Drainage and Flood Management Strategy

Herefordshire Council
Rotherwas Futures

September 2009

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APPENDIX D: DRAWINGS NUMBER 551392-SK-115 WELSH WATER SURFACE WATER SEWER LONG SECTION

1 Introduction

1.1 SCOPE OF WORK

1.1.1 This strategy document is to be used as a summary Technical Report. It is written in terms to ensure the understanding and adoption of the strategy for the Rotherwas Estate by planners and developers as well as the Environment Agency. It integrates all of the drainage, groundwater, surface water and flood risk management issues into a single strategy document.

1.1.2 The principal aims of the report are to ensure that flood risk is appropriately considered and sustainable drainage solutions are found which reduce flood risk to the sites and surrounding area.

1.1.3 The report will review the existing watercourses and drainage systems, topography and water resources on and around the site. It will then assess the effect of the development sites on these systems and resources.

1.1.4 A strategy to be applied across all development sites will be established and, on sites where the design is developed in more detail, the detailed design of drainage systems will be described showing how this strategy is being applied.

1.2 BACKGROUND

1.2.1 Herefordshire Council's Unitary Development Plan stresses that employment growth will be promoted principally in Hereford and the other market towns in the county. Efforts will be made to encourage the expansion of existing businesses whilst promoting Herefordshire as a suitable destination for inward investment. The UDP estimates that some 150 ha of land will be needed over the plan period for Part B employment development in the County and identifies the Rotherwas Industrial Estate as the key employment site for delivering this.

1.2.2 The proposed Rotherwas Industrial Estate development is split into phases. Phase 1, which includes several individual plots distributed within the estate; Phase 2, which is located within the southern boundary of the estate and Phase 3 to the North adjacent to the River Wye. The locations of these development sites can be seen on Figure 1.1 and described in Table 1.1 over the page:

1.2.3 All of the Phase 1, Phase 2 and Phase 3 plots are in the control of Herefordshire Council. However, also included within the strategic review is a site adjacent to Chapel Road to the south of the Sewage Works. This site is in private ownership and is referred to in this report as the Chapel Road Plot.

Table 1.1: Rotherwas Futures

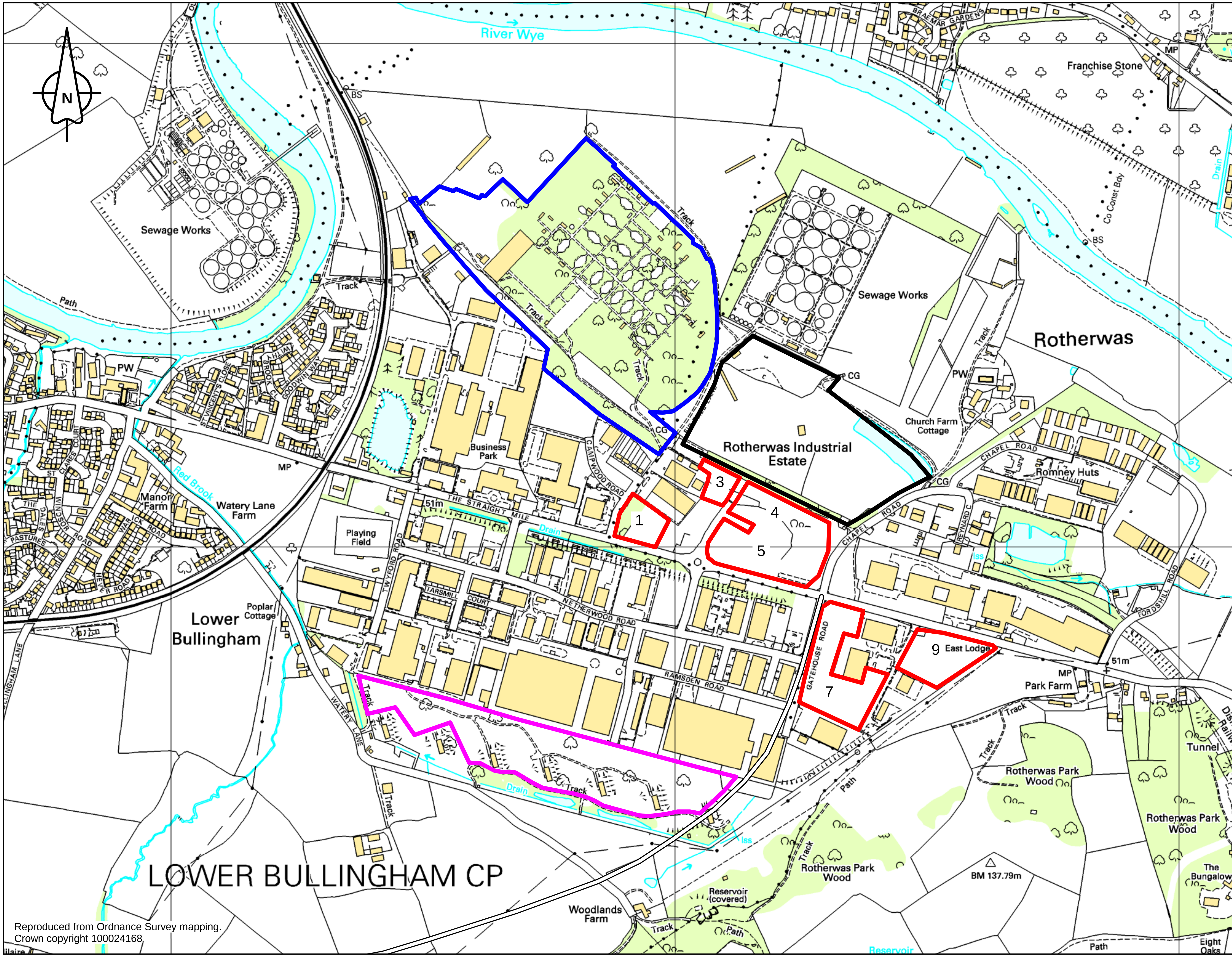
Plot Name	Area	UDP Status
Phase 1 Plot 3	0.7 ha	Safeguarded Employment Land
Phase 1 Plots 3, 4 and 5	4.3 ha	Safeguarded Employment Land
Phase 1 Plot 7	0.9 ha	Safeguarded Employment Land
Phase 1 Plot 9	1.4 ha	Safeguarded Employment Land
Phase 2	5.7 ha	Allocated for Consideration for Employment Use.
Phase 3	19.2 ha	Allocated for Consideration for Employment Use.
Chapel Road Plot	9.6 ha	Allocated for Consideration for Employment Use.

1.2.4 Outline Planning Applications for the future development of Phase 1 and Phase 2 have previously been unsuccessful due to Environment Agency concerns that the flooding, surface water drainage and potential contamination had not been fully assessed.

1.2.5 It is the intention of Herefordshire Council and their Agents to complete the strategic flooding and drainage studies including an assessment of risks to controlled water from contamination to the satisfaction of the Environment Agency. An outline application will also be re-submitted for the final change of use of Phases 1 and 2 in advance of any further sale of land for development of the plots. Separate detailed planning applications will be submitted for an access road up to the Phase 3 site and within the Phase 2 site.

1.2.6 No planning application has been submitted for change of use on Phase 3 and any application for the Chapel Road plot will be submitted through the private landowner or developer.

1.2.7 The construction of the Rotherwas Access Road was completed in 2008 and provides the primary access to the Rotherwas Industrial Estate and remains flood free in the Q100 with climate change scenario.



KEY

- Phase 1 Sites (with Plot numbers)
- Phase 2 Site
- Phase 3 Site
- Chapel Road Plot
- Rotherwas Access Road

Rev	Revision details	Chkd	Appd	Date
A	Chapel Lane Plot Added	PJ	AP	6.8.09

Drawn : PJ	For Comment
Design : AP	For tender
Chkd : AP	For Construction
Appd :	As Constructed
Date :	Other

File ref : g:\projects\

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Project Name
ROTHERWAS FUTURES

Drawing Title
HIGHWAYS
SCHEME LOCATION PLAN

Original Drawing Size : A3
Scale : NTS | Dimensions : -

FIGURE 1.1 | Rev **A**

2 Existing Drainage and Watercourse Systems

2.1 TOPOGRAPHY

2.1.1 The predominant topographic features at the Rotherwas Industrial Estate are Dinedor Hill to the South and West and the Rive Wye to the North. The topography within the estate follows the general falls in levels from south to north from Dinedor Hill to the River. However, the Holme Lacy Road is at a raised level through the estate creating two localised low spots located on Netherwood Road and under the railway bridge on Holme Lacy Road (Highlighted in orange on Figure 2.1).

2.2 WATERCOURSES AND SURFACE WATER DRAINAGE SYSTEMS

2.2.1 Figure 2.2 at the end of this chapter shows the existing watercourses and main surface water drainage systems at the Rotherwas Industrial Estate. The main feature is the River Wye to the North of the Industrial Estate. Other Watercourses include Red Brook which flows from Twyford to the south to the west of the Rotherwas Industrial Estate, passing beneath the railway bridge and outfalling into the River Wye. Other minor watercourses fed by land drains and groundwater springs on Dinedor Hill outfall into Red Brook and the large diameter storm sewer on the Industrial Estate.

2.2.2 The Rotherwas Industrial Estate is served by a network of storm sewers outfalling into the River Wye. Additional details of the storm sewers can be seen on Drawing Number 551392/SK/107 in Appendix A and are summarised by the main sewer lines shown on Figure 2.2. The Local Storm Sewers range in diameter from 150mm to 600mm with the large diameter sewer on Netherwood Road and Chapel Road up to 1200mm.

2.2.3 As a previously developed site, some of the existing ground has impermeable surface due to roads buildings, bunkers and concrete slabs. Drawing Number 551392/SK/107 in Appendix A also shows the areas of permeable and impermeable surface at the estate and in each of the Phases of the Development.

2.3 GROUNDWATER

2.3.1 Ground investigation works have been undertaken and a programme of ground water level monitoring is underway in the Phase 1 and Phase 2 sites. The monitoring undertaken to date has shown ground water to be between 2.7m and 3.4m from the existing ground level although anecdotal evidence at the industrial estate suggests that the ground water can rise to within 1.5m of the existing ground level. In any case there is little risk of surface flooding of the sites from groundwater although any deep excavations to facilitate the infrastructure works require consideration.

2.3.2 Although hard surface does exist within the existing Phase 1, 2 and 3 sites, the impermeable areas are far greater in quantity. Also, with no known working surface water drainage system within the sites, any rainfall on the hard areas will flow onto the surrounding, relatively flat, permeable ground.

2.3.3 Experience on the sites to date indicates that the ground permeability is extremely variable. Layers of gravels found close to the surface and also at greater depths have been seen to take significant quantities of surface water. In other areas the quantities of clay materials within the subsoil significantly reduce the infiltration of surface water.

2.3.4 Additional information on the ground conditions and underlying geology at the industrial estate can be found in the Geotechnical and Geo-Environmental Reports available from Amey Consulting in Hereford on request.

2.4 NOTABLE FLOOD EVENTS AND FLOOD IMPACTS

2.4.1 An updated review of the Wye hydrology and peak flood estimation has been carried out as part of this investigation. The major floods of 1960, 1998 and 2000 have all been used in various contexts to determine floodplain impacts at Rotherwas.

2.4.2 It is important that the peak levels, peak flows and the probabilities of these events are correctly identified to verify or discount model predictions and true floodplain extents.

1795 The 1795 flood event was particularly damaging on the River Wye, destroying many bridges and settlements. This flood predates any gauging information, but records were made at the Wye Bridge Recorder and this is estimated to have achieved a peak level of 52.334 m AOD.

1960 The 1960 flood event (4 December 1960) is most probably the largest on record. The Annual Maxima peak flow record on the River Wye at Rotherwas shows the 1960 flood of 600 m^3/s (extrapolated) to have been exceeded by the 1998 flood of 607 m^3/s extrapolated). However, these flow estimates do not correlate to the observed flood levels at the Wye Bridge, where the 1998 flood level was recorded as 52.054, compared to the 1960 level of 52.358 m AOD. WS Atkins has proposed alternative corrected estimates on the basis of hydraulic modelling.

The revised flood estimate for 1960 is put at 958 m^3/s and this event is thus probably the largest event on record, and is interestingly very close in level to that of 1795, suggesting a 150 – 200 year periodicity for this extreme event.

The 1960 flood event is currently used by the Environment Agency as the indicative flood line for development control purposes. There are no accurate photographs or wrack marks for this event however, and what are available are anecdotal recollections and small scale maps drawn by hand.

1979 The 1979 flood event (28 December 1979) is the 4th largest on record. There is little recorded information for this flood except for a recorded level of 51.65 mAOD at Wye Bridge.

March 1998 1998 was noteworthy in that it encountered two significant floods, on 7 March and 28 October. The first flood ranks 6th in the recorded series, and was overshadowed by the larger event of October. There is no recorded data other than the level at Wye Bridge.

October 1998 The second 1998 flood (28 October 1998, 21:45 PM) is the second largest recent flood (706 m^3/s), creating significant inundation and damage in and around Hereford. Unfortunately, this flood was not well recorded in terms of wrack marks, but several excellent aerial photographs have been obtained that show flood extents. However, it should be noted that the peak of the flood occurred at 21:45, and these photographs obviously date from AM of the following day. Herefordshire Council staff on-site have a clear recollection of this event, and in general in the centre of Rotherwas (Sewage Treatment Works), the maximum level was in the order of 49.2mAOD.

2000 The 2000 flood (31 October 2000, 10.00 AM) is listed as the equal 6th largest event on record (551 m³/s, under-estimated). This event is highly relevant to the Rotherwas technical analysis because it was extremely well documented in terms of flood level. Post 1998, Herefordshire Council and the Environment Agency installed some 7 flood gauges between the railway bridge and Holme Lacy causeway. These gauges were monitored and photographed at the peak of the flood, providing a high level of accuracy for subsequent model calibration.

A detailed summary of flood observations and photographs is contained in the Report Flood Data Record – Rotherwas Industrial Estate, HLH00/196, Halcrow, November 2000.

2002 The 2002 flood (2 February 2002, 23:30 PM) was marginally greater in magnitude to the flood of 2000, although the EA record records the same extrapolated discharge. There is no recorded data other than the level at Wye Bridge.

2004 The 2004 flood (5 February 2004, 15:30 PM) is listed as the 7th largest event on record (519 m³/s, under-estimated), so this is also a highly significant event. Unfortunately there was little recorded in the form of wrack marks. However, the event was photographed in great detail at the peak of the event, and it is possible to estimate approximate levels throughout Rotherwas from these data.

2.5 SUMMARY OF HISTORICAL EVENTS

2.5.1 Table 2.1 summarises the eight largest events on record, together with estimated return periods and comparative levels at Wye Bridge.

2.5.2 This Table corrects several misconceptions prevalent in current investigations for Rotherwas. In particular, it can be seen that the 1960 flood was an extreme flood well in excess of a 1% probability event. Although the flood frequency curve suggests a 1 in 400 year return period, the 900 m³/s discharge has been exceeded twice in 213 years, suggesting pragmatically that the 1960 event is likely to be more frequent than 1 in 400.

2.5.3 The 1998 event has also been viewed as an alternative to the 1% probability event, but the statistical record shows that in fact it was closer to a 1 in 40 year return period. This is in line with regional assessments of the 1998 floods, which were typically regarded as 1 in 40 to 1 in 50 year events.

2.5.4 There is general agreement amongst consultants that the 1 in 100 year flood is in the order of 809 m^3/s, and the climate change adjustment to this flow would therefore be 809 x 1.2 = 971m^3/s.

Table 2.1 – Summary of Historical Events

Year	Date	Time of Peak	Rank	Estimated Flow *	Event Probability **	Level at Wye Bridge
1795	February	?	2	900	1 in 250	52.334
1960	4 December	?	1	958	1 in 400	52.358
1979	28 December	?	4	663	1 in 25	51.650
1998	7 March	19:15	6	625	1 in 18	51.581
1998	28 October	21:45	3	706	1 in 40	52.054
2000	31 October	10:00	5	661	1 in 23	51.630
2002	2 February	23:30	5	661	1 in 23	51.730
2004	5 February	15:30	7	623	1 in 15	51.416

* Flows have generally been factored by 1.2 to provide matches with hydraulic models.
** Based on FEH-Pooling Group Method, Generalised Extreme Value Distribution

2.6 REASSESSMENT OF RIVER WYE FLOOD GROWTH CURVE

2.6.1 A standard Flood Estimation Handbook (FEH) assessment of the Flood Growth Curve at Belmont Gauge using Annual Maxima data to March 2007, (based on a Generalised Extreme Value Distribution and using Belmont as the primary gauge) has generated the Flood Frequency Curve shown as Table 2.2.

Table 2.2 – Updated Flood Frequency Curve, River Wye at Belmont

Event	MAF (1in2)	20% (1in5)	10% (1in10)	5% (1in20)	3.3% (1in30)	2% (1in50)	1% (1in100)	0.4% (1in250)	0.25% (1in400
Peak Flow	387	498	573	645	686	738	809	903	951

2.6.2 This shows for example that the 1% probability flood event has a peak flow value of approximately 809 m^3/s. This assessment coincides closely with that of the WS Atkins Report 5029863.70-DG06-R2, which suggests 807 m^3/s as the design discharge at the Bunch of Carrots Public House.

2.7 ISIS AND TUFLOW MODELS

2.7.1 A detailed description of the flood modelling can be read in the 'Flood modelling at Hereford Hydraulic model check file' in Appendix B and is summarised below.

2.7.2 A hydraulic model of the River Wye exists and has been used as the in-channel component of the linked model. This model has been developed using the 1D hydraulic modelling software ISIS. Two separate hydraulic models of smaller tributaries also exist. These are the Red Brook and the Withy Brook, both of which join the Wye from the right bank immediately upstream of the study area. Both of these models were available in HEC-RAS format and needed converting into ISIS format before they could be incorporated into a linked 1D-2D hydraulic model. The existing floodplain representation across the study area is as extended cross sections.

2.7.3 A LiDAR Digital Terrain Model (DTM) existed at a 2m resolution. For the basis of the TUFLOW model the filtered version of the data was used; this was processed by the Environment Agency in order to remove buildings and vegetation.

2.7.4 The TUFLOW model extents were defined using a combination of the existing ISIS model, the LiDAR derived DTM and the existing flood zone outlines. It was decided to extend the model to include all of the floodplain inside the meander upon which the Rotherwas Industrial Estate sits. Moreover, the North bank of the River Wye rises steeply to higher ground. This effectively provides a natural barrier to floodplain flow and avoids the need to dynamically link the floodplain in the ISIS and TUFLOW models.

2.7.5 The TUFLOW model has been built using 4m cells. This relatively fine modelling resolution was required in order to represent buildings and the flow paths between them on the Rotherwas Industrial Estate. Any smaller cell size would have resulted in unfeasibly long model run times. The model grid is orientated at approximately 15 degrees. This orientation has been chosen as it aligns with the road network in the Rotherwas Estate; these roads are expected to be the principal flow paths through the main area of interest. Every effort has been made to link the ISIS section extents with the location of the boundaries in the TUFLOW model. This has been done by comparing ground elevations in both model domains and also by measuring the river width. However as the TUFLOW domain only exists on the right bank of the model it is not possible to directly compare river widths in the two models.

2.7.6 Three culvert units have been used to represent flow paths through the railway embankment. ESTRY units have been used because they are able to completely dry out without becoming unstable. This is critical for floodplain structures which only become wet once water levels have risen sufficiently. The two most northerly structures have been modelled as rectangular culvert units with dimensions estimated from both the digital mapping and aerial photography provided. The final structure, the culvert on the Red Brook has more detailed dimensions provided in the hydraulic model so an irregular culvert unit has been used to provide an accurate representation of the structure dimensions.

2.7.7 TUFLOW provides the user with a powerful array of tools for modifying the topography. Utilising these tools leaves the original DTM unchanged and provides an easily followed audit trail of terrain modifications. It also allows the user model different combinations of terrain changes.

2.7.8 Model runs have been undertaken to illustrate the extent of flooding at 1 in 100 (Q100), 1 in 100 including the effects of climate change (Q100 +CC) and 1 in 1000 (Q1000) return periods assuming no significant terrain or structure modification.

2.7.9 Table 2.3 gives a comparison between the updated ISIS-TUFLOW model and the original EA ISIS model. There is 0.00 difference in the average flood level prediction through the model area.

2.7.10 Summed deviations of up to +0.11m to -0.16m cancel each other out since there are both +ve and –ve deviations showing that there is no systematic computational difference in the two models. It confirms that to within all reasonable expectations of the accuracy of the models, they are essentially the same.

2.7.11 +/- 0.15m is realistically the best accuracy likely to be achieved by any model as this is the accuracy of the LIDAR data on which the model is based.

2.7.12 The main difference between the models is the flow through the estate via the Holme Lacy Road Bridge, underpass and Watery Lane Bridge. An assessment of whether this has affected down stream flows has been made. The flows through these structures are:

- Underpass – 7.7m^3/s
- Holme Lacy Road – 6.1m^3/s
- Watery Lane – 1.6m^3/s

2.7.13 The Holme Lacy Road flow of 6.1m^3/s contributes over 95% of the overall volume entering the estate and represents 0.6% of the total river flow. The diverted flow is negligible and does not have any effect on downstream flow.

2.7.14 As there has been no flooding recorded through the railway embankment onto the estate there is no historic data against which to calibrate.

2.7.15 Sensitivity tests have been undertaken and are described in more detail in section 2.11 of this report.

Table 2.3 – Summary of ISIS – TUFLOW Modelling Assessments

		Baseline Output Original ISIS v TUFLOW Modified				TUFLOW + Climate Change			TUFLOW + Zone 2		TUFLOW + Bridge enlarged	TUFLOW + North Embankment (Sc 1)		TUFLOW + SC1 + South Embankments (Sc 2)			
Model Node	Location	Original ISIS (a)	100 Year TUFLOW (b)	Δ (b-a)	100 Year n+20%	100 year + CC TUFLOW (c	Δ (c-b)	100 year n+20%	1000 year TUFLOW (d)	Δ (d-b)	100 Year Bridge Mod (e)	100 year +CC TUFLOW (f)	Δ (f-c)	100 year +CC TUFLOW (g)	Δ (g-c)	1000 year TUFLOW (h)	Δ (h-d)
1.043		51.44	51.50	0.06	51.73	51.83	0.34	52.04	52.31	0.82	51.50	51.86	0.03	51.87	0.03	52.31	0.00
1.042		51.46	51.51	0.05	51.74	51.86	0.35	52.06	52.35	0.84	51.51	51.88	0.02	51.89	0.03	52.35	0.00
1.041		51.47	51.49	0.02	51.72	51.84	0.35	52.04	52.33	0.84	51.49	51.87	0.03	51.87	0.03	52.33	0.00
1.04		51.44	51.48	0.04	51.72	51.82	0.34	52.03	52.30	0.82	51.48	51.85	0.02	51.85	0.03	52.30	0.00
1.039	Confluence with Withy Brook	51.40	51.47	0.07	51.70	51.83	0.36	52.03	52.32	0.86	51.47	51.86	0.03	51.86	0.03	52.32	0.00
1.037	Confluence with Red Brook	51.18	51.27	0.09	51.56	51.68	0.41	51.93	52.21	0.94	51.27	51.72	0.04	51.73	0.05	52.22	0.00
1.036		51.19	51.20	0.01	51.50	51.61	0.41	51.87	52.15	0.95	51.20	51.65	0.04	51.66	0.05	52.15	0.00
1.035	50m upstream of arch underpass	51.04	51.13	0.09	51.44	51.56	0.43	51.83	52.12	0.99	51.13	51.60	0.05	51.61	0.05	52.12	0.00
1.034	125m upstream of Eign STW bridge	50.98	51.08	0.10	51.39	51.51	0.43	51.78	52.07	0.99	51.08	51.54	0.03	51.55	0.04	52.07	0.00
1.0339		50.91	51.01	0.10	51.32	51.44	0.43	51.71	51.99	0.98	51.01	51.47	0.03	51.48	0.04	51.99	0.00
1.0334		50.93	51.03	0.10	51.33	51.46	0.43	51.72	52.00	0.97	51.03	51.49	0.03	51.50	0.04	52.00	0.00
1.0333		50.93	51.03	0.10	51.33	51.46	0.43	51.72	52.01	0.98	51.03	51.49	0.03	51.50	0.04	52.01	0.00
1.033	175m downstream of Eign STW bridge	50.91	51.00	0.09	51.30	51.43	0.43	51.69	51.99	0.99	51.00	51.46	0.03	51.47	0.04	51.99	0.00
1.0325		50.84	50.95	0.11	51.25	51.39	0.43	51.64	51.95	1.00	50.95	51.42	0.03	51.42	0.04	51.95	0.00
1.032	35m upstream Bullingham Railway Bridge	50.54	50.55	0.01	50.88	50.95	0.41	51.26	51.55	1.00	50.55	50.98	0.03	50.99	0.03	51.55	0.00
1.03	Downstream Bullingham railway Bridge	50.35	50.31	-0.04	50.61	50.59	0.28	50.89	51.03	0.72	50.31	50.61	0.02	50.61	0.02	51.03	0.00
1.025		50.24	50.08	-0.16	50.39	50.36	0.28	50.67	50.83	0.75	50.08	50.37	0.01	50.38	0.02	50.83	0.00
1.024		50.08	50.02	-0.06	50.29	50.29	0.27	50.57	50.74	0.72	50.02	50.31	0.01	50.31	0.02	50.74	0.00
1.023	Upstream end Phase 3	49.99	49.94	-0.05	50.20	50.21	0.27	50.48	50.66	0.72	49.94	50.22	0.01	50.23	0.02	50.66	0.00
1.022		49.95	49.87	-0.08	50.12	50.14	0.27	50.39	50.58	0.70	49.87	50.15	0.01	50.15	0.01	50.58	0.00
1.021		49.84	49.73	-0.11	49.97	50.00	0.26	50.24	50.42	0.69	49.74	50.00	0.01	50.01	0.01	50.42	0.00
1.02		49.63	49.57	-0.06	49.79	49.83	0.26	50.06	50.26	0.70	49.57	49.83	0.00	49.83	0.01	50.26	0.00
1.019	Upstream end Rotherwas STW	49.43	49.40	-0.03	49.59	49.63	0.23	49.83	50.01	0.62	49.40	49.63	0.00	49.63	0.01	50.01	0.00
1.018		49.21	49.22	0.01	49.40	49.44	0.22	49.63	49.80	0.58	49.23	49.44	0.00	49.45	0.01	49.80	0.00
1.017	Downstream end Rotherwas STW	48.96	48.98	0.02	49.19	49.22	0.25	49.46	49.63	0.65	48.98	49.22	0.00	49.23	0.00	49.63	0.00
1.016		49.02	48.99	-0.03	49.19	49.25	0.26	49.46	49.66	0.66	48.99	49.25	0.00	49.25	0.00	49.65	0.00
1.015		48.93	48.92	-0.01	49.14	49.20	0.28	49.42	49.62	0.70	48.92	49.20	0.00	49.21	0.00	49.62	0.00
1.014	Outfall of Welsh Water storm sewer	48.86	48.87	0.01	49.10	49.16	0.29	49.38	49.57	0.70	48.87	49.16	0.00	49.16	0.00	49.57	0.00
1.013		48.86	48.84	-0.02	49.06	49.13	0.29	49.34	49.54	0.69	48.84	49.13	0.00	49.13	0.00	49.54	0.00
1.012		48.87	48.74	-0.13	48.94	49.01	0.27	49.21	49.38	0.64	48.74	49.00	-0.01	49.01	0.00	49.38	0.00
1.011		48.77	48.70	-0.07	48.92	48.97	0.27	49.18	49.35	0.65	48.70	48.96	-0.01	48.97	0.00	49.35	0.00
1.01		48.75	48.70	-0.05	48.91	48.96	0.26	49.18	49.33	0.64	48.70	48.95	-0.01	48.96	0.00	49.33	0.00
1.009		48.74	48.71	-0.03	48.92	48.97	0.27	49.18	49.34	0.63	48.71	48.97	-0.01	48.97	0.00	49.34	0.00
	Average Difference			0.00	0.25		0.33	0.24		0.79			0.02		0.02		0.00

2.8 Q100 FLOOD OUTLINE – ZONE 3

2.8.1 Figure 2.3 gives the Q100 flood outline derived from the TUFLOW modelling process. The floodplain is not shown on the left-bank as this is not relevant to the study and was not part of the TUFLOW model. Based on the TUFLOW model grid of 4m resolution, the floodplain outputs have been colour coded in the form of a flood outline-depth map to represent overall hazard. Essentially, moving through the spectrum from light blue to red illustrates an increasing depth of flood water. Areas coloured light blue are less than 0.25m depth, and hence represent minimal hazard as per the SFRA definitions.

2.8.2 Figure 2.3 shows a much reduced area of the industrial estate prone to flooding at this frequency in comparison to the EA's published flood-zone map. Generally, the flood depths are less than 0.25m, although there are small areas in the north-west and east of the Estate that exhibit greater depths of up to 1m (excluding the ponds).

2.8.3 Flooding of the Estate is principally via the Holme Lacy road bridge into the Estate, and to a lesser extent the underpass arch to the north.

2.8.4 It is noted that there is little flooding of the Estate south of The Straight Mile (including all of Phase 2 land), and minimal flood inundation of the Phase 3 land immediately west of the Rotherwas STW.

2.8.5 The modelling shows a conveyance route through yards and access roads north of The Straight Mile heading north-east to rejoin the Wye east of Rotherwas STW.

2.8.6 The new Rotherwas Access Road remains unaffected in this scenario.

2.9 Q100 OUTLINE + CLIMATE CHANGE

2.9.1 Figure 2.4 gives the Q100 + Climate Change outline and shows a somewhat larger area of the Estate subject to flooding. This is primarily due to the flood route through the Holme Lacy road bridge, reinforced by lesser inputs from the northern underpass and a small conveyance route across Holme Lacy road from the Red Brook west of the railway.

2.9.2 All Phase 1 sites exhibit some inundation in this event. Phase 2 remains unaffected. Phase 3 is more significantly affected, though again depths are generally shallow.

2.10 Q1000 OUTLINE

2.10.1 For completeness, Figure 2.5 shows the revised Flood Zone 2 or 0.1% flood outline. This exhibits a flood outline broadly similar to the climate change outline, albeit with slightly increased depths.

2.10.2 It is clear that the principal access/egress routes in the Estate, namely The Straight Mile and the Rotherwas Access Road have generally less than 0.25m depth of flooding in this event, and hence represent passable routes for pedestrians and vehicles.

2.10.3 Generally, in view of the low vulnerability of buildings, we currently consider the Zone 2 extent to be of marginal relevance.

2.11 Q100 + CLIMATE CHANGE + ROUGHNESS SENSITIVITY TEST

2.11.1 Sensitivity tests have been undertaken by means of increasing the model roughness coefficients by a conservative +20%. This shows an average increase in river levels of 0.25m in the Q100 and 0.24m in the Q100 + Climate Change scenario.

2.11.2 The effect on the estate is a typical depth increase of 0.10m – 0.17m. Given the accuracy of the model (+/- 0.15m) and the conservative sensitivity test, it is reasonable to use a minimum freeboard above the Q100 + Climate Change flood level of 600mm but where this is not possible an absolute minimum freeboard of 0.35m to inform the future site development.

2.12 RED BROOK Q100 AND Q100 + CLIMATE CHANGE

2.12.1 Due to substantial differences in scale and resolution between the Wye and Red Brook, it was not possible to explicitly model the Red Brook using the TUFLOW 2D model within the 2D grid. Hence, the Red Brook floodplain and hydraulic impacts have been established by normal 1D methods.

2.12.2 There are two scenarios to be assessed to ascertain worst case flood levels on the Red Brook and Withy Brook with respect to their potential impact on Rotherwas Estate:

- o River Wye in extreme flood condition, e.g. 1% annual probability of occurrence (Q100) with the potential to create reverse flow through the railway embankment, particularly so with the Red Brook. The Withy and Red Brooks will be well below their peak discharge in this instance since the critical duration storm is some 4 to 6 hours for the Withy and Red Brook respectively, whereas the River Wye has a critical duration of some 39 hours.
- o River Wye in Median Annual Flood condition i.e. 50% annual probability, but with severe localised storm(s) over Red and Withy Brooks leading to a Q100 event from these watercourses.
- o The hydrology of the Red Brook and Withy Brook has recently been updated, in line with the revised procedures of the FEH, Science Report SCO50050, and

the latest methods incorporated into WINFAP-FEH 3 to give the flood frequency curves shown below in Table 2.4.

Table 2.4 – Flood Frequency Curves (Flows m^3/s)

Flood Event	MAF (1in2)	20% (1in5)	10% (1in10)	5% (1in20)	3.3% (1in30)	2% (1in50)	1% (1in100)	0.4% (1in250)	0.25% (1in400
Red Brook	0.59	0.86	1.06	1.35	1.62	1.79	1.92	2.304	3.35
Withy Brook	1.11	1.61	1.96	2.46	2.89	3.16	3.37	4.044	5.45

2.12.3 Both scenarios have to be tested to ascertain the worst case effect with respect to the Estate.

Scenario A - River Wye in Q100 flood condition, Red Brook/Withy Brook at QMED to Q100

2.12.4 In the Q100 event there is a level of 51.27 mAOD on the west side of the railway embankment. 110m east of the embankment along Watery Lane there is a minor encroachment into rough ground within the Estate. This location corresponds to cross-section 34 of Figure 2.6. The flood level on Watery Lane is 51.30 mAOD but this is insufficient to create inflow into any developed area within the Estate, which is generally at levels of 51.5 mAOD or higher.

2.12.5 In the climate change scenario, flood level on the west side of the railway embankment is 51.68 mAOD, rising to 51.69 mAOD at the potential breach point into the Estate. This 51.69 mAOD flood level would be sufficient to create a shallow inflow route into the Estate, and contributes to some of the flooding seen in the south-west corner of the Estate. The encroachment inflow into Rotherwas Estate is a maximum of 0.262 m^3/s at t = 41 hours, and exceeds 0.1 m^3/s between t = 38.4 hours and t = 45.1 hours i.e. a time-span of 6.7 hours.

2.12.6 We are of the view that inflows of less than 0.1 m^3/s could be comfortably accommodated by the existing surface water drainage system (which will only be in full surcharge at the peak of the event of the Wye which occurs between 38 to 45 hours approximately).

2.12.7 Inspection of Figure 2.4 - Depth Hazard shows that the flood depths in the Estate associated with this negligible inflow at its peak are less than 0.25m, and the average depth is around 0.125m depth. There are several exit points from the south-west corner of the Estate to higher ground, and ultimately egress from the Estate onto dry ground either via Watery Lane or onto the Rotherwas Access Road.

2.12.8 Currently therefore we do not consider that any remedial flood defence works are necessary in this part of the Estate, although a defence could be readily implemented by means of a simple 0.5m high earth bund in rough ground parallel to Watery lane. This option will be kept under review.

Scenario B – River Wye at QMED, Withy Brook/Red Brook at QMED to Q100

2.12.9 In this scenario the flood peak assumptions are reversed, namely that the River Wye is at a moderate flood level, (taken to be the Median Annual Flood), but the Withy Brook and Red Brook are at a range of flood conditions ranging from QMED to Q100 flood condition as shown in Table 2.4, so the peak flows from these watercourses are at maximum.

2.12.10 Upstream of cross-section 35 (see Figure 2.6 for section locations) on the Red Brook, ground levels rise markedly. It is self-evident that upstream of this point the Q100. event and the climate change scenario both remain contained within the channel. Whilst this may appear unusual, the channel is clearly over-sized in relation to the 4.5 km^2 catchment that it drains. Typically, in the modelled length, the channel top width exceeds 4m and the depth 2.5m. Hence it has substantial capacity in relation to the flood peaks.

2.12.11 Modelling shows that downstream of cross-section 35 on the Red Brook, the River Wye in Q100 flood condition is by a significant margin the worst case scenario on the Red Brook. In other words, the tailwater level of the Wye is greater that the flood level due to the Red Brook in isolation. This entirely concurs with the earlier WS Atkins analysis. This is true for all events and scenarios tested.

2.12.12 As expected, the Q1000 flood scenario on the Red Brook produces out of bank flooding upstream of cross-section 38, but here the principal route is via the left-bank towards Watery Lane and the railway embankment. Upstream of cross-section 41, flooding is via the right-bank, and in this instance would create a flood route towards Rotherwas Estate. HEC modelling shows this is out of bank to be in the order of $0.26m^3/s$.

2.12.13 Modelled depths do not appear to exceed 0.15m, and therefore we do not consider the Q1000 floodplain of the Red Brook to constitute a significant hazard in terms of depth, velocity or obstruction of principal exit routes.

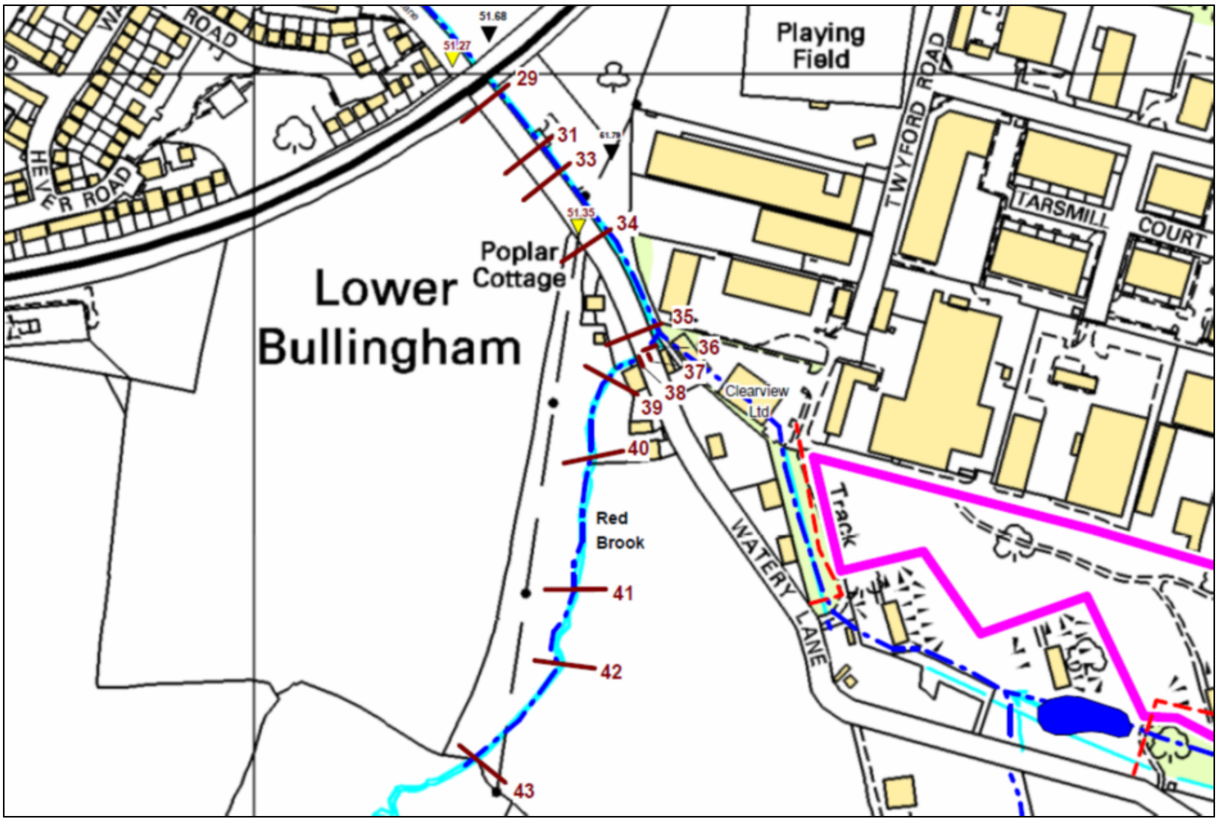

Figure 2.6 – Red Brook Cross Section Locations

Withy Brook Impact Assessment

2.12.14 The Environment Agency has postulated that this might be an alternative source of flooding reaching the Rotherwas Estate, although the watercourse is sited some 500m west of Watery Lane, with significant obstructions such as road verges and hedgerows in between.

2.12.15 HEC analysis, using the revised flood growth curves of Table 2.4 confirms that there is some potential overspill over the right bank at the railway culvert, as determined at cross-section 37 of the Withy Brook. Partitioning the flow at the right bank high point indicates that the overspill at this location amounts to approximately 0.57 m^3/s in the Q100 event, 0.82 m^3/s in the Q100 + climate change, and 1.36m^3/s in the Q1000 event.

2.12.16 Assuming a road width of 8m, and a hydraulic gradient along the road of 1/500 (the river hydraulic gradient is > 1/300), and a maximum flood plain depth on the road of 0.25m, this would provide an overflow capacity of approximately 1.6m^3/s. Hence, Hoarwithy Road has the potential to intercept the entire overspill identified for all three events, and this is likely to be the situation in practice.

2.12.17 We have inspected the potential flood route eastwards towards Rotherwas. We note in particular that Hoarwithy Road 120m east of the Brook is at a lower level than the adjacent ground on both sides. Consequently, a significant proportion of the overspill would in fact return to the Withy Brook via the Hoarwithy Road railway bridge.

2.12.18 However, between Bullingham Lane and Watery Lane, the land falls in an eastwards direction from 52.5m AOD to 51.5m AOD at a gradient of 1 in 500. Hence it is conceivable that a flood route exists and could be mobilised in extreme events.

2.12.19 Calculations support the contention that whilst a fall towards Red Brook from the Withy Brook does exist, the interceptions on route will make it extremely unlikely that any significant quantity of flood flow will pass from the latter to the former.

2.12.20 To test sensitivity of the Red Brook flood levels to additional inputs from Withy Brook, we have tested the extreme assumptions that all of the overspill could reach Red Brook, for each of the three events, Q100, Q100 + climate change and Q1000. These flows of 0.57m^3/s, 0.82m^3/s and 1.36m^3/s respectively have been added at cross section 29 of the Red Brook (see Figure 2.6), immediately upsteam of the Watery Lane bridge.

2.12.21 At cross-section 34 on the Red Brook (the potential breach point into the Estate), and assuming the River Wye to be in its Q100 flood condition, the analysis shows that the flood level is unchanged at 51.30 mAOD for the Q100 event. It increases relatively by 0.01m for the Q100 + climate change and the Q1000 events, giving flood levels of 51.70 and 52.24mAOD respectively. In simple terms the backwater effect from the River Wye is so significant that it is able to absorb additional input from the Withy Brook without any noticeable change in flood level. This scenario also assumes that the wye Q100 flow and the Red Brook Q100 flow would be coincident which is statistically extremely unlikely.

2.12.22 Hence, Red Brook flood levels are shown to be completely insensitive to any possible additional inflow from Withy Brook, and should be discounted from any further analysis.

2.12.23 The Red Brook flood levels are significantly greater when the River Wye is in flood when compared to the scenario of Red Brook flow in isolation. For example, the Red Brook Q100 flood level at cross-section 34 in the Wye Q100 scenario is 51.30 mAOD. This compares to the Red Brook Q100 flood level in isolation of 50.98 mAOD at the same location. Hence, the Withy Brook and Red Brook hydrology and their iterations have demonstrably lower flood risk to Rotherwas Estate than that posed by the River Wye when in flood.

Operational Considerations

2.12.24 We consider that the circular culvert and exit race located at model section 36 to 38 on the Red Brook is somewhat vulnerable to blockage (although this did not occur in 2004 and 2007). In this instance flows would back up in the channel and possibly create a flood path on the right bank in the direction of Clearview Ltd on the Estate.

2.12.25 The local drainage channel draining the proposed Phase 2 area is to be diverted in its upper reaches. This will provide additional capacity in the vicinity of Clearview Ltd to accommodate any potential overspill from the Red Brook.

2.12.26 We would however recommend as an additional precaution that a formal inspection and maintenance plan is adopted for Watery Lane downstream of the culvert, ensuring that all main and access culverts (3 no.) are regularly cleared, and the channel kept in open and free condition.

2.12.27 There is an existing exit route to flood free ground that provides easy egress from the Estate south along Twyford Road and Watery Lane. Currently however this is heavily bollarded to prevent short cuts and thus prevents emergency exit (or access). We would recommend that this exit be formalised with a gated exit, and marked as a Flood Exit Route. Designated key holders would have the responsibility to open this gate during periods of flood warning.

KEY

Direction of surface water flow

Area of localised depression

Drawn : PJ	For Comment
Design : AP	For tender
Chkd : AP	For Construction
Appd : AP	As Constructed
Date : 23 June 2009	Other

File ref : g:\projects\

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Project Name

ROTHERWAS FUTURES

Drawing Title
HIGHWAYS

FLOW ARROWS

Original Drawing Size : A3

Scale : NTS | Dimensions : -

FIGURE 2.1 | **Rev**

KEY

- Watercourse
- Minor watercourse
- Large diameter storm sewer
- Local storm sewer

Drawn :	PJ	For Comment
Design :	AP	For tender
Chkd :	AP	For Construction
Appd :	AP	As Constructed
Date :	23 June 2009	Other

File ref : g:\projects\

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Project Name

ROTHERWAS FUTURES

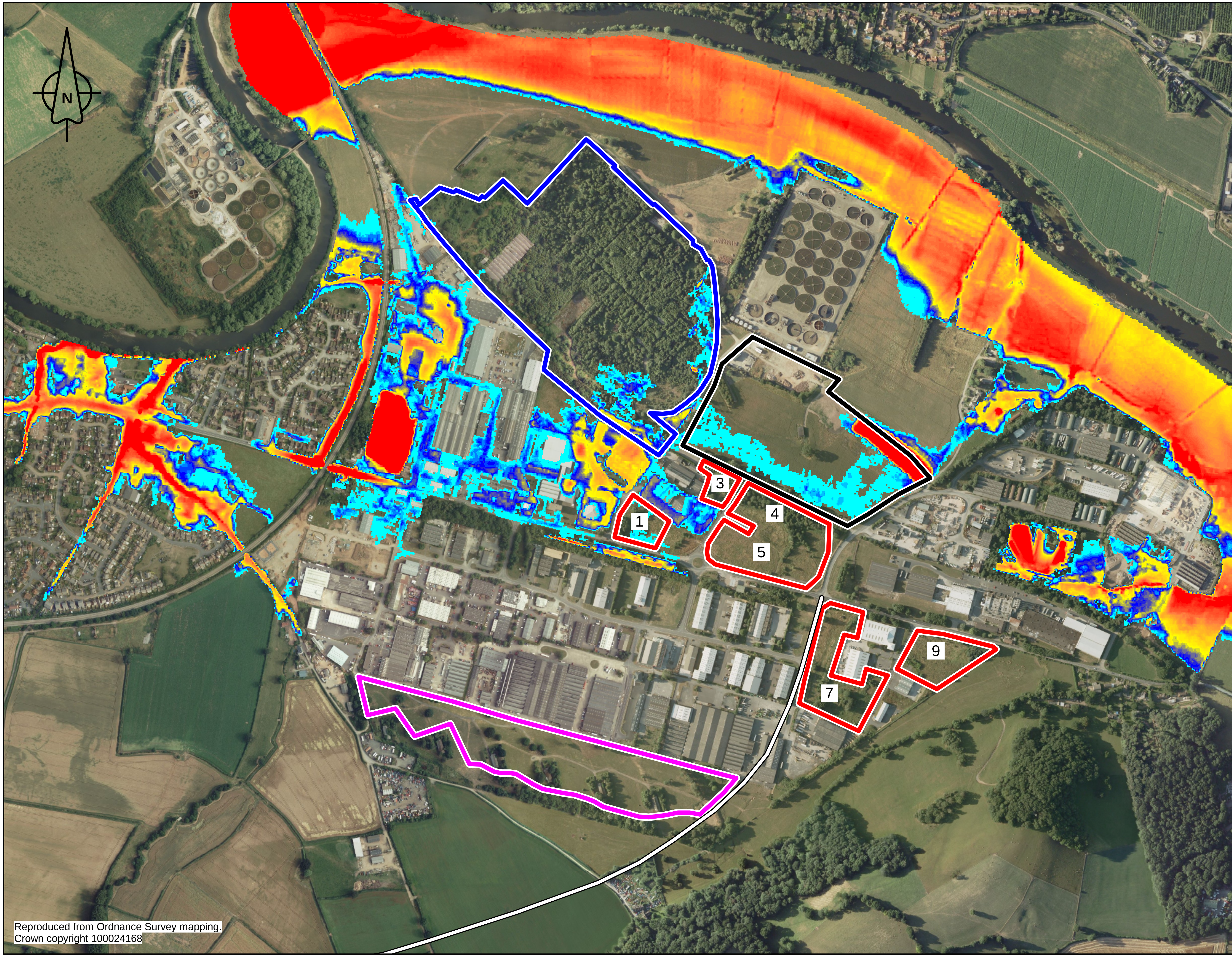
Drawing Title
HIGHWAYS

WATERCOURSES AND STORM SEWERS

Original Drawing Size : A3

Scale : NTS   Dimensions : -

FIGURE 2.2   **Rev**



KEY

- Phase 1 Sites (with Plot numbers)
- Phase 2 Site
- Phase 3 Site
- Chapel Road Plot
- Rotherwas Access Road

2D MODELLED FLOOD HAZARD

- Flood Depth = 0.10m
- Flood Depth = 0.25m
- Flood Depth = 0.50m
- Flood Depth = 1.00m
- Flood Depth = 1.50m

Rev	Revision details	Chkd	Appd	Date
A	Chapel Lane Plot Added	PJ	AP	6.8.09

Drawn : PJ	For Comment
Design : AP	For tender
Chkd : AP	For Construction
Appd : AP	As Constructed
Date : 26 June 2009	Other

File ref : g:\projects\

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Project Name

ROTHERWAS FUTURES

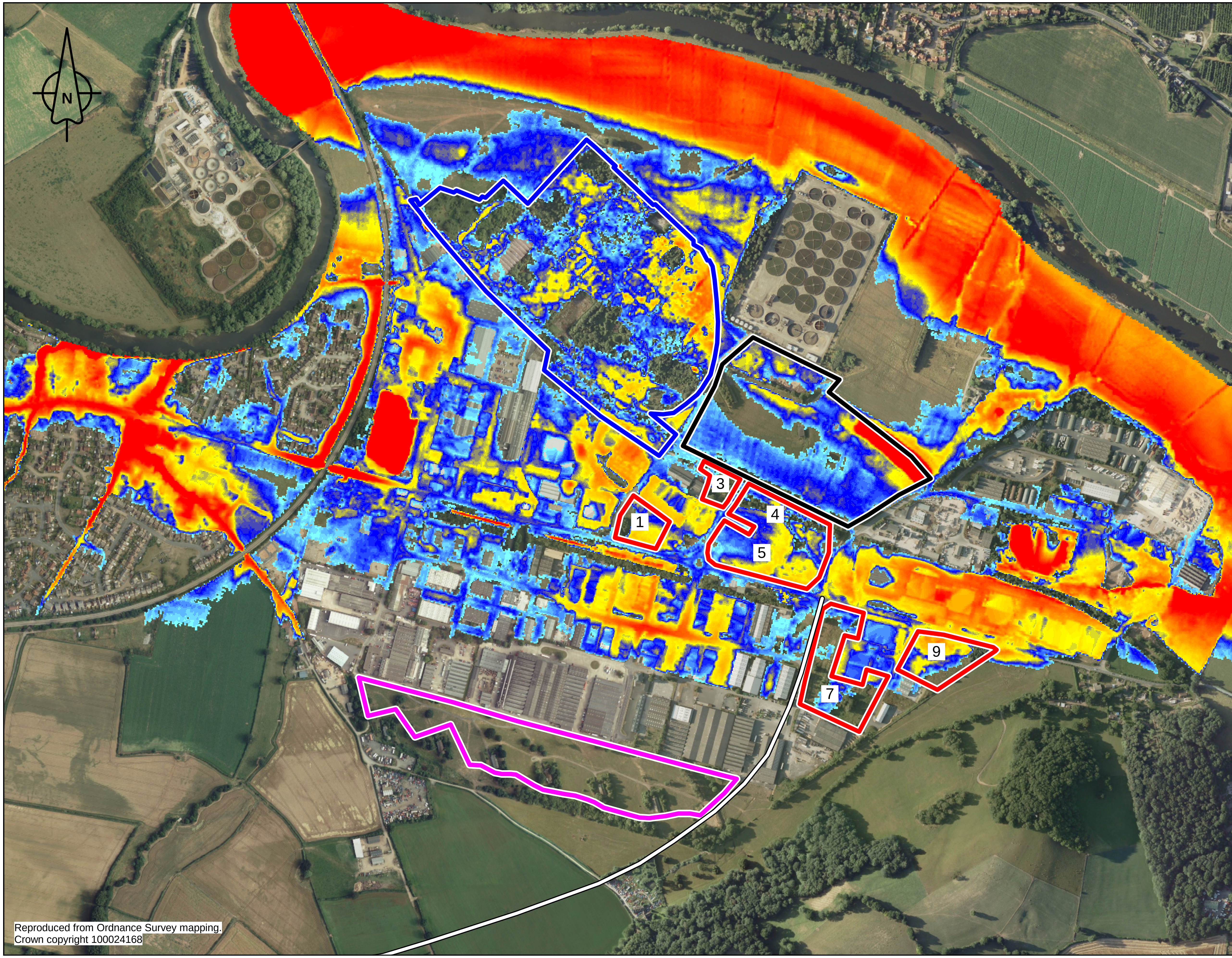
Drawing Title
HIGHWAYS

FLOOD MANAGEMENT STRATEGY
100 YEAR (FLOOD ZONE 3)

Original Drawing Size : A3

Scale : NTS | Dimensions : -

FIGURE 2.3 | **Rev** A



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Rev	Revision details	Chkd	Appd	Date
A	Chapel Lane Plot Added	PJ	AP	6.8.09

Drawn : PJ	For Comment
Design : AP	For tender
Chkd : AP	For Construction
Appd : AP	As Constructed
Date : 26 June 2009	Other

File ref : g:\projects\

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Project Name

ROTHERWAS FUTURES

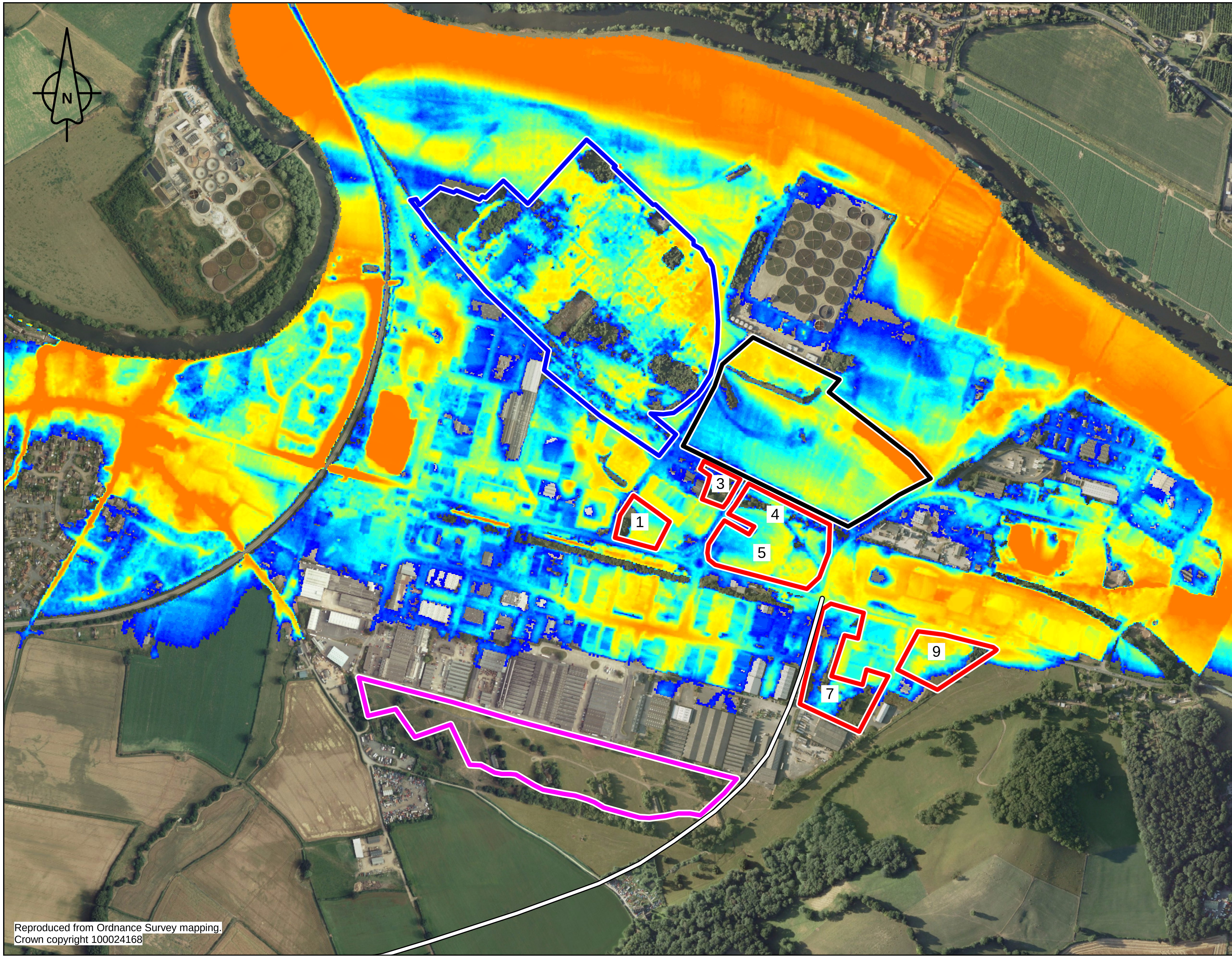
Drawing Title
HIGHWAYS

FLOOD MANAGEMENT STRATEGY
100 YEAR + CLIMATE CHANGE

Original Drawing Size : A3

Scale : NTS | Dimensions : -

FIGURE 2.4 | **Rev** A



KEY

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- Phase 2 Site
- Phase 3 Site
- Chapel Road Plot
- Rotherwas Access Road

2D MODELLED FLOOD HAZARD

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Project Name

ROTHERWAS FUTURES

Drawing Title
HIGHWAYS

FLOOD MANAGEMENT STRATEGY
1000 YEAR (FLOOD ZONE 2)

Original Drawing Size : A3

Scale : NTS | Dimensions : -

FIGURE 2.5

Rev
A

3 Overview Drainage and Flood Management Strategy

3.1 GENERAL EFFECT OF DEVELOPMENT

3.1.1 The development of the Rotherwas Industrial Estate will result in an increase in impermeable surface initially through the construction of highways and footways and later the development of plots with buildings, car parks and areas of hardstanding.

3.1.2 The historic and intended future development of the industrial estate plots is most likely to be based upon approximate ratios assigning 40% of land area to buildings, 40% to car parks and hardstanding and 20% to soft landscaping. The highway infrastructure will include grassed verge areas used as service strips resulting in a similar 20% allocation of permeable surface. Drawing Number 551392/SK/107 in Appendix A gives the approximate areas of hard surface following completion of the development.

3.1.3 The additional hard surface would increase the velocity of the surface runoff and reduce the infiltration rates. Without mitigation the scheme would have an impact upon the existing hydrology.

3.1.4 If the existing surface water drainage system was used for an unregulated flow from the development sites then sewer capacity issues may occur. Having consulted with Welsh Water, any requirement to connect into an adopted sewer would require the same test as the Environment Agency, giving priority to soakaways then watercourses before gaining any approval to connect to any adopted sewer.

3.1.5 Figures 2.3, 2.4 and 2.5 show the development plots and associated areas of flooding in the Q100, Q100 + climate change and Q1000 events. These are covered in more detail in the assessment of the specific plots in sections 4, 5 and 6 of this report and the Q100 + Climate Change figures are summarised in Table 3.1.

Table 3.1 – Summary of Flooding at Development Sites

Plot Name	Site Areas (ha)	Flooded Area (m2)	Max Depth (m)	Max Velocity (m/s)	Total Flood Storage Loss (m3)	Max Flood Hazard Rating
Phase 1 Plot 1	0.7	0.5	0.6	0.17	2,200	1.34
Phase 1 Plots 3, 4 and 5	4.3	4.1	0.4	0.53	21,700	1.24
Phase 1 Plot 7	1.7	1.2	0.4	0.01	2,746	1.22
Phase 1 Plot 9	1.4	1.0	0.7	0.04	5,300	1.37
Phase 2	5.7	None	None	None	None	N/A
Phase 3	19.2	14.2	0.6	0.19	30,000	1.32
Chapel Road Plot	9.6	8.1	0.5	0.25	15,000	0.4

3.1.6 Where possible, building floor levels and highway infrastructure will be raised 600mm above the Q100 + Climate Change flood levels. Car parks and landscaped areas may be appropriate below these levels, provided flood warning is available and areas are clearly signed. Car parks should ideally not be set more than 300mm below the Q100 + Climate Change levels. Despite this, the effect of the development will be a net loss in local flood storage and potential severance of flood paths. Without mitigation, this could have a detrimental effect on adjacent sites. Table 3.1 shows the total flood storage volume lost within each of the development plots in the climate change scenario base on a worst case assuming the loss of all flood storage at each plot.

3.2 GENERAL PRINCIPLES OF SUSTAINABLE DRAINAGE

3.2.1 The design of the site levels including buildings, car parks and highway infrastructure should follow the general existing topography and the following rules:

- Buildings need to be set at an appropriate level above Q100 + Climate Change flood levels as defined with Section 3.3 of this document. Flood proofing and flood resilience measures should also be implemented in the areas of higher risk.
- Car parks, hardstanding and landscaped areas need to be set at appropriate levels to minimise the impact upon the floodplain and storage capacity and or flows, whilst ensuring emergency access to buildings and reduce disruption to businesses during a flood event.
- The highway infrastructure should aim to provide a flood free access to all parts of the estate.
- Where a fully flood free access is not possible, the risk is assessed (in terms of depth and velocity) and alternative emergency flood free routes provided as necessary.
- For events with a return period in excess of 30 years, surface flooding of open spaces such as landscaping or car parks is acceptable for short periods and the layout should route water away from more vulnerable property and avoid creating hazards.
- No flooding of property should occur as a result of a 1 in 100 year storm event and the surface water system should ensure that there is little residual risk during more extreme events (design for exceedence).

3.2.2 The developers of the individual plots will have restrictions on the quantities of surface water runoff from their sites and will require source control features which will reduce flow. The calculated Greenfield runoff rate will be adopted as the appropriate outfall rate for each specific site. The source control features could include, but would not be limited to, the use of rain water harvesting/recycling, green roofs, use of tree cover and extended landscaped areas and permeable paving. Chemical or oil spillage risks will be assessed and bunded tanks and interceptors may be required depending upon the site uses. These drainage features would be assessed as part of the detailed planning applications for these individual sites.

3.2.3 The highway drainage will consider sustainable drainage principles as a priority. However, the construction, operation and maintenance of the highway network are a critical factor. As such a kerbed highway is likely to be required as the most appropriate highway edge feature. Most sites have very low gradients and as such kerb drains instead of kerb and gullies are likely to be used.

3.2.4 Where source control solutions are unsuitable for the highway drainage, additional downstream features will be provided. Priority will be given to open features which provide an amenity and environmental benefit.

3.2.5 Downstream, open features will be designed to:

- make best use of the general topography;
- utilise natural features and take account of varying infiltration rates;
- prevent the risk of groundwater contamination by the mobilisation of existing leachable contaminants within the ground;
- prevent pollution through the provision of oil interceptors;
- optimise treatment benefit through the shaping of features to including shallow forebays with marginal planting;
- give priority to infiltration systems;
- take account of seasonal fluctuation in groundwater levels;
- include overflow facilities as necessary in case of extreme events.

3.3 GENERAL PRINCIPLES OF SAFE DEVELOPMENT DURING FLUVIAL FLOODING

3.3.1 The Herefordshire Strategic Flood Risk Assessment outlines 'safe development' principles. It states that it is a policy requirement to ensure that all new development in flood risk areas is appropriately flood resilient and resistant, including safe access and escape routes where required, and that any residual risk can be safely managed.

3.3.2 The flood risk management infrastructure and mitigation measures needed to ensure the development is safe may differ between uses within particular vulnerability classifications.

3.3.3 Developers are required to submit Site Specific Flood Risk Assessments to show how their detailed proposals for each plot conform with the requirements of this Strategic document.

3.3.4 This Drainage and Flood Management Strategy and the developer's proof of conformance with the strategy within their site specific Flood Risk Assessments needs to consider:

- The vulnerability of those that could occupy and use the development, taking account of the Sequential Tests and the vulnerability classification, including arrangements for safe access. (The Rotherwas development is 'Safeguarded

Employment Land' and as such is less vulnerable and not requiring any exception test).

- o Include the assessment of the residual risk after risk reduction measures have been taken into account and demonstrate that this is acceptable for the particular development or land use.

3.3.5 The requirement for safe access and exit from the sites are as follows, in decreasing order of preference:

- o Safe dry route for people and vehicles
- o Safe dry route for people
- o If a dry route for people is not possible, a route for people where the flood hazard (in terms of depth and velocity of flooding) is low and should not cause risk to people. Generally we take this to mean depths less than 0.3m and velocities below 0.25m/s.
- o If a dry route is not possible, a route for vehicles where flood hazard (in terms of depth and velocity) is low to permit access for emergency services.

3.3.6 To assess safe access and exit the Local Planning Authority will be required to consult with the emergency services and will need to take into account the proposed use of the development, the vulnerability of the occupants and the availability of emergency services and flood forecasting. To assess the impact of flooding and the effects of any mitigation proposals for the Rotherwas Futures development a 'Detailed Approach' is required to ensure a rigorous analysis of the flood hazard based on hydraulic modelling. As part of this approach the risk to people of flooding will be assessed by a review of the modelled flood depths and velocities.

3.3.7 The sequential approach will apply to the layout and design of particular developments. More vulnerable uses will be directed to parts of the site at less probability and residual risk of flooding. The lower floors of buildings in areas at medium and high risk of flooding should be reserved for uses consistent with PPS25 Table D.1 of Annex D. Opportunities to provide sustainable drainage systems (See section 3.2 above), amenity areas, wildlife habitat areas and flood storage on the site should be maximised as well as reducing as far as possible the building footprint.

3.3.8 Any loss of flood storage on the specific sites will be mitigated by either the local provision of storage areas or by the provision of a strategic storage solution in the vicinity of the estate. Storage can either be provided on a level for level basis or in a form proven to inundate and discharge at the same frequency, providing the same volume.

3.3.9 Setting finished floor levels for developments at the estate requires an assessment of the flood risk (depths and velocities) and an assessment of the vulnerability of the development. Where developments have a high level of vulnerability then, as a general rule, 600mm of freeboard should be provided above the Q100 + Climate Change flood level.

3.3.10 Developments with a residual risk of flooding should be designed to include but not be limited to the following general measures:

Flood warning systems and emergency procedures in accordance with the Civil Contingencies Act 2004, Herefordshire Emergency Planning Unit and emergency planning exercises.

- Construct any sensitive sections of a building (for example sub-stations or server rooms) to be above the maximum flood level.
- Construct measures to prevent floodwater entering the building.
- Construct buildings in such a way that floodwater can enter the building but the impact is minimised (i.e. no permanent structural damage and designed features to ease any clean-up operation).

Specific advice can be found in 'Flood Performance of New Buildings' published by the Department of Communities and Local Government (DCLG).

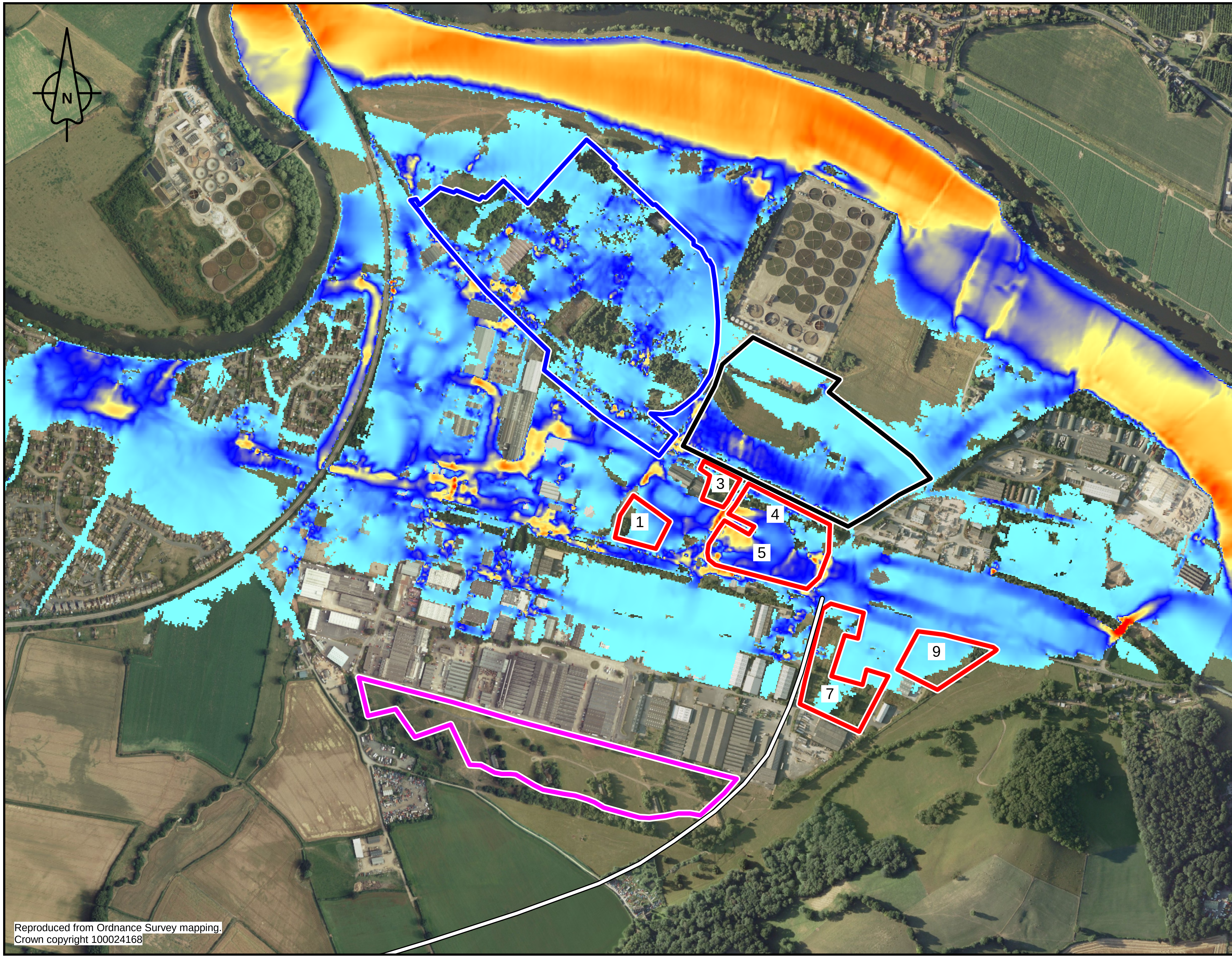
3.3.11 The velocity of flood water through the estate in the Q100 + Climate Change scenario can be seen on Figure 3.1 which identifies where the conveyance routes are and where flood water is static.

3.4 DEVELOPER COMPLIANCE WITH STRATEGY

3.4.1 Developers of individual plots will be required to produce a Site Specific Flood Risk Assessments in support of their detailed planning applications. However, unless they intend to depart from this strategy, this need only provide evidence with their Planning Applications of compliance with this Drainage and Flood Management Strategy for scrutiny and acceptance by the Planning Authority and the Environment Agency. In summary the Site Specific Flood Risk Assessments should include:

- Sustainable drainage design details in accordance with Section 3.2 of this strategy and the specific requirements within sections 4, 5 and 6.
- Design measures to mitigate risk from fluvial flooding including:
  - Site layout

        - Existing and proposed levels (slabs, car parks, landscaped areas etc)
        - Access routes including emergency routes as necessary
        - Flood resilience features (design for exceedance)
    - Management measures to mitigate flood risk including a draft ‘Business Flood Plan’ (see Appendix C).



KEY

- Phase 1 Sites (with Plot numbers)
- Phase 2 Site
- Phase 3 Site
- Chapel Road Plot
- Rotherwas Access Road

2D MODELLED FLOOD HAZARD

- Flood Velocity = 0.10m/s
- Flood Velocity = 0.25m/s
- Flood Velocity = 0.50m/s
- Flood Velocity = 1.00m/s
- Flood Velocity = 1.50m/s

Rev	Revision details	Chkd	Appd	Date
A	Chapel Lane Plot Added	PJ	AP	6.8.09

Drawn : PJ	For Comment
Design : AP	For tender
Chkd : AP	For Construction
Appd : AP	As Constructed
Date : 26 June 2009	Other

File ref : g:\projects\

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Project Name

ROTHERWAS FUTURES

Drawing Title
HIGHWAYS

FLOOD MANAGEMENT STRATEGY
100 YEAR + CLIMATE CHANGE
VELOCITY PLOT

Original Drawing Size : A3

Scale : NTS | Dimensions : -

FIGURE 3.1 | **Rev** A

4 Phase 1 – Proposed Drainage and Flood Management

4.1 PHASE 1 PROPOSALS

4.1.1 Phase 1 of the Rotherwas Futures development relates to a number of individual plots within the estate as shown on Figure 4.1. The land is allocated within the UDP as land safeguarded for employment use and a proposed mix of B1, B2 and B8 development is anticipated throughout the sites. These developments are all classed as Less Vulverable development under the definitions of PPS25.

4.1.2 Plot 1 occupies land on the corner of Holme Lacy Road and Fir Tree Lane covering an area of 0.7ha. The plot is part of the former munitions factory, however buildings on the site have been long since demolished and the site is currently occupied by grass, scrub and small trees.

4.1.3 For simplicity, the individual plots 3, 4 and 5 have been grouped for the purposes of this assessment covering an area of 4.3 ha (the plot is part of the former munitions factory, however buildings on the site have been long since demolished and the site is currently occupied by grass, scrub and a range of small and more mature trees). A recent new roundabout and access (known as Vincent Carey Road) has been constructed to access the site.

4.1.4 Plot 7 occupies land between the Rotherwas Access Road and Coldnose Road and is accessed from Coldnose Road and covers an area of 0.9ha (the plot is part of the former munitions factory, however buildings on the site have been long since demolished and the site is currently occupied by grass, scrub and a range of small and more mature trees). The northern limit of the site has been lowered to provide flood storage volume as mitigation for the Rotherwas Access Road with prior approval from the Environment Agency. This flood storage area is inundated and drained via surcharge from the Trunk Storm Sewer and through two 600mm culverts beneath the Holme Lacy Road.

4.1.5 Plot 9 occupies land on the corner of Holme Lacy Road and Cold Nose Road covering an area of 1.4ha (the plot is part of the former munitions factory, however buildings on the site have been long since demolished and the site is currently occupied by grass, scrub and a range of small and more mature trees).

4.2 PHASE 1 PLOT 1 RISKS AND MITIGATION

4.2.1 An existing adopted surface water drainage system is present crossing the southern boundary of the plot. A separate highway drainage system is also present within the highway on Fir Tree Lane and Holme Lacy Road. There is no proposal to install new adopted highway or drainage infrastructure; therefore, the surface water drainage systems will be the responsibility of the developer and subject to detailed design and planning consent.

4.2.2 In any case the surface water proposals for the developments will follow the principles outlined in Section 3 of this report.

4.2.3 Plot 1 has a small amount flooding during the Q100 flood event, and to depths no greater than 0.06m. However, the Q100 + Climate change event has a far greater impact on the Plot 1 with 72% of the site flooded to depths ranging up to 0.7m.

4.2.4 The total volume of flood inundation in the Q100 + Climate Change scenario is 2,200m3. Assuming a worst case that all flood storage is lost as a result of the development, then the full volume of 2,200m3 is required within the strategic storage solution defined in Section 4.6.

4.2.5 Details of the depths and velocities of the plot can be seen in Table 4.1 over the page. The flood hazard rating in the Q100 + Climate Change Scenario for the undeveloped plot is 0.6. However, following development in accordance with this strategy depths should be reduced in all but landscaped areas, reducing the flood hazard rating to an acceptable level.

4.2.6 Access to Plot 1 will be hampered during the Q100 + Climate Change event with up to 250mm of water on the Holme Lacy Road and Fir Tree Lane. There is no reasonable alternative route to this plot and, although the depths are not significant, the future development of the plot should note the Example Evacuation Management Plan included in Appendix C. Further guidance can be found on the Environment Agency Website and from Herefordshire Councils Emergency Planning Unit.

4.2.7 The flood level on the plot in the Q100 + Climate Change Scenario is 50.5m AOD. Taking account of the works undertaken on the sensitivity tests (See paragraph 2.11.2) the minimum floor level (600mm freeboard) is 51.1m AOD and absolute minimum floor level for buildings within the plot is 50.85m AOD.

Table 4.1 – Summary of Statistics for Phase 1 Plot 1

	Total Site Areas	0.7 ha
	Proposed Site Use	B1, B2 and B8
	Primary Site Access Route	Rotherwas Access Rd, Holme Lacy Rd, Fir Tree Lane
	Alternative Emergency Access Route	None
	Flood Zone	3a
	Site Vulnerability Classification	Less Vulnerable
	Appropriate for Development?	Subject to Site Specific Flood Risk Assessment
Q100	Maximum Depth (m)	0.10
	Maximum Velocity (m/s)	0.10
	Maximum Flood Hazard Rating	0.00
Q100 + Climate Change	Flooded Area (Q100 + CC) (ha)	0.5
	Maximum Depth (m)	1.0
	Maximum Velocity (m/s)	0.25
	Maximum Flood Hazard Rating	0.6
	Total Flood Water Storage Volume (m3)	2,200
	Maximum Depth on Primary Access (m)	0.19
	Maximum Velocity on Primary Access (m/s)	0.86
	Maximum Hazard Rating on Primary Access	0.78
	Maximum Flood Level (m AOD)	50.5

PHASE 1 PLOTS 3, 4 AND 5 RISKS AND MITIGATION

4.2.8 An existing adopted surface water drainage system is present crossing the southern boundary of the plot and along Chapel Road. A separate highway drainage system is also present within the highway on Vincent Carey Road and Holme Lacy Road. There is no proposal to install new adopted highway or drainage infrastructure; therefore, the surface water drainage systems will be the responsibility of the developer and subject to detailed design and planning consent.

4.2.9 In any case the surface water proposals for the developments will follow the principles outlined in Section 3 of this report.

4.2.10 Plots 3, 4 and 5 show no flooding during the Q100 flood event. However, the Q100 + Climate change event has a far greater impact on the Plots with 96% of the site flooded to depths ranging up to 0.4m.

4.2.11 The total volume of flood inundation in the Q100 + Climate Change scenario is 21,700m3. Assuming a worst case that all flood storage is lost as a result of the development, then the full volume of 21,700m3 is required within the strategic storage solution later defined in Section 4.6.

4.2.12 Details of the depths and velocities on plots 3, 4 and 5 can be seen in Tables 4.2 over the page. The flood hazard rating in the Q100 + Climate Change Scenario for the plot is 0.75. However, following development in accordance with this strategy depths should be reduced in all but landscaped areas, reducing the flood hazard rating to an acceptable level.

4.2.13 Access to plots 3, 4 and 5 will be hampered during the Q100 + Climate Change event with up to 250mm of water on the Holme Lacy Road and Vincent Carey Road. There is no reasonable alternative route to this plot and, although the depths are not significant, the future development of the plot should note the Example Evacuation Management Plan included in Appendix C. Further guidance can be found on the Environment Agency Website and from Herefordshire Councils Emergency Planning Unit.

4.2.14 The flood level on the plot in the Q100 + Climate Change Scenario is 50.0m AOD. Taking account of the works undertaken on the sensitivity tests (See paragraph 2.11.2) the minimum floor level (600mm freeboard) is 50.6m AOD and absolute minimum floor level (350mm freeboard) for buildings within the plot is 50.35m AOD.

Table 4.2 – Summary of Statistics for Phase 1 Plots 3, 4 and 5

		Phase 1 Plots 3, 4 and 5
	Total Site Areas	4.3 ha
	Primary Site Access Route	Rotherwas Access Rd, Holme Lacy Rd, Vincent Carey Rd
	Alternative Emergency Access Route	None
	Flood Zone	2
	Site Vulnerability Classification	Less Vulnerable
	Appropriate for Development?	Subject to Site Specific Flood Risk Assessment
Q100	Maximum Depth (m)	0
	Maximum Velocity (m/s)	0
	Maximum Flood Hazard Rating	0
Q100 + Climate Change	Flooded Area (Q100 + CC) (ha)	4.1
	Maximum Depth (m)	1.0
	Maximum Velocity (m/s)	1.0
	Maximum Flood Hazard Rating	0.75
	Total Flood Water Storage Volume (m3)	21,700
	Maximum Depth on Primary Access (m)	0.27
	Maximum Velocity on Primary Access (m/s)	0.86
	Maximum Hazard Rating on Primary Access	1.29
	Maximum Flood Level (m AOD)	50.0

4.3 PHASE 1 PLOT 7 RISKS AND MITIGATION

4.3.1 An existing adopted surface water drainage system is present adjacent to the Rotherwas Access Road along the western boundary of the plot. A separate highway drainage system is also present within the highway on the Rotherwas Access Road. There is no proposal to install new adopted highway or drainage infrastructure; therefore, the surface water drainage systems will be the responsibility of the developer and subject to detailed design and planning consent.

4.3.2 In any case the surface water proposals for the developments will follow the principles outlined in Section 3 of this report.

4.3.3 Plot 7 has no flooding during the Q100 flood event. However, the Q100 + Climate change event has a far greater impact on Plot 7 with 67% of the site flooded to depths up to 0.43m.

4.3.4 The total volume of flood inundation in the Q100 + Climate Change scenario is 2,746m3. Assuming a worst case that all flood storage is lost as a result of the development, then the full volume of 2,746m3 is required within the strategic storage solution defined in Section 4.6.

4.3.5 Details of the depths and velocities on the plot can be seen in Table 4.3 over the page. The flood hazard rating in the Q100 + Climate Change Scenario for the plot is 0.1.

4.3.6 Access to plot 7 will be hampered during the Q100 + Climate Change event with up to 500mm of water on the Holme Lacy Road and Cold Nose Road. However a flood free access will be provided directly onto the Rotherwas Access Road for emergency use only. This access route will be available for use by all businesses on Coldnose road (including Plot 9) who currently have no flood free route to exit the estate in the event of a Q100 + Climate Change event.

4.3.7 The flood level on the plot in the Q100 + Climate Change Scenario is 49.9m AOD. Taking account of the works undertaken on the sensitivity tests (See paragraph 2.11.2) the minimum floor level (600mm freeboard) is 50.5m AOD and absolute minimum floor level (350mm freeboard) for buildings within the plot is 50.25m AOD.

Table 4.3 – Summary of Statistics for Phase 1 Plot 7

	Total Site Areas	1.7 ha
	Primary Site Access Route	Rotherwas Access Rd, Holme Lacy Rd, Coldnose Rd
	Alternative Emergency Access Route	Gate onto the Rotherwas Access Rd (Flood Free)
	Flood Zone	2
	Site Vulnerability Classification	Less Vulnerable
	Appropriate for Development?	Subject to Site Specific Flood Risk Assessment
Q100	Maximum Depth (m)	0
	Maximum Velocity (m/s)	0
	Maximum Flood Hazard Rating	0
Q100 + Climate Change	Flooded Area (Q100 + CC) (ha)	1.2
	Maximum Depth (m)	0.25
	Maximum Velocity (m/s)	0.1
	Maximum Flood Hazard Rating	0.1
	Total Flood Water Storage Volume (m3)	2,746
	Maximum Depth on Primary Access (m)	0.42
	Maximum Velocity on Primary Access (m/s)	0.16
	Maximum Hazard Rating on Primary Access	1.28
	Maximum Flood Level (m AOD)	49.9

4.4 PHASE 1 PLOT 9 RISKS AND MITIGATION

4.4.1 An existing adopted surface water drainage system is present adjacent to the Rotherwas Access Road but none directly adjacent to this plot. A separate highway drainage system is also present within the highway on Coldnose Road. There is no proposal to install new adopted highway or drainage infrastructure; therefore, the surface water drainage systems will be the responsibility of the developer and subject to detailed design and planning consent.

4.4.2 In any case the surface water proposals for the developments will follow the principles outlined in Section 3 of this report.

4.4.3 Plot 9 has no flooding during the Q100 flood event. However, the Q100 + Climate change event has a far greater impact on Plot 9 with 73% of the site flooded to depths up to 0.7m.

4.4.4 The total volume of flood inundation in the Q100 + Climate Change scenario is 5,300m3. Assuming a worst case that all flood storage is lost as a result of the development, then the full volume of 5,300m3 is required within the strategic storage solution defined in Section 4.6.

4.4.5 Details of the depths and velocities of the plot can be seen in Table 4.4 over the page. The flood hazard rating in the Q100 + Climate Change Scenario for the plot is 0.6. However, following development in accordance with this strategy depths should be reduced in all but landscaped areas, reducing the flood hazard rating to an acceptable level.

4.4.6 Access to plot 9 will be hampered during the Q100 + Climate Change event with up to 500mm of water on the Holme Lacy Road and Cold Nose Road. However a flood free access will be provided directly onto the Rotherwas Access Road for emergency use only via Plot 7 described in 4.3.6. This access route will be available for use by all businesses on Coldnose road who currently have no flood free route to exit the estate in the event of a Q100 + Climate Change event.

4.4.7 The flood level on the plot in the Q100 + Climate Change Scenario is 49.7m AOD. Taking account of the works undertaken on the sensitivity tests (See paragraph 2.11.2) the minimum floor level (600mm freeboard) is 50.3m AOD and absolute minimum floor level (350mm freeboard) for buildings within the plot is 50.05m AOD.

Table 4.4 – Summary of Statistics for Phase 1 Plot 9

	Total Site Areas	1.4 ha
	Primary Site Access Route	Rotherwas Access Road, Holme Lacy Road, Coldnose Road
	Alternative Emergency Access Route	Via Plot 7 (Flood Free)
	Flood Zone	2
	Site Vulnerability Classification	Less Vulnerable
	Appropriate for Development?	Subject to Site Specific Flood Risk Assessment
Q100	Maximum Depth (m)	0
	Maximum Velocity (m/s)	0
	Maximum Flood Hazard Rating	0
Q100 + Climate Change	Flooded Area (Q100 + CC) (ha)	1.0
	Maximum Depth (m)	1.0
	Maximum Velocity (m/s)	0.1
	Maximum Flood Hazard Rating	0.6
	Total Flood Water Storage Volume (m3)	5,300
	Maximum Depth on Primary Access	0.42
	Maximum Velocity on Primary Access	0.16
	Maximum Hazard Rating on Primary Access	1.28
	Maximum Flood Level (m AOD)	49.7

PHASE 1 STRATEGIC STORAGE

4.4.8 The maximum loss of flood storage from the development of the Phase 1 plots is 32,000m3 assuming the plot levels are fully raised above the Q100 + Climate Change flood level.

4.4.9 As mitigation, a strategic storage solution is proposed. This utilises an area of land to the Northeast of the Phase 3 plot and West of the Sewage Works (shown on Figure 6.1).

4.4.10 The land is bunded from the River Wye by a ridge running east to west along the northern limit of the site. Other constraints associated with the plot include an existing, disused munitions building which will require archaeological assessment before demolition and a Welsh Water foul rising main which will require location and avoidance. The scheme will also seek to avoid a buried canal lock adjacent to the railway which may require archaeological assessment.

4.4.11 The area of land available for the storage mitigation is 5ha and so would require reducing in level by approximately 650mm to provide the appropriate volume.

4.4.12 Ground Investigation works will be necessary and will be undertaken to assess the re-usability of the arisings from the earthworks operations and highlight any contamination or groundwater effects.

4.4.13 The land is privately owned and used for agriculture, currently planted with arable crop. Liaison with the landowner has already commenced and a positive dialogue is underway. In the event that the land cannot be used for any reason the flood storage will be provided within the adjacent Phase 3 (North Magazine) site. The Phase 3 site comprises a total of 19.2ha and so has ample capacity. However, this would not be the current preferred solution as this land is allocated within the UDP for employment use.

5 Phase 2 – Proposed Drainage and Flood Management

5.1 PHASE 2 PROPOSALS

5.1.1 The Phase 2 site is currently a single 5.7ha plot located within the Rotherwas Industrial Estate on the southern boundary (see figure 1.1).

5.1.2 Access to the site is through the Industrial estate via, Netherwood Road and Haugh Road from the Rotherwas Access Road. As Netherwood Road, at its junction with Haugh Road, is subject to flooding during the Q100 + Climate Change Event at depths greater than 250mm, an alternative flood free access will be provided onto Watery Lane. This access route will be gated at all other times to prevent rat running.

5.1.3 The site is currently occupied by six former munitions storage building. Four of these buildings are to be demolished as part of the development of the site, two being retained as enhance habitat for bats. Other ecological mitigation for the development of the site includes the enhancement of a field and existing ponds to the south of the site for use by Great Crested Newts. The ecological mitigation solutions are already in place.

5.1.4 The design of a proposed new highway and surface water drainage system is complete for Plot 2. This is described in more detail in Section 5.2 of this report.

Table 4.5 – Summary of Statistics for Phase 2

	Total Site Areas	5.7 ha
	Primary Site Access Route	Rotherwas Access Rd, Holme Lacy Road, Netherwood Rd, Haugh Rd
	Alternative Emergency Access Route	Watery Lane, Rotherwas Access Rd (Flood Free)
	Flood Zone	N/A
	Site Vulnerability Classification	Less Vulnerable
	Appropriate for Development?	Subject to Site Specific Flood Risk Assessment
Q100	Maximum Depth (m)	0
	Maximum Velocity (m/s)	0
	Maximum Flood Hazard Rating	0
Q100 + Climate Change	Flooded Area (Q100 + CC) (ha)	0
	Maximum Depth (m)	0
	Maximum Velocity (m/s)	0
	Maximum Flood Hazard Rating	0
	Total Flood Water Storage Volume (m3)	0
	Maximum Depth on Primary Access	0.19
	Maximum Velocity on Primary Access	0.86
	Maximum Hazard Rating on Primary Access	0.78
	Maximum Flood Level (m AOD)	N/A

5.2 SURFACE WATER DRAINAGE

5.2.1 The proposed Phase 2 development is located within the industrial estate and is a brownfield site. Rough grass dominates the site with three ponds located to the south of the site and a small stream located 20m to the west. However, both the ponds and the stream are at a level preventing direct outfall from the site. Red Brook is located approximately 180m to the west and again does not provide a viable outfall for surface water.

5.2.2 A number of manholes are present within the site, however, they are not believed to form part of a working drainage system as no apparent surface water drainage features are fed into these manholes. It is believed that surface water currently soaks into the ground due to the absence of any obvious drainage system but also the site topography and infiltration tests undertaken as part of the recent ground investigation.

5.2.3 An existing combined kerb and drainage system, carrier pipes and manholes exist adjacent to the site on Haugh Road. CCTV surveys carried out to establish the type of drainage have confirmed that there are both foul and surface water drainage systems. Both systems located along Haugh Road connect into Welsh Water storm and foul sewers on Netherwood Road to the north.

5.2.4 Swales and filter drains are found to the east of the site on the verge of the Rotherwas access road. These features are used for the surface water drainage of the highway.

5.2.5 Given the existing routing of surface water soaking into the ground to the groundwater, priority is given to providing soakaways for the surface water drainage system at Phase 2 to closely follow the site hydrology.

5.2.6 Soakage tests were carried out on the 15 of December 2008 to determine the infiltration properties of the ground. 3 number trial pits 2.5m x 2.5m x 2.2m deep were dug for the test and the results are as shown in Table 5.1.

Table 5.1 Soakage Test Results

Pit Ref	Calculated permeability (m/s)	Hydraulic conductivity (m/day)	Infiltration rate (litres/m²/min)
STP1	6.65 x 10-6	0.575	0.318
STP2	8.34 x 10-6	0.721	0.657
STP3	1.37 x 10-5	1.182	1.192

5.2.7 There is no risk from groundwater contamination from any contaminants within the existing ground as a result of the use of soakaways. The first round (Tier 1 risk assessment) indicated some risk from leachable contaminants – TPH and potassium. The additional testing undertaken in the soakage pits in December for these contaminants did not indicate the presence of leachable forms of these contaminants in the ground where the soakaway is proposed. Therefore, the soakaway can be proposed with no risk of mobilising insitu contaminants in the current proposed location.

5.2.8 An oil Interceptor is proposed and is designed in accordance with PPG3 to protect the groundwater from oils from vehicles. A By-Bass Class 2 Separator is proposed as there is a risk of oil contaminating the system (although there is a low likelihood of frequent oil contamination or large spillage incidents). The interceptor selected for the site is a Klargester NSB12 based on a catchment area of 5850m2.

5.2.9 An open pond is proposed for the Soakaway increasing its ecological, water treatment and amenity value. The pond size is based on the worst case permeability of 6.65×10^{-6} m/s and results in a pond with a storage capacity of 730m3 and a total depth of 2.2m. An overflow is provided to the surface water sewer on Haugh Road in the event of extreme flooding or unusually high ground water affecting the performance of the soakaway.

5.2.10 The pond is shaped such that the inlet outfalls onto a shallow slope with marginal planting improving the treatment performance and ecological value.

5.2.11 Source control features will be required as part of the development of the plots including porous paving and rainwater harvesting. Oil interceptors may be required prior to outfall to the open ditch depending upon the final site use.

5.3 FLUVIAL FLOODING

5.3.1 The river flood modelling of the River Wye and Red Brook, as described in Section 2 of this report, show that the Phase 2 plot is not subject to fluvial flooding. However, the access route to the site through the existing industrial estate will be subject to extensive shallow flooding with deeper flood depths at the junction of Netherwood Road and Haugh Road during the Q100 + Climate Change scenario. As such an alternative, emergency access route is to be provided as part of the proposals from the new access road in the Phase 2 site onto Watery Lane. This emergency route will remain flood free and will be gated for security at other times.

5.3.2 Drawing number 551392-SK-115 in Appendix D shows a long section along the trunk sewer through the estate to investigate whether fluvial flooding would cause additional flooding to the low area on Netherwood Road. The levels show that flood water would surcharge the sewer but not cause surface flooding. However, the trunk sewer would have a reduced performance in relation to surface water drainage when surcharged. This further supports the use of the Soakaway described in Section 5.2 of this report to minimise the impact of the new development on the existing infrastructure.

5.3.3 As no flooding occurs on the Phase 2 plot, no storage volumes are required to be provided in the strategic storage solution.

6 Phase 3 – Proposed Drainage and Flood Management

6.1 PHASE 3 PROPOSALS

6.1.1 The Phase 3 site is currently a single 19.2ha plot located within the Rotherwas Industrial Estate on the Northern boundary. Extensive highway infrastructure will be required as part of the site development to allow the further division into several smaller plots.

6.1.2 Access to the site is from the Rotherwas Access Road, the Holme Lacy road, Vincent Carey Road and a new access road to that is to be constructed to the north of the disused railway (see figure 6.2) The Holme Lacy Road and Vincent Carey Road are subject to flooding although at depths below 250mm. In any case an alternative route will be available along Fir Tree Lane and Holme Lacy Road (although this alternative route will also be subject to shallow flooding in the Q100 + Climate Change scenario).

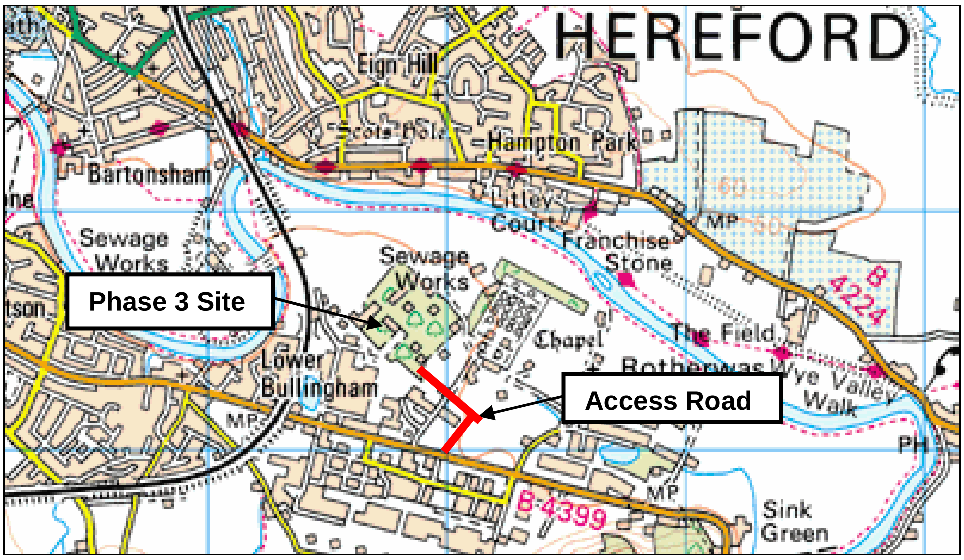

Figure 6.2 Access Road to Phase 3 Site

6.1.3 Access to the site is from the Rotherwas Access Road, the Holme Lacy road, Vincent Carey Road and a new access to the north of the disused railway. The Holme Lacy Road and Vincent Carey Road are subject to flooding although at depths below 250mm. In any case an alternative route will be available along Fir Tree Lane and Holme Lacy Road. However, this alternative route will also be subject to shallow flooding in the Q100 + Climate Change scenario.

6.1.4 The site is currently occupied by a large number of former munitions buildings and roadways. The site is also heavily wooded although the majority of this is new growth following site clearance activities 10 years ago. The site (with the exception of a 25m perimeter buffer) is currently subject to a programme of site clearance where a third of the site is cleared each winter over a three year period to minimise the ecological effects.

6.1.5 The flood level on the site in the Q100 + Climate Change Scenario is 50.0m AOD. Taking account of the works undertaken on the sensitivity tests (See paragraph 2.11.2) the minimum floor level (600mm freeboard) is 50.6m AOD and absolute minimum floor level (350mm freeboard) for buildings within the plot is 50.35m AOD.

Table 4.6 – Summary of Statistics for Phase 3

	Total Site Areas	19.2 ha
	Primary Site Access Route	Rotherwas Access Rd, Holme Lacy Rd, Vincent Carey Rd
	Alternative Emergency Access Route	Fir Tree Lane
	Flood Zone	3a
	Site Vulnerability Classification	Less Vulnerable
	Appropriate Development?	Subject to Site Specific Flood Risk Assessment
Q100	Maximum Depth (m)	0.17
	Maximum Velocity (m/s)	0.00
	Maximum Flood Hazard Rating	0.586
Q100 + Climate Change	Approx' Flooded Area (ha)	14.2
	Maximum Depth (m)	1.5
	Maximum Velocity (m/s)	1.0
	Maximum Flood Hazard Rating	0.9
	Approx' Flood Water Storage Volume (m3)	30,000
	Maximum Depth on Primary Access	0.27
	Maximum Velocity on Primary Access	0.86
	Maximum Hazard Rating on Primary Access	1.29
	Maximum Flood Level (m AOD)	50.0

6.2 SURFACE WATER DRAINAGE

6.2.1 The topography on the Phase 3 site is relatively flat with slight falls towards the river to the north. Buildings within the plots will require some elevation above the Q100 + Climate Change levels. Hardstanding and car park areas will be set at levels as appropriate to allow some flooding (see paragraph 3.1.6) and ensure the continued conveyance of flood water and shedding of storm water. The Highway network will be elevated to provide a passable access throughout the site requiring an increase in levels above existing.

6.2.2 Figure 6.1 shows an indicative layout for the drainage at Phase 3.

6.2.3 Due to the ecological constraints relating to protected bat species a 25m green corridor will be retained and enhanced around the whole phase 3 site.

6.2.4 The strategic proposal is to utilise part of this green corridor to include an open drainage channel (swale) along the south boundary of the site falling to the West. The swale will outfall into a locally lowered area of land shown on Figure 6.1. Under normal flow conditions surface water flows from the phase 3 site will be conveyed to this area and then through the low area to an outfall on the northeast corner and to the river via a flap valve to prevent backing up from high river levels.

6.2.5 Filter drains adjacent to the proposed highways will take runoff from the footways and convey storm water from the highway. This will outfall into the swales through an oil interceptor(s).

6.2.6 Source control features will be required as part of the development of the plots including porous paving and rainwater harvesting. Oil interceptors may be required prior to outfall to the open ditch depending upon the final site use.

6.2.7 The treatment potential of the swales will be excellent and, if site security allows, the corridor could be opened as a walking/cycling route to increase its amenity value. This would double as a maintenance route for the ongoing management of the features.

6.2.8 The highway drainage design for the Phase 3 access road considers sustainable drainage principles as a priority. However, as the construction, operation and maintenance of the highway network is a critical factor a kerbed highway is considered to be the most appropriate solution.

6.2.9 The access road drainage consists of a combined kerb and drainage system entering a filter drain within the grass verge. The grass verge is dished to provide a swale above the filter drain which takes the surface water flow from an adjacent shared footway/cycleway. The filter drain outfalls through an oil interceptor into an open pond / soakaway feature.

6.3 FLUVIAL FLOODING

6.3.1 The impact of the Q100 flood event on Phase 3 is minimal with only a small area in the south east corner subject to flooding. The majority of this area will be retained as the 25m ecological corridor and therefore will not be subject to development or alterations to levels.

6.3.2 The Q100 + Climate Change scenario has a greater effect on the development site with approximately 14.2ha, 74% of the site subject to flooding although most of this flooding would be at depths less than 250mm.

6.3.3 The main impact of the development is the effect on a conveyance route which crosses the site of the proposed Phase 3 access Road. This conveyance route is to be diverted via a culvert beneath the road and an open ditch running adjacent to the Phase 3 site (see figure 6.1). The ditch will fall into a second locally lowered compensation area to the north. The access road will be flood free and will ensure that the conveyance route running across Vincent Carey Road and to the south of the disused railway is maintained.

6.3.4 The volume of the compensation area will be equivalent to the volume lost as a result of the phase 1 developments (as described in Section 4) and the access road itself. The ditch will carry no flow under normal conditions but under a Q100 + Climate change flood event it will channel flow into the compensation area before out falling to the river via a pipe with a flap valve to prevent backing up from high river levels.

PHASE 3 STRATEGIC STORAGE

6.3.5 The maximum loss of flood storage from the development of the Phase 3 plot is 30,000m3 assuming the plot levels are fully raised above the Q100 + Climate Change flood level.

6.3.6 As mitigation, a strategic storage solution is proposed. This utilises an area of land to the Northwest of the Phase 3 plot and West of the Sewage Works (shown on Figure 6.1).

6.3.7 The land is bunded from the River Wye by a ridge running east to west along the northern limit of the site. Other constraints associated with the plot include an existing, disused munition building which will require archaeological assessment before demolition and a Welsh Water foul rising main which will require location and avoidance. The scheme will also seek to avoid a buried canal lock adjacent to the railway which may require archaeological assessment.

6.3.8 The area of land available for the storage mitigation is 5ha and so would require reducing in level by approximately 650mm to provide the appropriate volume.

6.3.9 Ground Investigation works will be necessary and will be undertaken to assess the re-usability of the arisings from the earthworks operations and highlight any contamination or groundwater effects.

6.3.10 The land is privately owned and used for agriculture, currently planted with arable crop. Liaison with the landowner has already commenced and a positive dialogue is underway. In the event that the land cannot be used for any reason the flood storage will be provided within part of the Phase 3 (North Magazine) site. The Phase 3 site comprises a total of 19.2ha and so has ample capacity. However, this would not be the current preferred solution as this land is allocated within the UDP for employment use.

KEY

- Open drainage ditch
- Outfall
- Highway drain
- Strategic flood storage area
- Drainage points
- Assumed line of rising main
- Proposed Cycleway
- Green Corridor with width of 25m
- Highway/Footway (See figure 4.2)
- Alternative/ Emergency Access
- Development plots Indicative Layout

Rev	Revision details	Chkd	Appd	Date
A	Chapel Lane Plot Added	PJ	AP	13.8.09

Drawn :	PJ	For Comment
Design :	AP	For tender
Chkd :	AP	For Construction
Appd :	AP	As Constructed
Date :	11.08.09	Other

File ref : g:\projects\

amey

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Project Name

ROTHERWAS FUTURES

Drawing Title
HIGHWAYS

PHASE 3 - STRATEGIC DRAINAGE DESIGN

Original Drawing Size : A3

Scale : NTS Dimensions : -

FIGURE 6.1 Rev **A**

7 Chapel Road Plot – Proposed Drainage and Flood Management

7.1 CHAPEL ROAD PLOT

7.1.1 The Chapel Road Plot is a single 9.6 ha plot located within the Rotherwas Industrial Estate on the Northern boundary currently used for agriculture. The site is in private ownership but is allocated for consideration for Employment use within the Herefordshire Council Unitary Development Plan.

7.1.2 Access to the site is from the Rotherwas Access Road, the Holme Lacy road, Vincent Carey Road and a new access to the north of the disused railway. The Holme Lacy Road and Vincent Carey Road are subject to flooding although at depths below 250mm. In any case an alternative route will be available along Fir Tree Lane and Holme Lacy Road. However, this alternative route will also be subject to shallow flooding in the Q100 + Climate Change scenario.

7.1.3 Details of the depths and velocities of the plot can be seen in Table 7.1 over the page. The flood hazard rating in the Q100 + Climate Change Scenario for the undeveloped plot is 0.4based upon the following formula:

Flood Hazard Rating = ((V + 0.5) x D) x DF

Where V = Velocity (m/s)

D = Depth (m)

DF = Debris Factor (taken as 0.5 for depths < 0.5m and 1.0 for depths > 0.25m)

7.1.4 The maximum flood level on the site in the Q100 + Climate Change Scenario is 50.0m AOD. Taking account of the works undertaken on the sensitivity tests (See paragraph 2.11.2) the minimum floor level (600mm freeboard) is 50.6m AOD and absolute minimum floor level (350mm freeboard) for buildings within the plot is 50.35m AOD.

Table 7.1 – Summary of Statistics for the C hapel Road Plot

	Total Site Areas	9.6 ha
	Primary Site Access Route	Rotherwas Access Rd, Holme Lacy Rd, Vincent Carey Rd
	Alternative Emergency Access Route	Fir Tree Lane
	Flood Zone	3a
	Site Vulnerability Classification	Less Vulnerable
	Appropriate Development?	Subject to compliance with this Drainage and Flood Management Strategy
Q100 + Climate Change	Approx' Flooded Area (ha)	8.1
	Maximum Depth (m)	0.5
	Maximum Velocity (m/s)	0.5
	Maximum Flood Hazard Rating	0.4
	Approx' Flood Water Storage Volume (m3)	15,000
	Maximum Depth on Primary Access	0.27
	Maximum Velocity on Primary Access	0.86
	Maximum Hazard Rating on Primary Access	1.29
	Maximum Flood Level (m AOD)	50.0

7.2 SURFACE WATER DRAINAGE

7.2.1 The topography on the Chapel Road site is relatively flat with slight falls to the North and East. A large diameter storm sewer exists on Chapel Road to the east adopted by Welsh Water.

7.2.2 A sustainable surface water drainage system will be required in accordance section 3.2 of this report and could utilise the swale recommended for the management of the conveyance route in 7.3 below.

7.3 FLUVIAL FLOODING

7.3.1 The main impact of the Q100 + Climate Change scenario is the conveyance route which exists flowing from the south west corner to the north east corner of the plot. This conveyance route will need to be maintained, the preference being to use open channels such as swales. These swales could also be used as part of a sustainable surface water drainage system within the plot.

7.3.2 The total volume of flood water within the plot in the Q100 + Climate Change scenario is approximately 15,000m^3. Some of this storage will be retained by the inclusion of the swales, and within the retaining pond and by designing some low areas of landscaping and allowing shallow inundation of car-parking. The remainder will be provided for within the strategic storage area shown on Figure 6.1.

8 Ongoing Maintenance and Emergency Procedures

8.1 ONGOING MAINTENANCE

8.1.1 Existing culverts and drains require regular maintenance and inspection to ensure their performance during a storm event. It is recommended that this is on a 3 monthly basis but with additional inspection as necessary following any reported blockages or following any significant weather event which may have contributed to the collection of excess debris.

8.1.2 The capacity of the existing and proposed ponds as attenuation devises needs to be maximised by inspection and de-silting as necessary. Inspections should be on an annual basis with any large debris or fly tipped material removed and outlet controls checked. De-silting will be undertaken as necessary but may be subject to ecological constraints and restricted to times of year to minimise impact.

8.1.3 Emergency access routes need to be checked regularly to ensure they are clear of debris and fly tipping material and ensure gates and locks are in working order. It is recommended that this is on a 3 monthly basis but with additional inspection as necessary following any reported blockages or following any early flood warnings.

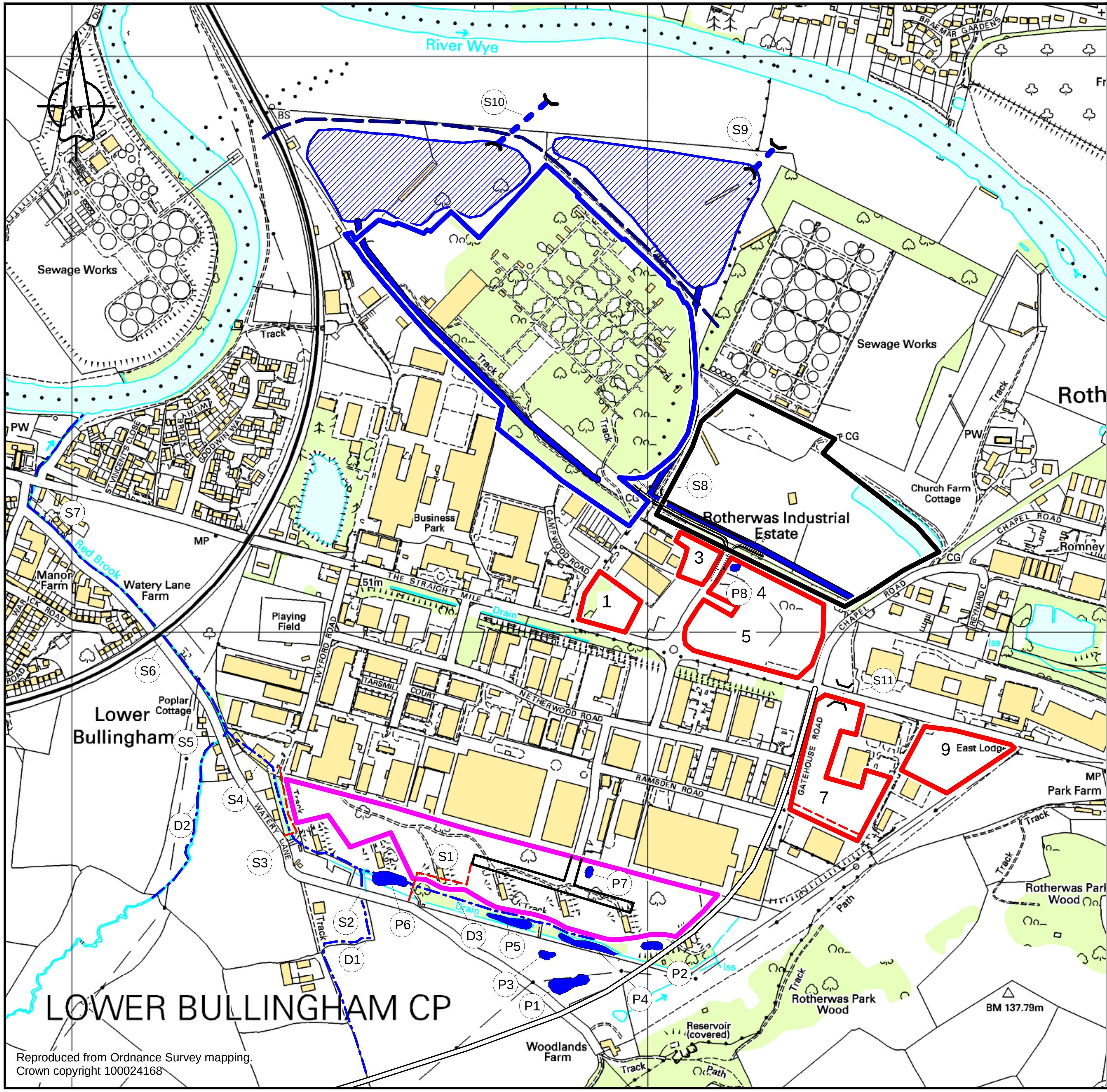
8.2 EMERGENCY PROCEDURE

8.2.1 Existing and new businesses on the industrial estate will be encourage to sign up to the Environment Agency 'Floodline Warnings Direct' which notifies flood warnings by phone, text or email.

8.2.2 Existing and new businesses on the estate should ensure they are familiar with the emergency entry and exit routes from the estate in the event of a flood.

8.2.3 This drainage and flood management strategy document should be consolidated into a document for issue to all existing and new businesses to the estate in the form of a short, easily understood leaflet. This information leaflet will outline the latest flood maps, the emergency exit routes and key flood and drainage infrastructure and provide links to where more detailed information can be found on protecting their businesses and properties.

8.2.4 Information Signing at the estate should include the location of the emergency accesses.



PONDS

- P1 Rotherwas Access Road Balancing Pond
- P2 New Newt Mitigation Pond
- P3 New Newt Mitigation Pond
- P4 Existing Newt Mitigation Pond
- P5 Existing Newt Mitigation Pond
- P6 New Pond & Drainage Ditch Overflow Soakaway and Attenuation Pond
- P7 Phase 2 Access Road Soakaway and Attenuation Pond
- P8 Phase 3 Access Road Soakaway and Attenuation Pond

OPEN DITCHES AND WATERCOURSES

- D1 Land Drainage Ditch
- D2 Red Brook
- D3 Phase 2 Cut-off Ditch

CULVERTS / HEADWAYS & OUTFALL STRUCTURES

- S1 Phase 2 Cut-off Ditch Overflow to Highway Drain
- S2 Land Drainage Ditch Culvert under Watery Lane
- S3 Land Drainage Ditch Culvert under Emergency Access
- S4 Land Drainage Ditch Culvert under Clearview Unit
- S5 Red Brook Culvert under Watery Lane
- S6 Red Brook Culvert under Railway Embankment
- S7 Red Brook Culvert under Holme Lacy Road
- S8 Phase 3 Access Road Flood Relief Culvert
- S9 Strategic Storage Outflow Structure
- S10 Strategic Storage Outflow Structure
- S11 Straight Mile Flood Relief Culvert

KEY

- Phase 1 Sites (with Plot numbers)
- Phase 2 Site
- Phase 3 Site
- Chapel Road Plot
- Rotherwas Access Road
- Emergency Access Route

NOTE :
For Public and Private storm sewers see figure 2.2

Rev	Revision details	Chkd	Appd	Date

Drawn :	PJ	For Comment
Design :	AP	For tender
Chkd :	AP	For Consttruction
Appd :	AP	As Constructed
Date :	11.8.09	Other

File ref : g:\projects\

amey

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HEREFORDSHIRE COUNCIL

Project Name

ROTHERWAS FUTURES

Drawing Title
HIGHWAYS

MAINTENANCE AND EMERGENCY ACCESS SCHEDULE

Original Drawing Size : A3

Scale : NTS | Dimensions : -

FIGURE 8.1

Rev

Appendix A: Drawing Number 551392-SK-107

File ref - g:\000 project files\002 major projects\551392 rotherwas futures\drafts\cad\551392-sk-107.dwg

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NOTES

Phase 1

Total Area =7.22ha			
Existing		Proposed	
Permeable	Impermeable	Permeable	Impermeable
7.22ha	0.00ha	5.78ha	1.44ha

Phase 2

Total Area =7.60ha			
Existing		Proposed	
Permeable	Impermeable	Permeable	Impermeable
7.5ha	0.10ha	1.52ha	6.08ha

Phase 3

Total Area =19.1ha			
Existing		Proposed	
Permeable	Impermeable	Permeable	Impermeable
16.08ha	3.02ha	3.83ha	15.27ha

STORM — Welsh Water underground storm water sewer
Private drainage/ Highway drainage
48.540 Road level

Rev	Revision details	Chkd	Appd	Date

Drawn:	.	Preliminary	✓
Design:	.	For comment	
Chkd:	.	For tender	
Appd:	.	For construction	
Date:	.	As constructed	
		Other	

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Project Name

Rotherwas Futures

Drawing Title

SURFACE WATER SEWER AT ROTHERWAS INDUSTRIAL ESTATE

Original Drawing Size : A1

Scale : As Shown | Dimensions : -

Drawing No

551392-SK-107

Rev

Appendix B: Flood modelling at Hereford

Hydraulic model check file

CONTENTS

APPROVAL

	Name and qualifications
Calculations prepared by:	Colin Riggs MSc BSc
Calculations checked by:	Duncan Faulkner MA MSc CSci FCIWEM

ABBREVIATIONS

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
DTM	Digital Terrain Model
dV	Change in volume over time, in the context of TUFLOW it refers to the volume of water in the TUFLOW model domain.
ESTRY	One-dimensional hydraulic model packaged with TUFLOW
HX	A 1D-2D boundary unit in TUFLOW in which the 1D model supplied the head and the 2D model calculates the flow onto the floodplain.
ID	Identifier
ISIS	Hydrology and hydraulic modelling software
LiDAR	Light Detection And Ranging
NGR	National Grid Reference
PO	Plot Observation (TUFLOW results specification layer)
OS	Ordnance Survey
SAAR	Synthetic-aperture radar
SX	A 1D-2D boundary unit in TUFLOW in which the 1D model calculates flow in the 2D domain based on levels in both models, used for flow over 1D structures.
TUFLOW	Two-dimensional Unsteady FLOW (a hydraulic model)

1 MODEL OVERVIEW AND DATA SUMMARY

1.1 Overview of modelling requirements

Give an overview which includes: • Purpose of study • Number of return periods • Study extent • Specific areas of interest • Broad scale or detailed model? • Hydraulic outputs required • Approx. time available	To add a TUFLOW floodplain model domain to an existing ISIS model of the River Wye. This is to be done with the intention of improving our understanding of the flood extent in the Rotherwas Industrial Estate. The Environment Agency has stipulated that the effects of the tributaries Red Brook and Withy Brook should also be considered. The model is to be run at both the 100-year and 1,000-year return periods as well the 100-year event including the estimated effects of climate change. The TUFLOW model domain must include the Rotherwas Industrial Estate; beyond this the extent should be chosen to provide a stable and accurate model.

1.2 Summary of existing data

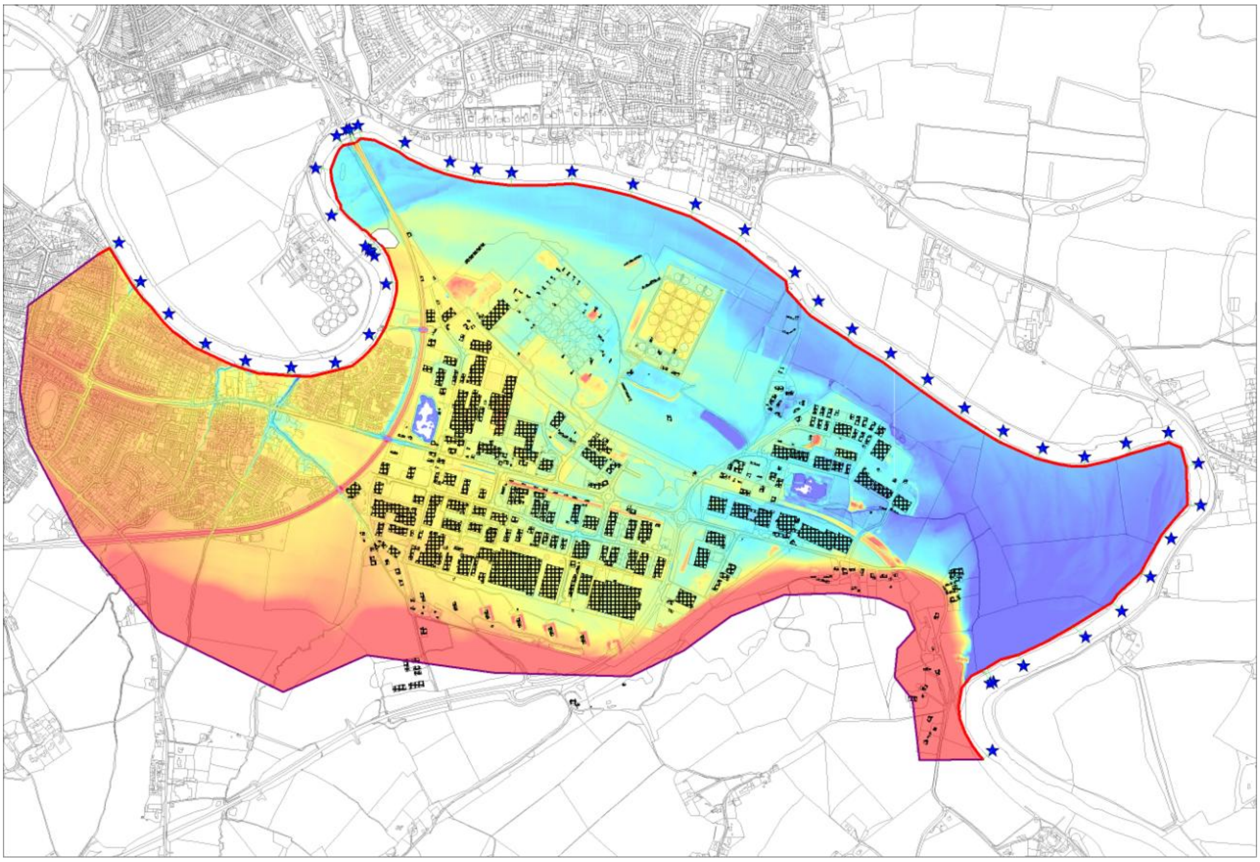
Are any **existing models** being incorporated into this study? If so summarise • Model type • Model extent • Broad scale or detailed model? • Existing floodplain representation.	A hydraulic model of the River Wye already exists and has been provided to us for use as the in-channel component of the linked model. This model has been developed using the 1D hydraulic modelling software ISIS. Two separate hydraulic models of smaller tributaries have also been supplied to us. These are the Red Brook and the Withy Brook, both of which join the Wye from the right bank immediately upstream of the study area. Both of these models have been supplied in HEC-RAS format meaning that they will have to be converted in to ISIS format before they can be incorporated into a linked 1D-2D hydraulic model. Currently the floodplain representation across the study area is as extended cross sections.
What **DTM data** is available for this study? • LiDAR • SAR • Filtered/unfiltered • Resolution Date of surveying and processing. Summarise any problems with this data, inc. holes and/or overlapping data sets.	A LiDAR derived DTM has been supplied to us for use on this project. This has been supplied at a 2m resolution in both filtered and unfiltered formats. For the basis of the TUFLOW model the filtered version of the data will be used; this has been processed by the Environment Agency in order to remove buildings and vegetation from the DEM. There were some small areas of null data within the supplied LiDAR DTM. These were usually attributable to standing water e.g. ponds etc. However there was alone one thin line of null values at the seam of two LiDAR tiles in the north east of the study area. Ground elevation values for these areas were derived by interpolated of surrounding values using tools within TUFLOW.
What **mapping data** is available? Are building footprints required/available?	We have been supplied with both Mastermap data and aerial photography for the study area.

1.3 Modelling software

TUFLOW version used?	2008-08-AG-iSP
ISIS version used?	V3

1.4 Model schematisation

Are there **multiple TUFLOW domains** in the model? If so, how many and why?	No.
What is the **geographical extent of the TUFLOW domain(s)**, and why were these limits selected as boundaries to the 2D model?	The TUFLOW model extents were defined using a combination of the existing ISIS model, the LiDAR derived DTM and the existing flood zone outlines. It was decided to extend the model from section "1.043" at the upstream end to "CS1.40". These extents were chosen because they include all of the floodplain inside the meander upon which the Rotherwas Industrial Estate sits. Moreover, at both these locations, the right bank of the River Wye rises steeply to higher ground. This effectively provides a natural barrier to floodplain flow and avoids the need to dynamically link the floodplain domains of the ISIS and TUFLOW models.
What is the total **area of the TUFLOW model** domain(s)?	4.22km^2
What is the total **length of the ISIS model**?	29.65km
What is the total **length of the ISIS-TUFLOW boundary**? This should include both banks if applicable.	6.20km

Schematic of model domain	
	
Key:	
DTM (only displayed within 2D model domain) 47mAOD 49mAOD 51mAOD 53mAOD 55mAOD	HX line – ISIS-TUFLOW model boundary ISIS nodes Buildings Culverts - modelled in ESTRY

1.5 Model folder structure

This model has been built using the standard folder structure described in the TUFLOW manual. In order to get the model to run the supplied folder structure must first be copied onto the "C" drive of the machine on which it is going to be run. So long as the path is the same as that given below then none of the control files will need any modification.

C:\2008s3772_Hereford\TUFLOW\

2 TUFLOW MODEL DOMAIN

2.1 TUFLOW domain summary

What is the **cell size** and why has it been chosen?	The model has been built using 4m cells. This relatively fine modelling resolution was required in order to represent buildings and the flow paths between them on the Rotherwas Industrial Estate. Any smaller cell size would have resulted in unfeasibly long model run times.
Has the model's **sensitivity to cell size** been assessed?	No, but there was little scope to realistically increase or decrease the cell size.
What is (are) the **grid orientation(s)**? What is the reason for choosing this (these) orientation(s)?	The model grid is orientated at approximately 15 degrees. This orientation has been chosen as it aligns with the road network in the Rotherwas Estate; these roads are expected to be the principal flow paths through the main area of interest.
Was the **grid orientation altered** during model development? Why?	No.
Is the **1D model area inactive in the TUFLOW domain**?	Yes
Is the inactive **channel width** in the TUFLOW domain the same width as the linked 1D model?	Every effort has been made to link the ISIS section extents with the location of the HX boundaries in the TUFLOW model. This was done by comparing ground elevations in both model domains and also by measuring the river width. However as the TUFLOW domain only exists on the right bank of the model it is not possible to directly compare river widths in the two model domains.
How is underlying DTM derived? Is it based on LiDAR, SAR or surveyed data? Has it been filtered?	The DTM used for querying the Z points (ground elevations in the TUFLOW model) is derived from a filtered version of the Environment Agency LiDAR dataset.
Are there any **holes in the DTM** and if so have they been filled using the in-house Arc Map routine or using TUFLOW shape layers?	On this occasion, as there were only a few holes in the LiDAR data, these were filled using the TUFLOW shape layers. This approach offers the advantage of being able to see where interpolated values have been used as no physical change is made to the underlying LiDAR data. Interpolated areas can be checked by displaying the "2d_zsh_LiDAR_fill" and "zsh_zpt_check" layers.
Have all **GIS layers been checked** for erroneous flags etc?	Yes
Are there any **ESTRY components** in the model? If so discuss where and why they have been used.	Yes, three culvert units have been used to represent flow paths through the railway embankment. ESTRY units have been used because they are able to completely dry out without becoming unstable. This is critical for floodplain structures which only become wet once water levels have risen sufficiently. The two most northerly structures have been modelled as rectangular culvert units with dimensions estimated from both the digital mapping and aerial photography provided. The final structure, the culvert on the Red Brook has more detailed dimensions provided in the hydraulic model so an irregular culvert unit has been used to provide an accurate representation of the structure dimensions.

2.2 Bed and floodplain resistance

Approach to building bed and floodplain resistance			
	Land Cover Category	**Land Type**	**Manning's *n***
Manning's roughness coefficients *n* used	1	Grass	0.04
	2	Dense trees	0.06
	5	Footpaths and paved areas	0.025
	8	Channel Banks (used to stabilise model)	0.1
	9	Urban areas (including buildings)	0.06
	10	Buildings	0.1

2.3 Modifications to ground model

TUFLOW provides the user with a powerful array of tools for modifying the topography. Utilising these tools leaves the original DTM unchanged and provides an easily followed audit trail of terrain modifications. It also allows the user model different combinations of terrain changes. The order in which terrain modifications are read into the geometry control file is important as each new layer modifies or overwrites the changes made by previous layers.

The following table summarises each of the terrain modification layers in the same order that they are read into the geometry control file.

Layer name	Command (e.g. "Read MI Z Shape ADD")	Purpose of terrain modification and source of elevation data
2d_zsh_LiDAR_fill	Read MI z Shape	See section 2.1
2d_zpts_Buildings_001	Read MI Zpts ADD	See section 0
2d_zpts_Railway_002	Read MI Zpts	This layer has been used to block holes in the railway embankment that have been removed from the DTM. This has been done because the representation of these opening has been improved by using 1D structures in ESTRY. It is therefore important to be sure that the flow path is not also available in the TUFLOW model.
2d_zsh_HFD_Stability_001	Read MI Z Shape	These represent patches that have been added to the DTM in order to improve stability. In this case there is only one area to the west of the railway embankment where steep topography appeared to be the cause of instabilities in the model. This area has been smoothed slightly with this shape layer. This approach reduced the instability in the model but did not have a significant impact on the final model results.

2.4 Representation of buildings

Does the model include **urban areas**?	Yes.
Have **buildings** been represented individually or as a uniform urban roughness? Why?	Both – buildings to the east of the railway embankment have been modelled individually in order to provide the best possible representation of flow paths in the Rotherwas Industrial Estate.

	However, the less project critical buildings to the west of the railway embankment have been modelled using a uniform urban roughness
How were **building footprint** areas derived?	The building footprints were extracted from OS Master map data.
Describe how buildings are represented.	The buildings polygons were used to both increase the ground elevation within the buildings to an estimated threshold level and to increase the hydraulic roughness. As no threshold levels were surveyed for this study, ground levels were increased by an estimated 0.2m above the elevations in the filtered LiDAR DTM. To represent the obstruction to flow through buildings, the Manning's n value of 0.1 was adopted within the building footprints. This approach was adopted because it allows a small amount of flow to pass through buildings once the threshold level has been exceeded. This should provide a good representation of both floodplain storage and conveyance.

2.5 Plot observation features

No plot output features were used in this study. The only locations where they would have been required were the flow paths under the railway. However, as these were modelled as 1D structures it is already possible to view a time series of flow through them.

3 ISIS MODIFICATIONS

If this study requires a TUFLOW domain to be added to an existing ISIS model then this chapter summarises the modifications that have been made to the existing ISIS domain.

Name of existing ISIS model	Q100_36hr.dat
Modification	**Relevant nodes and or structure names**
Truncated cross sections	The area of floodplain being represented by the new TULFOW domain was originally modelled as extended cross sections and lateral reservoirs in the ISIS model. The original ISIS cross sections were trimmed to bank level on the right bank between the following nodes: Upstream – 1.043 Downstream – CS1.040
Lateral spills removed	S1.040RW, S1.039RW, S1.037RW
Lateral reservoirs removed	S1.040RR
Lateral reservoirs modified	None
Interpolated sections added	None
Parameters modified	

4 HYDRAULIC STRUCTURES (1D)

4.1 In channel structures

For this study all in-channel structures were retained in the ISIS model and they were not modified in any way. The only exception to this is the additional runs that were undertaken to assess the effect of lowering the ground levels under the arches of the railway bridge.

4.2 Floodplain structures

In this context, floodplain structures can include any area of the floodplain where the original DTM was not capable of accurately representing the local flow conditions and some modification was required. This section aims to both record and justify the modelling decisions that have been made in this regard. Typically these structures are modelled using either TUFLOW or ESTRY as both software packages allow for complete drying and rewetting – usually a crucial requirement on the floodplain.

In this study, it was necessary to add three floodplain structures to the model. All of these represent potential flow paths under the railway embankment running along the western boundary of the Rotherwas Industrial estate. In each case it was decided to represent the structure with culvert units modelled in ESTRY.

Structure Name	Structure location (NGR)	How has the structure been modelled and why was this approach chosen?
RB_Culvert	The culvert where Red Brook passes under the railway line (352148 237994).	Modelled as an irregular culvert unit in ESTRY. Structure dimensions defined as a height width table derived from the supplied HEC-RAS model of Red Brook. Modelled as being 10m long with a Manning's n value of 0.025.
Holme_Lacy_R	Where Holme Lacy Road passes under the railway embankment (352308 238163).	Modelled as a rectangular culvert unit in ESTRY. Structure dimensions (height = 4m; width = 7.5m) were estimated from available mapping and aerial photography, the heights of the culvert unit was estimated. Modelled as being 10m long with a Manning's n value of 0.03
Path	A footpath under the railway linking the northwest extent of the Rotherwas Estate to just north of Goodwin Way (352427 238528).	Modelled as a rectangular culvert unit in ESTRY. Structure dimensions (height = 4m; width = 6.8m) were estimated from available mapping and aerial photography, the heights of the culvert unit was estimated. Modelled as being 10m long with a Manning's n value of 0.03

5 MODEL BOUNDARIES

Check	Answer	Comments
Is there provision for **floodplain flow to both enter and leave the TUFLOW model** without being forced in-channel? What approach has been adopted?	Yes	HX lines are extended laterally across the floodplain at both the upstream and downstream ends of the TUFLOW domain. However the TUFLOW domain has been chosen so both the upstream and downstream occur at topographic constrictions where there is very little space for right bank floodplain flow.
Do the **channel widths** in ISIS match the width of the inactive area in the TUFLOW domain (to within 1 cell width)?	Yes	There is only a TUFLOW domain on the right bank of the ISIS model so it has not been possible to compare channel widths in the two domains. However, every effort has been made to unsure that the ISIS cross sections have been trimmed to the same location as the HX line has been digitised.
Are all areas accounted for in one model domain and one only? I. e. have all extended sections and reservoir units been removed from the ISIS model where the floodplain is now represented in TUFLOW? Was it necessary to alter the dimensions of any ISIS reservoir units?	Yes	Existing ISIS cross sections were truncated and one reservoir unit was removed from the ISIS model.
What **boundaries** have been used between the ISIS and TUFLOW domains? Why was this boundary type preferred?	HX, SX.	ISIS-TUFLOW boundaries are all modelled as HX linkages, i.e. the water level from ISIS is used by TUFLOW to determine a flow passing between the two model domains. However the linkages between the ESTRY structures and the TUFLOW use an SX connection whereby the 1d model (ESTRY) calculates the flow through the structure based on the water levels provided by the adjoining cells in the TUFLOW model.
How was the **location of the boundary lines** defined?	LiDAR, X-section data, OS mapping, Aerial photography.	No bank level survey was available to aid defining the ISIS-TUFLOW boundary. However, when digitising the HX lines their locations were based on ISIS cross section data, LiDAR data, OS mapping data and aerial photography.
How was the **elevation of the boundary lines** defined?	LiDAR, X-section data.	The elevations of the HX lines (derived from the LiDAR DTM) were checked for consistency with the (survey derived) ISIS cross sections.

6 STABILITY FIXES

Unfortunately the reality of using hydraulic modelling software to model real world situations is that some assumptions and modifications must be made in order to minimise numerical instability occurring in the model. Whilst these modelling decisions are important, when developing a reliable model they are often not recorded. This chapter should be used to record some of the key processes that have been undertaken to limit instability in the model.

Location	Description of instability – include details of possible causes	Details of what measures have been taken to reduce the instability
Along the HX lines forming the 1D-2D boundaries.	Oscillations of flow between the two modelling domain. These were evident when analysing the ISIS 2D flow output.	A narrow region of increased roughness along the river bank. This has the effect of controlling unrealistic fluxes with having a significant effect on final results.
On the right bank near section 1.0336, opposite the STW	Some instability was developing on the floodplain as this area became inundated. The most likely cause was the some uneven topography surrounding the end of the bridge.	A z shape layer was used to smooth out this area of topography. This did remove the instability and is very unlikely to have much impact on the model results. The total area of the z shape polygon is less than 0.004km2.

7 MODEL RUNS

7.1 Design Runs

Summarise the **purpose** of this group of model runs.	To illustrate the extent of flooding at various return periods assuming no significant terrain or structure modification.
Return periods modelled (years)	100, 100 (including effects of climate change), and 1,000.
Model **start time** (hrs)	0
Model **run time** (hrs)	100
CPU time (hrs)	22.5
Initial conditions files (ISIS and TUFLOW)	None – ISIS initial conditions are contained in the data file.
Results save interval (ISIS and TUFLOW) (seconds)	**TUFLOW:** Map output interval = 900 Time series output interval = 300 Display interval = 60 **ISIS:** Save interval = 300
PO save interval (TUFLOW)	n/a
Have **1D-2D fluxes** been recorded as additional (zzx) results files?	Yes
Map Save Options (TUFLOW)	d v q h
Discuss any **ISIS parameters** that have been changed from default settings.	The maximum number of iterations has been increased to 17
Discuss any **TUFLOW parameters** that have been changed from default settings.	None
ISIS data file names	HFD_411 = 1,000 years HFD_414 = 100 years HFD_419 = 100 years including the effects of climate change
ISIS event file names	n/a
TUFLOW control file names	HFD_411 = 1,000 years HFD_414 = 100 years HFD_419 = 100 years including the effects of climate change
Summary of **any other specific modifications** for this group of models.	

7.2 Structure modification

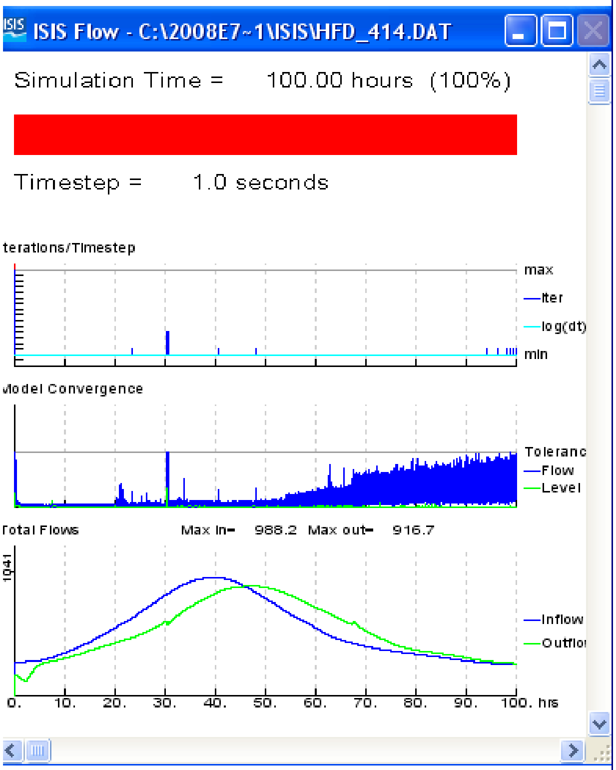
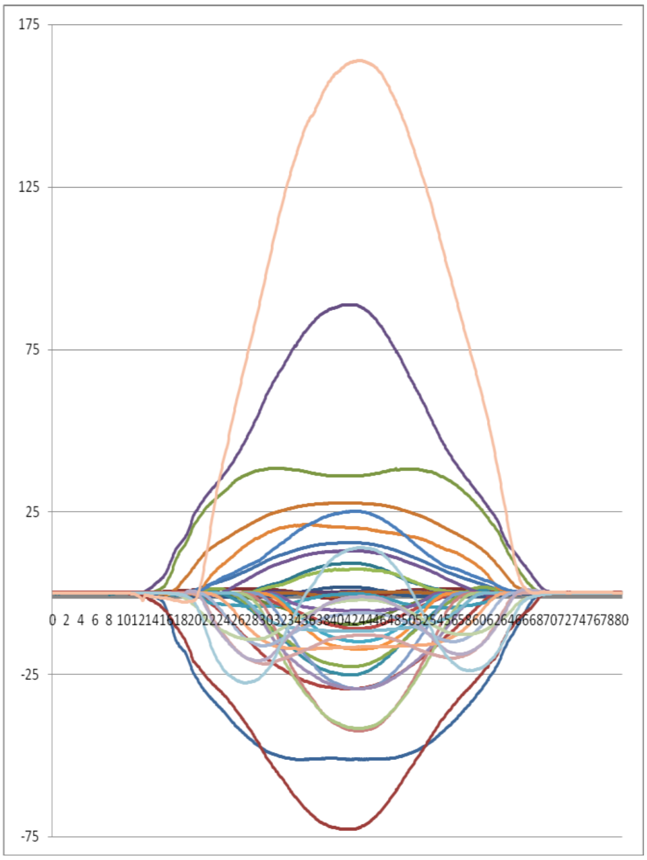
Summarise the **purpose** of this group of model runs.	To test the effects of lowering the ground level under each of the four arches of the railway bridge over the River Wye. Under each arch the ground level was reduced by 1m. This modification was modelled in the ISIS domain.
Return periods modelled (years)	100, and 100 (including effects of climate change).
Model **start time** (hrs)	0
Model **run time** (hrs)	100
CPU time (hrs)	22.5
Initial conditions files (ISIS and TUFLOW)	None – ISIS initial conditions are contained in the data file.
Results save interval (ISIS and TUFLOW) (seconds)	**TUFLOW:** Map output interval = 900 Time series output interval = 300 Display interval = 60 **ISIS:** Save interval = 300
PO save interval (TUFLOW)	n/a
Have **1D-2D fluxes** been recorded as additional (zzx) results files?	Yes
Map Save Options (TUFLOW)	d v q h
Discuss any **ISIS parameters** that have been changed from default settings.	The maximum number of iterations has been increased to 17
Discuss any **TUFLOW parameters** that have been changed from default settings.	None
ISIS data file names	HFD_418 = 100 years HFD_417 = 100 years including the effects of climate change
ISIS event file names	n/a
TUFLOW control file names	HFD_418 = 100 years HFD_417 = 100 years including the effects of climate change
Summary of **any other specific modifications** for this group of models.	

8 MODEL RESULTS AND SUMMARY

8.1 Summary of the model stability

Is there any **non convergence** in the ISIS model? If yes where and what steps have been taken to minimise it?	There is almost no non convergence in the final version of the model. The exception to this is at the 1,000 year run where there is some slight non convergence but it is not sufficient to cause concern.
Are there any **warnings and/or checks** generated by the TUFLOW model? If yes how many, to what do they refer, and what if any impact do they have on model results?	Yes there are some warnings produced by TUFLOW in most of the model runs but these always represent brief and localised periods of instability usually associated with the inlet and outlets of the floodplain hydraulic structures. None of the periods of instability are enduring enough to be a concern.
Does the plot of **dV** indicate any periods of instability?	There are some very minor oscillations but the hydraulic models built for this study represent extreme scenarios, and oscillations of this magnitiude are nothing to be concerned about. Combined with the 2D flux output we can see that there are no locations along the 1D-2D model boundaries which are causing significant instability.
Has the ISIS additional output **2D flow** been generated? If yes does this provide any information on localised areas of instability across the ISIS-TUFLOW domain boundaries?	A plot of the 2D flux flow has been generated from the 100-year design results and included in Section 8.2. Similar model outputs have been supplied in CSV for all model runs.
What does the **mass balance error** indicate about model stability?	All of the models have a short period at the very beginning of the model runs where mass balance errors are larger than 1%. However, this is usual at the beginning of a model run as the TUFLOW domain initially wets up. The mass balance error drops below 1% within the first 30mins of the model run and then remains at or below 0.1% (well within the recommended range) for the remainder of the model run. This indicates good model stability.

8.2 Graphical representations

ISIS Run Time Plot	1D-2D Flux Plot
1% AEP Fluvial Event	
	

8.3 Summary of the model results

Does the model meet all the **original requirements**?	The model does provide a good tool for establishing flood risk to the study site. However, it does not include the two small tributaries that which were originally going to be added to the model. We did try to include the Red Brook in the linked ISIS-TUFLOW model as an ISIS channel however this resulted in severe instability and usually caused the model to crash. The cause of this instability is essentially the difference in size between the Wye and the Red Brook; when the River Wye is in spate, it's floodplain flow overwhelms the in channel flow on the Red Brook. The result is that the dominant flow direction is across the 1D channel, with more flow entering and exiting each reach laterally than flowing downstream. 1D river models such as ISIS assume that the flow direction is along the channel (1D flow) and failure to meet this assumption not only causes the model to be unstable but indicates that it is not the correct way of modelling that scenario. As a result, we decided not to include the tributaries as 1D channels in the final linked model but instead to that the Red Book's culvert under the railway was accurately represented in the model to allow floodplain flow from the River Wye to pass back through the culvert and provide a possible flow path onto the estate. This was done using an irregular culvert unit in ESTRY.

Summarise the **key results/findings**.	The main result of this modelling study was to provide an improved understanding of flood risk to the Rotherwas Industrial Estate. To this end this study has been successful and as a result has shown a decrease in the area at risk of flood from both the 100 and 1,000-year flood events when compared to the existing flood zones data.
What are the **limitations** of the model, what considerations should be given before using it for other studies?	This model was developed with a very specific aim, to understand flood risk on and around the Rotherwas Industrial Estate. As a result we have only worked on the model in this area, other watercourses remain in the ISIS model but their inflows have not been updated and should not be taken to be correct without more investigation.

Appendix C: Example Evacuation Management Plan

BUSINESS FLOOD PLAN

Date: ________________

Company name ________________________________

Registered address ____________________________

____

____________Postcode________

General contact list

	Company name	**Contact name**	**Telephone**	**Mobile**
Floodline	Floodline	--	0845 988 1188	--
Electricity provider				
Gas provider				
Water company				
Telephone provider				
Local public transport				
Local council emergency services				
Insurance company				
Insurance agent				

Alternate office premises, contact details

Office / branch	**Telephone**	**Fax**	**Address**

Staff

Staff contact list - please continue on a separate sheet if necessary

Name	Job title	Home telephone & address	Mobile	Emergency contact	Emergency telephone & address

Note staff who may require assistance in the event of a flood.

Special needs staff member	Office location	Volunteer aide/s

Key locations

Service cut-off	Description of location
Electricity	
Gas	
Water	

Answer the following if applicable

Hazardous material	Description of location	How to protect from a flood (i.e. move, cover, tie down)
Chemicals (including cleaning products)		
Oil based products (gasoline, oil, cooking oil etc.)		
Other contaminants (i.e. asbestos insulation, lead-based paint)		

Protective actions

Identify stock, equipment and possessions that may need special protective measures, and describe the actions you will take to prevent their damage in the event of a flood. We have suggested items and ways to protect them, but make sure you follow through on your plans. For example, if you say you will move an item to a safer location, then do it!

Please continue on a separate sheet if necessary.

Items to consider

Computers	In-store stock	Chairs / stools	Computer files
Machinery	Warehouse stock	Tables / heavy furniture	Staff files
Vehicles	Fittings	Soft furnishings	Paper files
Electrical	Movable goods		Databases
	Food		

Ways to protect items

- Make a copy and store in safe location
- Raise above ground level
- Buy flood protection products
- Buy new flood-resistant item
- Move to safer location

Valuable item	**Protective action**	**New location (if applicable)**	**Done**

Note basic building materials required. If materials are not needed, leave the relevant section blank.

Materials	Used for	Items to protect / where to use	Storage Location	Done
Sand & sand bags (unfilled), shovel	Creating flood barriers (used with plastic sheeting)			
Tools - hammer, nails, saw	Boarding up doors, windows and openings, creating shelves			
Wood - plywood, blocks of wood	Boarding up doors, windows and openings, creating shelves			
Sturdy plastic sheeting	Sandbag barriers, pulling up around furniture and appliances			
Plastic bags	Putting around legs of tables and chairs			
Pallets	Raising stored stock above flood level			
Emergency power generator	Maintaining function of air conditioning units (can help dry out a building), running fridges & freezers			

Note options for moving key operations to another site in the event of a flood. If you are a small business and relocation is not an option, leave this section blank.

Function	Temporary relocation	Telephone	Fax
Shipping & receiving			
Production			
Customer services			
Payroll			
Information support systems			

Suppliers and external links

Identify back-up plans for disruption of deliveries, or arrangements for short-notice cancellation with suppliers. Suggested back-up arrangements are listed below. Make sure that you follow through on your plans. For example, if you say you will use an alternate delivery address, make sure you provide that delivery address to your supplier in advance.

Please continue on a separate sheet if necessary.

Possible contingency plans

- (1) Contact supplier immediately on evacuation
- (2) Use alternate supplier
- (3) Use alternate delivery address
- (4) Individual terms detailed in separate document (attach document to this plan)

Supplier	**Contingency plan**	**1) Supplier contact & telephone**	**2) Alternate supplier contact & telephone**	**3) New delivery address**	**4) Own agreement (attached)**

List companies whose help you may need after a flood. Make sure that you follow through on your plans, and get contracts in place, or know who to call for assistance. If help is not needed, you can leave this section blank. If you contract in advance, attach the contract to this flood plan.

Flood service company	**Company name**	**Contact**	**Telephone / mobile**	**Contract agreed**
Hazardous materials response team				
Security services				
Water pumping services				
Suppliers of emergency power / equipment				
Equipment repair				
Earthmoving or engineering				

Identify people who can help you before, during and after a flood, and what they can do. We have suggested ways they might be able to help, but you'll need to discuss this with them.

Please continue on a separate sheet if necessary.

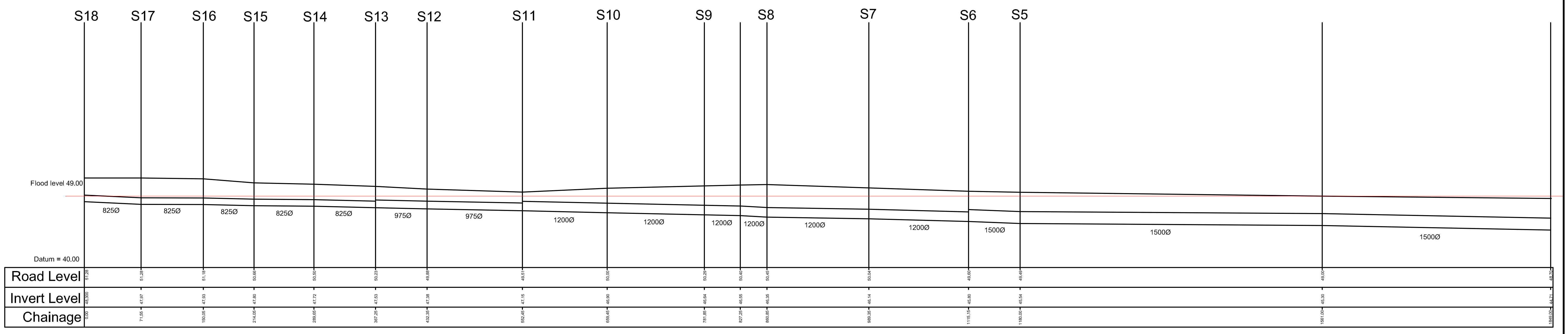
Ways people can help

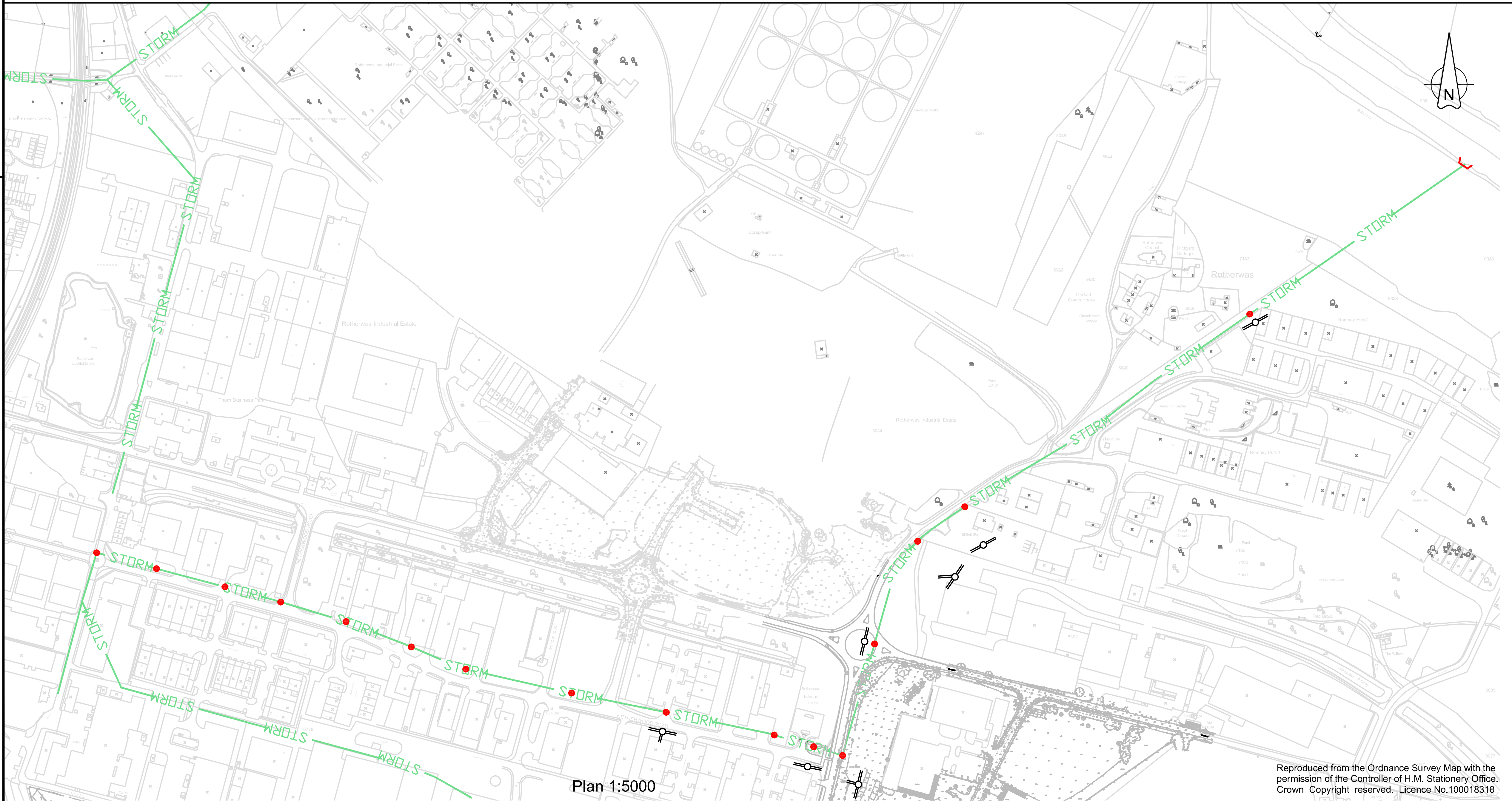
- Assistance with installing flood products
- Assistance with evacuation transport
- Able to use their property for shelter
- Able to use their property as assembly point
- Provision of emergency storage
- Provision of emergency supplies or medical support

Relationship	**Name**	**Contact details**	**How they can help**	**Help agreed**
Neighbour				
Neighbour				
Volunteer				
Volunteer				
Other				

Appendix D: Drawings Number 551392-SK-115 Welsh Water Surface Water Sewer Long Section

File ref - g:\000 project files\002 major projects\551392 rotherwas futures\drafts\cad\551392-sk-115.dwg





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Rev	Revision details	Chkd	Appd	Date

Drawn: .	Preliminary ✓
Design: .	For comment
Chkd: .	For tender
Appd: .	For construction
Date: .	As constructed
	Other

amey

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Project Name
Rotherwas Futures

Drawing Title
Welsh Water Surface Water Sewer Long Section

Original Drawing Size : A3
Scale : As Shown | Dimensions : -

Drawing No
551392-SK-115
Rev

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