Appendix D: Modelling Report

Tolney Lane, Newark

Nottinghamshire

Hydraulic Modelling Report

April 2019

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Introduction

Waterco has been commissioned to undertake a detailed hydraulic modelling study of the River Trent and its tributaries through Newark adjacent to a proposed development site at Tolney Lane, Newark, NG24 1BZ.

The outputs of the hydraulic modelling study provide a detailed, up-to-date assessment of the existing fluvial flood risk at the site and quantify the change in flood risk elsewhere as a result of the development (if any). This report also supports the Flood Risk Assessment being prepared for the development by WYG.

A location plan and an aerial photograph of the site are included in Appendix A. The National Grid Reference (NGR) of the site is 478850 353870.

Site Description and Proposed Development

The site is currently a mixed use traveller site with existing residential development and caravan plots. The site is located off Tolney Lane, just south of the Nottingham to Lincoln railway line. It is bordered by open fields to the south and the River Trent flowing in a north-easterly direction further south, the A46 to the west and Old Trent Dyke to the west. The site covers an area of approximately 13.06ha.

A ground elevation plan of the site has been prepared using 1m resolution Light Detection and Ranging (LiDAR) dataset (downloaded from EA website in December 2018) and included in Appendix B for information. The LiDAR data shows existing site levels generally fall from north-west to south-east, with a highest ground level of approximately 13.9m AOD at the north-western site boundary, and lowest ground level of approximately 10m AOD near to the north-eastern site boundary.

To mitigate flood risk on the site and to aid in the proposed development design, three Flood Alleviation Scheme (FAS) Options (OPT1, OPT2 and OPT3) have been investigated. WYG provided the option layouts for Waterco to incorporate into the model. A brief description of each option is provided below and options layouts are included in Appendix C for reference.

FAS Option 1 (OPT1) – This option includes:

- Raise a stretch of Tolney Lane adjacent to the site (from NGR 479590 354145 to NGR 479055 353910 and NGR 479050 353850) to a road level of the existing 1% AEP maximum water level plus 100mm freeboard.
- A new flood storage area south of Tolney Lane (NGR 479480 354070) with a proposed ground level of 11m AOD.

- A new 1.5m high x 5m wide flood relief culvert under Tolney Lane (NGR 479380 354020).
- A new flood relief channel on the site from south of the proposed Tolney Lane flood relief culvert (NGR 479410 353970) up to existing Railway culvert opening (NGR 479390 354100).
- New flood defence walls alongside Tolney Lane (between NGR 479375 354020 and NGR 479065 353905) and adjacent to the proposed flood relief channel (between NGR 479370 354020 and NGR 479330 354070) with crest elevations of approximately 1% AEP maximum water level plus 600mm freeboard.

FAS Option 2 (OPT2) – This option includes:

- A new flood storage area south of Tolney Lane with a proposed ground level of 11m AOD as per OPT1.
- A new 1.5m high x 5m wide flood relief culvert under Tolney Lane as per OPT1.
- Raise a 35m stretch of Tolney Lane, local to the flood relief culvert, to a road level of the 1% AEP maximum water level plus 100mm freeboard, in order to provide cover over the proposed culvert. A 1:20 slope to existing road levels has been specified either side of the culvert soffit location.
- A new flood relief channel on the site starting south of the proposed Tolney Lane flood relief culvert up to existing Railway culvert opening as per OPT1.
- A new highway road (between NGR 478631 353575 and NGR 478200 353435) with embankments providing access/egress to the site with the proposed road levels set to the 1% AEP + 50% CC maximum water level plus 300mm freeboard.
- A flat infill of the area between proposed access/egress highway road and existing A46 Road at NGR 478330 353630.
- Four new flood relief culverts under the proposed highway, details of which are provided in Table 1 below.

Table 1 – Proposed Highway Culvert Information

Proposed Culvert no.	Location (NGR)	Height (m)	Width (m)
Culvert 1	478450 353720	1.68	10
Culvert 2	478310 353580	3.07	10
Culvert 3	478260 353500	2.25	5
Culvert 4	478220 353420	2.59	5

FAS Option 3 (OPT3) – This option includes:

- All the proposed features in FAS Option 2.
- A new flood defence wall which surrounds the majority of site, with crest levels set to the 1% AEP + 50%CC maximum water level plus 300mm freeboard.

Nearby Watercourses and Existing Flood Risk Data

The site is situated adjacent to the River Trent – an Environment Agency (EA) designated 'main river'. The watercourse flows in a north-easterly direction at this location. The River Devon, a tributary of the River Trent flows from the south-west and joins the River Trent approximately 315m south from the site, near to the Newark Rowing Club (NGR 478955 353380).

Flooding at the site could occur if water levels are sufficient to overtop local banks during, or following, an extreme fluvial event. The River Trent is considered the primary source of fluvial flood risk at the site and is the main focus of this study. Three other watercourses namely, the River Greet and River Devon which are tributaries of the River Trent, and Middle Beck which is a tributary of the River Devon, have also been included in the study. The flood risk to the site directly from the River Devon, River Greet and Middle Beck watercourses is considered negligible as they are located at a significantly large distance (>3km) from the site.

Tidal flood risk has not been considered during this study given the site is located approximately 9km upstream of Cromwell Lock (NGR 480825 361100) which is the location of the River Trent tidal limit and distance from the coast (>60km).

A review of publicly available information on the internet and the information within the 2009 Newark and Sherwood District Council SFRA report show that the Newark area has experienced flooding in the years 1795, 1910, 1945, 2000 and 2008. The historical flood map within the SFRA report (Appendix D) shows Tolney Lane and part of the site to have flooded in the year 2000. The EA historical flood maps (Appendix D) show the entire site to have flooded historically.

The current EA Flood Maps for Planning (April 2019) show almost the entire site to be located within Flood Zone 3 – an area considered to be at relatively high risk of fluvial flooding with an annual probability of the flooding greater than 1% (1 in 100) AEP (annual exceedance probability). A minor portion of the site area near to the north-western site boundary is located within Flood Zone 2 – an area considered to be at medium risk of fluvial flooding with an annual probability of the flooding greater than 0.1% (1 in 1000) AEP. An extract of the current EA Flood Zones is included in Appendix D for reference.

It is understood that the current River Trent flood maps are based on the outputs of a detailed EA 1D/2D[1] ISIS-TUFLOW River Trent model. This model covers a very long stretch (~100km) of the River Trent and its tributaries, starting downstream of the railway bridge at Radcliffe (NGR 463655 339725) and ending just south-west of Cromwell Quarry (NGR 480800 361895). The TUFLOW component of this model has multiple 2D domains with grid sizes between 10-20m, and covers a total area of approximately 110 km^2, both upstream and downstream of the development site.

To provide a site-specific assessment of fluvial flood risk from the River Trent, the current EA (multi-domain) model has been truncated and a new 1D/2D hydraulic (single domain) model has been constructed, and the model grid size has been reduced to 5m. In addition to providing a more accurate assessment of fluvial flood at the existing site, the change in flood risk elsewhere (if any) arising as a result of the proposed FAS options has been quantified.

[1] A 1D/2D hydrodynamic model is comprised of a 1-Dimensional (1D) river network model (based on surveyed river cross-sections) coupled with a 2-Dimensional (2D) Digital Terrain Model (DTM) of the potential floodplain (created from LiDAR).

Hydraulic Modelling

A copy of the current EA River Trent model has been sourced and used as the base for this study.

Following an initial assessment of the existing fluvial flood risk at the development site, simulation outputs will be compared against those generated using the proposed FAS options levels and layouts to quantify the change in flood risk elsewhere as a result of the proposed FAS options (if any).

The latest version(s) of hydraulic modelling software Flood Modeller Pro (FMP – previously ISIS) and TUFLOW available at the start of the project have been used for all simulations; 4.4 and 2018-03-AC respectively.

The hydraulic models have been simulated for 95hrs of simulation time in order to capture the maximum water levels at the site whilst retaining sensible run times. There is potential that maximum water levels further downstream from the site may occur after 95hrs. When considering any of the FAS options for more detailed design, this limitation should be considered, and any increase in off-site flood risk further downstream later in the simulation than the 95hr cut off time should be assessed.

Events Considered

To fully investigate the fluvial flood risk at the site during both the existing (EXG) and proposed FAS options (OPT1-3), a range of fluvial events have been simulated; namely the 5% (Q20), 1% (Q100) and 0.1% (Q1000) AEP events. The impact of future climate change (CC) has also been investigated during the 1% AEP event by increasing flows by 30% (Q100CC1), 50% (Q100CC2); Site located in the River Humber Basin; development considered 'More Vulnerable' with predicted 100-year lifetime – 'Higher central estimate' and 'Upper end estimate' allowance categories chosen. A list of simulations completed is given in Table 2.

To provide the required model inflows, the EA model has been re-run for the above events including the climate change scenarios. The inflow data within the EA model remains unchanged and model results have been extracted at EA model node *403556620* on the River Trent (NGR 471000 346590), node *RD5891* on the River Devon (NGR 478470 349120), node *74* on the River Greet (NGR 473230 353350), and node *MB2125D* on Middle Beck (NGR 480400 350790), and applied as inflows in the trimmed 1D model. PO flow-time lines have been used to extract floodplain flows (from the 2D TUFLOW domain) and have been specified as inflows in the truncated 2D model, as discussed in detail further in the report. All existing lateral inflows within the trimmed model extent remain unchanged and utilised as existing. Peak values of 1D model inflows and 2D model floodplain inflows extracted from the EA model, and applied in the truncated Waterco model, are summarised in Table 2 and Table 3, respectively.

Table 2 - Primary Simulation Summary - 1D Model Inflows

Fluvial Event (AEP)	Peak Flows River Trent (m^3/s)	Peak Flows River Devon (m^3/s)	Peak Flows River Greet (m^3/s)	Peak Flows Middle Beck (m^3/s)	Development Scenario
5% (Q20)	716.76	43.41	3.79	2.09	Existing Site Layout (EXG) & Proposed FAS Options (OPT1-3)
1% (Q100)	895.43	50.57	4.03	2.73	
1% + 30% CC (Q100CC1)	1020.88	53.97	4.23	3.35	
1% + 50% CC (Q100CC2)	1068.42	54.85	4.31	3.61	
0.1% (Q1000)	1085.87	55.65	4.38	4.04	

Table 3 - Primary Simulation Summary - 2D Model Inflows

Fluvial Event (AEP)	Peak 2D Flows River Trent (m^3/s)	Peak 2D Flows River Devon (m^3/s)	Peak 2D Flows River Greet (m^3/s)	Development Scenario
5% (Q20)	170.22	17.37	4.12	Existing Site Layout (EXG) & Proposed FAS Options (OPT1-3)
1% (Q100)	286.20	46.69	6.72	
1% + 30% CC (Q100CC1)	519.80	73.54	9.55	
1% + 50% CC (Q100CC2)	730.40	91.39	11.42	
0.1% (Q1000)	823.53	110.56	15.01	

1D Model Details

The current EA 1D network of River Trent has been truncated both upstream and downstream of the site, and then hydrodynamically connected to a new 2D TUFLOW domain constructed from 1m and 2m LiDAR data.

The truncated 1D network of the River Trent starts at approximately 650m east of Hoveringham Road (Node Ref: *403556620*; NGR 471000 346590) and ends at approximately 1km east of Cromwell House Farm (Node

Ref: *RTEx5*; NGR 480800 361890). The truncated 1D model network of the River Devon starts at approximately 840m east of Honeys Lane (Node Ref: *RD5891*; NGR 478470 349120) and ends at the watercourse's confluence with the River Trent (Node Ref: *RD0000*; NGR 478940 353360). The truncated 1D model network of the River Greet starts at approximately 280m south-east of Mill Lane (Node Ref: *74*; NGR 473230 353350) and ends on floodplain north of the Railway Line (Node Ref: *GRE1687*; NGR 474005 352695). The truncated 1D model network of Middle Beck starts at approximately 195m south-east of Bow Bridge Lane (Node Ref: *MB2125D*; NGR 480400 350790) and ends at the watercourse's confluence with the River Devon (Node Ref: *MB0000*; NGR 478450 351430). In total, approximately 34.6km of the River Trent, 1.15km of the River Greet, 2.2km of Middle Beck and 5.9km of the River Devon watercourses is modelled.

The upstream boundaries of the 1D model use discharge time (QT) boundary conditions applied to the most upstream nodes of the new truncated 1D model (i.e. nodes: *403556620* on the River Trent, *74* on the River Greet, *MB2125D* on Middle Beck and *RD5891* on the River Devon). Inflow hydrographs for these locations have been extracted from the current EA model results and applied to the truncated model.

The downstream boundary of the 1D model has been established approximately 10km downstream of the site using a normal-depth (NCD) boundary condition (Node Ref: *RTEx5*). Required local slope data has been taken from existing EA model cross-section data with a slope value of 0.00098 (~1 in 1020) being specified. The extent of the linked 1D/2D model is presented in Appendix E.

Conveyance checks for all cross-sections were completed and panel markers have been added where necessary. Structure and spill widths have been reviewed throughout the model and updated to match with the cross-section widths as required. No other changes have been made to the 1D model data, including lateral inflow locations and hydrographs, Manning's n roughness etc.

To improve model stability of two floodplain culverts (Node Ref: *A46_18307 and A46_18315*; NGR: 478235 353520 and 478720 354190), previously represented as orifice units within the current EA model, have been represented as ESTRY culverts. Representation of all other structures within the model remains unchanged from the EA model.

2D Model Details

The new 2D TUFLOW domain has been constructed using a combination of 1m and 2m resolution LiDAR data (downloaded from EA website in December 2018), no additional survey data of the site exists or has been procured for the assessment.

The 2D cell size has been lowered from between 10-20m within the existing multi-domain model and set at

5m within a single domain. This resolution is adequate to represent the flow paths on site and within the wider floodplain whilst maintaining a reasonable run time.

The 1D-2D HX links have been updated as required and appropriate bank levels have been enforced using z-lines where necessary from LiDAR and/or cross-section data as required. To improve model stability the ‘a’ attribute of HX links have been updated from default value of ‘0’ and set to values of ‘0.3’ or ‘0.5’ at several locations within the model where there is a steep drop in elevation over the links. Sensitivity testing of the ‘a’ attribute value applied has been performed as discussed below.

2D floodplain flows extracted from EA model results using PO lines (Table 3) have been specified as inflows in the 2D model using a QT boundary condition applied near to the upstream inflow locations of the River Trent (NGR 470470 347130), River Devon (NGRs 476740 348680, 477890 349310 and 478660 349010) and River Greet (NGRs 472900 353010, 473260 353410 and 473340 353510).

A 2D QH downstream boundary condition has been set local to the 1D model downstream boundary. The QH relationship data has been automatically calculated by the software at the boundary location using an appreciation of the local ground slope (assessed using LiDAR).

OS MasterMap data (provided with the current EA model) has been used to classify land use and assign Manning’s n roughness coefficients throughout the floodplain. The coefficients used are given in Table 4.

Table 4 - 2D Model Manning’s n Roughness Coefficients

Land Use	Manning’s n Roughness Coefficient (s/m$^{1/3}$)
Smooth Grass	0.035
Trees	0.07
Scrubby Grass	0.06
Garden/Yards	0.035
Roads	0.022
Open Water	0.030
Channel	0.035
Buildings	0.5
Dense Scrubs	0.06
Overgrown Vegetation	0.06

To simulate and compare the proposed FAS options (OPT1, OPT2 and OPT3), alternative 2D TUFLOW model domains have been created using the proposed level data provided (Appendix C).

The OPT1 TUFLOW model setup included the following:

- A z-shape feature to raise a stretch of Tolney Lane adjacent to the site (from NGR 479590 354145 to NGR 479055 353910 and NGR 479050 353850) to a level varying between 12.02m AOD to 12.53m AOD, based on the existing the Q100 event maximum water level in this region plus a freeboard of 100mm.

- A z-shape feature to represent and lower the ground levels within the proposed flood storage area, set to a uniform elevation of 11m AOD at NGR 479480 354070.

- A 1D ESTRY 1.5m high x 5m wide rectangular culvert to represent the proposed flood relief culvert under Tolney Lane at NGR 479380 354020.

- A z-shape feature to represent the proposed flood relief channel on the site starting south (NGR 479410 353970) of the proposed Tolney Lane flood relief culvert up to existing Railway culvert opening (NGR 479390 354100). The bed levels of the proposed channel south of Tolney Lane culvert are set to uniform level of 10m AOD. North of the culvert, as existing ground levels allowed a gradient, the levels fall from 9.96m AOD to 9.35m AOD at the Railway Culvert. The proposed channel is 5m wide and has a total length of approximately 185m.

- A z-line feature used to represent and raise the defence walls along Tolney Lane and the flood relief channel to a level varying between 12.59m AOD to 12.66m AOD, based on the Q100 event maximum flood levels plus a freeboard of 600mm.

The OPT2 TUFLOW model setup included the following:

- As per OPT1, a z-shape feature to represent and lower the ground levels within the proposed flood storage area.

- As per OPT1, a rectangular culvert to represent the proposed flood relief culvert under Tolney Lane.

- As per OPT1, a z-shape feature to represent the proposed flood relief channel on the site.

- A z-shape feature to raise a 35m stretch of Tolney Lane local to the proposed culvert to a maximum level of 12.1m AOD above the culvert and to model drop in levels by 1:20 slope on either side (to merge with existing ground levels), which is equivalent to the Q100 event maximum water level at this region plus a freeboard of 100mm.

- A number of z-shape features to represent the proposed 3m wide highway road (between NGR 478630 353570 and NGR 478200 353430); embankments with 1 in 3 side slopes, and flat in-fill area (NGR 478330 353630) between the proposed highway and A46 Road. The elevation of the proposed highway road is set to vary between 13.18m AOD to 14.12m AOD, based on the Q100CC2 event maximum water level at this region plus a freeboard of 300mm.

- Four new culverts under the proposed highway road, details are discussed in Table 1 within the proposed development section of the report.

The OPT3 TUFLOW model setup included the following:

- All features included in OPT2 detailed above.

- A z-line feature to represent a flood defence wall along the site boundary with a crest level varying between 12.8m AOD to 13.18m AOD, based on the Q100CC2 maximum water level at this region plus a freeboard of 300mm.

Sensitivity Testing

The EA historical flood map and the historical flood map within the 2009 Newark and Sherwood District Council SFRA report (Appendix D) have been used to compare model outputs as discussed in the results section below.

In the absence of available calibration data, increased significance has been placed on sensitivity testing to improve confidence in the model outputs and assess the sensitivity of the model parameters. Six sensitivity tests have been carried out (ST1-6) with respect to the EXG, 1% AEP + 30% CC fluvial event.

Sensitivity tests “ST1” and “ST2” investigate +/-20% variation of Manning’s roughness coefficients in both the River Trent and tributaries also across the floodplain.

Sensitivity tests “ST3” and “ST4” investigate a +/-20% variation in the slope used to calculate the QH curve of the downstream boundary conditions of both the 1D and 2D model.

Sensitivity tests “ST5” and “ST6” investigate a +/-0.1 variation to ‘a’ attribute value applied to HX links within the model.

Results & Conclusions

This section of the report documents the results obtained from the primary simulations, including EXG, OPT1-3 models and sensitivity tests.

Maximum flood depth, velocity and hazard mapping has been provided for each primary simulation in Appendix F. Flood hazard ratings have been calculated in accordance with DEFRA document 'FD2320: Flood Risks to People' and EA guidance document 'Supplementary Note on Flood Hazard Ratings and Thresholds'.

In addition to the mapping, calculated maximum water levels were extracted at each node along the 1D network model and compared for each simulation. A table of this data has been provided in Appendix G. Flood depth and water level data has also been extracted at certain node locations across the site in the 2D domain, and represented in tabulated form in Appendix H.

Detailed below is a summary of the flood mechanisms for the simulated events, which is to be read in conjunction with the above detailed information.

EXG Simulations - Existing Site Layout

The results of the hydraulic modelling show the development site to partially flood during all the simulated flood events. In line with the greater model inflows, the extent of flooding on the site increases from lower to higher AEP events. The majority of the area adjacent to the northern site boundary (between NGR 478535 353700 and NGR 478795 353900), is shown to remain flood free during all events simulated.

During all the simulated flood events, floodwater is shown to exceed channel capacity on the left bank of the River Trent at several locations near to the site. A description of flood mechanisms on the site is provided below.

A. During all simulated flood events out-of-bank spilling on the left bank of the River Trent downstream of the A46 Road Bridge (NGR 478100 352840) causes floodwater to flow in a northern direction along the A46 Rd towards the Railway embankment. From here floodwater flows in an eastern direction and enters the site via the northern site boundary causing small amount of flooding in the nearby site areas (NGR 478820 353930).

B. During all simulated flood events, spilling over the left bank of the River Trent at Tolney Lane (NGR 479130 353750) causes floodwater to enter the eastern portion of the site area (NGR 479220 353960) via the southern site boundary. Floodwater flows in an eastern direction through the site causing flooding of low-lying site areas before flowing out of the site via the north-eastern site boundary towards the Railway culvert opening (NGR 479390 354100).

C. During the 5% AEP and 1% AEP events floodplain flow causes small portions of the site area near the western (NGR 478490 353640) and southern (NGR 478910 353760) site boundaries to experience flooding. The extent of flooding at these locations during the 1% AEP event is larger relative to the 5% AEP event.

D. During the 1% AEP + 30%CC and higher AEP events, significant out-of-bank spilling on the left bank of the River Trent downstream of the A46 Road Bridge causes floodplain flow to enter the site via the southern and western site boundaries. The majority of the site is inundated as floodwater flows in an eastern direction through the site generally parallel to the watercourse.

FAS Options Simulations – OPT1

The hydraulic model results for the FAS OPT1 scenario show the development site to partially flood during all simulated flood events. Unlike in the EXG scenario, the eastern portion of the site (NGR 479220 353960) is shown to be flood free during the OPT1 scenario 5% and 1% AEP events. Flood extents during the 1% AEP + 30%CC and higher AEP events are similar to the EXG scenario. During all simulated flood events OPT1 model results show the proposed flood storage area and proposed flood relief channel to be inundated. The proposed road section of Tolney Lane is completely flood-free during all events up to and including the 1% AEP event.

The flooding mechanisms on the site during the OPT1 scenario are similar to the EXG flooding mechanisms ‘A’, ‘C’, and ‘D’ described above. Spilling on the left bank of the River Trent at Tolney Lane (NGR 479130 353750) similar to EXG flooding mechanism ‘B’ does occur, however, the proposed raising of Tolney Lane, inclusion of flood defence walls and Tolney Lane flood relief culvert in OPT1 scenario prevent the eastern portion of the site area from flooding during the 5% and 1% AEP events. During the 1% AEP + 30%CC and higher AEP events floodwater flows around the flood defence wall causing inundation of the eastern portion of the site area.

FAS Options Simulations – OPT2

The hydraulic model results for the FAS OPT2 scenario show the development site to partially flood during all the simulated flood events. The extent of flooding on site is similar to the EXG scenario flood extents. During all simulated flood events OPT2 model results show the proposed flood storage area and proposed flood relief channel to be inundated. The proposed highway road is completely flood-free during all the simulated events.

The flooding mechanisms on the site during the OPT2 scenario are similar to the EXG flooding mechanisms (‘A’, ‘B’, ‘C’, and ‘D’). Although out-of-bank spilling on the left bank of the River Trent downstream of the A46 Road Bridge causes floodwater to flow in a northern direction along the A46 Rd (similar to EXG flooding mechanism ‘A’), the proposed highway restricts floodplain flow and diverts water via the proposed culvert under the highway towards the railway embankment and thereon towards the site areas near the northern site boundary. During the 5% and 1% AEP events eastern portion of the site area experiences flooding due to spilling on the left bank of the River Trent at Tolney Lane similar to EXG scenario and during the 1% AEP + 30%CC and higher AEP events majority of the site is inundated.

FAS Options Simulations – OPT3

The hydraulic model results for the FAS OPT3 scenario show the entire development site enclosed within the defence wall to be flood-free during all the simulated flood events. Small portions of the site area outside the defence wall at the northern (NGR 478810 353930) and western (NGR 478500 353650) site boundaries experience flooding during all the simulated events. Similar to the OPT2 scenario the proposed flood storage area and proposed flood relief channel are inundated, but the proposed highway road is completely flood-free during all the simulated events.

Similar to the EXG scenario, during the OTP3 scenario out-of-bank spilling occurs on the left bank of the River Trent at several locations near to the site, however, the proposed flood defence wall around the site boundary keeps the enclosed site area completely flood-free up to the extreme 0.1% AEP event.

Flood Risk Elsewhere

The potential impact of the proposed development on flood risk elsewhere has been quantified by comparing the results of the existing (EXG) site layout simulations with the proposed FAS options (OPT1-3). To provide a detailed assessment of the relative changes in flood depths throughout the floodplain, a series of water level difference maps comparing the EXG and OPT1-3 maximum water levels have been created and are included in Appendix F.

FAS OPT1 – Flood risk Elsewhere

Given the lower lying areas of the eastern portion of the site (NGR 479220 353960) are shown to flood during the 5% and 1% AEP events in the EXG scenario, the proposed raising of Tolney Lane Road in OPT1 scenario allows these areas to remain flood free but displaces some floodwater elsewhere, specifically towards the proposed flood storage area and flood relief channels.

During the 1% AEP event, OPT1 vs. EXG depth difference maps show that flood depths within the flood storage area increase by up to 1m whereas flood depths north of the railway line generally reduce by up to 1m during this event. A small area south of the site near Tolney Lane (NGR 479090 353850) experiences an increase in flood depths of up to 25mm during this event.

During the 1% AEP + 30%CC and higher AEP events, OPT1 vs. EXG depth difference maps show that flood depths at floodplain areas north of the site reduce by 40-65mm. Whilst there is a relative reduction of flood risk at this location and also through the site, flood depths generally increase by up to 30mm in the floodplain areas south of the site and by up to 140mm at several isolated locations near Tolney Lane during the 0.1% AEP event.

FAS OPT2 – Flood risk Elsewhere

The OPT2 vs. EXG depth difference maps show that during all the simulated events the proposed OPT2 highway causes a reduction in flood depths in floodplain areas north of the highway. However, an increase in flood depths in the wider floodplain throughout the majority of the model domain south-west of the site is observed. This is due to the very flat topography and proposed access/egress route which limits passage of water through the Tolney Lane site.

Floodplain areas south of the highway experience an increase in flood depths during all the simulated events with the maximum increase being approximately 70mm (during the 0.1% AEP event). Flood depths are also shown to increase far away from the site, however, the increases are generally less than 5mm with some isolated pockets experiencing greater increases due to localised topographic changes. Whilst there is an increase in flood risk south of the highway, a reduction in flood depths in floodplain areas north of the highway by up to 110mm is noticed during the 0.1% AEP event.

FAS OPT3 – Flood risk Elsewhere

Similar to OPT2, the OPT3 vs. EXG depth difference maps show that during all the simulated events the OPT2 proposed highway and OPT3 defence wall along the site boundary causes an increase in flood depths in the floodplain throughout the majority of the model domain south-west of the site, due to the very flat topography.

The OPT3 vs. EXG depth difference maps show that during all the simulated events the proposed OPT3 flood defence wall along the site boundary causes an increase in flood depths in the floodplain areas south-west of the site by up to 120mm (during the 0.1% AEP event). The proposed defence wall allows the site to remain flood-free and restricts floodplain flow movement towards the areas north of the site, causing a reduction in flood depths by up to 100mm north of the site during the 0.1% AEP event. Flood depths on the site and in few areas south of Tolney Lane (enclosed by the defence wall) reduce by 1-2m during the 0.1% AEP event.

Model Verification and Sensitivity Tests

A comparison of model results against the EA historical flood map (Appendix D) has been carried out. The modelled flood extents during the 0.1% AEP event is similar but slightly smaller than the latest EA historical flood outline. There is no information available on how these extents were produced, as such no further verification can be carried out. Similarly, the modelled flood extents, which are very widespread during the 0.1% AEP event, matches well with the historical flood outline within the 2009 Newark and Sherwood District Council SFRA report (Appendix D), however, as no further detail of this flood event (such as estimated AEP event or maximum water levels at the site) can be found, the model cannot be verified against the historical data.

The results of sensitivity tests ST1 and ST2 show that a significant variation (+/-20%) in the Manning's 'n' coefficients used within the channel and floodplain does not increase/decrease the maximum water levels near the site by more than 150mm. Changes to the flood extent across the site during this event are negligible.

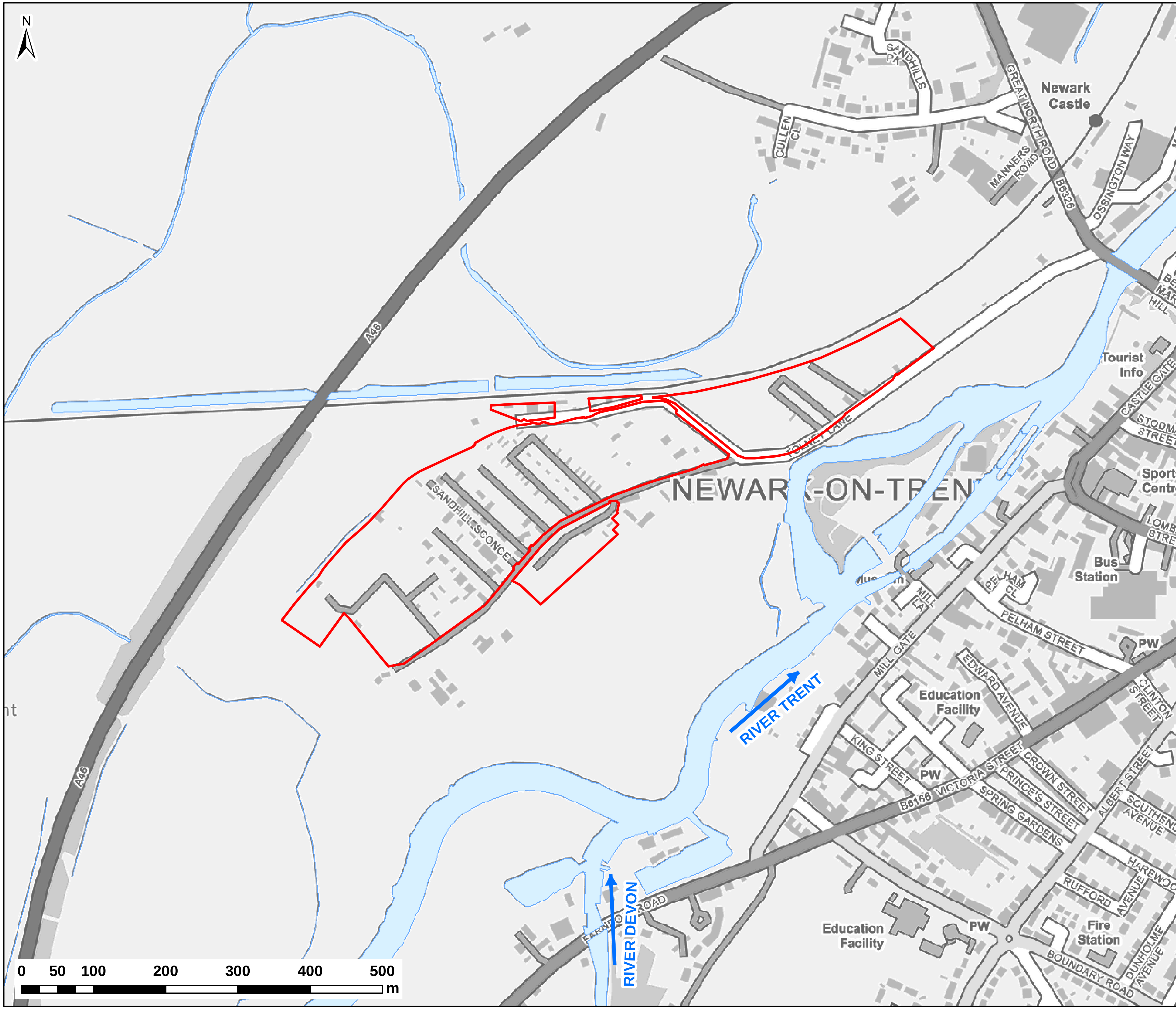
The results of sensitivity tests ST3 and ST4 show that significantly varying the slope value used at the downstream boundary by +/-20% does not have any effect on the maximum water levels at the site – any minor variation are local to the boundary only. The assessment of flood risk at the site remains unaffected.

The results of sensitivity tests ST5 and ST6 show that significantly varying the form loss coefficients (FLC) used at the HX links by +/-0.1 respectively does not increase/decrease the maximum water levels on the site by more than 60mm and very localised to areas near HX links. Changes to the flood extent across the site during this event are negligible.

Recommendations

The hydraulic models and associated report should be submitted to the EA for review and approval as a reasonable representation of the fluvial flood risk at the site from the River Trent and its tributaries when both the existing and proposed FAS Options layouts are considered.

Appendix A Location Plan and Aerial Image

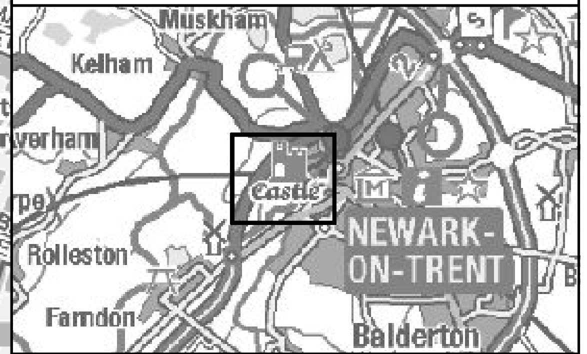


NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

Site Boundary

Watercourses / Water Bodies



CLIENT:

www.waterco.co.uk

SCHEME:

TOLNEY LANE, NEWARK

PLOT TITLE:

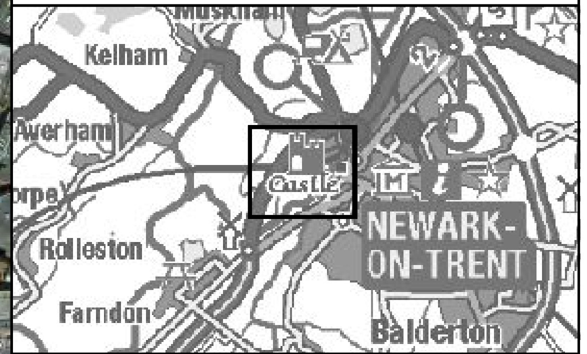
LOCATION PLAN

PLOT STATUS:			DATE:
FINAL			26-Apr-19
DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
CM	RC	LS	1:5,000 (UNLESS STATED OTHERWISE)
PLOT NAME:			REV:
w3375-Location_Plan			-

NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

Site Boundary



CLIENT:

wyg

waterco

www.waterco.co.uk

SCHEME:

TOLNEY LANE, NEWARK

PLOT TITLE:

AERIAL PLAN

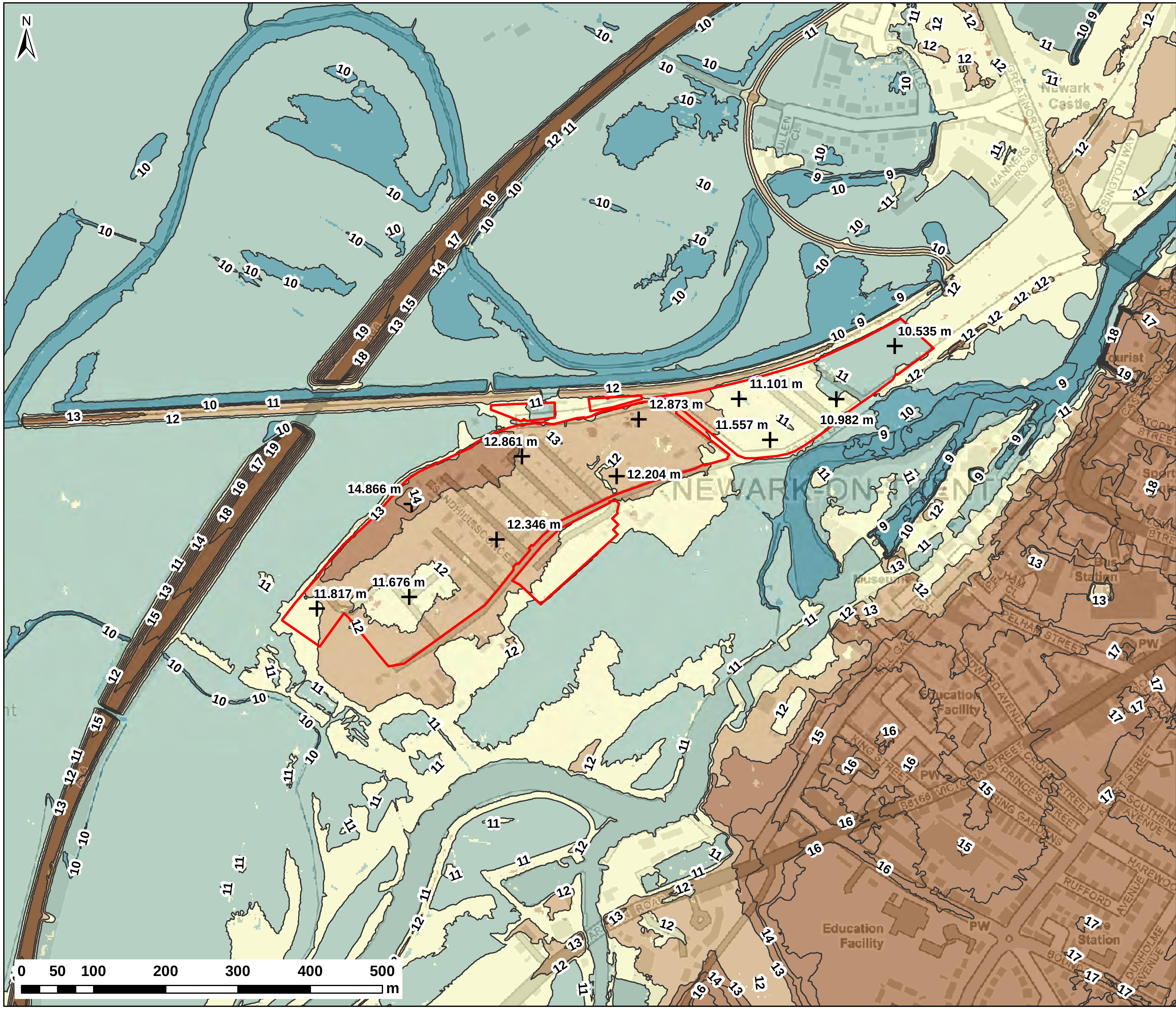
PLOT STATUS:	DATE:
FINAL	29-Jan-19

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
AR	RC	LS	1:5,000 (UNLESS STATED OTHERWISE)

PLOT NAME:	REV:
w3375-Aerial_Plan	-

BASEMAP: WORLD IMAGERY. SOURCES: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, GIS USER COMMUNITY

Appendix B LiDAR Elevations Plan



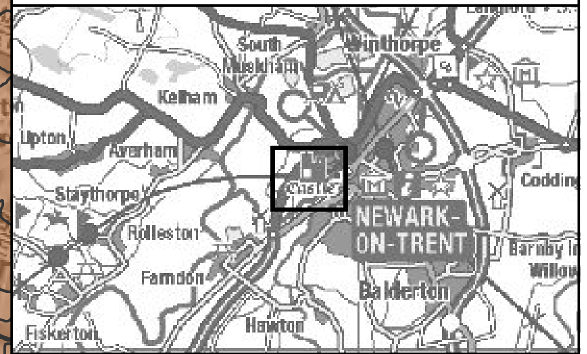
NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

- Site Boundary
- Site Levels

Ground Elevation (m AOD)

- < 10
- 10 - 11
- 11 - 12
- 12 - 13
- > 13



CLIENT:

www.waterco.co.uk

SCHEME:

TOLNEY LANE, NEWARK

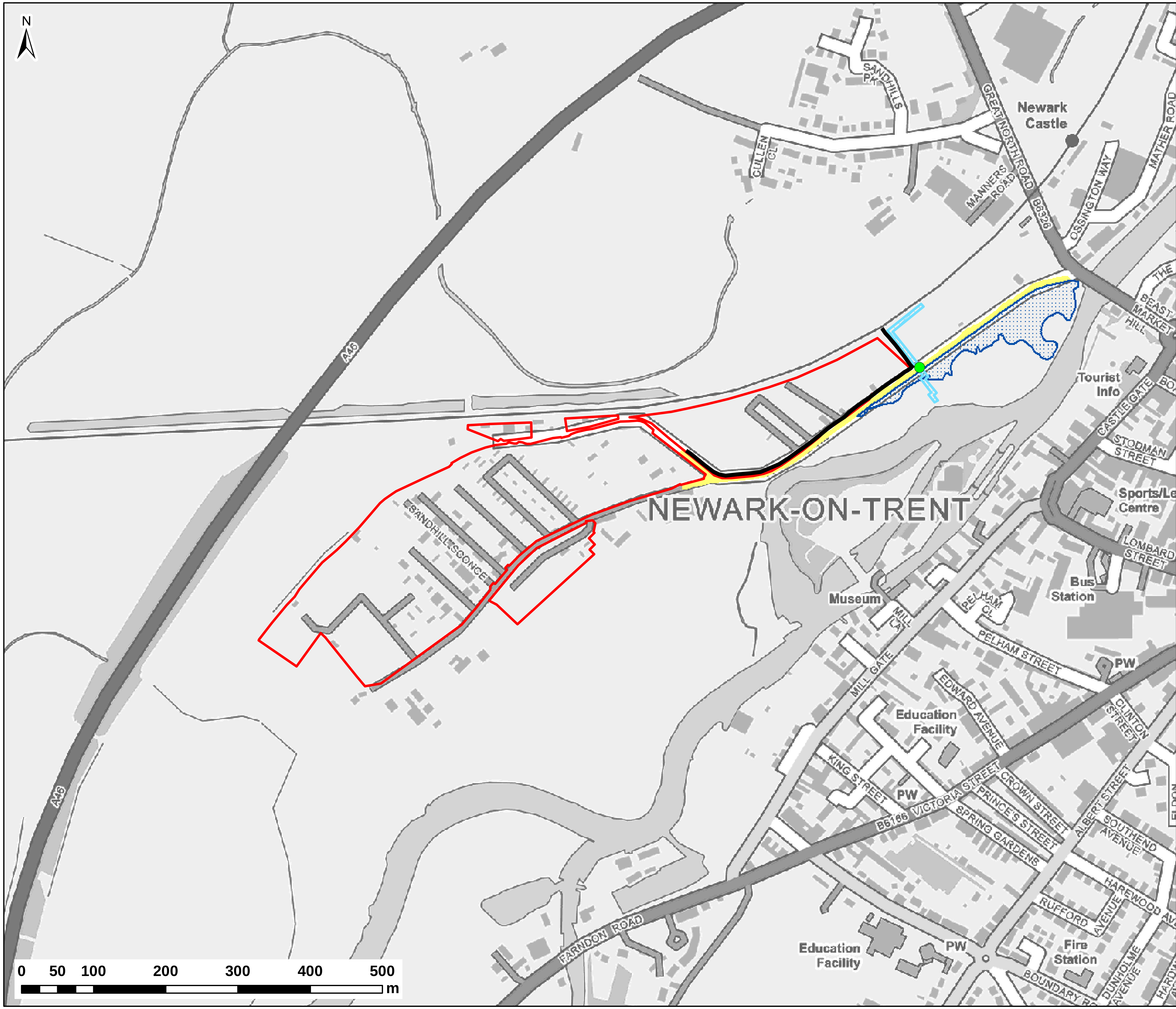
PLOT TITLE:

LIDAR ELEVATIONS

2m RESOLUTION

PLOT STATUS:			DATE:
FINAL			25/04/2019
DRAWN: CM	CHECKED: RC	APPROVED: LS	PLOT SCALE @ A3: 1:5,000 (UNLESS STATED OTHERWISE)
PLOT NAME: w3375-LiDAR			REV: -

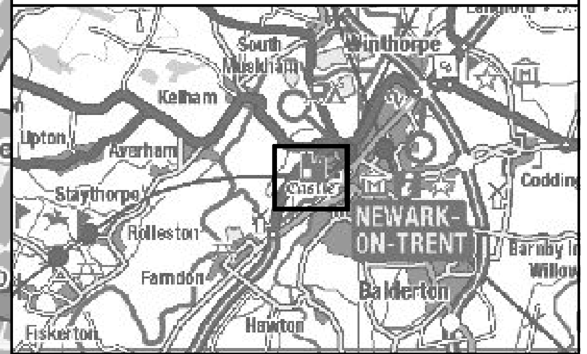
Appendix C Proposed Options Layouts



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

- Site Location
- Proposed Flood Relief Culvert
- Proposed Flood Wall
- Proposed Flood Relief Channel
- Proposed Flood Relief Area
- Proposed Tolney Lane Raising



CLIENT:

www.waterco.co.uk

SCHEME:

TOLNEY LANE, NEWARK

PLOT TITLE:

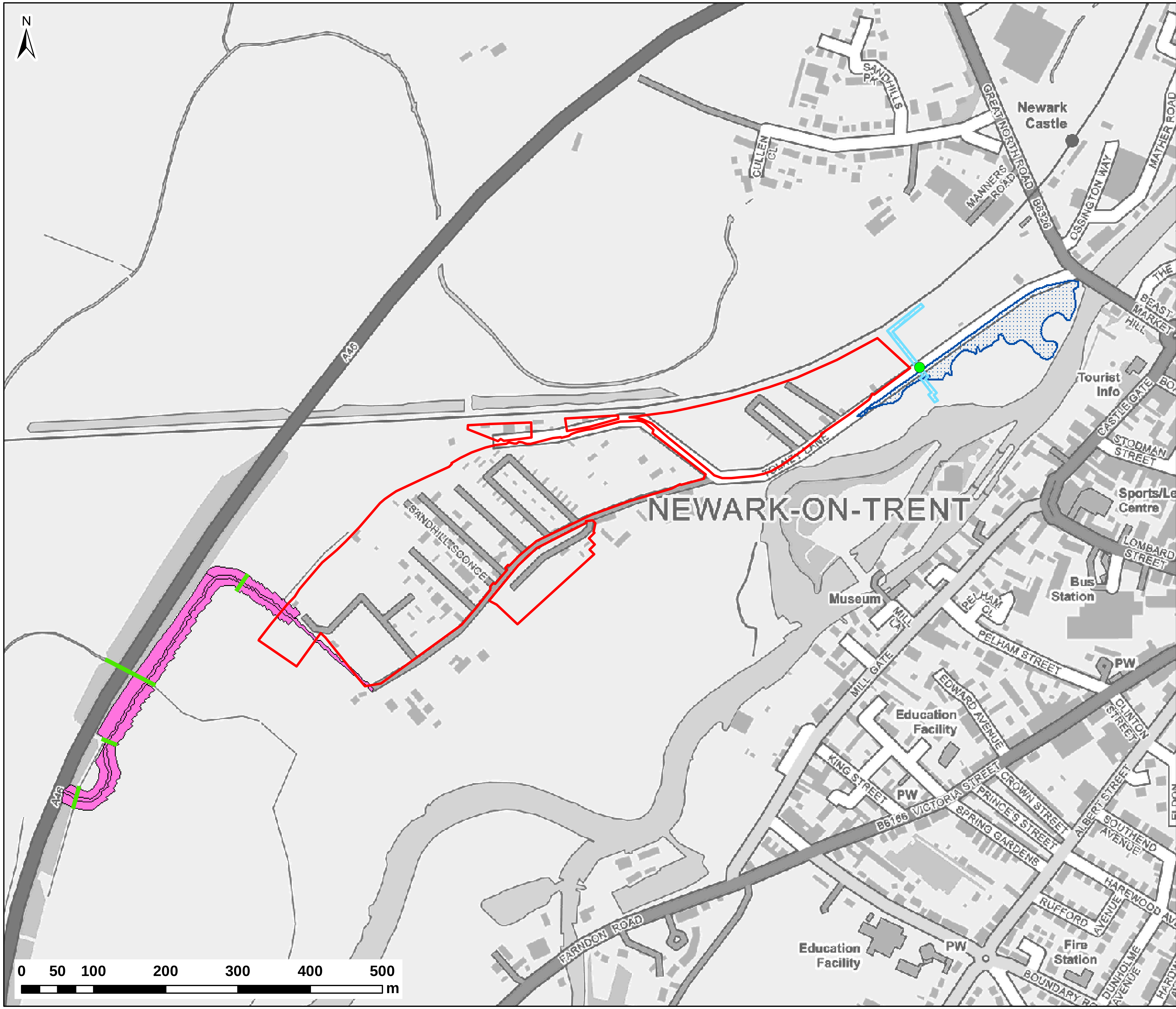
OPTION 1

FLOOD ALLEVIATION SCHEME LAYOUT

PLOT STATUS:	DATE:
FINAL	26-Apr-19

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
CM	RC	LS	1:5,000 (UNLESS STATED OTHERWISE)

PLOT NAME:	REV:
TRE_Q1000_OPT3_NFC_019_ZUK0_Max.asc	-

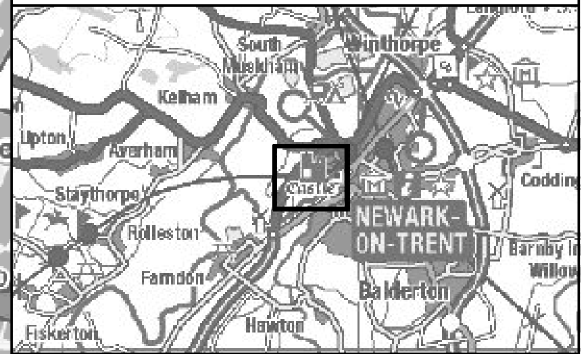


CONTAINS OS DATA © CROWN COPYRIGHT (2019)

NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

- Site Location
- Proposed Flood Relief Culvert
- Proposed Culverts
- Proposed Flood Relief Channel
- Proposed Flood Relief Area
- Proposed Highway Land Raising



CLIENT:

www.waterco.co.uk

SCHEME:

TOLNEY LANE, NEWARK

PLOT TITLE:

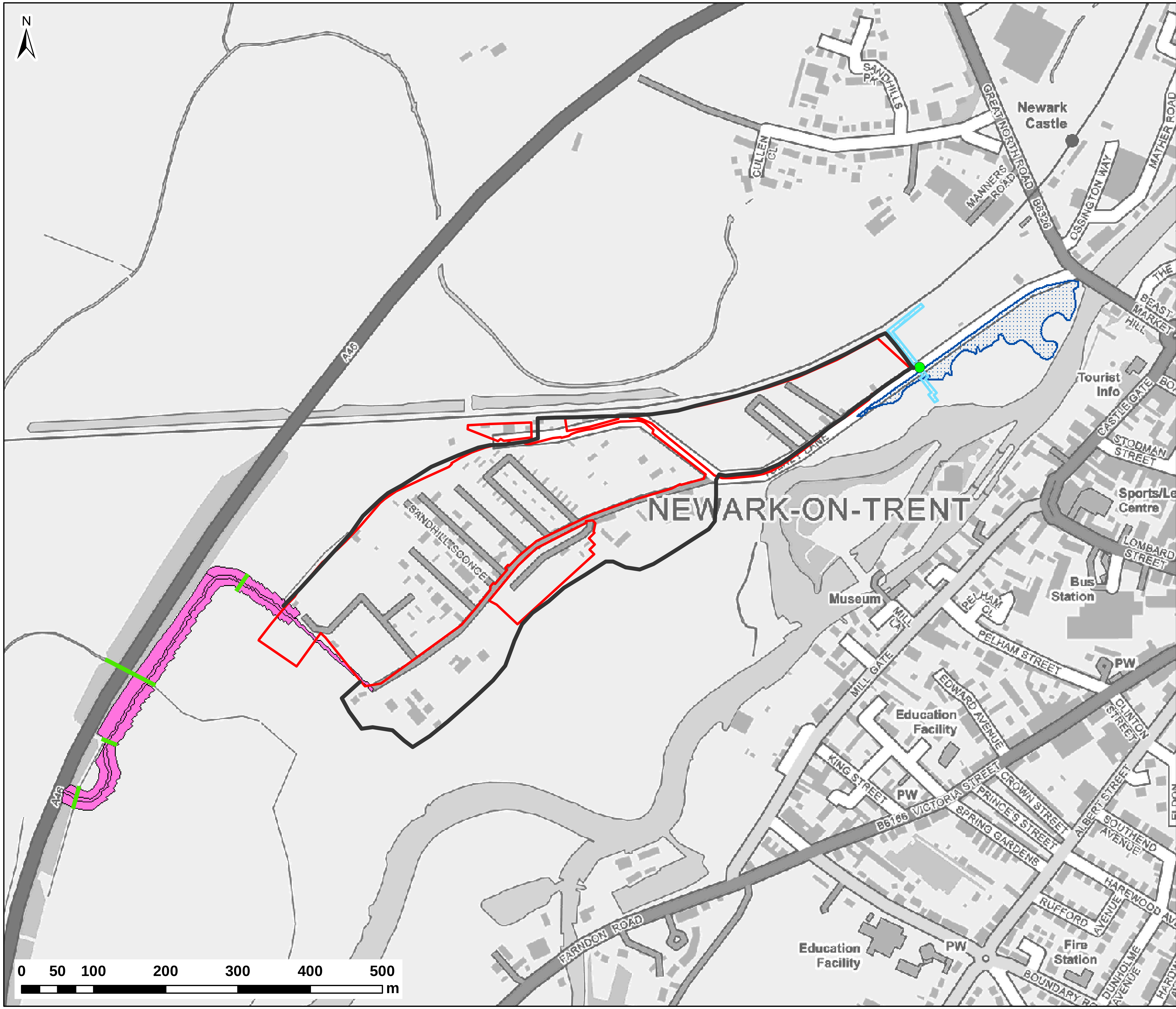
OPTION 2

FLOOD ALLEVIATION SCHEME LAYOUT

PLOT STATUS:			DATE:
FINAL			26-Apr-19

DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
CM	RC	LS	1:5,000 (UNLESS STATED OTHERWISE)

PLOT NAME:	REV:
TRE_Q1000_OPT3_NFC_019_ZUK0_Max.asc	-

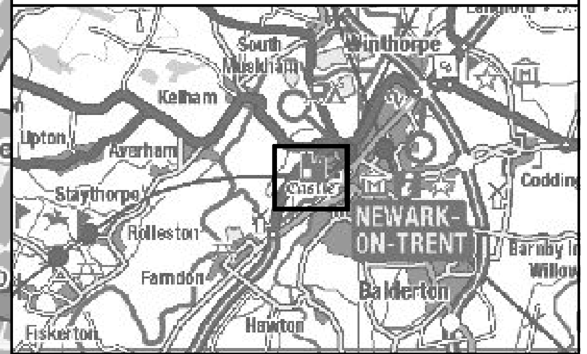


CONTAINS OS DATA © CROWN COPYRIGHT (2019)

NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

- Site Location
- Proposed Flood Relief Culvert
- Proposed Flood Defence Wall
- Proposed Culverts
- Proposed Flood Relief Channel
- Proposed Flood Relief Area
- Proposed Highway Land Raising



CLIENT:

www.waterco.co.uk

SCHEME:

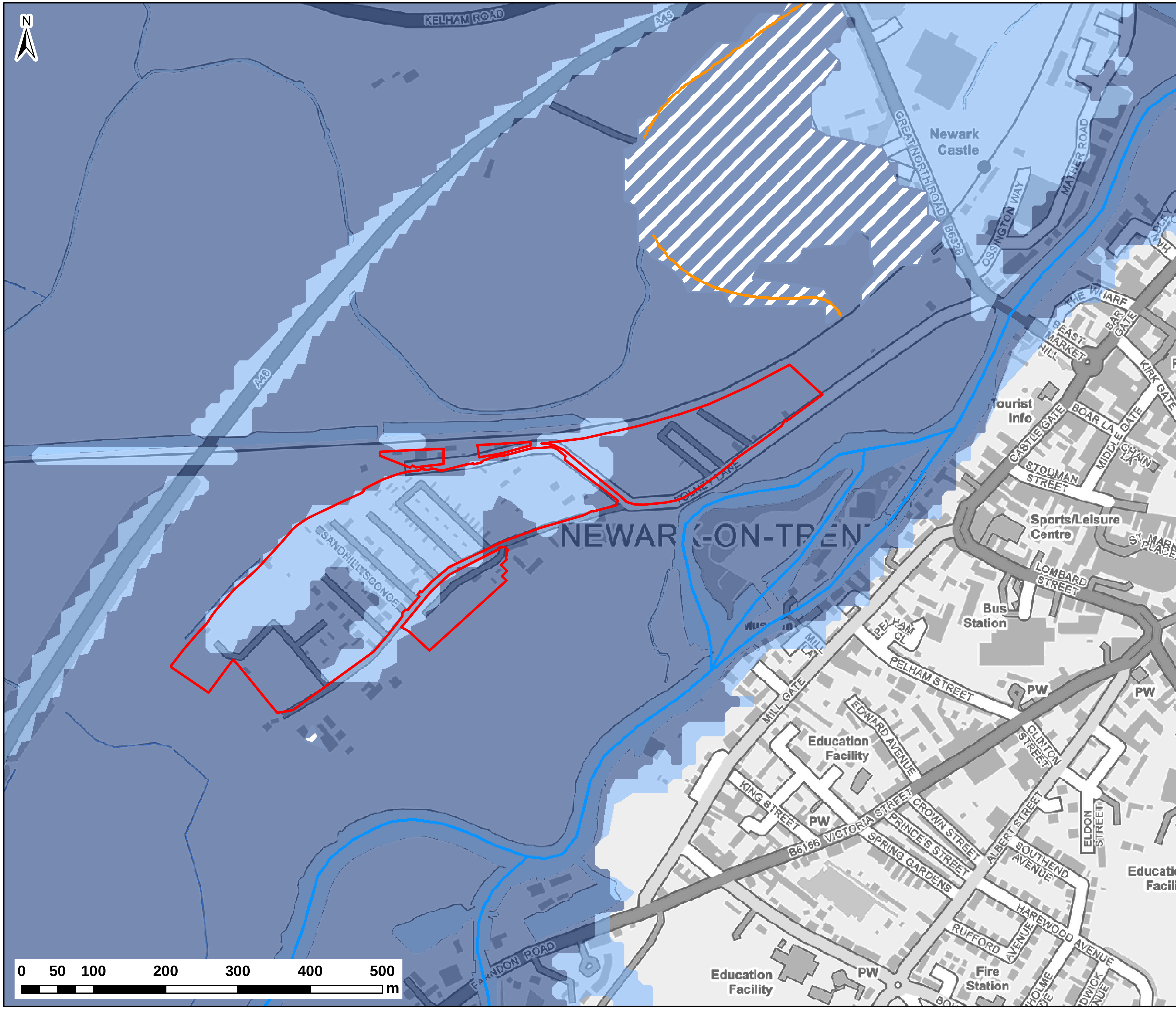
TOLNEY LANE, NEWARK

PLOT TITLE:

OPTION 3
FLOOD ALLEVIATION SCHEME LAYOUT

PLOT STATUS: FINAL			DATE: 26-Apr-19
DRAWN: CM	CHECKED: RC	APPROVED: LS	PLOT SCALE @ A3: 1:5,000 (UNLESS STATED OTHERWISE)
PLOT NAME: TRE_Q1000_OPT3_NFC_019_ZUK0_Max.asc			REV: -

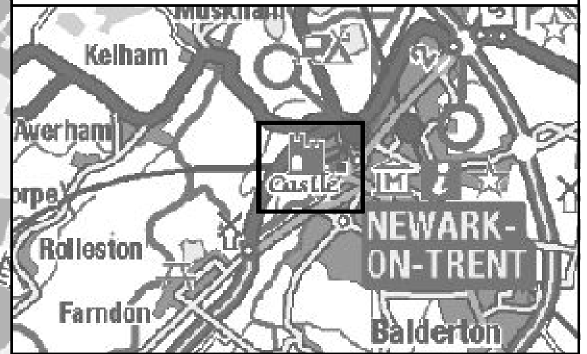
Appendix D EA Flood Maps



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

- Site Location
- EA Main Rivers
- EA Flood Defences
- Areas Benefitting from Flood Defence
- Flood Storage Areas
- EA Flood Zone 3
- EA Flood Zone 2



CLIENT:

www.waterco.co.uk

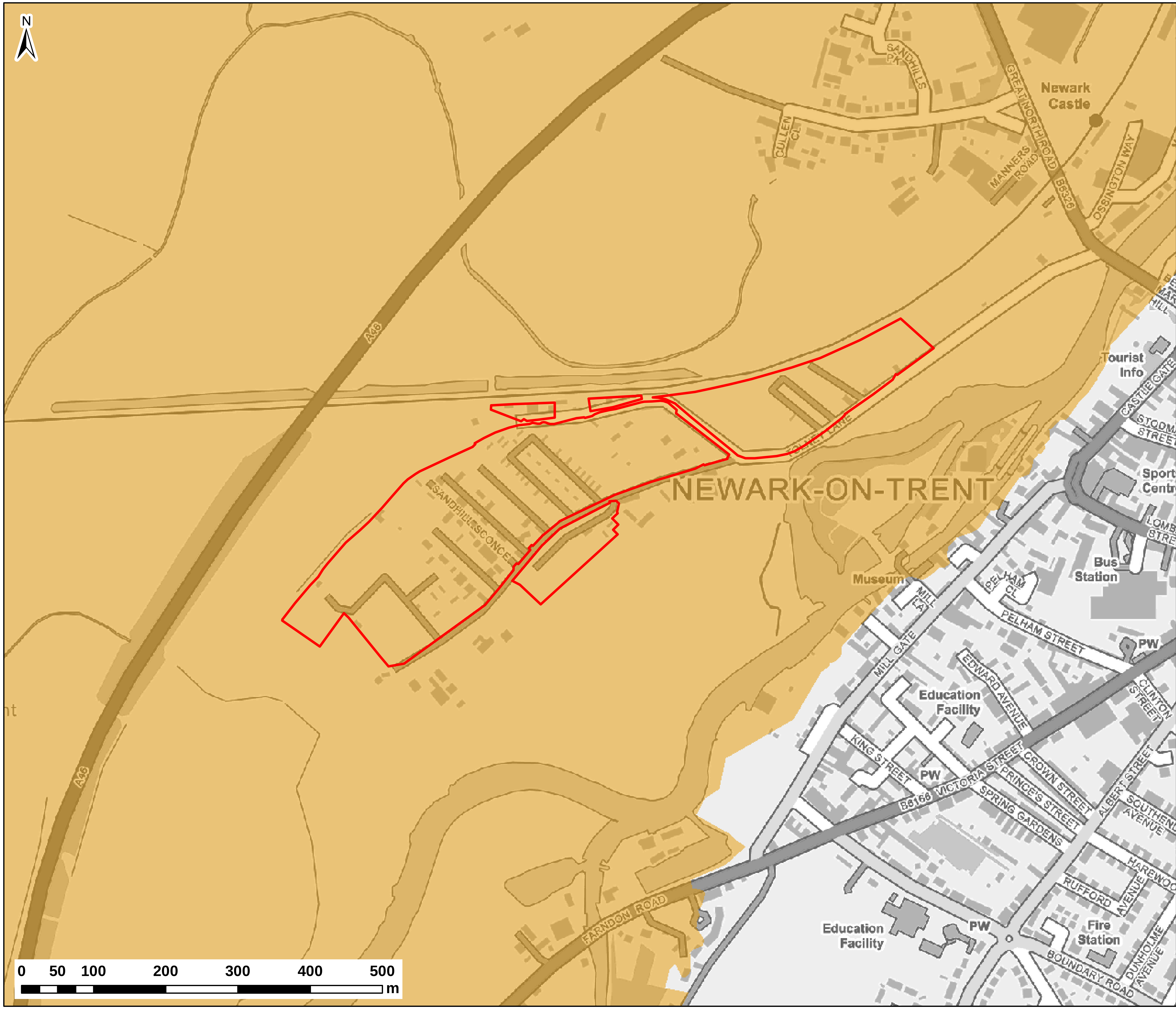
SCHEME:

TOLNEY LANE, NEWARK

PLOT TITLE:

EA FLOOD MAP FOR PLANNING

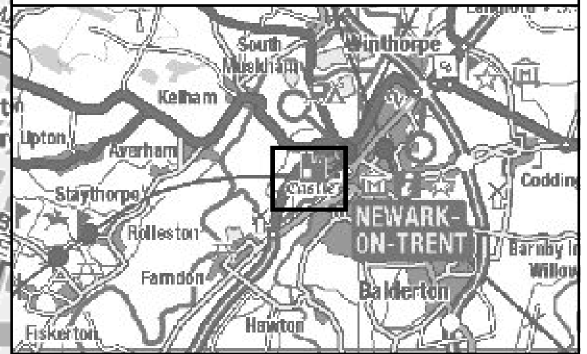
PLOT STATUS:			DATE:
FINAL			29-Jan-19
DRAWN: AR	CHECKED: RC	APPROVED: LS	PLOT SCALE @ A3: 1:5,000 (UNLESS STATED OTHERWISE)
PLOT NAME: w3375-EA_FM			REV: -



NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

- Site Boundary
- Historical Flood Map



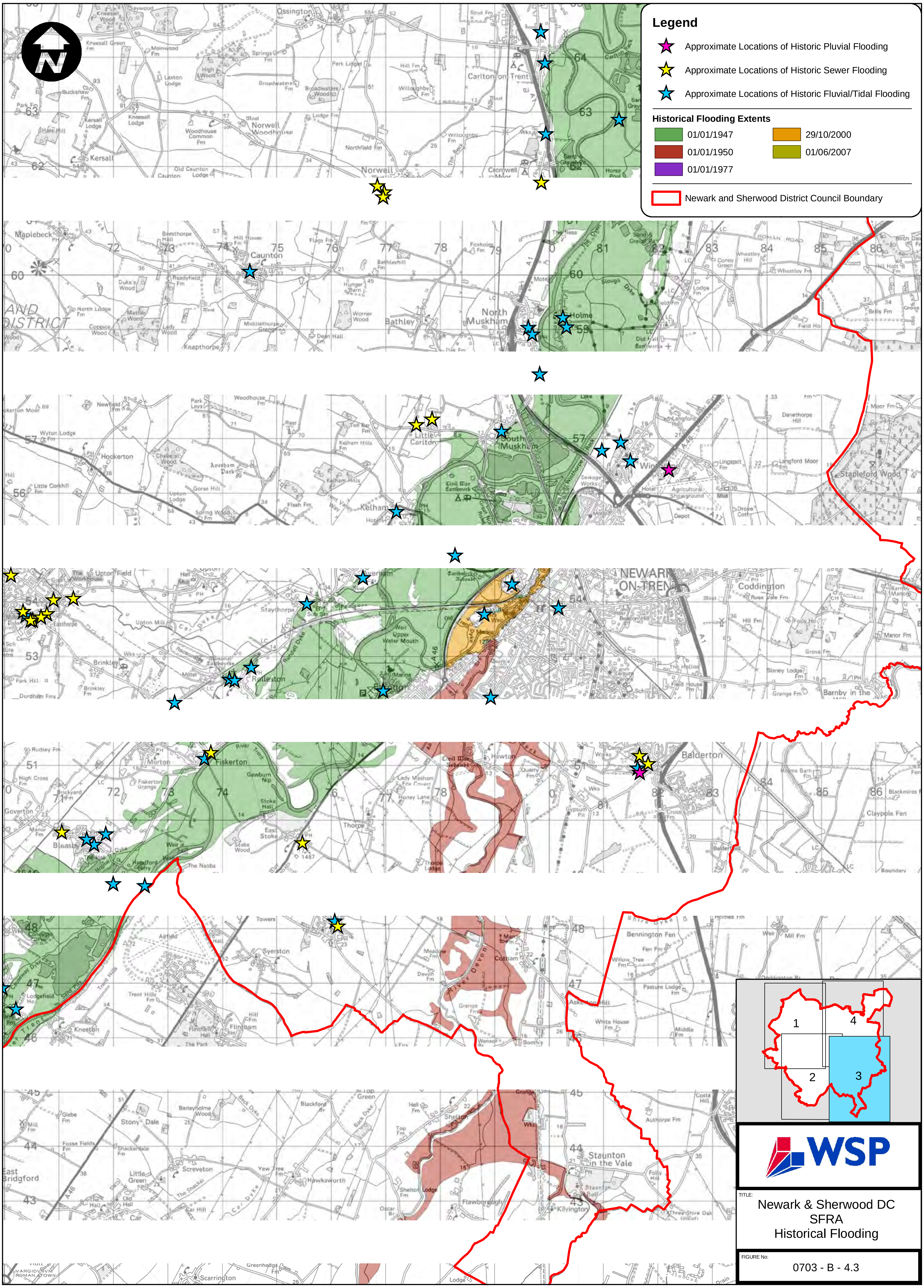
CLIENT:

www.waterco.co.uk

SCHEME:
TOLNEY LANE, NEWARK

PLOT TITLE:
EA HISTORICAL FLOOD MAP

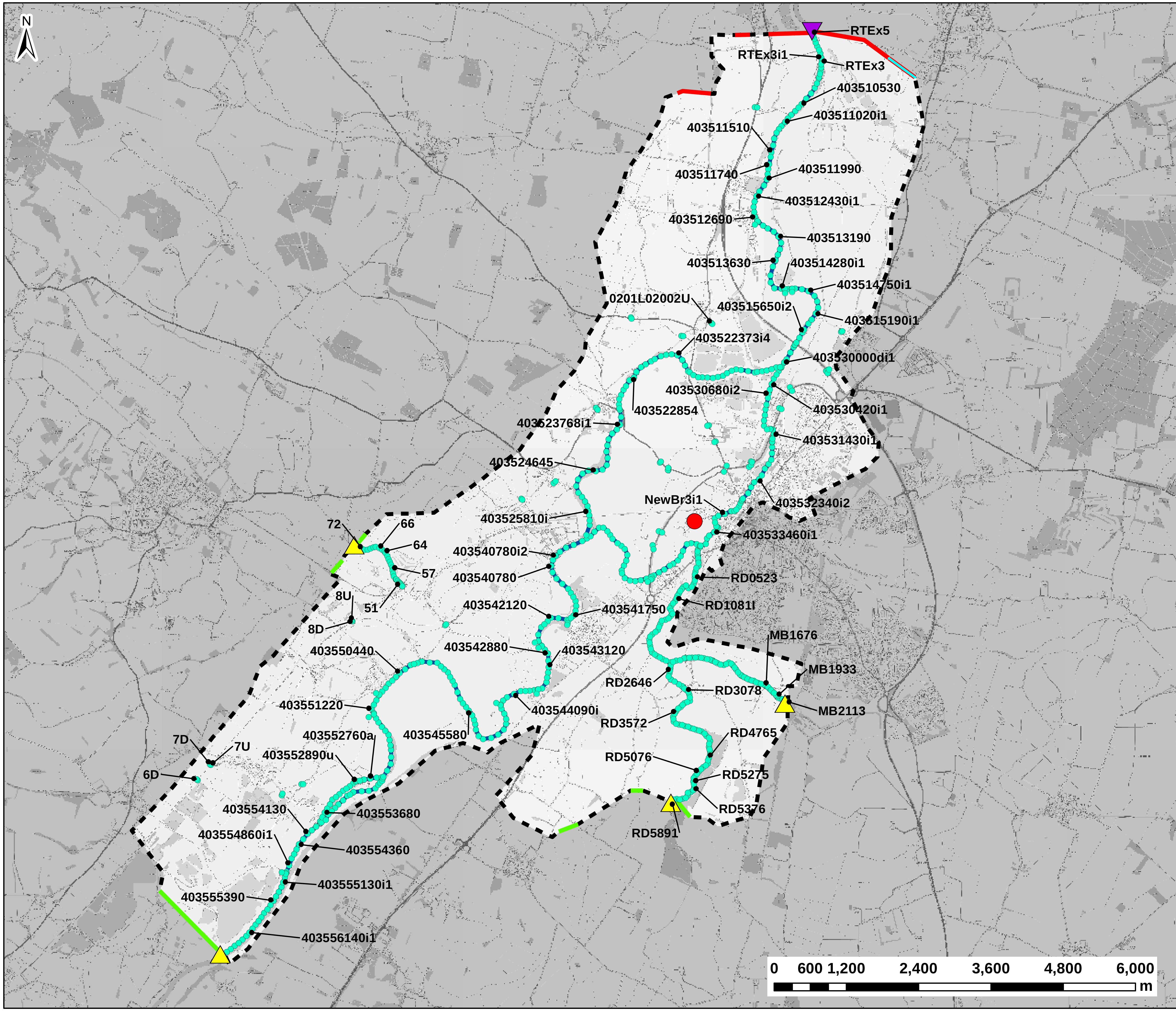
PLOT STATUS:			DATE:
FINAL			23/04/2019
DRAWN: AR	CHECKED: RC	APPROVED: LS	PLOT SCALE @ A3: 1:5,000 (UNLESS STATED OTHERWISE)
PLOT NAME: w3375-EA_HIST			REV: -



0 1 2 Kilometers

SCALE: 1:60,000

Appendix E 1D/2D Model Extents



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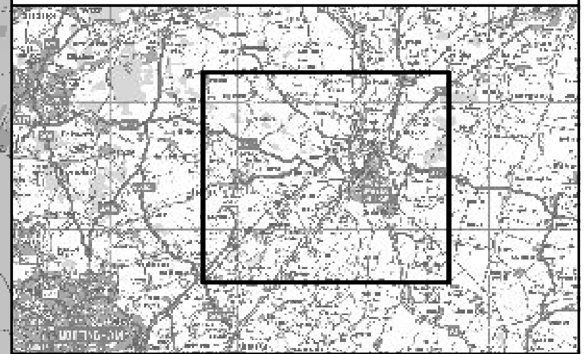
NOTES:
1) ALL DIMENSIONS ARE IN METRES AND ALL LEVELS IN METRES ABOVE ORDNANCE DATUM UNLESS STATED OTHERWISE

LEGEND

- Site Location
- Model Extent
- Outflow Location
- Inflow Location
- 1D Nodes
- 1D Channel Network
- Downstream Boundary
- Upstream Boundary



CLIENT:

www.waterco.co.uk

SCHEME:

TOLNEY LANE, NEWARK

PLOT TITLE:

MODEL EXTENT

PLOT STATUS:	DATE:		
FINAL	25/04/2019		
DRAWN:	CHECKED:	APPROVED:	PLOT SCALE @ A3:
CM	RC	LS	1:60,000 (UNLESS STATED OTHERWISE)
PLOT NAME:			REV:
w3375-ModelExtentPlan			-