FRA (APP-177) only provide summary information from the analysis of NRD data.

1.3.3 For the purposes of this technical note, NRD class descriptions have been used to assign NPPF vulnerabilities, where possible, to all receptors within the study area. The tabulated NPPF vulnerability classification for each NRD class description is provided in Appendix A of this technical note.

1.3.4 However, not all NRD receptors have class descriptions. Specifically, any receptors with an MCM code of '999' lack class description information. Consequently, for all receptors with an MCM code of '999', aerial imagery was assessed to assign a probable land-use type and therefore vulnerability. The qualifier 'Low confidence' was added to the NPPF vulnerability for these receptors, e.g. "More Vulnerable (Low Confidence)" and "Less Vulnerable (Low Confidence)".

1.3.5 Although the NRD is very useful in assessing flood risk to receptors across the modelled area, there are potential sources of error in the location and classification of individual receptors. The NRD is a snapshot at a given moment in time, informed by underlying Ordnance Survey receptor address data and topology. Any inaccuracies noted in the review of NRD receptors are flagged in the relevant sections of this technical note.

1.4 Structure of the technical note

1.4.1 This technical note provides details and a narrative on the flood risk impacts arising from the Scheme. The document has been split into the following sections:

- **Section 2 – Modelling uncertainty:** A discussion of the uncertainties in the hydraulic modelling results that are important context for the consideration of flood risk impacts predicted by the model.

[5] Environment Agency (2014) NRD2014 Guidance Version 1, September 2015

[6] The Handbook MCM online https://www.mcm-online.co.uk/handbook/

This section contains discussion points that are relevant for the responses for the Environment Agency Relevant Representations being considered in this technical note.

- **Section 3 – Receptor impacts for the design event**: This section summarises the flood depth differences at receptors for the Mitigated Scheme versus baseline scenarios using the NRD and the NPPF receptor classifications for the 1% AEP plus climate change event.

  This section provides information supporting the responses for EAFR-001 and EAFR-002.

- **Section 4 – Slough Dyke realignment:** This section documents a sensitivity test in relation to the Slough Dyke realignment.

  This is relevant to the response for EAFR-007.

- **Section 5 – Climate change allowances applied in the hydraulic model:** This section discusses the assessment of a credible maximum river flow climate change scenario that was included in the Scheme FRA (APP-177).

  This section provides information to support the response for EAFR-009.

- **Appendix A – NRD to NPPF receptor vulnerabilities:** This section presents the methodology for assigning NPPF flood risk vulnerabilities to all receptors within the study area to inform the detailed receptor analysis.

- **Appendix B – Receptor analysis for low magnitude events:** This section summarises the flood depth differences at receptors for the Mitigated Scheme versus baseline scenarios using the NRD and NPPF receptor classifications for events of lower magnitude than the 1% AEP plus climate change event. These are the 50%, 20%, 5%, 3.33% and 1% AEP events.

  This section provides information to support the response for EAFR-001 and EAFR-002.

1.5 Policy context and guidelines

1.5.1 Guidance, standards, and best practice have been followed in the FRA (APP-177) and within this document, with particular reference to:

- DMRB LA 113 - Road drainage and the water environment[1]
- DMRB LA 104 - Environmental assessment and monitoring[2]
- National Planning Policy Framework (NPPF)[7]
- Planning Practice Guidance: Flood risk and coastal change[8]

[7] Ministry of Housing, Communities and Local Government (2012): National Planning Policy Framework. Available at National Planning Policy Framework - Guidance - GOV.UK (www.gov.uk)

[8] Department for Levelling Up (2022) Planning Policy Guidance: Flood risk and coastal change [online] Available at: Flood risk and coastal change - GOV.UK (www.gov.uk)

1.5.2 The FRA (APP-177) has been developed in accordance with Design Manual for Roads and Bridges LA 113 and LA 104 (DMRB) guidelines. The DRMB provides guidance tables on receptor sensitivity, magnitude of impact and significance of effect[9].

1.5.3 Guidance on receptor sensitivity which is provided within Table 3.70 of the DRMB LA 113, broadly aligns with NPPF receptor vulnerability classifications[3], and examples of both are provided in Table 4.2 of the Scheme FRA (APP-177).

1.5.4 Of particular relevance to the assessment of impacts to receptors within the Scheme FRA (APP-177), Table 3.71 of DRMB LA 113 specifies a change in peak flood level of +/- 10mm to be a "negligible" impact.

1.5.5 In accordance with DMRB guidance therefore, Tables 13-9 and 13-10 of Chapter 13 Road Drainage and the Water Environment (APP-057) demonstrate that the Scheme would not result in significant adverse effects in terms of fluvial flood risk during both construction and operation.

[9] Receptor sensitivity and magnitude of impact tables are provided in DMRB LA 113 Table 3.70 and Table 3.71, respectively. The significance of effect table is provided in DMRB LA 104 Table 3.8.1.

2. Modelling uncertainty

2.1 Introduction

2.1.1 This section provides an overview of the sources of modelling uncertainty that need to be understood in the context of the hydraulic modelling undertaken to support the Scheme FRA.

2.1.2 The discussion on model uncertainty is important for background context as the flood depth differences discussed in this technical note are very small in magnitude and are often smaller than modelling uncertainties for this this type of complex 1D-2D linked model.

2.2 Sources of modelling uncertainty

2.2.1 Two sources of modelling uncertainties that are relevant to this technical note are in the modelling setup and in the numerical solver behaviour.

2.2.2 Uncertainties in modelling setup include model inputs and model configuration. Model inputs, such as survey data, LiDAR, inflows and design geometry are data that are incorporated into the modelling relatively unchanged from various sources and all come with some level of error. However, the errors in these data are typically accepted on the basis that the best available data has been used for the model development.

2.2.3 During the development of a hydraulic model, there are occasions when decisions must be made regarding the best way to incorporate the input data into the model configuration. This may require interpretation of survey data, combining conflicting geometry sources, adapting design details for representation inside the model's numerical mesh and enforcing ground features and structure elevations.

2.2.4 In the development of the original hydraulic model, a conservative approach was used for decisions on the model representation in order that it captured the worst-case impact. This technical note revisits locations where a conservative approach was initially taken and refines them with a more realistic approach for proposed structures and other surface topographical features that might affect flow paths or flooding risk.

2.2.5 The large scale and complexity of the linked watercourse and floodplain components of this model are relevant in relation to this point. The large area represented meant the decisions had to be made on the level of resolution in the model. While the model provides an appropriate tool for evaluating the Scheme, uncertainties arise from inevitable modelling choices such as the selection of the grid cell size(s). This, in turn, limits the level of detail in assessing localised flood risk impacts as the grid size governs the approaches for the representation of ground features and structures in the model.

2.2.6 Modelling uncertainties due to numerical solver behaviour can arise due to poor-convergence, threshold condition impacts and localised flow conditions that do not fit comfortably inside the limitations of the computational model solver's numerical schemes (for TUFLOW, this would include conditions such as fast, deep flows which stretch the assumption that a 2D shallow water equation is applicable).

2.2.7 Numerical solver uncertainties generally have a lesser impact on the flood risk outputs of hydraulic models than model input and configuration uncertainties. However, they are relevant to this technical note because they can cause localised fluctuations and water level differences in areas away from the parts of the model that have been updated with the Scheme geometry and where the flood risk would otherwise be independent of the Mitigated Scheme.

2.3 Modelling tolerance

2.3.1 The consequence of numerical solver uncertainty, which may stem from solver approach or convergence difficulties, is that the Flood Modeller and TUFLOW hydraulic modelling software will undertake multiple iterations to converge to within a specified tolerance in water level or to minimise mass balance error.

2.3.2 Flood Modeller has a default tolerance of 0.01m (10mm) in water level and, according to the Environment Agency report SC120002, “Benchmarking the latest generation of 2D hydraulic packages” (2013), TUFLOW exhibits differences in water level compared to other packages of between 0.01m (10mm) and 0.05m (50mm), or up to 10% of the water depth. It may therefore be expected that there is an inherent level of uncertainty in model outputs. It should be noted that the DMRB guidance adopts a pragmatic approach by defining a change in peak flood level of +/- 10mm as having a "negligible" impact.

2.3.3 It should be noted that where convergence difficulties arise, oscillations may be induced in the water surface, even though the model is achieving a desired level of mass balance. There would therefore be areas over which the baseline and Mitigated Scheme model scenarios exhibit such oscillations differently and comparing their peak water levels will expose the effect tolerances as a striped or dappled pattern in the depth comparison figures.

2.4 Scheme FRA (APP-177) model proving

2.4.1 Hydraulic modelling was used to support the flood risk assessment of the Mitigated Scheme (Scheme FRA (APP-177)). The hydraulic modelling included sensitivity testing to understand the impact of assumptions, including changes in hydraulic roughness, adjustments to inflows, blockages applied to structures and adjustments to weir coefficients. The model was subsequently calibrated and was then signed off by the Environment Agency (email correspondence with Paul Goldsmith, 1 February 2024) with regards to its technical function.

2.4.2 As discussed in the Scheme FRA (APP-177), modelling instabilities have been observed by way of localised velocity and depth fluctuations in the modelling results in locations away from the area of interest. However, these numerical uncertainties were deemed in the Scheme FRA (APP-177) not to reflect flood risk changes due to the Scheme.

2.5 Additional sensitivity testing

2.5.1 This technical note focusses on how sensitive flood risk impacts at specific enforcement points are to changes in the representation of components within the original hydraulic model.

2.5.2 Sensitivity testing was undertaken on the 1% AEP plus climate change event to further investigate flood risk increases at specific locations. These consist of alternative representation of design details at:

- Windmill Viaduct, discussed in Section 3
- Slough Dyke, discussed in Section 4

2.6 Summary

2.6.1 This technical note details the flood depth increases at receptors in the original model and assesses the potential reasons for these increases through sensitivity testing for the 1% AEP plus climate change event.

2.6.2 The presentation and analysis of flood risk impacts below 0.01m (10mm) helps to provide a fuller picture of the model results when considering the impact of the Mitigated Scheme on flood risk. It should be noted that increases in flood depths less than 0.01m (10mm) are considered “negligible” impacts in accordance with DMRB guidance.

2.6.3 Care must be taken to avoid applying a false level of accuracy to flood depth changes in the model that are of the order of only a few millimetres. The discussions in this section highlight that model uncertainties occur for all models and have a potential magnitude that is comparable to or greater than the very small changes in flood depth assessed in this technical note.

2.6.4 The sensitivity testing consisted of enforcements to ground features and structures in the original hydraulic model at specific locations. The objective of the sensitivity testing was to assess whether predicted flood risk impacts to specific receptors in the model could be reduced or removed. It is important to note that while enforcements in the model representation have been made, these adjustments are only intended to test the model’s sensitivities and the predicted impacts on receptors. Furthermore, the model does not predict increases above 10mm for the 1% AEP plus climate change event, therefore sensitivity testing has been undertaken to provide further understanding for increases below this level.

3. Design event analysis – 1% AEP plus climate change

3.1 Introduction

3.1.1 To provide further context on the Scheme's approach to passing the Exception Test, this section of the Technical Note provides further analysis on the Scheme design event, in addition to that provided in the Flood Risk Assessment. It looks at receptor impacts at locations 4 (Windmill Viaduct), 11 (Cattle Market roundabout) and 8 (Embankment on floodplain between Kelham Road and Nottingham to Lincoln railway line) in further detail to expand upon data provided in the FRA.

3.1.2 Section 3.5 looks at receptor impacts in further detail for the design event in line with DMRB guidance on assessing significant effects. It should be noted that receptor impacts for lower magnitude flood events were also analysed and details are provided in Appendix B.

3.2 Windmill Viaduct

3.2.1 Original model

3.2.1.1 In the 1% AEP plus climate change event, flood depth increases between 0.005m and 0.01m (5-10mm) are predicted west of Windmill Viaduct[10] on the right bank of the River Trent (Figure 1). Despite the predicted increase in flood depths, the flood hazard classification is not predicted to change between the baseline and Mitigated Scheme, remaining "Significant" (Figure 2 and Figure 3). Furthermore, changes in peak flood level less than 10mm such as at this location are considered "negligible" impacts in accordance with DMRB guidance.

3.2.1.2 The increase in depth west of Windmill Viaduct is caused by the representation of its extension on the right bank of the River Trent in the Mitigated Scheme model scenario. The representation of the embankment footprint in the original Mitigated Scheme model was conservatively estimated. Although the change in peak flood level at this location is considered 'negligible', sensitivity testing of the embankment footprint was undertaken to determine if a more detailed representation affected the assessment, and this is discussed further in Section 3.2.2.

[10] Windmill Viaduct is marked as Location 4 in Figure 8.1 of in Chapter 6.3 Environmental Statement - Appendix 13.2 Flood Risk Assessment (APP-177)

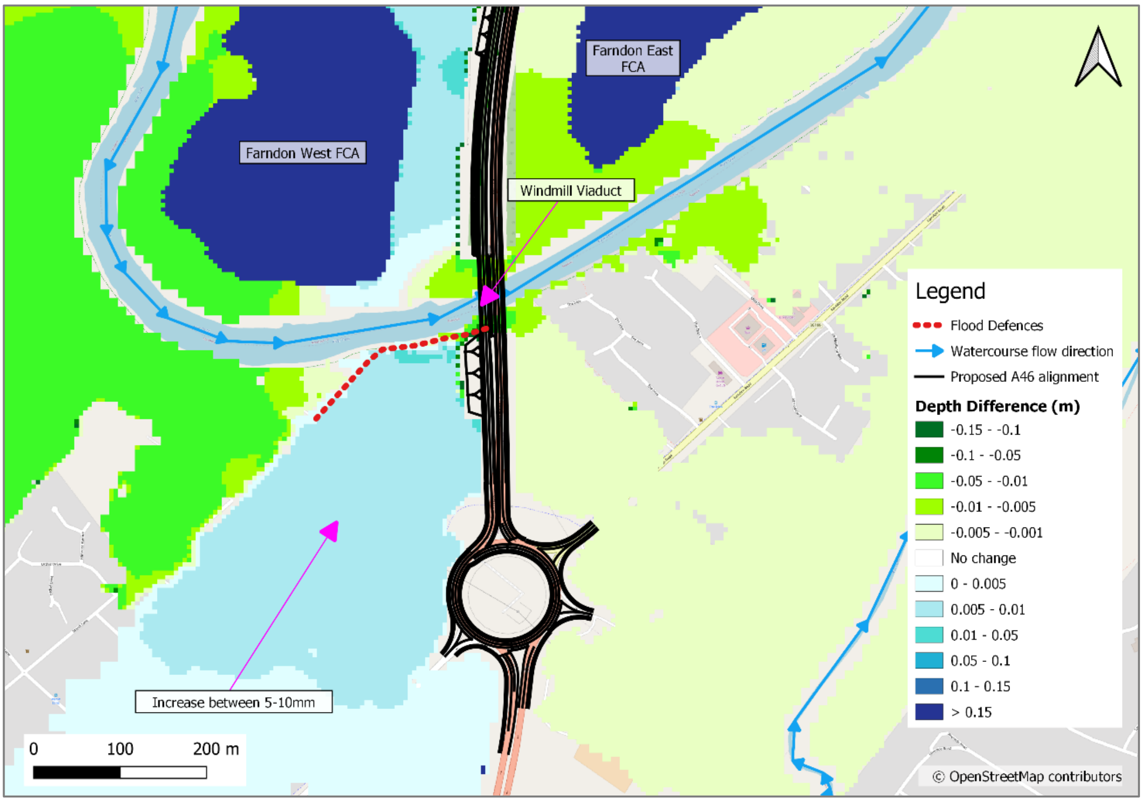

Figure 1: 1% AEP plus climate change. Windmill viaduct. Flood depth differences. Mitigated Scheme versus baseline. Original model.

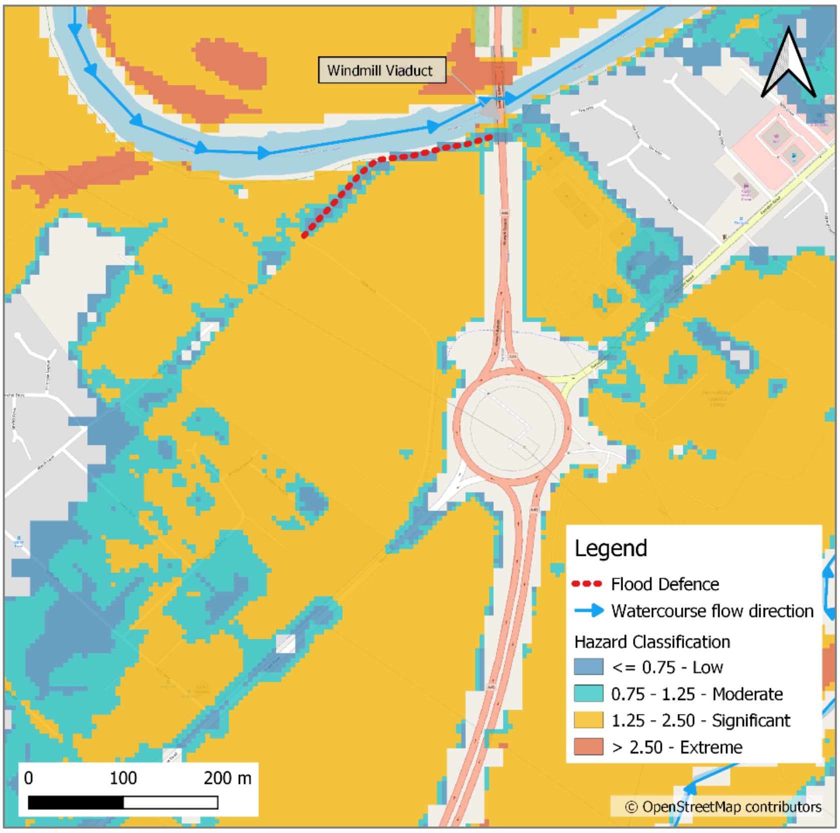

Figure 2: 1%AEP plus climate change. Windmill viaduct. Flood hazard. Original baseline.

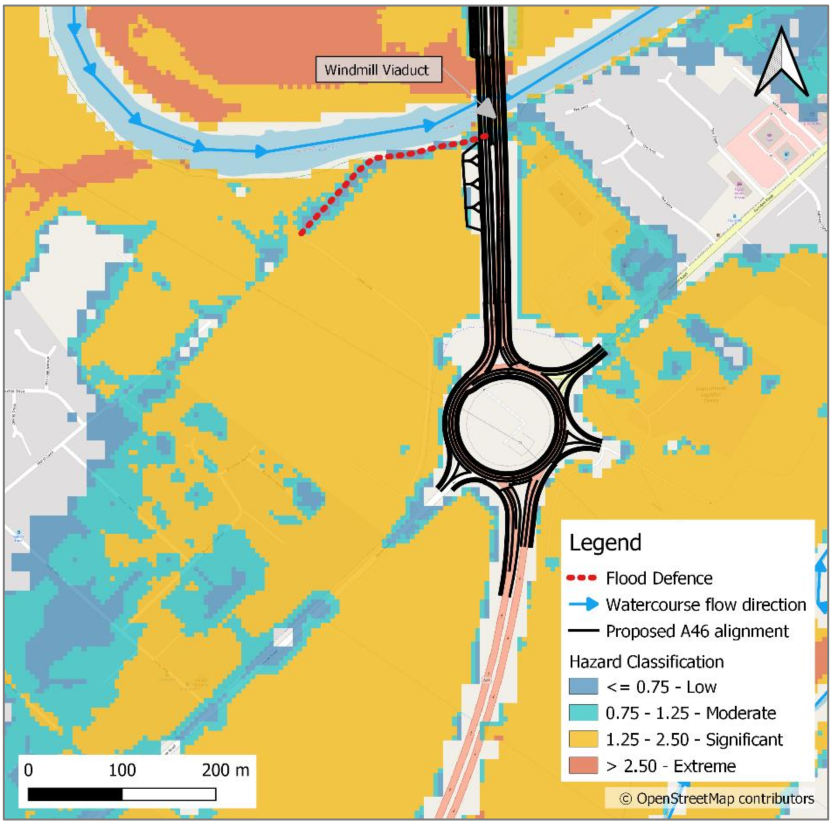

Figure 3: 1%AEP plus climate change. Windmill viaduct. Flood hazard. Mitigated Scheme.

3.2.2 Sensitivity testing

3.2.2.1 In the original model, a conservative approach was taken with respect to the representation of the embankment, in order to provide a conservative estimate of peak water levels in the floodplain. In the sensitivity test, the elevation of four 10m^2 grid cells at the northern end of the embankment was reduced, which allowed a small but significant increase in conveyance beneath the viaduct on the right bank of the River Trent, bringing the water levels and flows through the viaduct back towards baseline conditions. This test indicates the sensitivity of the model to the adjustment of just four grid cells in this area.

3.2.2.2 As a result of the modified representation of the Scheme embankment and abutment, sensitivity testing demonstrates that the area south of Windmill Viaduct now shows flood depth differences less than 0.002m (2mm) compared to the baseline (Figure 5, with Figure 4 enabling direct comparison with the depth differences from the original model as shown in Figure 1). The area of depth increase has also reduced. Detailed analysis of the results of this sensitivity test provided in Section 3.5.3.

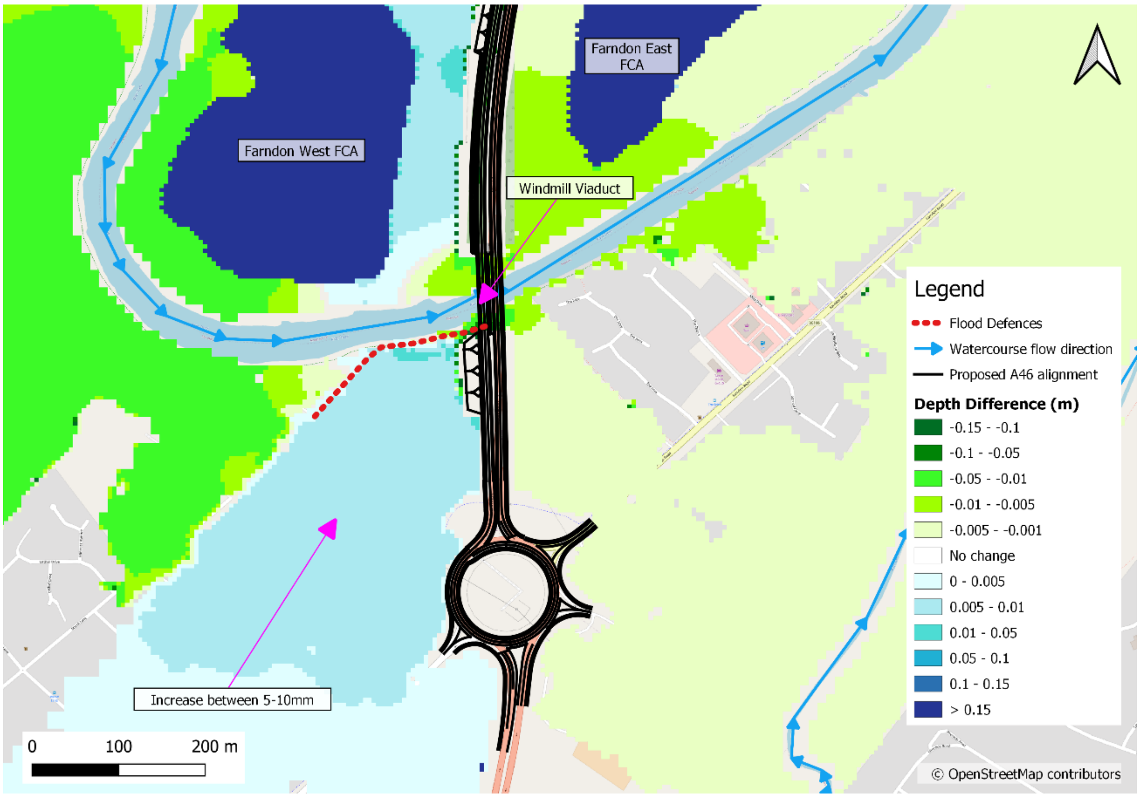

Figure 4: 1% AEP plus climate change. Windmill viaduct. Flood depth differences. Mitigated Scheme versus baseline. Original model. (this is a duplication of the depth differences shown in Figure 1 for ease of comparison with Figure 5)

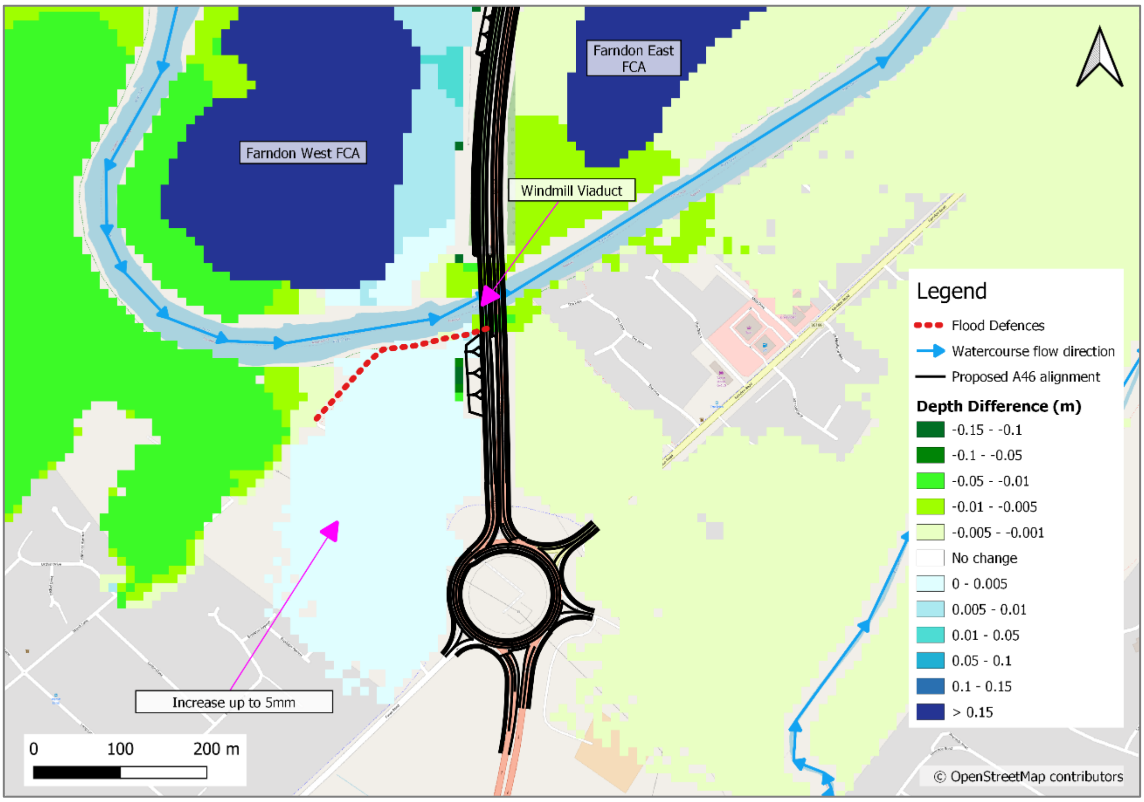

Figure 5: 1% AEP plus climate change. Windmill viaduct. Flood depth differences. Sensitivity test.

3.3 South of Cattle Market roundabout

3.3.1 Figure 6 presents the change in flood depths in the area south of Cattle Market roundabout. The Scheme FRA (APP-177) notes an increase in water levels up to 0.02m (20mm) in the vicinity of Cattle Market[11]. However, this increase affects a localised area to the north-east and does not impact any vulnerable receptors.

3.3.2 Depth increases south of Cattle Market roundabout are less than 0.01m (10mm), averaging 0.006m (6mm). This increase is considered a “negligible” impact in accordance with DMRB guidance. Baseline flood depths in this area are up to 3m for this event and the baseline flood hazard classification in the area is “Significant”. The flood hazard classification is unchanged by the Mitigated Scheme as shown in Figure 7 and Figure 8.

3.3.3 No additional sensitivity tests were undertaken for this location as the design representation of the Scheme in the original model is considered appropriate. The design representation cannot therefore reasonably be modified for sensitivity testing. Nevertheless, flood depth differences within this area resulting from the Mitigated Scheme are considered a “negligible” impact in accordance with DMRB guidance.

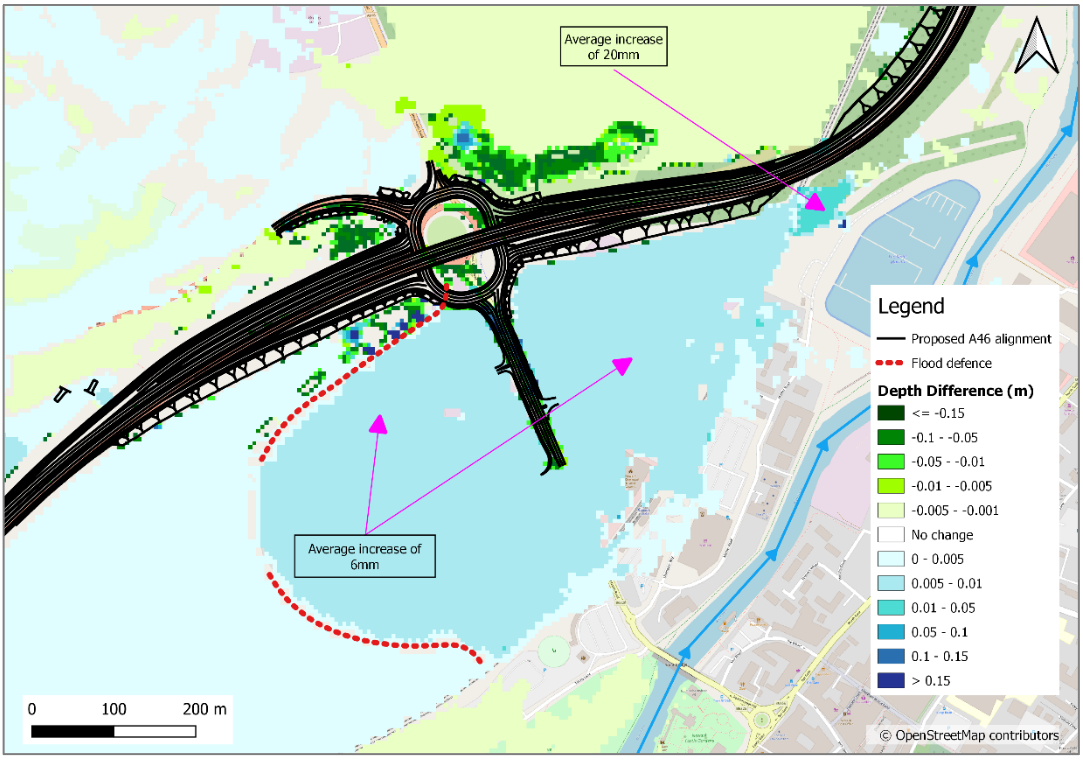

Figure 6: 1%AEP plus climate change. Flood depth differences. Mitigated Scheme versus baseline. Original model.

[11] The area south of Cattle Market roundabout is marked as Location 11 in Figure 8.1 of in Chapter 6.3 Environmental Statement - Appendix 13.2 Flood Risk Assessment (APP-177)

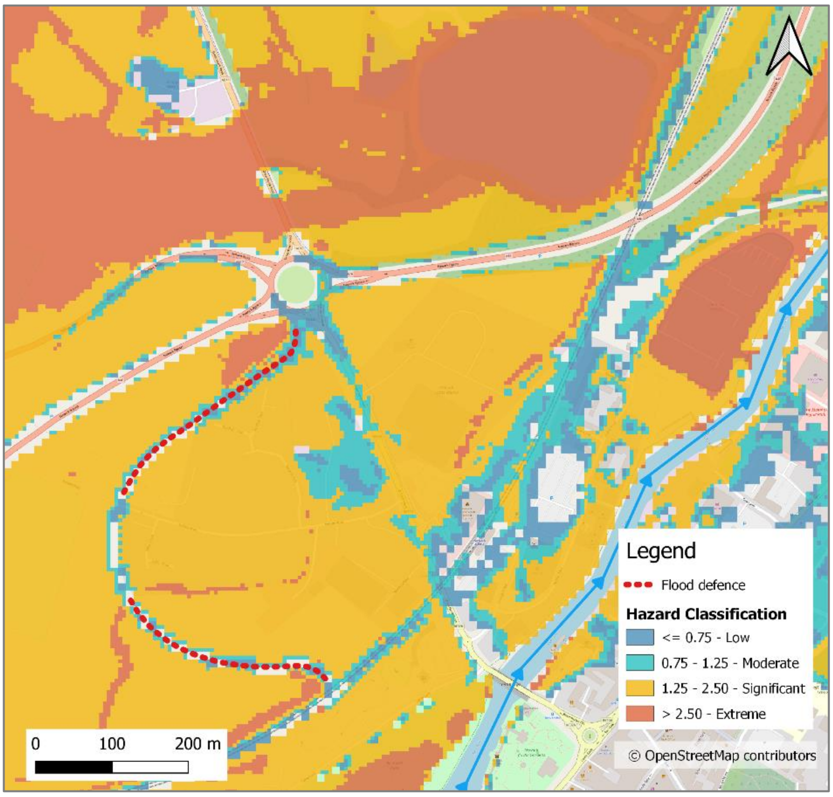

Figure 7: 1%AEP plus climate change. Cattle Market roundabout. Flood hazard. Original baseline.

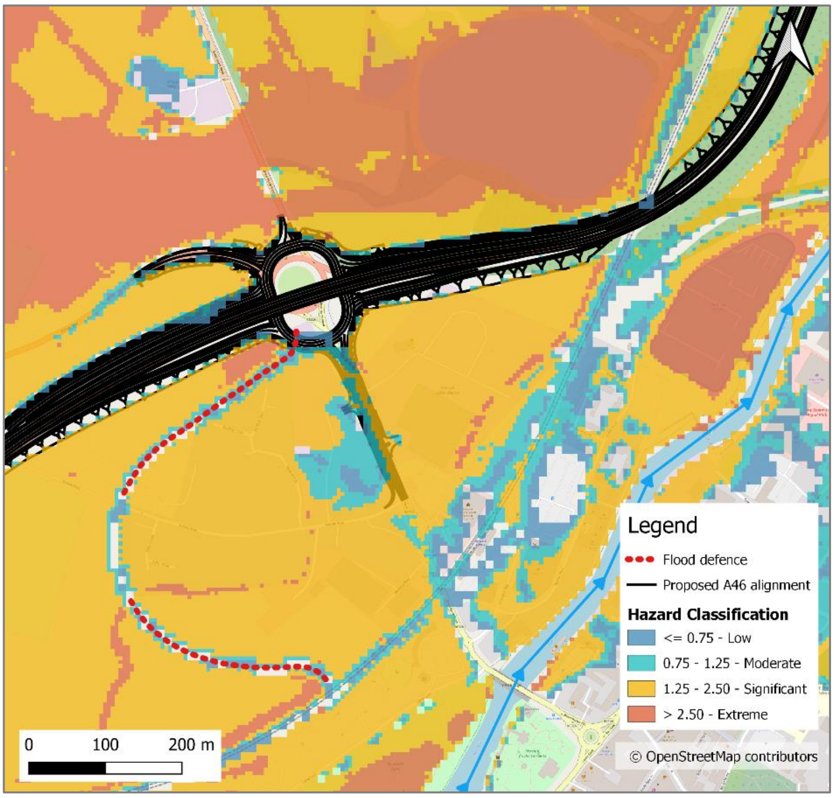

Figure 8: 1%AEP plus climate change. Cattle Market roundabout. Flood hazard. Mitigated Scheme.

3.4 Embankment on floodplain between Kelham Road and Nottingham to Lincoln railway line

3.4.1 The Scheme FRA (APP-177) notes that the water level at the base of the new embankment between Kelham Road and the Nottingham to Lincoln railway line[12] has a localised increase of up to 0.086m (86mm) from the baseline. It is important to note that this increase represents only one modelled 10m grid cell as shown in Figure 9. Elsewhere, flood depth increases are generally less than 0.01m (10mm), and decreases are also observed nearby, as shown in green in Figure 9. Changes in peak flood level less than 0.01m (10mm) are considered a "negligible" impact, in accordance with DMRB guidance.

3.4.2 There are no vulnerable receptors at this location, and the wider area is predominantly agricultural.

3.4.3 No additional sensitivity tests were run for this location due to the absence of vulnerable receptors at this location.

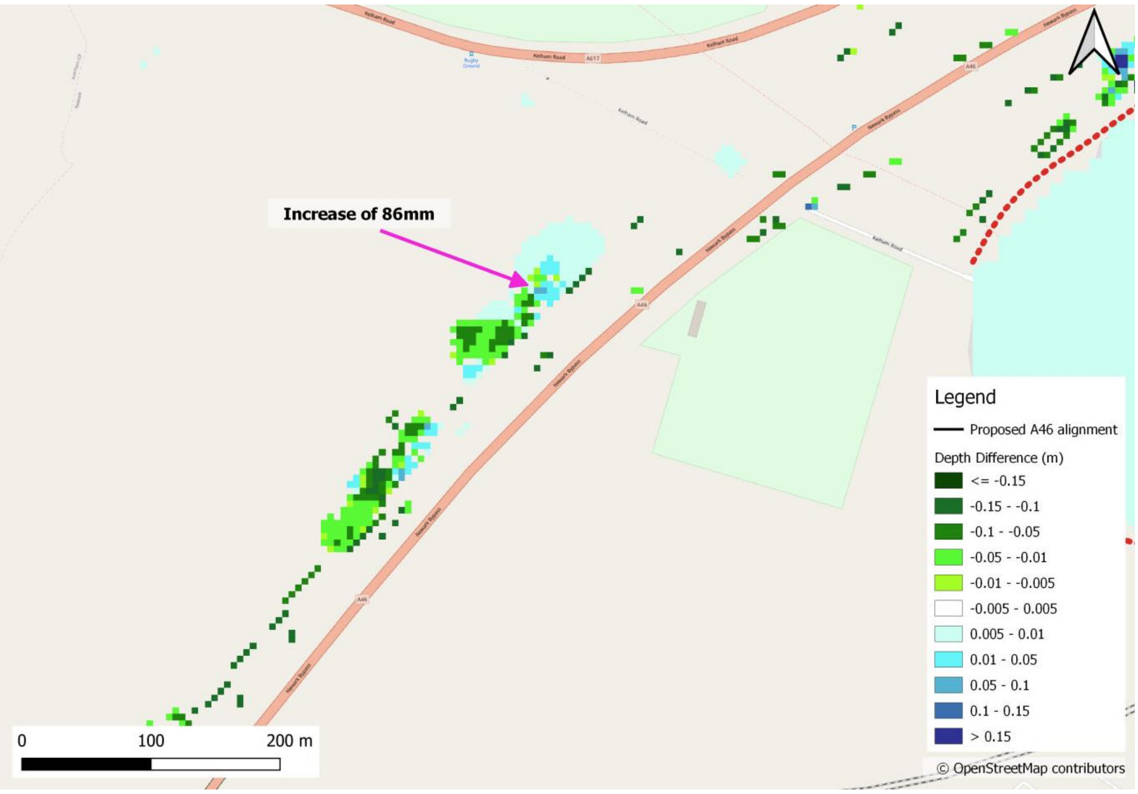

Figure 9: 1%AEP plus climate change. Flood depth differences. Mitigated Scheme versus baseline. Original model.

[12] The embankment between Kelham Road and Nottingham to Lincoln railway line, is marked as Location 8 in Figure 8.1 of in Chapter 6.3 Environmental Statement - Appendix 13.2 Flood Risk Assessment (APP-177)

3.5 Detailed receptor analysis

3.5.1 Introduction

3.5.1.1 This section provides further detail on the changes in flood depths at receptors arising from the Mitigated Scheme for the 1% AEP event plus climate change, drawing on results of the sensitivity testing undertaken at Windmill Viaduct outlined in Section 3.2.2.

3.5.1.2 Table 1 summarises the results for the original hydraulic model. Table 2 summarises the results of the sensitivity test at Windmill Viaduct. The total numbers of receptors with increases or decreases in flood depth exclude "Water Compatible" receptors, as identified in Appendix A, which by their nature are resilient to minor changes in flood level.

3.5.2 Original model

3.5.2.1 A comparison between the baseline and Mitigated Scheme scenarios for the original model (Table 1) indicates that flood depths at 1,619 receptors are predicted to decrease, whilst they are predicted to increase at 1,058 receptors. Receptors with a predicted increase are summarised as follows:

- Seven "Essential Infrastructure" receptors with flood depth increases less than 0.01m (10mm) as outlined in the following points. Note that the flood hazard is not predicted to change at any of these receptors due to the Mitigated Scheme.
    - One electricity substation at the model boundary 5km north of the Scheme which shows a flood depth difference of 0.0004m (0.4mm) on top of a baseline depth of 0.08m (80mm).
    - One electricity sub-station at South Muskham 1.5km north of the Scheme which shows depth differences of 0.0001m (0.1mm) on top of a baseline flood depth of 0.92m (920mm).
    - One electricity sub-station located south of Cattle Market roundabout just off the Great North Road which shows a depth difference of 0.007m (7mm) on top of baseline flood depths of 0.27m (270mm).
    - Two electricity sub-stations located south of Windmill viaduct near Fosse Road which show depth differences of less than 0.002m (2mm) on top of baseline flood depths exceeding 0.26m (260mm).
    - One sewage pumping station located south of Windmill viaduct near Fosse Road which shows a flood depth difference of 0.001m (1mm) on top of a baseline flood depth of 0.90m (900mm).
    - One wind turbine, however the physical location of the turbine as observed on satellite imagery is approximately 250m from the assigned NRD receptor location, and no depth differences are observed at this location in this event.
- Seven "Highly Vulnerable" receptors with flood depth increases of 0.005m to 0.010m (5mm to 10mm) as outlined in the following points. Note that the flood hazard is not predicted to change at any of these receptors due to the Scheme.
    - Two telecommunications cabinets with depth differences less than 0.007m (7mm) on top of baseline flood depths of greater than 0.05m (50mm).

- Five telecommunications infrastructure, including a cabinet and a mast with depth increases of less than 0.001m (1mm), where baseline flood depths are up 0.64m (640mm).
- 171 "More Vulnerable" receptors with flood depth increases between 0.005 to 0.01m (5-10mm) as below.
  - 123 receptors are located south of Cattle Market roundabout. The average depth increase at the Cattle Market roundabout receptors is 0.006m (6mm) on top of an average baseline depth of 0.965m (965mm). Note that the flood hazard is not predicted to change at any of these receptors due to the Scheme.
  - 48 receptors are located upstream of Windmill Viaduct near Fosse Road, where the average depth increase is 0.006m (6mm) on top of an average baseline depth of 0.44m (440mm). Note that the flood hazard is not predicted to change at the majority of these receptors due to the Scheme, aside from at four receptors where it increases from either "Low" to "Moderate" or "Moderate" to "Low".
- 25 "More Vulnerable (Low Confidence)" receptors with flood depth increases between 0.005m and 0.01m (5-10mm) as below. Flood depth increases for these receptors are identical to those discussed for "More Vulnerable" receptors for this event;
  - 12 receptors are located south of Cattle Market roundabout.
  - 13 receptors are located upstream of Windmill Viaduct near Fosse Road.

3.5.2.2 Note that the above increases in flood depths are less than 10mm and are therefore considered "negligible" impacts in accordance with DMRB guidance. No "More Vulnerable", "Highly Vulnerable" or "Essential Infrastructure" receptors show flood depth increases of greater than 0.01m (10mm).

3.5.2.3 Furthermore, the model predicts that there would generally be no change in the flood hazard at receptors where an increase in flood depth is predicted, with the exception of four receptors upstream of Windmill Viaduct. The sensitivity of the receptors at this location have been assessed further and the outcomes are discussed in Section 3.5.3.

3.5.3 Sensitivity testing

3.5.3.1 A sensitivity test was undertaken on the 1% plus climate change event which involved amendments to the abutment and embankment representation, as discussed in Section 3.2.2. The purpose of this test was to determine whether flood depth changes at the 48 receptors upstream of Windmill Viaduct were sensitive to these amendments. The baseline for this sensitivity test was that of the original model.

3.5.3.2 The outcomes of the sensitivity test, presented in Table 2, are as follows:

- As per the original model, no "More Vulnerable", "Highly Vulnerable" or "Essential Infrastructure" receptors show flood depth increases of greater than 0.01m (10mm).
- The number of "More Vulnerable" receptors with an increase between 0.005m to 0.010m (5mm to 10mm) has reduced by 27 from 171 to 144. Following the

sensitivity test, there are no longer any “More Vulnerable” receptors seeing a depth increase above 5mm upstream of the Windmill Viaduct.

- The number of receptors showing depth differences greater than 2mm has reduced, with smaller depth changes now predicted following the sensitivity test.
- Seven “Essential Infrastructure” locations with flood depth increases less than 0.01m (10mm), six of which are electricity sub-stations:
  - One at the model boundary 5km north of the Scheme which shows a flood depth difference of 0.0004m (0.4mm) on top of a baseline depth of 0.08m (80mm).
  - Two in South Muskham over 1.5km from the Scheme showing maximum depth differences of between 0.0003m to 0.0004m (0.3-0.4mm) on top of baseline flood depths between 0.57m to 0.92m (570mm-920mm).
  - One sub-station in North Muskham over 2km from the Scheme which shows maximum depth differences of 0.0001m (0.1mm) on top of a baseline flood depth of up to 0.83m (830mm).
  - One sub-station located south of Cattle Market roundabout just off the Great North Road which shows a depth difference of 0.007m (7mm) on top of baseline flood depths of 0.27m (270mm).
  - One sub-station located 800m from the sewage works at Quibells Lane which shows a depth difference of 0.0001m (0.1mm) on top of baseline flood depths of 1.62m (1,620mm).
  - The remaining “Essential Infrastructure” receptor is a wind turbine according to the NRD. However, the physical location of the turbine as observed on satellite imagery is approximately 250m from the assigned NRD receptor location, and no depth differences are observed at this location in this event.
- Six "Highly Vulnerable" receptors:
  - Four telecommunications cabinets with depth differences ranging from 0.0004m to 0.0081m (0.4mm-8mm), on top of baseline flood depths of 0.03m to 0.29m (30-290mm).
  - One phone mast, with a flood depth difference of 0.0007m (0.7mm) on top of baseline flood depth of 0.19m (190mm).
  - One caravan at Tolney Lane, which sees an increase of flood depths of 0.0005m (0.5mm) on top of baseline flood depths of 0.50m (500mm). The baseline flood hazard classification at this location is “Significant” and does not change as a result of the Scheme or the sensitivity test.

3.5.3.3 For the majority of receptors other than those itemised below, the hazard classification for receptors in the sensitivity test does not change compared to the baseline.

- Hazard decrease from “Moderate” to “Low” at three “More Vulnerable” receptors.
- Hazard decrease from “Significant” to “Moderate” at one “More Vulnerable” and one “Less Vulnerable (Low Confidence)” receptors.

- Hazard increase from “Low” to “Moderate” at one “Less Vulnerable” receptor.
- Hazard increase from “Significant” to “Extreme” at water features Farndon East FCA and Farndon West FCA. Since the FCAs are designed to fill up and store water within the floodplain, this is expected.

3.5.4 Summary

3.5.4.1 During the 1% AEP event plus climate change, reductions in flood depth are predicted at 1,619 receptors. Furthermore, the Scheme is not predicted to cause increases in flood depths above 10mm at any “Essential Infrastructure”, “Highly Vulnerable”, “More Vulnerable”, “More Vulnerable (Low Confidence)”, or “Less Vulnerable (Low Confidence)”. Increases are predicted at two “Less Vulnerable” receptors, however these are the Farndon West and East FCAs and are expected. Therefore, the flood risk impacts arising due to the Scheme during the 1% AEP plus climate change event are considered “negligible” in accordance with the DMRB guidance.

3.5.4.2 The original model predicts depth increases between 5mm-10mm at 171 “More Vulnerable” receptors, 123 of these are located south of Cattle Market roundabout and 48 are located south of Windmill Viaduct. Although increases of less than 0.01m (10mm) are considered a ‘negligible’ impact in accordance with DMRB guidance, sensitivity testing of the model at Windmill Viaduct was undertaken to better understand the increases at these receptors.

3.5.4.3 Amendments to the Windmill Viaduct Scheme embankment in the sensitivity model involved a modified representation of the Scheme embankment and abutment taking into consideration the 10m model grid size. This amendment led to a reduction in the number of “More Vulnerable” properties from 171 to 144 where a depth increase is predicted.

3.5.4.4 As a result of the amendments to the Scheme embankment at Windmill Viaduct, no “More Vulnerable” receptors upstream of Windmill Viaduct show a depth increase greater than 0.005m (5mm) or an increase in flood hazard.

3.5.4.5 The remaining 144 “More Vulnerable” receptors with a predicted depth increase between 0.005m to 0.01m (5-10mm), all are located south of Cattle Market roundabout, and the average predicted depth increase is 0.006m (6mm). Furthermore, flood hazard is not predicted to change at these receptors as a result of the Scheme. It should be noted that these increases are considered a “negligible” impact in accordance with the DMRB guidance and are on top of an average baseline depth of 0.965m (965mm) and are therefore considered acceptable by the Applicant.

Table 1: 1% AEP plus climate change. Flood depths differences. Mitigated Scheme versus baseline. Original model

	Count of receptors with change in depth							
NPPF Class	**<0mm**	**0-1mm**	**1-2mm**	**2-3mm**	**3-4mm**	**4-5mm**	**5-10mm**	**>10mm**
Essential Infrastructure	11	3	2	1	0	0	1	0
Highly Vulnerable	90	5	0	0	0	0	2	0
More Vulnerable	940	265	101	73	30	51	171	0
More Vulnerable (Low Confidence)	236	109	16	13	5	3	25	0
Less Vulnerable	234	46	11	6	1	0	44	2
Less Vulnerable (Low Confidence)	108	53	1	1	0	0	17	0
Water Compatible	213	54	7	4	0	1	10	0
Total number with decrease (excluding water compatible)								**1619**
Total number with increase (excluding water compatible)								**1058**

Table 2: 1% AEP plus climate change. Flood depth differences. Mitigated Scheme versus baseline. Sensitivity test

	Count of receptors with change in depth							
NPPF Class	**<0mm**	**0-1mm**	**1-2mm**	**2-3mm**	**3-4mm**	**4-5mm**	**5-10mm**	**>10mm**
Essential Infrastructure	10	5	1	0	0	0	1	0
Highly Vulnerable	91	4	0	0	0	0	2	0
More Vulnerable	804	315	16	2	5	3	144	0
More Vulnerable (Low Confidence)	216	126	10	0	0	0	12	0
Less Vulnerable	191	56	7	4	3	0	39	2
Less Vulnerable (Low Confidence)	94	55	6	1	0	0	12	0
Water Compatible	141	70	5	1	3	1	9	0
Total number with decrease (excluding water compatible)								**1406**
Total number with increase (excluding water compatible)								**831**

4. Slough Dyke realignment

4.1.1 The Slough Dyke watercourse is a designated Environment Agency Main River and is a tributary of the River Trent. Realignment of the watercourse is proposed at the location where it crosses the Scheme alignment near Brownhills Junction.

4.1.2 The realignment would move the existing watercourse by approximately 7m to 8m to the east to be aligned closer to the A1 highway. A schematic of the Slough Dyke realignment is shown in Figure 10. Details of the cross-section plan can be found in TR010065/APP/2.6 "Engineering Plans and Sections Part 6 - Structures General Arrangements APP-14", Sheet 12.

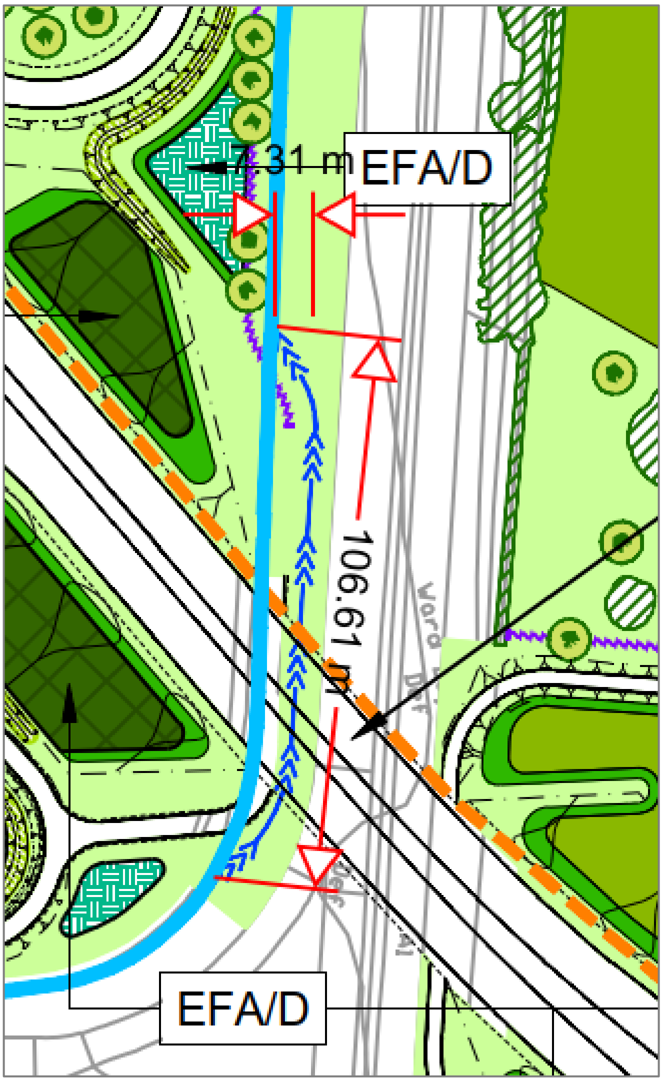

Figure 10: Slough Dyke realignment – extract from AS-007 (General Arrangement Plans) Sheet 25005

4.1.3 The existing channel cross-section shape would be retained and is not expected to change the current hydraulics or risk of flooding in the local area. The realignment was therefore not included in the original model. For this technical note, sensitivity testing of the realignment has been undertaken to assess any potential change in flood risk due to the representation of the Slough Dyke realignment. Enforcements to the hydraulic model for sensitivity testing consisted of:

- Increasing the channel length by 33m.

- Shifting the channel to the east by 8 to 10m.

4.1.4 The hydraulic model results for the 1% AEP event plus climate change event demonstrate changes in peak water level of up to 0.015m (15mm) immediately upstream of the realigned section of Slough Dyke (Figure 11) within the channel. However, this has no impact on flood depths on the floodplain. It has therefore been demonstrated that the Slough Dyke realignment representation would not increase the risk of flooding.

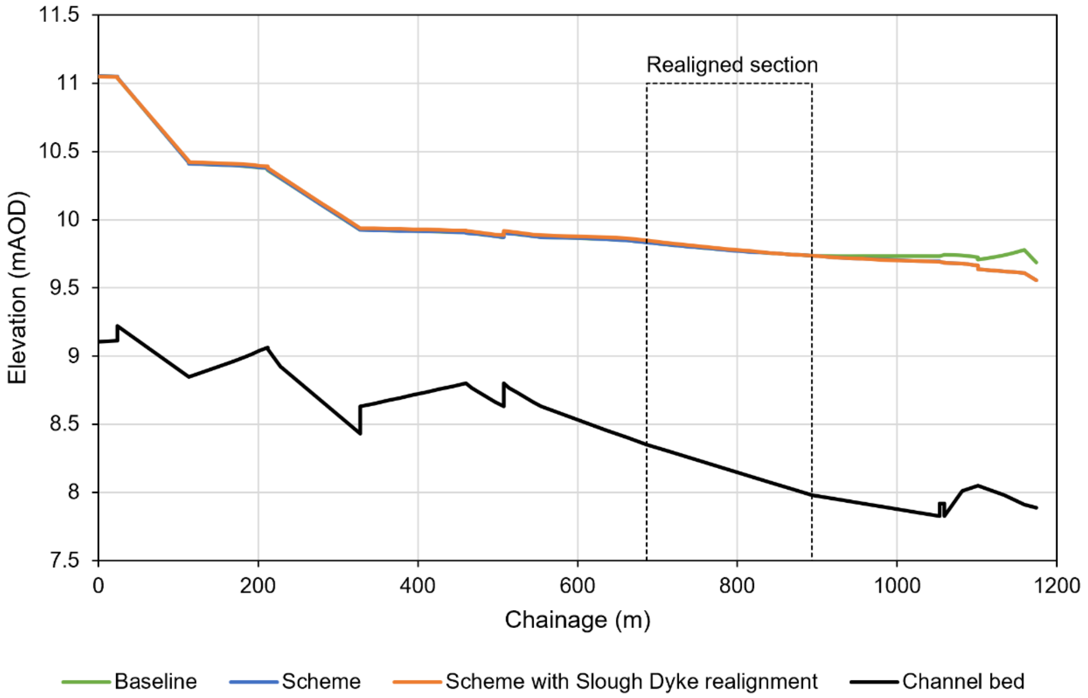

Figure 11: Comparison of peak water levels through Slough Dyke with and without realignment

5. Climate change allowances applied in the hydraulic model

5.1.1 The use of the hydraulic model for the assessment of the flood risk for the baseline and Mitigated Scheme scenarios for the Scheme FRA (APP-177) included consideration of a credible maximum climate change scenario (H++).

5.1.2 The design flood event assessed for the Mitigated Scheme was the 1% AEP plus climate change event, using the higher central allowance of 39% for the 2080s epoch (Section 8 of the Scheme FRA (APP-177)).

5.1.3 However, the credible maximum climate change scenario was also assessed. The event assessed was the 0.5% AEP plus the upper end climate change allowance of 62%. As discussed in Section 7.2 of the Scheme FRA (APP-177), this event was selected as the 'check event' required for assessment in the DMRB document CD356[13]. The 0.1% AEP event was used as a proxy event for the 0.5% plus 62% climate change uplift.

5.1.4 Table 3 shows the peak flows applied in the model for the major and dominant fluvial inflow from the Upper River Trent ('TRENT 01'). It can be seen from the table that the peak flow for the 0.5% AEP plus 62% climate change event (2028m^3/s) is within 1% of the peak flow for the 0.1% AEP event (2007m^3/s) and therefore is a suitable proxy event as discussed in the Scheme FRA.

Table 3: Peak flows for model inflows from the Upper River Trent catchment

	Flood peak (m^3/s) for the following AEP (%) events												
	50	**20**	**10**	**5**	**4**	**3.3**	**2**	**1.3**	**1**	**1 plus 39% climate change**	**0.5**	**0.5 plus 62% climate change**	**0.1**
TRENT 01	463	635	752	867	904	933	1018	1085	1134	1576	1252	2028	2007

5.1.5 The deck levels of the bridges and the elevations of the road surface for the main carriageway of the Scheme are preset, as the nature of the Scheme is a widening of an existing road rather than the construction of a new road. The analysis presented in the Scheme FRA (APP-177) shows that the main carriageway of the Scheme is not at flood risk for the 0.5% AEP plus 62% climate change event and therefore the Scheme is resilient to a credible maximum climate change scenario.

5.1.6 Some of the ancillary road connections to the Scheme, including Cattle Market roundabout for example, are at lower elevations than the rest of the Scheme as they tie in with existing sections of highway which are not to be altered as part of the Scheme and thus are not applicable for flood resilience.

[13] Design Manual for Roads and Bridges, CD 356 Design of highway structures for hydraulic action, Revision 1, Highways England, March 2020

Appendix A - NRD to NPPF receptor vulnerabilities

NRD class descriptions have been used to assign NPPF flood risk vulnerabilities, where possible, to all receptors within the study area. NPPF receptor vulnerability is described in Annex 3: Flood risk vulnerability classification[3]. The table that was used to convert NRD class descriptions to NPPF vulnerabilities is provided in Table 4, and includes the following assumptions:

- Any points where “Housetype” is "office" and “Floorlevel” is "dB" (definite basement) are assigned as "Less Vulnerable".
- Any points where “Housetype” is "flat" and “Floorlevel” is "dB" are assigned as "Highly Vulnerable".
- The flood risk vulnerability classification mandates that essential utility infrastructure be categorised as “Essential Infrastructure”. Although there are 77 electricity sub-stations in the Study area, most of these are smaller sub-stations serving residential areas.
- Any points labelled as “Caravan” are considered “Highly Vulnerable”, regardless of whether the caravan is permanent or temporary. Please note that the NRD may not have identified all caravans.

Table 4 Lookup table for mapping of NRD class description to NPPF vulnerability

NRD Class Description	NPPF vulnerability
Electricity Sub-Station Power Station / Energy Production Water / Waste Water / Sewage Treatment Works	Essential Infrastructure
Ambulance Station Army Caravan Emergency / Rescue Service Fire Station Telecommunication	Highly Vulnerable
Boarding / Guest House / Bed And Breakfast / Youth Hostel Care / Nursing Home Children’s Nursery / Crèche College Detached Dwelling General Practice Surgery / Clinic Health Care Services Health Centre Holiday / Campsite Holiday Let/Accommodation/Short-Term Let Other Than CH01 Hotel/Motel Landfill Medical Preparatory / First / Primary / Infant / Junior / Middle School Primary School	More Vulnerable

NRD Class Description	NPPF vulnerability
Public House / Bar / Nightclub Residential Residential Institution Secondary / High School Self-Contained Flat (Includes Maisonette / Apartment) Semi-Detached Sheltered Accommodation Terraced Waste Management	
Activity / Leisure / Sports Centre Agricultural Agricultural - Applicable to land in farm ownership and not run as a separate business enterprise Allotment Amenity - Open areas not attracting visitors Amusements Ancillary Building Animal Centre Animal Services Bank / Financial Service Bingo Hall / Cinema / Conference / Exhibition Centre / Theatre / Concert Hall Builders' Yard Bus / Coach Station Car / Coach / Commercial Vehicle / Taxi Parking / Park And Ride Site Central Government Service Church Church Hall / Religious Meeting Place / Hall Cinema Commercial Community Service Centre / Office Community Services Crane / Hoist / Winch / Material Elevator Dentist Equestrian Factory/Manufacturing Farm / Non-Residential Associated Building Fast Food Outlet / Takeaway (Hot / Cold) Football Facility Forestry Garage Grab / Skip / Other Industrial Waste Machinery / Discharging Grazing Land Hopper / Silo / Cistern / Tank Horticulture Indoor / Outdoor Leisure / Sporting Activity / Centre Industrial Applicable to manufacturing, engineering, maintenance, storage / wholesale distribution and extraction sites	Less Vulnerable

NRD Class Description	NPPF vulnerability
Industrial Support	
Job Centre	
Land	
Law Court	
Leisure - Applicable to recreational sites and enterprises	
Library	
Local Government Service	
Manufacturing	
Market (Indoor / Outdoor)	
Mineral / Ore Working / Quarry / Mine	
Museum / Gallery	
Office	
Office / Work Studio	
Other Licensed Premise / Vendor	
Park	
Permanent Crop / Crop Rotation	
Petrol Filling Station	
Place Of Worship	
Playground	
Police Box / Kiosk	
Police Training	
Post Office	
Public / Village Hall / Other Community Facility	
Public Car Parking	
Public Park / Garden	
Racquet Sports Facility	
Railway Asset	
Recreational / Social Club	
Recycling Site	
Restaurant / Cafeteria	
Retail	
Retail Service Agent	
Servicing Garage	
Shop / Showroom	
Station / Interchange / Terminal / Halt	
Steel Works	
Theatre	
Vehicle Storage	
Vet / Animal Medical Treatment	
Warehouse / Store / Storage Depot	
Wholesale Distribution	
Workshop / Light Industrial	
Chimney / Flue	
Other Educational Establishment	
Water Sports Facility	

NRD Class Description	NPPF vulnerability
Transport Transport Track / Way Transport Related Infrastructure Underground Feature Castle / Historic Ruin Development Site Development Dual Use	
Advertising Hoarding Bus Shelter Cemetery / Crematorium / Graveyard. In Current Use. Channel / Conveyor / Conduit / Pipe House Boat Lake / Reservoir Maintained Amenity Land Marina Memorial / Market Cross Monument Mooring Named Pond Object of Interest Open Space Other Utility Use Parent Shell PO Box Postal Box Property Shell Public Convenience Pump House / Pumping Station / Water Tower (water compatible) Static Water Street Record Telephone Box Tourist Information Signage Traffic Information Signage Unused Land Utility Vacant / Derelict Land Verge / Central Reservation	Water Compatible

Appendix B - Receptor analysis for low magnitude events

Introduction

This Appendix summarises the flood depth differences at receptors for the Mitigated Scheme versus baseline scenarios for lower magnitude events than the 1% AEP plus climate change event. The analysis uses the same methodology as used for the 1% AEP plus climate change analysis in Section 3 of this technical note.

The summary tables present the total numbers of receptors with increases or decreases in flood depth. The totals exclude “Water Compatible” receptors, as identified in Appendix A, which by their nature are resilient to minor changes in flood level.

DMRB guidance sets out flood depth thresholds only for the 1% AEP plus climate change event. Therefore, for the smaller events reported in Appendix B these thresholds (and subsequent conclusions of significance of effect) are provided for context only. Changes in peak flood level less than 0.01m (10mm) are still considered a "negligible" impact, in accordance with the DMRB guidance. However, for the purpose of reporting, all depth increases above 0.001m (1mm) have been reported in the summary tables, and those with flood depth increases greater than 0.005m (5mm) are discussed.

50% AEP event (2-year return period event)

A comparison between the baseline and Mitigated Scheme scenarios for the original model (Table 5) indicates that 14 receptors are predicted to decrease in flood depths, whilst 15 receptors are predicted to increase.

Vulnerable receptors with a predicted increase are summarised as follows:

- One “Essential Infrastructure” receptor with a flood depth increase of less than 0.002m (2mm) compared to the baseline.
    - This is a wind turbine. However, the physical location of the turbine as observed on satellite imagery appears to be approximately 250m from the assigned NRD receptor point, and no depth differences are observed at this location.
- Three “Highly Vulnerable” receptors with flood depth differences of less than 0.005m (5mm) on top of baseline flood depths between 0.045m and 0.10m (45mm-100mm).
- Three “More Vulnerable (Low Confidence)” receptors with flood depth increases of less than 0.01m (10mm) on top of baseline flood depths between 0.02m and 0.47m (20mm-470mm).

No flood depth increases above 10mm are predicted at any “Essential Infrastructure”, “Highly Vulnerable”, “More Vulnerable”, “More Vulnerable (Low Confidence)”, or “Less Vulnerable (Low Confidence)” receptors.

No flood depth increases above 5mm are predicted at any “Essential Infrastructure”, “Highly Vulnerable”, or “More Vulnerable” receptors.

“Less Vulnerable” receptors with a predicted depth increase are summarised as follows:

- Eight “Less Vulnerable” receptors with flood depth increases of greater than 0.005m (5mm) include the cricket club, the rugby club, five greenfield locations, and one hopper located 1.2km north of the Scheme, with baseline flood depths between 0.02m and 0.79m (20mm-790mm).
- Four “Less Vulnerable” receptors where increases in flood depths greater than 0.01m (10mm) are predicted, one of these being an increase of 0.031m (31mm) at the cricket club, and the remaining three being greenfield sites. It should be noted that at the cricket club, the baseline depth is 0.40m (400mm), and there would be no change in flood hazard due to the Scheme.

The model predicts that the Scheme would not change the flood hazard classification at most receptors other than those below:

- Increase from “Low” to “Significant” at one “Less Vulnerable” receptor at the Farndon West FCA. This change is expected, as the FCA is designed to fill up and store water within the floodplain. There is no change at the Farndon East FCA as the hazard rating is already “Significant”.
- Decrease from “Significant” to “Moderate” at one “Less Vulnerable” receptor at agricultural land near Cattle Market roundabout.

Summary - 50% AEP

During the 50% AEP event, reductions in flood depths are predicted at 14 receptors. Furthermore, the Scheme is not predicted to cause increases in flood depths above 0.005m (5mm) at any “Essential Infrastructure”, “Highly Vulnerable”, or “More Vulnerable” receptors.

There are eight “Less Vulnerable” receptors with increases above 0.005m (5mm) due to the Scheme, two of which are the rugby and cricket clubs. Baseline depths at the rugby and cricket clubs are 0.02m (20mm) and 0.40m (400mm) respectively, and there would be no change in flood hazard due to the Scheme.

Table 5: 50% AEP. Flood depth differences. Mitigated Scheme versus baseline. Original model.

	Count of receptors with change in depth							
NPPF Class	**<0mm**	**0-1mm**	**1-2mm**	**2-3mm**	**3-4mm**	**4-5mm**	**5-10mm**	**>10mm**
Essential Infrastructure	0	0	1	0	0	0	0	0
Highly Vulnerable	0	0	0	1	0	2	0	0
More Vulnerable	0	0	0	0	0	0	0	0
More Vulnerable (Low Confidence)	0	0	0	0	0	1	2	0
Less Vulnerable	14	0	0	0	0	0	4	4
Less Vulnerable (Low Confidence)	0	0	0	0	0	0	0	0
Water Compatible	54	0	0	3	5	0	9	1
Total number with decrease (excluding water compatible)								**14**
Total number with increase (excluding water compatible)								**15**

20% AEP event (5-year return period event)

A comparison between baseline and Mitigated Scheme scenarios for the original model (Table 6) indicates that 44 receptors are predicted to decrease in flood depths, whilst 36 receptors are predicted to increase.

Vulnerable receptors with a predicted increase are summarised as follows:

- Two "Essential Infrastructure" receptors with flood depth increases less than 1mm on top of baseline flood depths between 0.20m and 0.77m (200-770mm).
  - One is a wind turbine according to the NRD. However, the physical location of the turbine, as observed on satellite imagery is approximately 250m from the assigned NRD receptor location, and no depth differences are observed at this location.
  - One is an electricity sub-station 1.2km northwest of the Scheme where the baseline flood depth is already 0.77m (770mm).
- Four "Highly Vulnerable" receptors with flood depth differences of less than 0.005m (5mm) on top of baseline depths of up to 0.35m (350mm). These receptors are caravans in the western end of the Tolney Lane area adjacent to Old Trent Dyke. Flood hazard is not predicted to change at these receptors.
- One "More Vulnerable" receptor and one "More Vulnerable (Low Confidence)" receptor at Tolney Lane with flood depth differences greater than 0.005m (5mm). Flood hazard is not predicted to change at these receptors.
  - At the "More Vulnerable" receptor, the predicted flood depth increase of 0.006m (6mm) is on top of a baseline depth of 0.14m (140mm). However, upon close inspection of the results, the respective depths in the baseline and Mitigated Scheme scenarios both show minor numerical fluctuations in this area at the peak of up to 0.005m (5mm), indicating that the modelled depth increases in this area are a result of modelling uncertainty (see Section 2) rather than a material flood risk impact.
  - Based on aerial imagery, the receptor marked as "More Vulnerable (Low Confidence)" appears unlikely to be a "More Vulnerable" residential dwelling.

No increases above 0.01m (10mm) are predicted at any "Essential Infrastructure", "Highly Vulnerable", or "More Vulnerable" receptors. No other changes in flood hazard are predicted.

"Less Vulnerable" receptors with a predicted depth increase are summarised as follows:

- Seven "Less Vulnerable" receptors with flood depth increases of greater than 0.005m (5mm) include the cricket club, the rugby club, and five greenfield locations with baseline flood depths between 0.30m and 1.20m (300mm-1200mm). Flood hazard is not predicted to change at these receptors, aside from one which is agricultural land and is predicted to increase from "Moderate" to "Significant".

- Three “Less Vulnerable (Low Confidence)” receptors with flood depth increases of greater than 0.005m (5mm), including the rugby club, one at the British Sugar Factory 750m north of the Scheme, and one at agricultural land 150m west of the Scheme. Flood hazard is not predicted to change at these receptors, aside from one which is located at the British Sugar Factory and is predicted to increase from “Low” to “Moderate”.

Summary – 20% AEP

During the 20% AEP event, reductions in flood depths due to the Scheme are predicted at 44 receptors ranging from “More Vulnerable” to “Less Vulnerable (Low Confidence)”. The Scheme is also not predicted to increase flood depths above 0.01m (10mm) at any “Essential Infrastructure”, “Highly Vulnerable”, “More Vulnerable”, “More Vulnerable (Low Confidence)” or “Less Vulnerable (Low Confidence)” receptors.

There is one “More Vulnerable” receptor at Tolney Lane where an increase of 0.006m (6mm) is predicted, however it should be noted that this is on top of a baseline depth of 0.14m (140mm) and flood hazard is not predicted to change.

Table 6: 20% AEP. Flood depth differences. Mitigated Scheme versus baseline. Original model.

	Count of receptors with change in depth							
NPPF Class	**<0mm**	**0-1mm**	**1-2mm**	**2-3mm**	**3-4mm**	**4-5mm**	**5-10mm**	**>10mm**
Essential Infrastructure	0	2	0	0	0	0	0	0
Highly Vulnerable	0	0	0	1	0	3	0	0
More Vulnerable	4	4	0	1	0	0	1	0
More Vulnerable (Low Confidence)	9	2	0	1	0	0	4	0
Less Vulnerable	30	3	0	2	0	0	4	3
Less Vulnerable (Low Confidence)	1	0	0	2	0	0	3	0
Water Compatible	78	2	0	4	1	1	3	8
Total number with decrease (excluding water compatible)								**44**
Total number with increase (excluding water compatible								**36**

5% AEP event (20-year return period event)

A comparison between the baseline and Mitigated Scheme scenarios for the original model (Table 7) indicates that 201 receptors are predicted to see a decrease in flood depth, whilst 69 receptors are expected to see an increase.

Vulnerable receptors with a predicted depth increase are summarised as follows:

- One “Essential Infrastructure” receptor with a flood depth increase of less than 0.001m (1mm). This is an electricity sub-station located 800m northwest of the Scheme, where baseline depths are 0.65m (650mm). Flood hazard is not predicted to change at this receptor.
- Three “More Vulnerable” receptors and two “More Vulnerable (Low Confidence)” receptors experience flood depths of greater than 0.01m (10mm) and less than 0.02m (20mm) on top of baseline depths between 0.045m and 0.40m (45-400mm). These receptors are located at Tolney Lane. Flood hazard is not predicted to change at these receptors. It is noted that these receptors at Tolney Lane appear sensitive to an adjacent opening under the Nottingham-Lincoln railway line.

“Less Vulnerable” receptors with a predicted depth increase are summarised as follows:

- Three “Less Vulnerable” receptors experience an increase greater than 0.01m (10mm), two of which are located within the Farndon East and West FCAs. This change is expected, as the FCA is designed to fill up and store water within the floodplain. The remaining “Less Vulnerable” receptor is the cricket club, where a depth increase of 0.025m (25mm) is predicted on top of a baseline depth of 0.98m (980mm), though flood hazard is not predicted to change.
- One “Less Vulnerable” receptor which is not predicted to flood in the baseline is now predicted to flood due to the Scheme, this is the Tolney Lane Car Park. The hazard classification at this location due to the Scheme is “Low”. The flood depths due to the Scheme at this location range between 0.0075m to 0.05m (7.5-50mm).

There are no increases in flood depths at “Highly Vulnerable” receptors, and no increases above 1mm at “Essential Infrastructure” receptors. No depth increases above 10mm are predicted at any “Less Vulnerable (Low Confidence)” receptors. The model predicts that the Scheme would not change the flood hazard classification at most receptors, decreasing flood hazard at four receptors and increasing it at five.

Summary – 5% AEP

During the 5% AEP event, reductions in flood depths are predicted at 201 receptors.

Flood depths are predicted to increase by more than 10mm at five “More Vulnerable” or “More Vulnerable (Low Confidence)” receptors at Tolney Lane, which are sensitive to an adjacent opening under the Nottingham-Lincoln railway line. No change in flood hazard is predicted at these receptors.

Depth increases above 0.01m (10mm) are also predicted at three “Less Vulnerable” receptors, although two of these are the Farndon West and East FCAs, as expected, and the third is the cricket club. It should be noted that the predicted increase at the cricket club is 0.025m (25mm) on top of a baseline depth of 0.98m (980mm). Flood hazard is also not predicted to change and remains “Significant”.

Table 7: 5% AEP. Flood depth differences. Mitigated Scheme versus baseline. Original model.

	Count of receptors with change in depth							
NPPF Class	**<0mm**	**0-1mm**	**1-2mm**	**2-3mm**	**3-4mm**	**4-5mm**	**5-10mm**	**>10mm**
Essential Infrastructure	3	1	0	0	0	0	0	0
Highly Vulnerable	37	0	0	0	0	0	0	0
More Vulnerable	56	2	0	3	2	1	0	3
More Vulnerable (Low Confidence)	35	12	2	1	2	2	2	2
Less Vulnerable	53	12	1	1	0	1	5	4
Less Vulnerable (Low Confidence)	17	1	0	3	1	3	2	0
Water Compatible	81	16	2	3	10	1	4	0
Total number with decrease (excluding water compatible)								**201**
Total number with increase (excluding water compatible								**69**

3.33% AEP event (30-year return period event)

A comparison between the baseline and Mitigated Scheme scenarios for the original model (Table 8) indicates that 265 receptors are predicted to decrease in flood depth, whilst 73 are predicted to increase.

Vulnerable receptors with predicted increases are summarised as follows:

- Three “Essential Infrastructure” receptors with increases less than 0.001m (1mm), all of which are electricity sub-stations. Two of the sub-stations are at the model boundary 2.5km southeast of the Scheme, the third is located 1.5km north of the Scheme. Baseline flood depths across the three locations ranges from 0.37m (370mm) to 0.79m (790mm), and flood hazard is not predicted to change.

“Less Vulnerable” receptors with a predicted depth increase are summarised as follows:

- Two “Less Vulnerable” receptors with increases above 0.01 (10mm). These are the Farndon West and East FCAs. This change is expected, as the FCA is designed to fill up and store water within the floodplain.

There are no other receptors where flood depths are predicted to increase above 0.005m (5mm), and no other instances of increased hazard.

Summary – 3.33% AEP

During the 3.33% AEP event, reductions in flood depths are predicted at 265 receptors. The Scheme is not predicted to increase flood depths to any receptors above 0.005m (5mm), aside from two “Less Vulnerable” receptors which are the Farndon West and East FCAs as expected. In addition to this, there are no instances of increased hazard arising from the Scheme.

Table 8: 3.33% AEP. Flood depth differences. Mitigated Scheme versus baseline. Original model.

	Count of receptors with change in depth							
NPPF Class	**<0mm**	**0-1mm**	**1-2mm**	**2-3mm**	**3-4mm**	**4-5mm**	**5-10mm**	**>10mm**
Essential Infrastructure	2	3	0	0	0	0	0	0
Highly Vulnerable	49	0	0	0	0	0	0	0
More Vulnerable	71	10	3	3	2	1	0	0
More Vulnerable (Low Confidence)	50	12	5	2	3	1	0	0
Less Vulnerable	71	5	2	1	4	0	2	2
Less Vulnerable (Low Confidence)	22	1	5	1	5	0	0	0
Water Compatible	98	8	10	2	5	0	0	0
Total number with decrease (excluding water compatible)								**265**
Total number with increase (excluding water compatible								**73**

1% AEP event (100-year return period event)

A comparison between baseline and Mitigated Scheme scenarios for the original model (Table 9) indicates that 644 receptors are predicted to decrease in depth, whilst 306 receptors are predicted to increase.

Vulnerable receptors with a predicted increase are summarised as follows:

- Two “Essential Infrastructure” receptors with increases above 0.003m (3mm). Flood hazard is not predicted to change at either of these receptors.
    - One is an electricity sub-station near Fosse Road with an increase of 0.027m (27mm) on top of a baseline flood depth of 0.22m (220mm).
    - The other is a sewage pumping station near Fosse Road with an increase of 0.004m (4mm) on top of a baseline flood depth of 0.6m (600mm).
- Five “Highly Vulnerable” receptors with increases up to 0.002m (2mm). Two of these are caravans at Tolney Lane, with increases of 2mm on top of baseline depths of 0.1m (100mm), the remaining three are telecommunications phone masts with increases of less than 0.002m (2mm) on top of baseline depths of 0.27m (270mm).
- 53 “More Vulnerable” receptors with increases greater than 0.005m (5mm), all of which are located near Fosse Road, 300m southwest of Farndon Roundabout, and are attributed to modelling uncertainties. Impacts at Fosse Road are discussed further in the following sub-section. It should be noted that except for two receptors, flood hazard is not predicted to change; the two “More Vulnerable” residential properties show an increase in flood hazard classification from “Low” to “Moderate”. However, this is reflective only of the NRD point position at the centroid of the properties. The overall hazard across the wider area is “Moderate”.
- Two of the 53 “More Vulnerable” receptors near Fosse Road are not predicted to flood in the baseline and are now predicted to flood due to the Scheme, these are dwellings at Village Close. The hazard classification at these receptors with the Scheme is “Low”. The flood depth with the Scheme is up to 0.021m (21mm) at these properties.
- Five “More Vulnerable (Low Confidence)” receptors with increases greater than 0.01m (10mm) located near Fosse Road 300m southwest of Farndon Roundabout. Flood hazard is not predicted to change at these receptors.

“Less Vulnerable” receptors with a predicted depth increase are summarised as follows:

- Three “Less Vulnerable” receptors, two of which are the Farndon West and East FCAs, and the third is a showroom at Fosse Road. At the showroom, a depth increase of 0.027m (27mm) is predicted on top of a baseline depth of 0.310m (310mm), and the flood hazard is not predicted to change.

1% AEP receptors at Fosse Road

Near Fosse Road, there is an area of depth increase greater than 0.01m (10mm). This location is shown in Figure 12. The “More Vulnerable” and “More Vulnerable (Low Confidence)” receptors with an increase above 10mm are located here. A review of model grid cells at this location provides some indication that this impact may be attributed to modelling uncertainties and may not be a material increase in flood risk.

The area of increase at Fosse Road is outside of the Scheme boundary, and model grid size switches from 10m to 20m immediately north of this zone, resulting in minor edge effects at the model domain boundaries. The coarser grid size may also lead to inaccuracies when representing very localised elevation changes in topographic data. The terrain model appears conservative, with one 20m grid cell in the area assigned a comparatively higher elevation than its neighbours. This discrepancy controls the only flow path into the area, resulting in overestimated flood risk impacts. A review of detailed topographic data indicates no physical basis for this topographic hydraulic control, and therefore it is considered unlikely that the modelled flood impacts in this area are an accurate representation of flood risk.

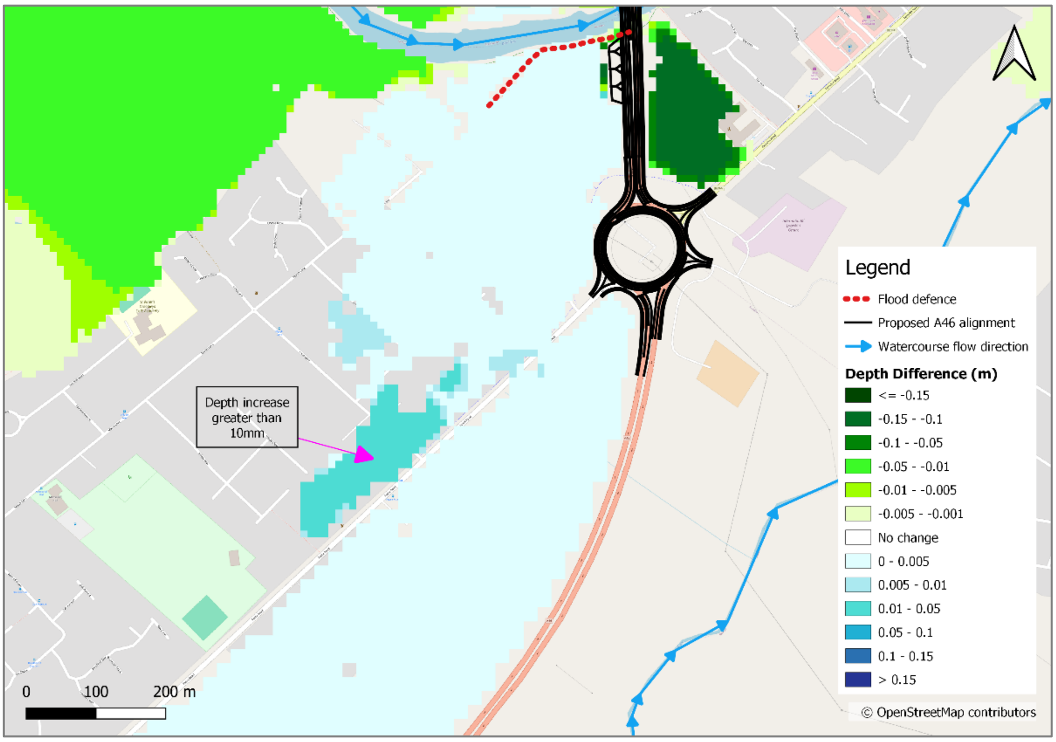

Figure 12: 1% AEP. Fosse Road. Flood depth differences. Mitigated Scheme versus baseline. Original model.

Summary – 1% AEP

During the 1% AEP event, reductions in flood depth are predicted at 644 receptors. Increases at two “Essential Infrastructure” receptors are predicted, however these changes are very small in relation to baseline depths, and flood hazard Is not predicted to increase.

At Fosse Road immediately upstream of Windmill Viaduct, 36 “More Vulnerable” and five “More Vulnerable (Low Confidence)” receptors are predicted to increase in flood depth by more than 10mm; however there is typically no change in flood hazard at these receptors. These receptors are in an area of model uncertainty which may be leading to overestimation of flood risk impacts.

Table 9: 1% AEP. Flood depth differences. Mitigated Scheme versus baseline. Original model

	Count of receptors with change in depth							
NPPF Class	**<0mm**	**0-1mm**	**1-2mm**	**2-3mm**	**3-4mm**	**4-5mm**	**5-10mm**	**>10mm**
Essential Infrastructure	9	0	0	0	1	0	0	1
Highly Vulnerable	63	2	3	0	0	0	0	0
More Vulnerable	220	14	20	9	49	40	17	36
More Vulnerable (Low Confidence)	106	18	10	6	4	19	4	5
Less Vulnerable	166	4	5	1	3	9	0	3
Less Vulnerable (Low Confidence)	80	5	10	1	2	5	0	0
Water Compatible	141	7	7	2	0	0	0	3
Total number with decrease (excluding water compatible)								**644**
Total number with increase (excluding water compatible								**306**