Norwich Western Link

Drainage Strategy Report

Appendix 9: Ringland lane flood modelling report

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1 Introduction

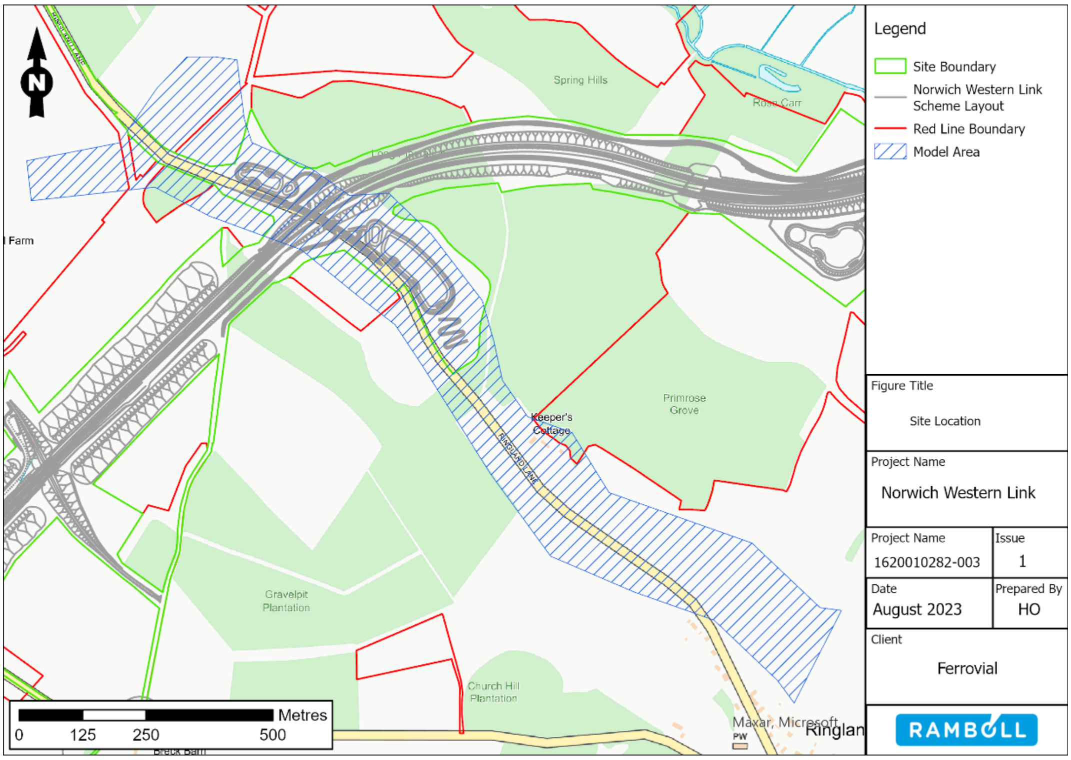
1.1 Overview

1.1.1 Ramboll were commissioned by Ferrovial, working on behalf of Norwich County Council, to undertake a flood modelling exercise for the Proposed Scheme. This work has included hydraulic modelling of the overland flow pathway at Ringland Lane.

1.1.2 WSP UK Limited (WSP) completed hydraulic modelling of the Ringland Lane overland flow path (April 2023) to inform the FRA accompanying the Environmental Impact Assessment (EIA) for the Proposed Scheme. WSP created this model as no previous modelling studies of the Ringland Lane overland flow path existed. The model was created using 1D-2D ESTRY-TUFLOW software.

1.1.3 WSP issued the complete Ringland Lane Hydraulic Model control files to Ramboll (June 2023). The WSP model was reviewed internally, and several updates were proposed to add in new data and design details that have since become available.

Figure 1.1: Norwich Western Link Scheme Layout with Hydraulic Model area for Ringland Lane



1.1.4 The Proposed Scheme design at Ringland Lane consists of the following:

- The Norwich Western Link relief road scheme (NWL) road itself which includes a bridge to pass over Ringland Lane and earth embankments in the area of existing Ringland Lane overland flow paths (established from the WSP modelling). The road level is between 32.0 m Above Ordnance Datum (mAOD) to 33.0mAOD;
- Two surface water infiltration ponds located upstream (Basin 3) and downstream (Basin 4) of NWL;
- An access track on an embankment to provide maintenance access to Basin 3 and which crosses the Ringland Lane overland flow paths in two locations;
- The Preliminary Earthwork Drain (PED) network that collects surface water runoff from the surrounding catchments and conveys this runoff around the infiltration ponds and beneath the Proposed Scheme to

discharge the runoff along the existing overland flow path to the east of Basin 4;

- A flood attenuation basin upstream of the Proposed Scheme that controls the flow of flood waters into the PEDs through flow control devices (e.g. Hydro-Brakes); and
- Three culvert structures beneath the various embankments connect the PED networks upstream and downstream of the Proposed Scheme as follows:
  - Basin 4 maintenance access track culvert upstream = 1 x 0.9m diameter culverts, 6.27m long;
  - Basin 4 maintenance access track culvert downstream = 1 x 0.9m diameter culvert, 12.9m long; and
  - NWL Road culvert = 1 x 0.9m diameter culvert 77.8m long.

1.2 Aims

1.2.1 The Proposed Scheme crosses the Ringland Lane overland flow path. The aim of this study is to use hydraulic modelling to understand the impact of the Proposed Scheme on flood risk at the flow path and to the downstream wedding venue (The Keeper and the Dell) to inform the FRA.

1.3 Objectives

1.3.1 To satisfy the study aim, the objectives of the hydraulic modelling are to;

- update WSP's Hydraulic Model so that it is a suitable basis for assessment;
- refine the model grid resolution;
- update the ground model with topographic survey data and newer LiDAR;
- define the PEDs based on the updated Ramboll Design;

- Refine flood mitigation options included in the WSP model including the attenuation basin upstream of scheme, flow control devices from the attenuation feature and meanders downstream of scheme;
- add in roughness definitions for buildings;
- test various flood bund options upstream of the Proposed Scheme;
- use the updated 1D-2D ESTRY-TUFLOW hydraulic model to assess the Baseline flood risk and the Development flood risk for a range of return periods; and
- develop a technical report covering the model updates completed, modelling results and an assessment of the flood risk impact of the Proposed Scheme.

2 PREVIOUS HYDRAULIC MODELLING STUDIES

2.1 WSP, Norwich Western Link

2.1.1 WSP created a 1D-2D ESTRY-TUFLOW model, finalised in April 2023 to assess the flood risk impact of NWL for their FRA. WSP included various features of the Proposed Scheme based on the outline design. These are detailed in WSP's Norwich Western Link Ringland Lane Hydraulic Modelling Report v0.1 April 2023. WSP tested the suitability of flood mitigation proposals to convey flood waters past the scheme.

2.2 Hydrological Approach

2.2.1 WSP conducted a detailed hydrological assessment in 2020 of the ordinary watercourse which crosses the proposed NWL. The ordinary watercourse is a surface water flood route, crossing the NWL at 612615, 315120.

2.2.2 The catchment is 4.02km2 and is predominantly rural, with small pockets of woodland scattered throughout. The catchment drains west to east and has a high point of 55mAOD, sloping down to 25mAOD where the NWL crosses the overland flow route.

2.2.3 2.2.3 The WSP 2020 study derived model inflows using the statistical method up to the 100 year return period. For the higher return periods, the ratio method has been applied. Design hydrograph shapes have been derived from ReFH2, as well as determining a critical storm duration of 10.5 hours. Further details are provided in Appendix B of the Norwich Western Link Ringland Lane Hydraulic Modelling Report, April 2023.

2.2.4 2.2.4 The climate change allowances applied for the WSP model included 35%, 44% and 65% uplifts. A detailed review of the hydrology has not been completed by Ramboll and no changes to the hydrological assessment have been made by Ramboll unless otherwise stated in this report.

3 MODEL APPROACH AND JUSTIFICATION

3.1 Hydrological Approach

3.1.1 The hydrological approach used for the WSP modelling study has been applied in this study. This is to encourage consistency and comparability between the models, both of which are used to assess the same scheme. The design events simulated were the 1 in 30 year, 1 in 100 year and 1 in 1,000 year return periods (3.33%, 1% and 0.1% Annual Exceedance Probability (AEP) events respectively).

3.1.2 The climate change allowances were updated to follow the latest Government guidance. The development site is located within the Broadlands Management Catchment. To be conservative, the 2050s upper end allowance (for the 1% AEP rainfall event) for peak river flows was applied (45%). The rainfall uplift is more appropriate in this scenario as it is an overland flow path, based on surface water flows rather than fluvial flows.

3.2 Hydraulic Modelling Approach

3.2.1 A hydrodynamically linked 1D-2D ESTRY-TUFLOW model was used to understand the impact on flood risk from the Proposed Scheme. ESTRY-TUFLOW is industry-standard hydraulic modelling software for flood risk modelling, well understood by the EA. The original model provided by WSP was constructed using this software.

3.2.2 The hydraulic modelling approach was chosen with consideration of the trade-off between computational demands, the required spatial extent, and the accuracy of results. A 1D-2D model was selected for the following reasons:

- A 1D model linked to a 2D domain allows flow interactions between individual watercourses and structures to be accurately modelled, effectively representing the complex flow routes expected along the watercourses and within the floodplain of the study area.

- The 1D-2D linked model allows for an accurate simulation of in-channel hydraulics, coupled with detailed out-of-bank representation of flood routes, depths, flows and velocities. This provides a robust simulation of the effect of key hydraulic features both in and out of bank.
- A combined 1D-2D approach enables robust estimation of hazard in the floodplain, including the combined impact of coincident velocities and depths.

3.2.3 It was significantly more time-effective to use WSP's hydraulic model constructed for the area. Updates and changes were required to meet the objectives of the Ramboll study, detailed in Section 4 of this Report, summarised as follows:

- Model grid was refined;
- PEDs were input into the model topography, based on Ramboll design;
- Topographic survey and updated LiDAR included in the base model;
- Flood mitigation options included in the WSP model including the attenuation basin upstream of the scheme, flow control devices from attenuation feature and meanders downstream of scheme were refined;
- Roughness definitions for buildings included; and
- Various flood bund options upstream of the Proposed Scheme tested.

3.3 Model conceptualisation

3.3.1 The aim of this study is to use hydraulic modelling to understand the impact on flood risk from the Proposed Scheme to both the road itself and to third parties. The following scenarios have been considered:

1. Baseline Scenario (BAS)

- Representing the current setup of the Ringland Lane overland flow path.

2. Design Scenario (DEV2)

- Representing the Proposed Scheme crossing Ringland Lane, including access roads, new culverts and the PEDs. Flood mitigation options also included – flood attenuation basin, flood bund and meanders downstream of the Proposed Scheme.

4 HYDRAULIC MODEL UPDATES

4.1 Overview

4.1.1 Following a review of the WSP model of Ringland Lane, Ramboll identified several updates that would allow the model to be a suitable base for assessment of the detailed design of the Proposed Scheme. This section summarises these updates.

4.2 Grid Resolution

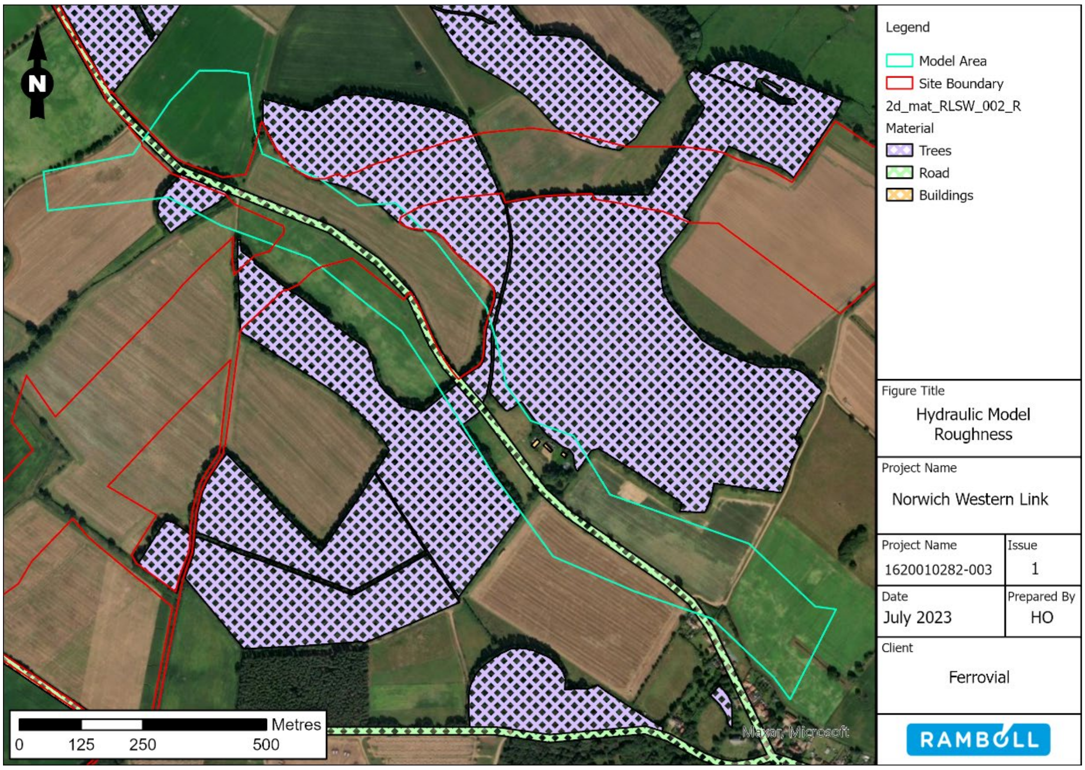
4.2.1 The WSP model used a 4 m grid resolution in the 2D TUFLOW domain. This was considered too coarse to represent the features of the Proposed Scheme, in particular the PEDs which are represented in the 1D domain. Ramboll has refined the model grid resolution to 2 m.

4.3 Model Roughness

4.3.1 Ramboll has updated to the hydraulic model roughness representation. The buildings downstream of the scheme have been defined in the roughness layer for both scenarios as the flood levels at that location are of interest. The buildings have been given a Manning's n roughness value of 0.3.

4.3.2 Figure 4.1 shows the updated hydraulic model roughness representation for the Design scenario.

Figure 4.1: Updated Hydraulic Model Roughness Representation for the Design Scenario (DEV2)

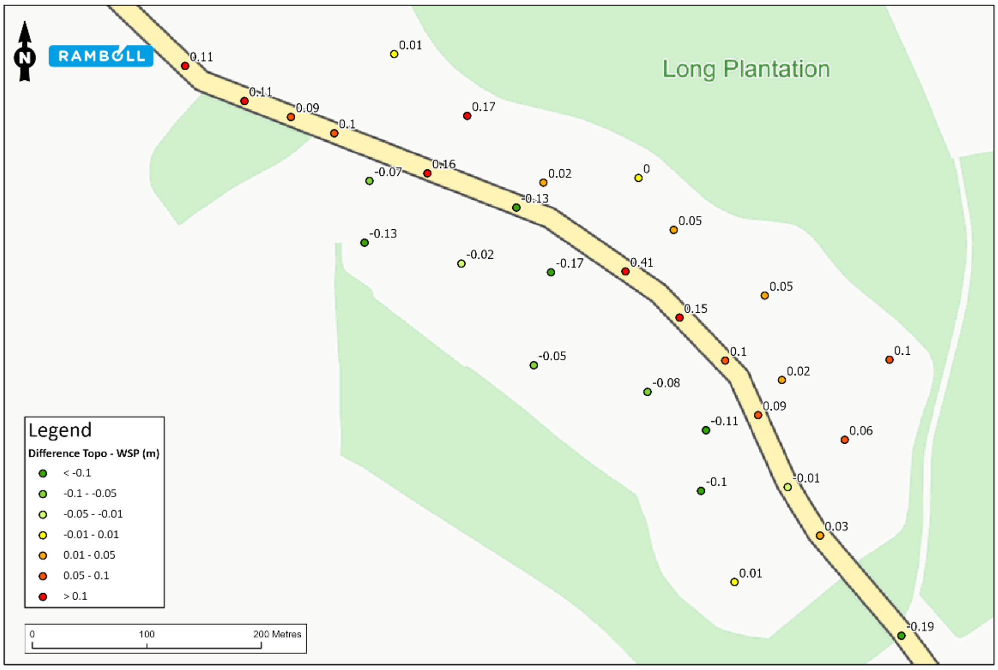


4.4 Model Terrain

4.4.1 Topographic Survey data by Survey Solutions Ltd. was provided to Ramboll and was surveyed in 2021. A newer LiDAR dataset (2022) was available to download from the DEFRA webservice.

Figure 4.2: Elevation comparison between 2022 Lidar and Topographic Survey

Figure 4.3: Elevation comparison between 2019 Lidar and Topographic Survey



4.4.2 A spot check was undertaken between the topo survey, 2022 LiDAR and 2019 LiDAR dataset to determine the most appropriate data to use in the hydraulic modelling. It was assumed that the topographic survey data was the most accurate and was used in preference of additional datasets. The new

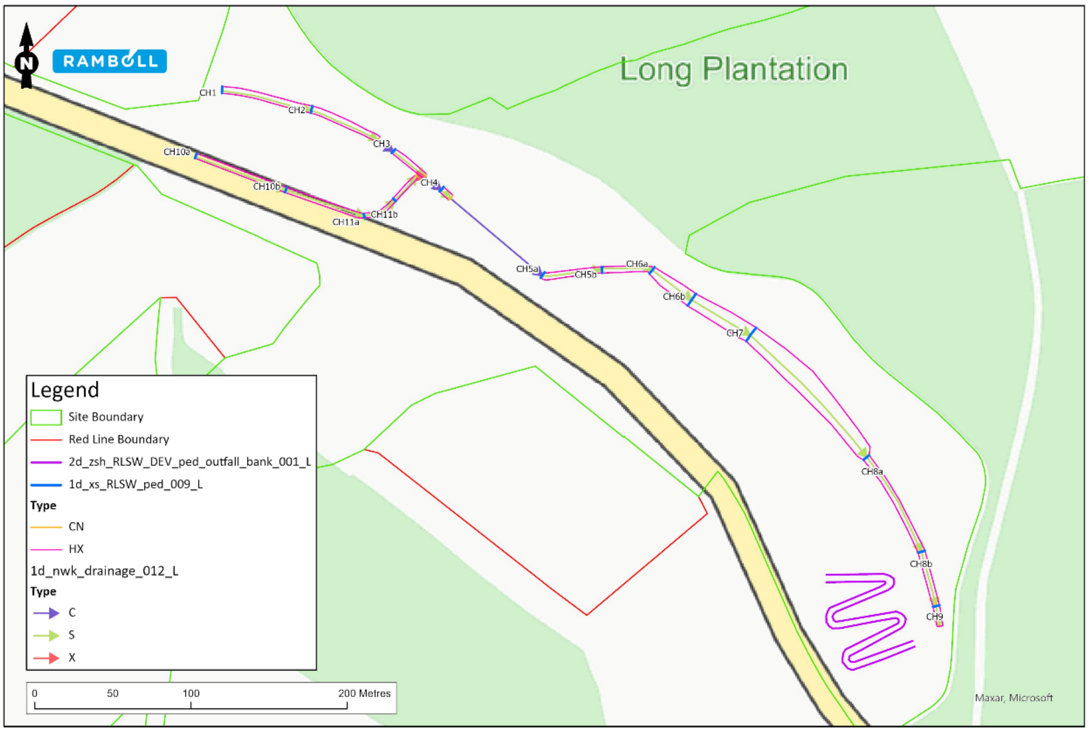
2022 LiDAR dataset had elevations closest to the topo survey and was therefore chosen instead of the previous 2019 LiDAR where applicable.

4.5 Preliminary Earthwork Drains

4.5.1 The WSP model defined the PEDs across the floodplain in the base model topography, however the geometry and location has been refined by Ramboll. The PEDs were defined using relative elevations for each cross section and stamped into the LiDAR.

4.5.2 The representation of the PEDs has been updated upstream and downstream of the Proposed Scheme. The new PEDs are generally wider and deeper than previous schematisation of them in the WSP model (Figure 4.4).

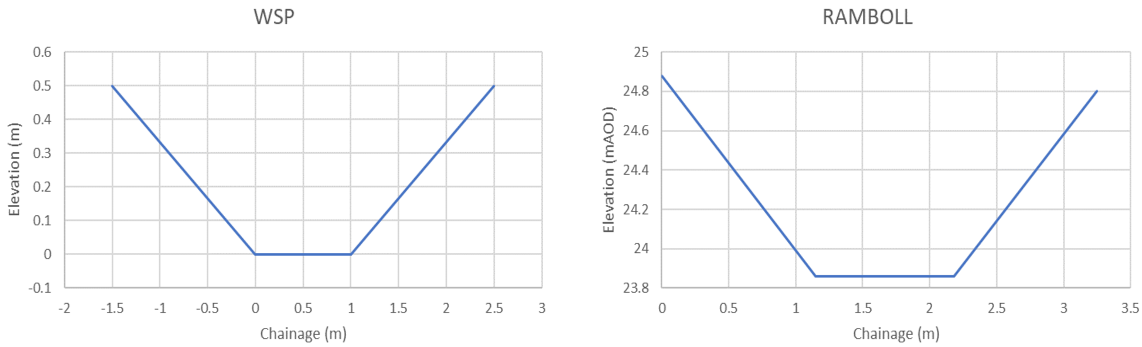
Figure 4.4: Location of Preliminary Earthwork Drains



4.6 Flood Bund

4.6.1 A flood bund was proposed to create a flood attenuation basin upstream of the scheme in the natural depression that is present. Several geometries of the bund were tested with varying crest levels. Various factors had to be taken into account, including the red line boundary and the location of trees, and the final bund design is shown in Figure 4.6.

Figure 4.5: PED cross section upstream of the scheme



4.6.2 The bund has been represented in the model using a 2d_zsh line to enforce the crest level, as well as a raster to smooth the bund into the terrain data underneath. The final crest height was set at 28mAOD. Ground elevations in close proximity but outside the area of the bund were represented based on site survey.

Figure 4.6: Flood Bund Schematisation Options

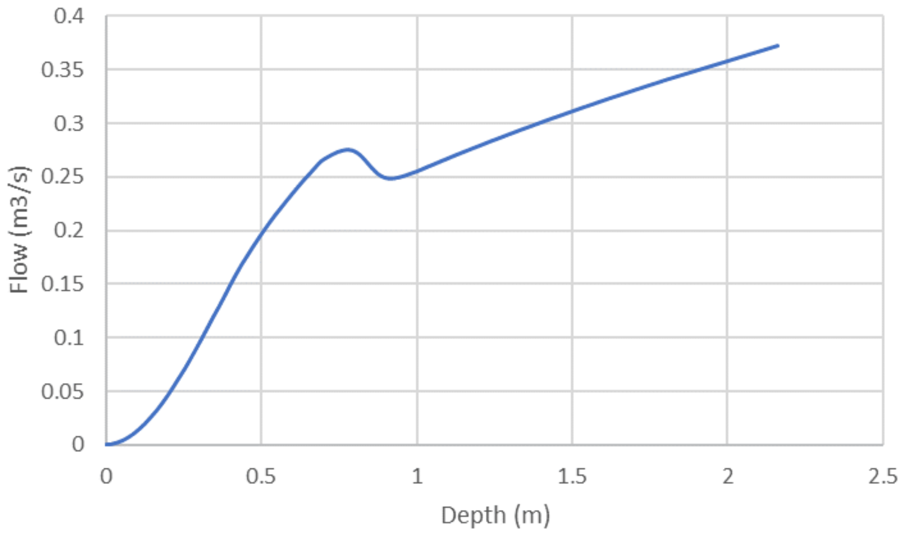
4.7 Flow Control Devices

4.7.1 Flow Control Devices were schematised to convey flow from the flood attenuation basin (behind the flood bund) into the PEDs downstream at a restricted rate. The setup had to be designed to ensure that flood depths do not increase at the wedding venue, as that is a key receptor, and to ensure that water is retained within the flood attenuation basin and does not bypass the bund.

4.7.2 The preferred setup includes one flow control device at 25.5mAOD, the lowest elevation within the attenuation basin. Two flow control devices are set at 26.63mAOD, above the 3.33% AEP (30 Year) water level (as determined from preliminary model iterations). An additional structure was set above the 1% AEP (100 Year) water level (27.4mAOD) (also determined from preliminary model iterations) to determine the requirement for an overspill feature (e.g. weir). The water depths during the 1% AEP (100 Year) + 45% CC event were unlikely to suit the optimisation of flow control devices.

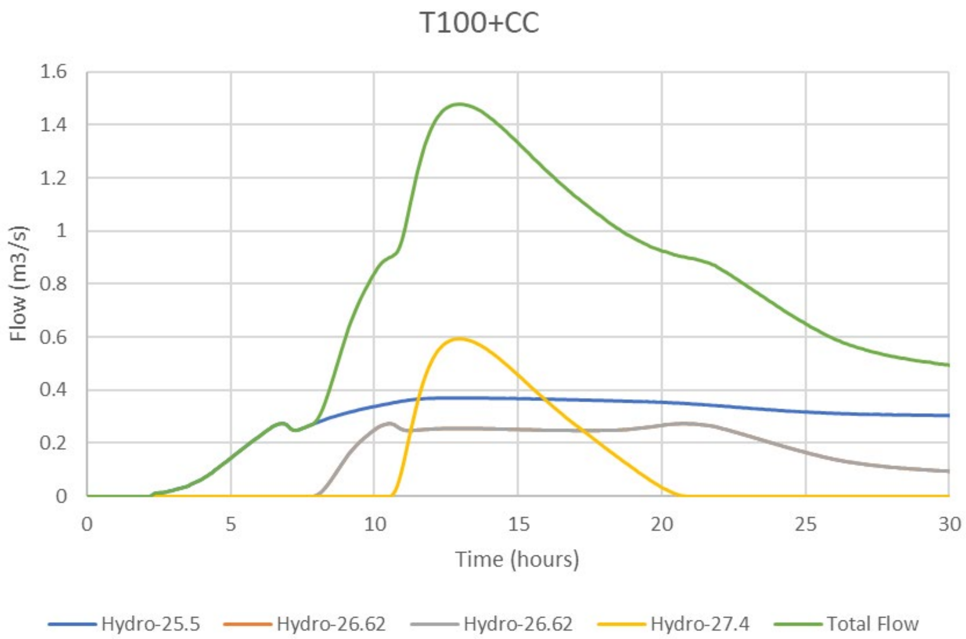
4.7.3 The depth flow relationship used for each flow control devices is shown below (Figure 4.7).

Figure 4.7: Depth/Flow Relationship used for each Flow Control Device



4.7.4 The total flow going through the flow control devices in the 1% AEP (100 Year) + 45% CC event is shown in Figure 4.8 (note that there are two flow control devices at 26.63mAOD, ‘Hydro-26.62’, with the same flow characteristics).

Figure 4.8: Flow through the hydrobrakes during the 1% AEP (100 Year) + 45% CC even



5 MODEL SCENARIOS

5.1 Model Scenarios

5.1.1 Two ESTRY-TUFLOW 1D/2D model scenarios have been considered to assess the impact of the Proposed Scheme. Table 5 1 provides a summary of each modelled scenario.

Table 5-1: Summary of the Norwich Western Link Hydraulic model scenarios

Modelled Scenario	TUFLOW Reference	Description
Baseline (Undefended)	BAS	Representing the pre-development setup of the Ringland Lane overland flow path.
Design	DEV2	Representing the Norwich Western Link Road scheme crossing Ringland Lane, including access roads, culverts, PEDs and the new flood bund.

5.2 Model Events

5.2.1 Table 5 2 Details the range of fluvial return period events simulated. Model inflows were not updated for this study and are equal to those used in the WSP Model for Ringland Lane, as part of the NWL project.

Table 5-2: Fluvial return period events simulated for the Norwich Western Link modelling study

AEP (%)	EPOCH	Model Run ID
3.33%	Present day	0030C00
2%	Present day	0050C00
1%	Present day	0100C00

AEP (%)	EPOCH	Model Run ID
0.1%	Present day	1000C00
3.33%+CC45	Climate Change 2050s Upper allowance (45%)	0030C45
1%+CC45	Climate Change 2050s Upper allowance (45%)	0100C45

6 MODEL PROVING

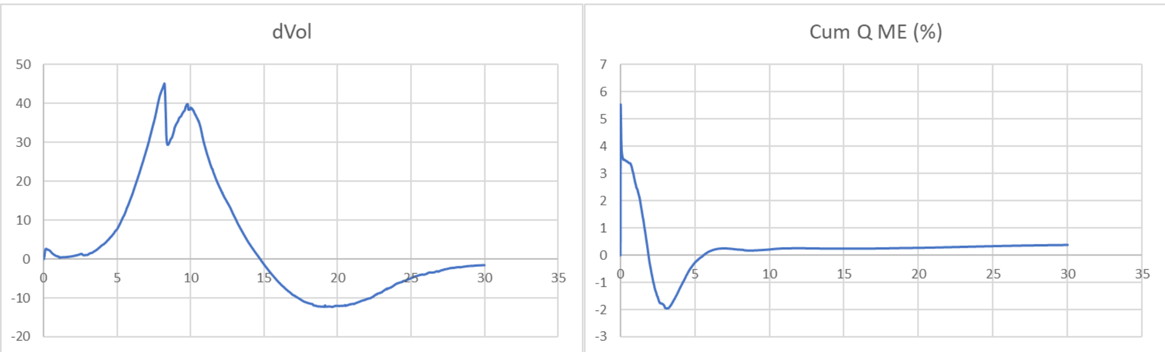
6.1 TUFLOW Run Performance

6.1.1 Figure 6.1 summarises the mass balance error for the 2D TUFLOW model domain. The accepted tolerance range recommended by the software manual is +/-1% [1]

6.1.2 A sharp peak of cumulative mass balance error occurs at the very start of the simulation for a few hours however this decreases to close to 0% before the peak of the event, and for the rest of the duration of the model run. This is within the acceptable error range for such models and does not coincide with the peak of flooding which is of critical concern for this study.

6.1.3 The dVol shows a smooth input and output of water throughout the simulation, which is acceptable.

Figure 6.1: 2D domain dVol and Cum Q ME (%)



[1] BMT TUFLOW 1D/2D Fixed Grid Hydraulic Modelling – TUFLOW Classic/HPC User Manual Build 2018-03-AD

7 RESULTS

7.1 Flood Extents

7.1.1 Figure 7.1, Figure 7.2 and Figure 7.3 show the flood extent for the Baseline and Design Scenario for the model area for the 3.33%, 1%, 1% + 45% CC AEP events respectively. The hydraulic modelling simulated that the Proposed Scheme reduces flood extents around the scheme and has negligible impact on flood extents downstream of the Proposed Scheme.

7.1.2 The smaller flood extents around the scheme are due to the new PEDs which constrict the flow of water under the new road, access and maintenance tracks. Less water is flowing across the floodplain, and therefore the flood extents are less in this area.

7.1.3 During the 1% AEP (100 Year) + 45% Climate Change event, water is seen to come out of bank of the PEDs upstream of the proposed crossing in some locations. The main areas of flooding are between the maintenance track and access track upstream of the proposed crossing as the culverts beneath these roads act as flow restrictions.

7.1.4 None of the surface water attenuation basins are inundated during the modelled events.

7.1.5 The area that experiences an increase in flood extents is the flood storage basin, at the upstream end of the scheme.

7.1.6 The flood extents around the wedding venue are slightly smaller during the Design scenario compared to the Baseline, however the difference is minimal.

Figure 7.1: Flood Extents for the Baseline and Design Scenario for the 3.33% AEP (30 Year) event

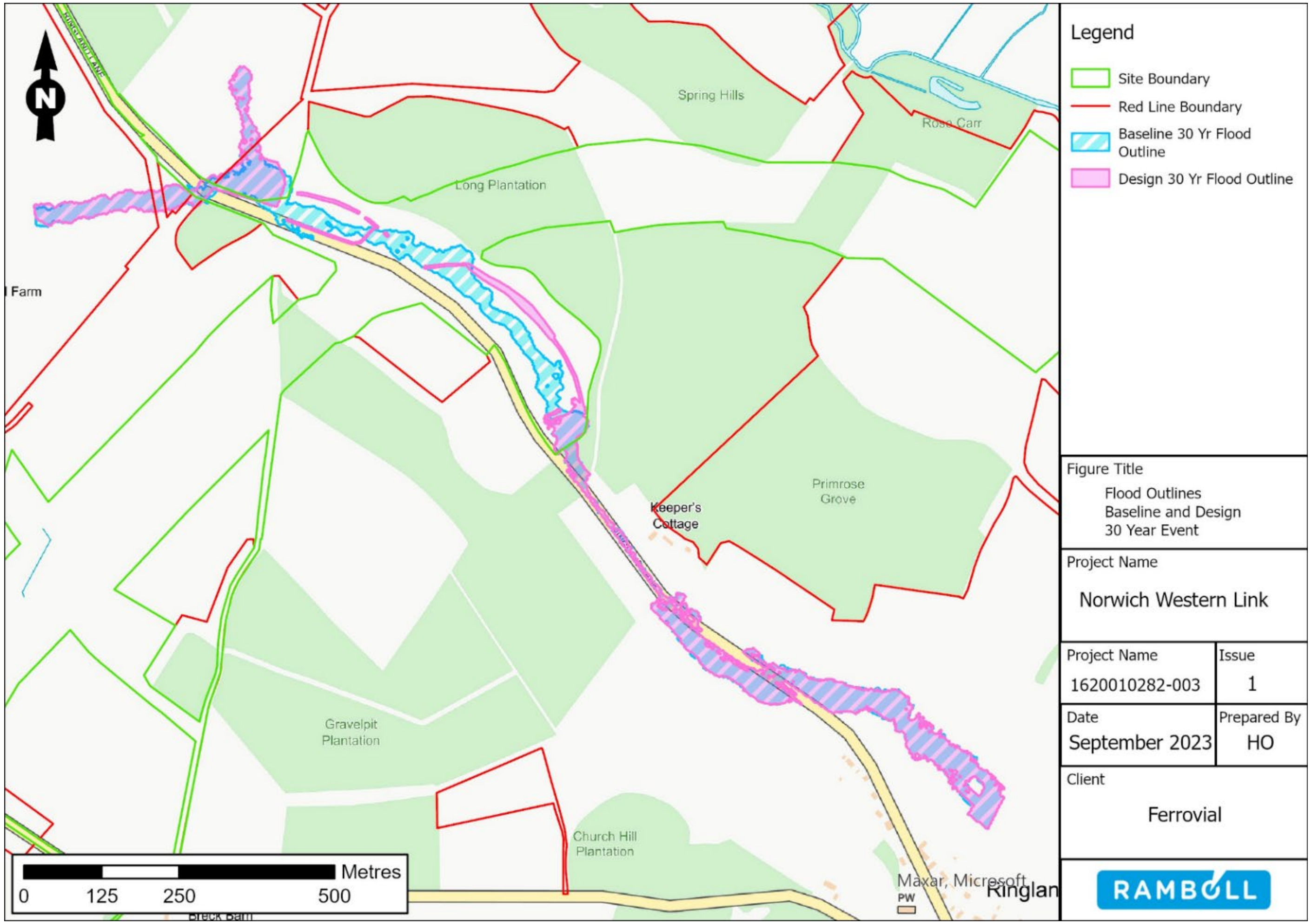


Figure 7.2: Flood Extents for the Baseline and Design Scenario for the 1% AEP (100 Year) event

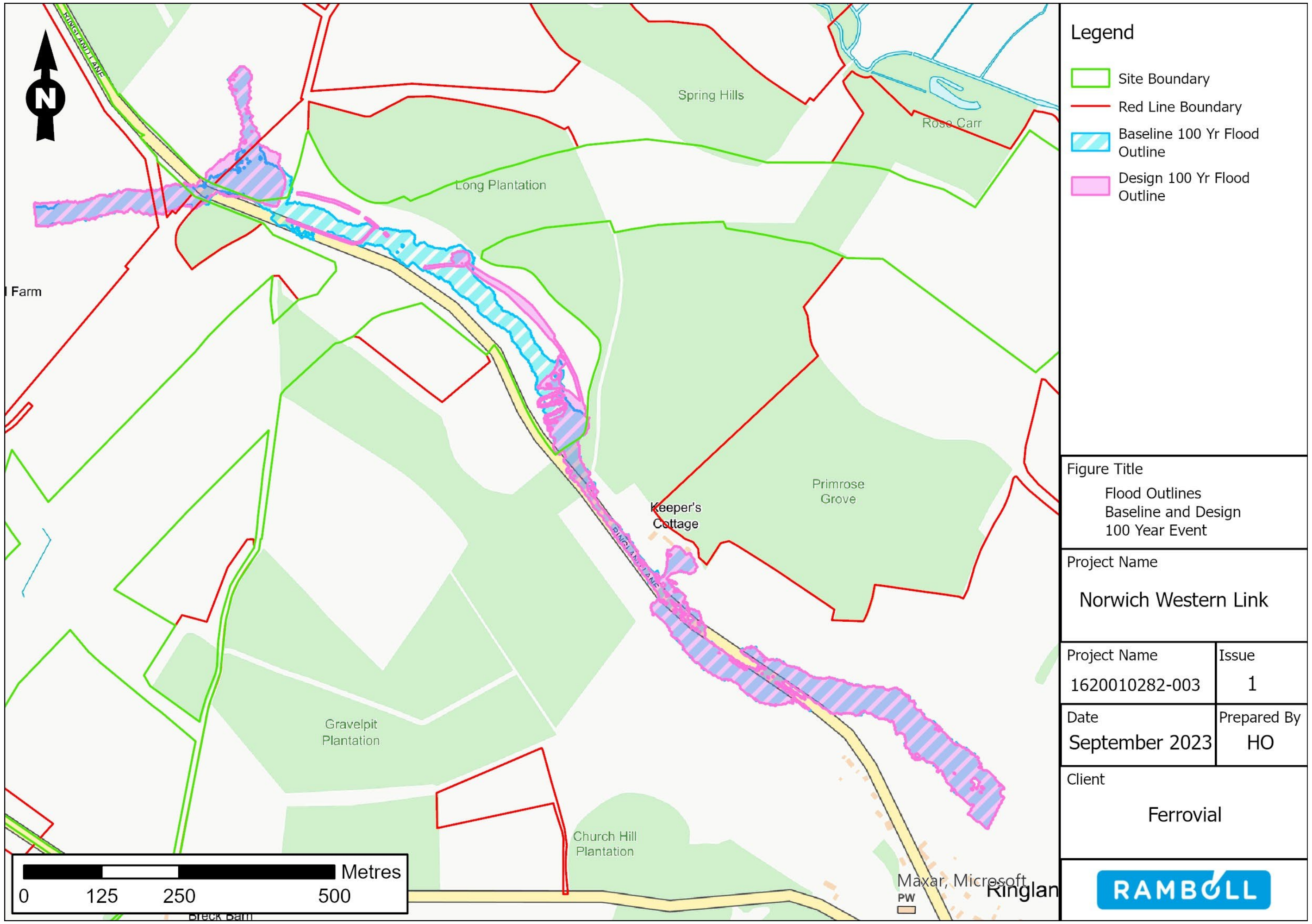
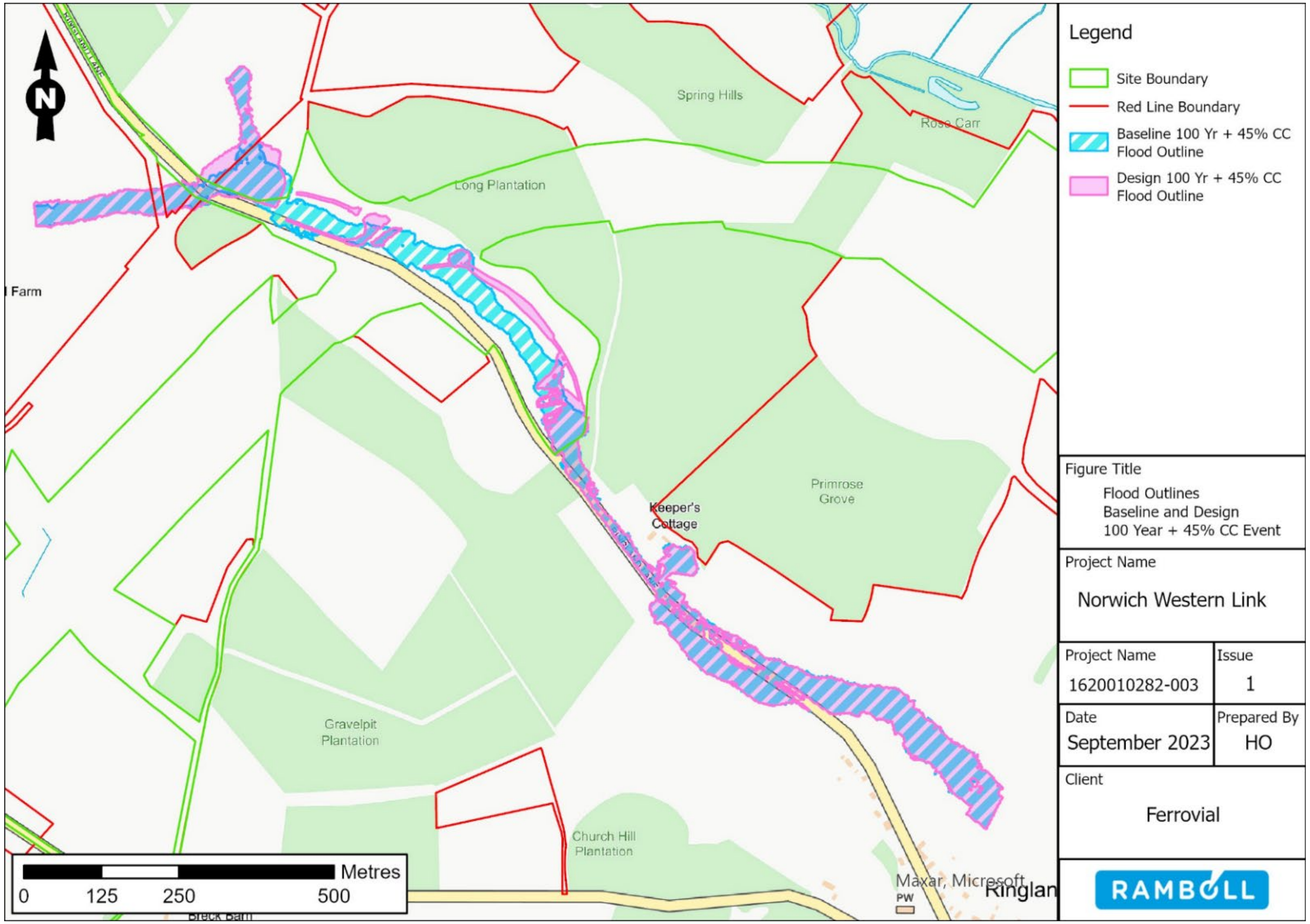


Figure 7.3: Flood Extents for the Baseline and Design Scenario for the 1% AEP (100 Year) +45% CC eve



7.2 Flood Levels and Depths

7.2.1 Figure 7.4, Figure 7.6 and Figure 7.8 show flood levels across the model area for the 3.33%, 1% and 1% + 45% CC AEP events respectively.

7.2.2 Flood levels in the flood attenuation basin range from 26.62mAOD in the 3.33% AEP (30 Year) event, 27.39mAOD in the 1% AEP (100 Year) event to 27.64mAOD in the 1% AEP (100 Year) + 45% CC event.

7.2.3 Flood levels at the wedding venue (during the Proposed Scheme model runs) are 12.29mAOD in the 1% AEP (100 Year) event and 14.21mAOD in the 1% AEP (100 Year) + 45% CC event. The wedding venue is not inundated during the 3.33% AEP (30 Year) event.

7.2.4 Figure 7.5, Figure 7.7 and Figure 7.9 show flood depth differences between the Baseline and Design Scenario across the wider area for the 3.33%, 1% and 1% + 45% CC AEP events respectively.

7.2.5 The locations simulated to have the most significant changes in flood depths are the flood attenuation basin upstream of the proposed crossing, and the wedding venue downstream of the scheme. The flood attenuation basin has been designed to accumulate flood waters during extreme events and reduce the volume of water flowing downstream through the scheme and to the wedding venue by controlling the flow through the hydrobrake.

7.2.6 For all events, the flood attenuation basin experiences an increase in flood depths, up to 0.98m in the 1% AEP event and around 1.21m in the 1% AEP + 45% CC event.

7.2.7 The wedding venue experiences a reduction in flood depths by -0.04m in the 1% AEP event and by -0.33m in the 1% AEP + 45% CC event.

7.2.8 The majority of flood depth differences are contained within the red line boundary, with the exception of the wedding venue and just upstream of the flood attenuation basin, for the higher return periods.

Figure 7.4: Flood levels in the Design Scenario for the 3.33% AEP (30 Year) even

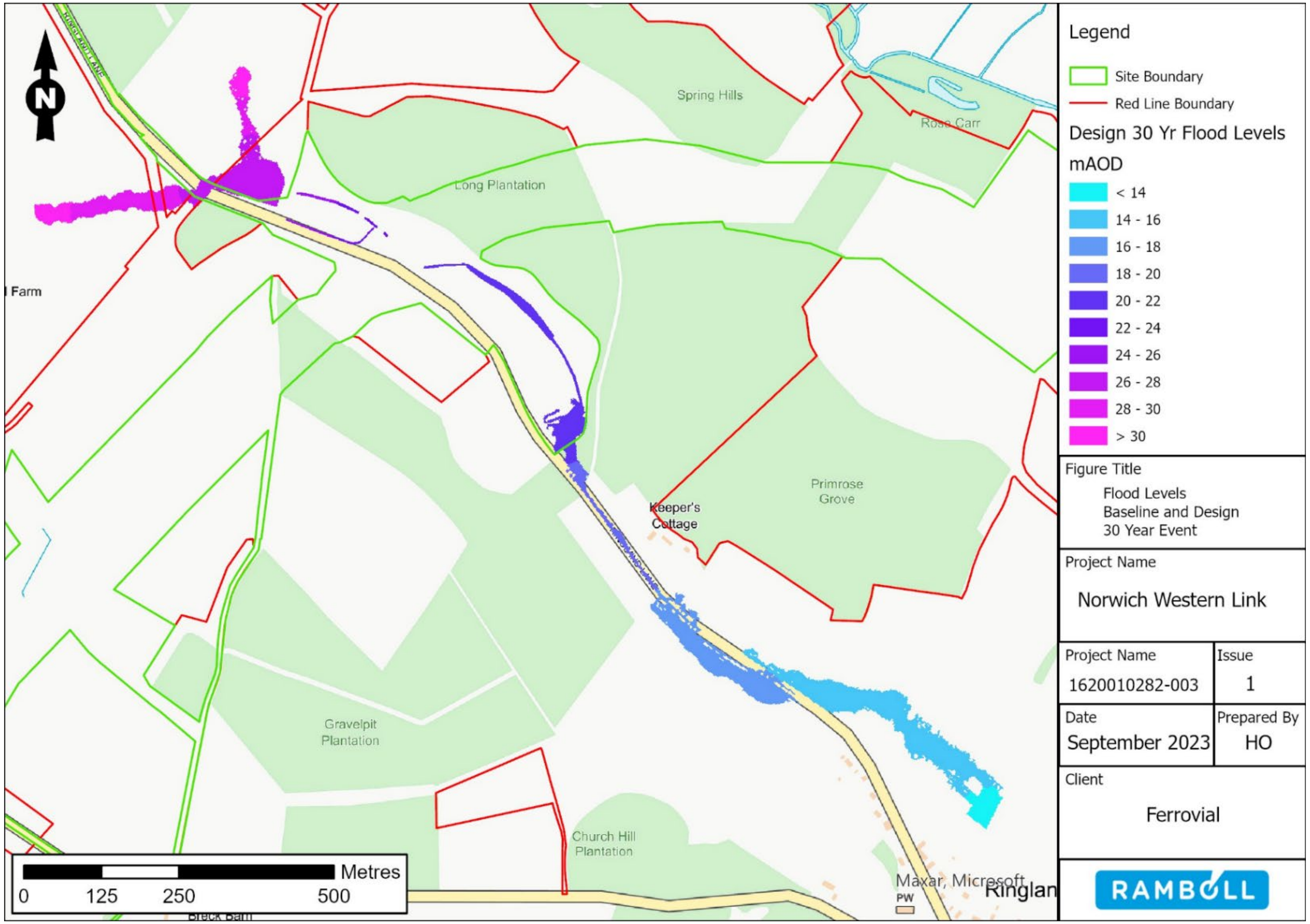


Figure 7.5: Flood depth difference between the Baseline and Design Scenario for the 3.33% AEP (30 Year) event

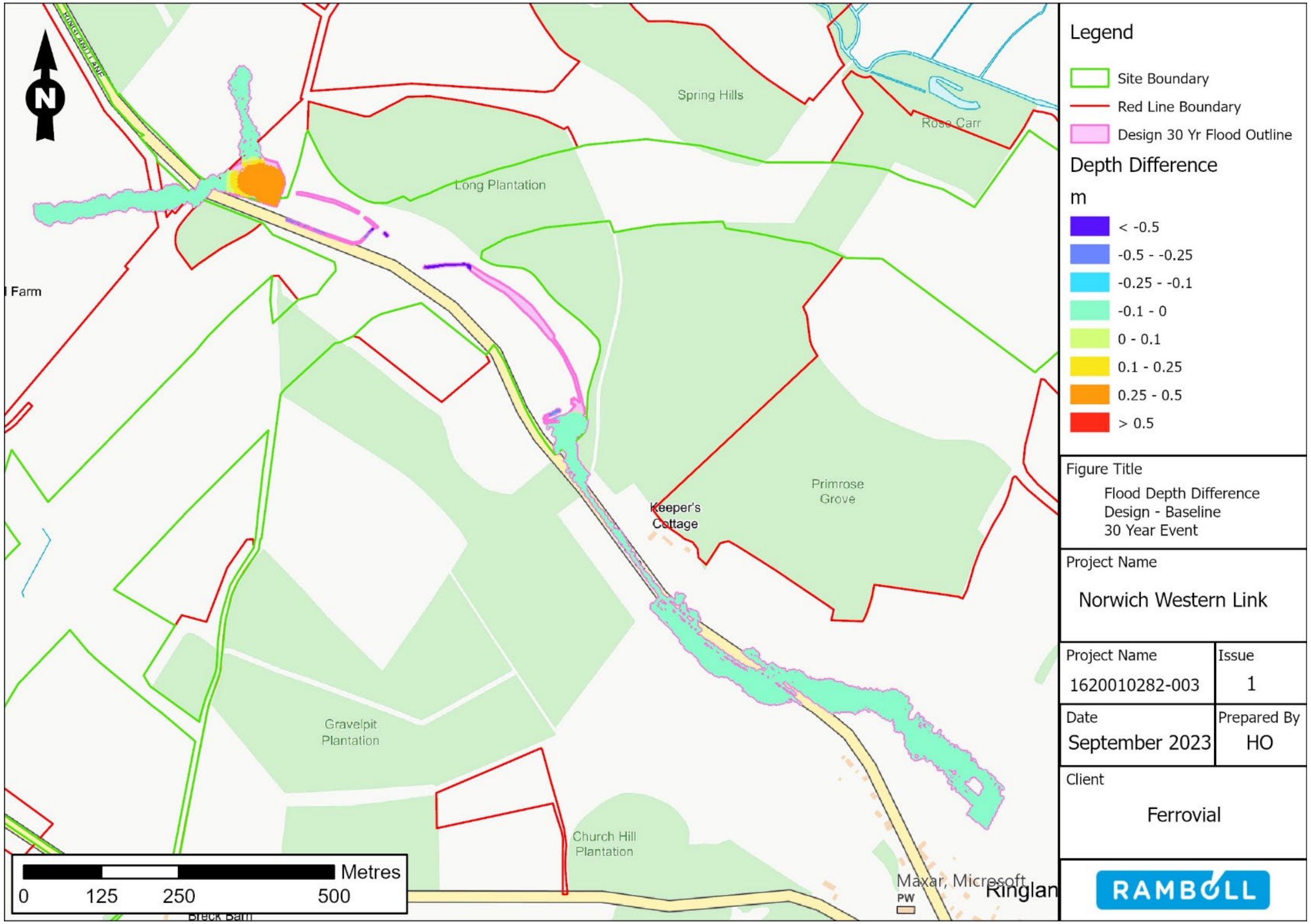


Figure 7.6: Flood levels in the Design Scenario for the 1% AEP (100 Year) event

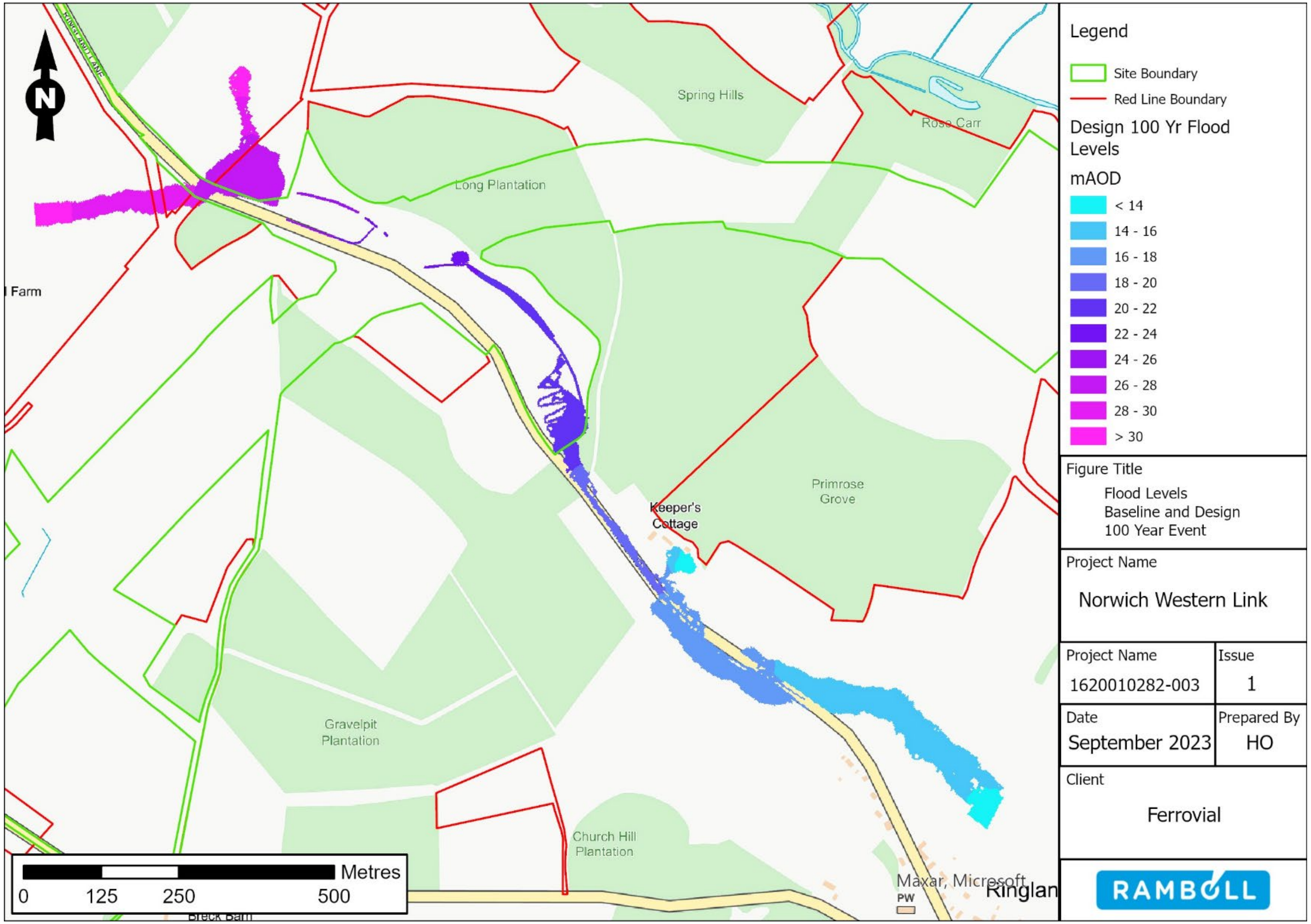


Figure 7.7: Flood depth difference between the Baseline and Design Scenario for the 1% AEP (100 Year) even

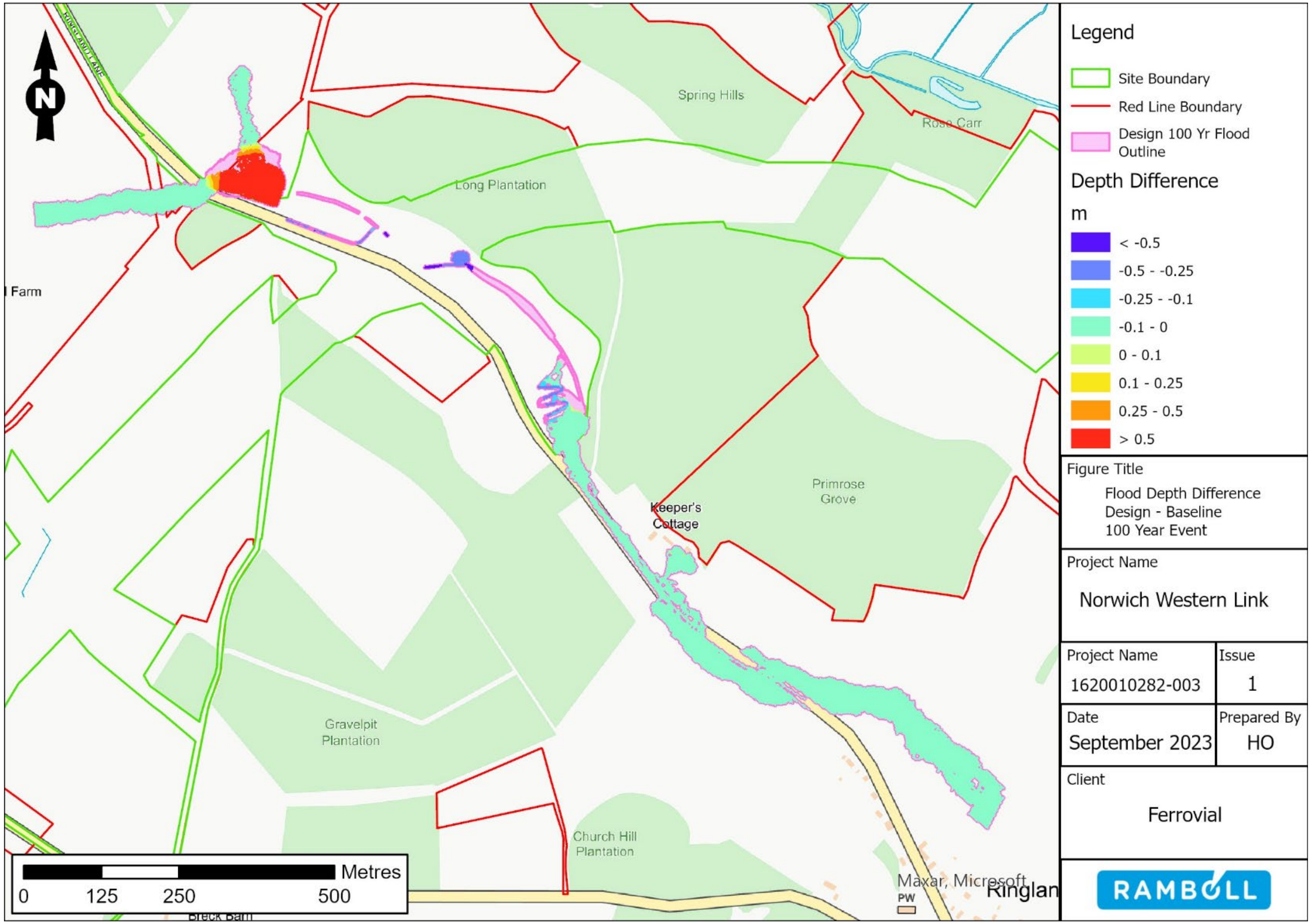


Figure 7.8: Flood levels in the Design Scenario for the 1% AEP (100 Year) + 45% Climate Change event

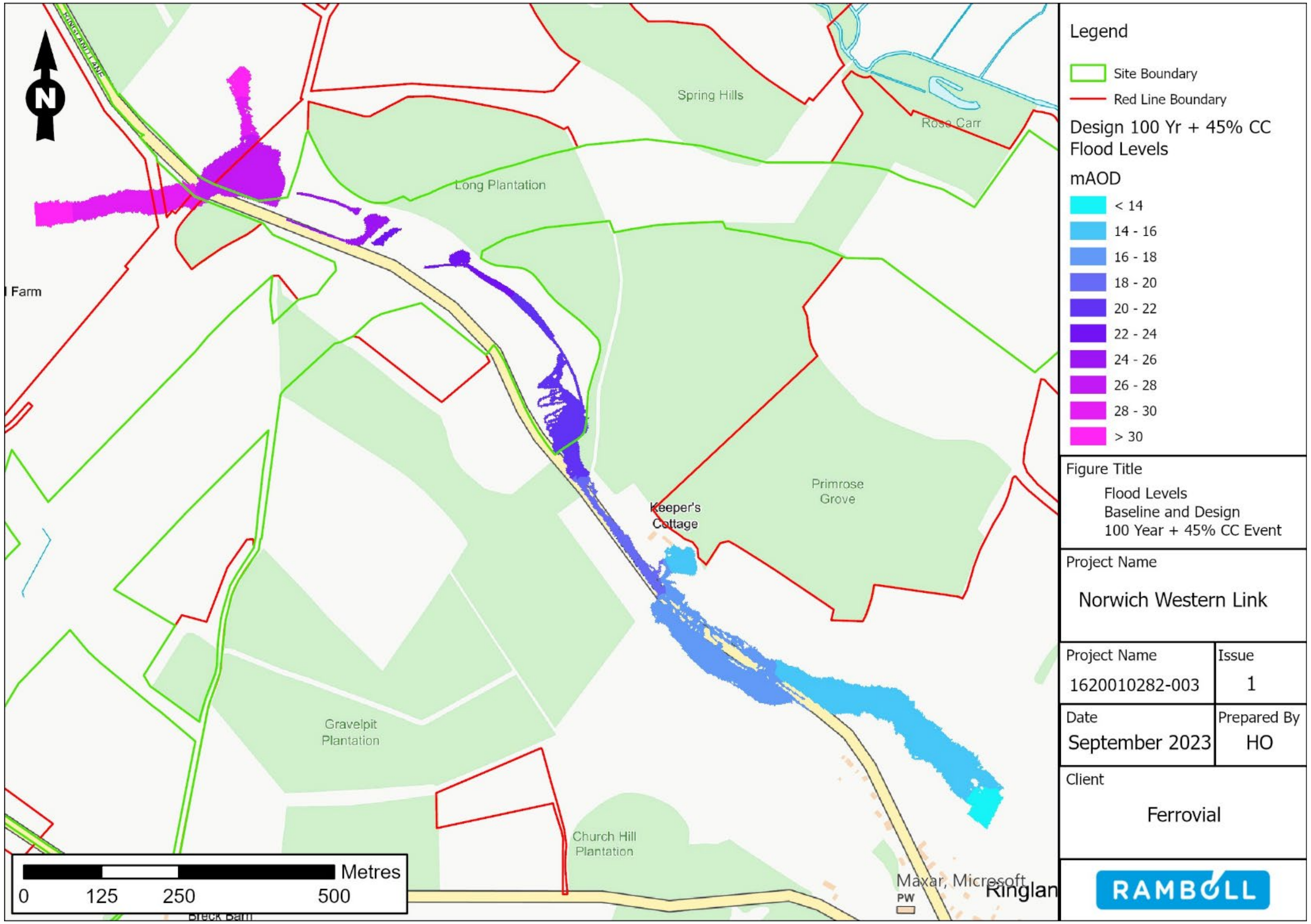
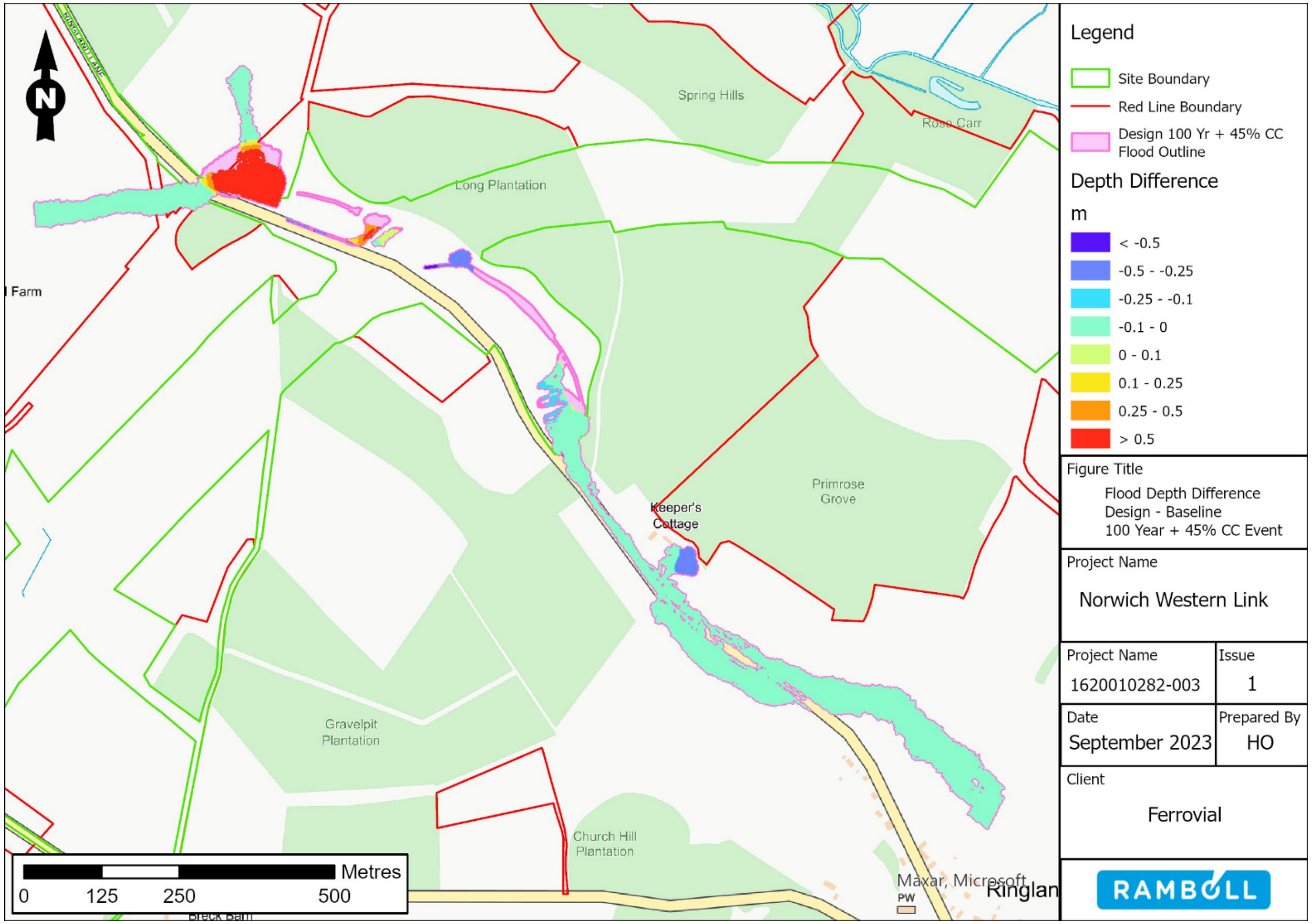


Figure 7.9: Flood depth difference between the Baseline and Design Scenario for the 1% AEP (100 Year) + 45%



8 LIMITATIONS

8.1 Limitations

8.1.1 During any hydraulic modelling study, there will always be associated limitations, for example with uncertainty, data availability etc. The representation of any complex system by a model requires several assumptions to be made. In the case of the hydraulic modelling prepared by Ramboll for this report, it has been assumed that:

- Cross sections accurately represent the shape and variation of the drainage channels.
- Model parameters have been determined appropriately.
- Design flows are an accurate representation of a given return period.
- The details of hydraulic structures and units used to represent them in the model adequately represent the situation.
- Topographic survey and LiDAR accurately reflect bank heights and that the filtered LIDAR has appropriately removed the influence of vegetation along the banks.

8.1.2 The accuracy of hydraulic models is heavily dependent on the accuracy of the hydrological and topographic data on which they are based.

8.1.3 While every effort has been made to accurately reflect the situation on the ground and estimate appropriate model parameters, these can never be completely certain. Therefore, assumptions are made as part of the modelling process.

8.1.4 The model has been built for the purpose of flood risk mapping. It has been optimised for high flows and would need adapting to be suitable to be used for more low flows.

8.1.5 Most of the overland flow path is represented in 2D only based on LiDAR. Only the PEDs are represented in 1D using information from the design drawings. Channel conveyance within the 2D channels will therefore not be fully represented in the model, and in some places may be overestimated where the channel width is not known.

8.1.6 The methodologies adopted were informed by best practice and use of available data. Whilst the modelling approaches are deemed suitable and acceptable, there will always be future improvements and updates that can be made.

9 CONCLUSION AND RECOMMENDATIONS

9.1 Summary

9.1.1 Ramboll were commissioned by Ferrovial, working on behalf of Norfolk County Council, to complete hydraulic modelling of the overland flow path at Ringland Lane to inform an FRA for the Proposed Scheme, the Norwich Western Link Road. The aim of the hydraulic modelling was to understand the impact of the Proposed Scheme on flood risks to the road itself and to third parties. WSP previously developed a 1D-2D ESTRY-TUFLOW hydraulic model for the Proposed Scheme to inform an FRA accompanying the EIA for the Proposed Scheme.

9.1.2 Following a review of the WSP Hydraulic Model, Ramboll proposed several model updates to allow more features of the Proposed Scheme to be represented in the hydraulic model:

- Model grid resolution refined to 2m to allow for a better representation of the detailed design;
- Preliminary Earthwork Drains were input into the model in the 1D domain, based on Ramboll design;
- Topographic survey and updated LiDAR included in the base model to update the terrain;
- Refined flood mitigation options included in the WSP model including the attenuation basin upstream of the Proposed Scheme, flow control devices from attenuation feature and meanders downstream of scheme;
- Roughness definitions for buildings added in; and
- Various flood bund options upstream of the Proposed Scheme tested.

9.1.3 Once the hydraulic model had been updated, two model scenarios were considered:

- Baseline scenario - Representing the current setup of the overland flow path at Ringland Lane;
- Design Scenario – Representing the Norwich Western Link Road scheme crossing Ringland Lane, including PEDs, attenuation basin and meanders downstream of the PEDs.

9.1.4 The design events simulated were the 3.33%, 5%, 2%, 1% and 0.1% Annual Exceedance Probability (AEP) event and the 1% AEP plus climate change. The climate change uplift followed the Broadlands Management Catchment Upper 2050s allowance for peak rainfall (45%).

9.2 Conclusions

Proposed Scheme

9.2.1 The hydraulic modelling results indicate the Proposed Scheme has a positive impact on both flood depths and extents. Flood extents are reduced in the scheme area as flow is conveyed through the PEDs rather than flowing across the floodplain. During the 1% AEP (100 Year) + 45% CC event, there are some increases in flood extents upstream of the three culverts that are included in the model. The culverts have been designed to act as flow constrictions for higher return periods to reduce the conveyance of flows downstream.

9.2.2 During the 1% AEP (100 Year) + 45% CC event, there are some increases in flood levels within the PEDs upstream of the proposed crossing compared to the baseline levels. However, this is because the schematisation of the PEDs lowered ground levels by up to 1m in places to define the 1D channel, so the resulting water depths are deeper in these locations. Flood depths increase in the flood attenuation basin for all events, however the remainder of the area near the Proposed Scheme experiences generally small differences in flood depths.

Wedding Venue

9.2.3 Around the wedding venue, the hydraulic modelling results indicate that the Proposed Scheme has a negligible to positive impact on flood extents and flood depths.

9.2.4 During the higher return periods, flood depths are seen to decrease, by up to -0.33m in the 1% AEP (100 Year) + 45% CC event, and flood extents are slightly smaller. In the 3.33 AEP event, no significant changes in flood depths or flood extents are seen around the wedding venue but, in any case, the area is not flooded during this event.

9.3 Recommendations

9.3.1 The Hydraulic Model results show that the new access road, maintenance track and Norwich Western Link Road are not simulated to flood during any return period events. During higher return periods (1% AEP (100 Year) + 45% CC event onwards) the flood waters will not be fully contained within the culverts beneath the road and there may be water ponding at the bottom of the road embankments. It is important that the new road embankments are designed to withstand small depths of water at their base.