The Sizewell C Project

5.6 Sizewell Link Road Flood Risk Assessment Appendix A Sizewell Link Road Modelling Report

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1 Introduction

1.1.1. The proposed development is Sizewell link road, one of the Sizewell C Project's Associated Development Sites. Sizewell link road is a permanent single carriageway road that would run 6.8 kilometres (km) from the A12 just south of Yoxford in an easterly direction, joining the B1122 south of the town of Theberton.

1.1.2. The Sizewell link road would create a new route around the south of the villages of Yoxford, Middleton Moor and Theberton, helping to reduce the amount of traffic on the B1122 during the peak construction phase of the Sizewell C Project.

1.1.3. The aim of this report is to record the modelling undertaken and discuss the derived results for each crossing to determine flood risk to the development itself and its potential impact on flood risk in the surrounding areas and off-site receptors. This information feeds into the Flood Risk Assessment (FRA) which will form part of the application for development consent for Sizewell C Project

1.1.4. This report describes the hydrological assessment undertaken to derive inputs to the model, presents schematisation of the developed hydraulic models for each of the watercourses which the proposed link road would cross, and summarises results from the model runs carried out to date.

2 Proposed design

2.1.1. The route of the Sizewell link road would bypass a section of the B1122 with a new 6.8km single carriageway road to the south-west. The proposed road would be 7.3m wide, with additional 1m hard strips and 2.5m wide verges. Along the route of the Sizewell link road, there would be swales approximately 3.5m wide for highway drainage, with a 5m grassed area between earthworks and fencing.

2.1.2. The proposed link road is entirely located in the Minsmere Old River catchment (Ref 1) and would cross six watercourses west to east at seven locations along its route, crossing the same ordinary watercourse at locations four and five.

2.1.3. The locations of the crossings are displayed in **Plate 2.1** and listed below:

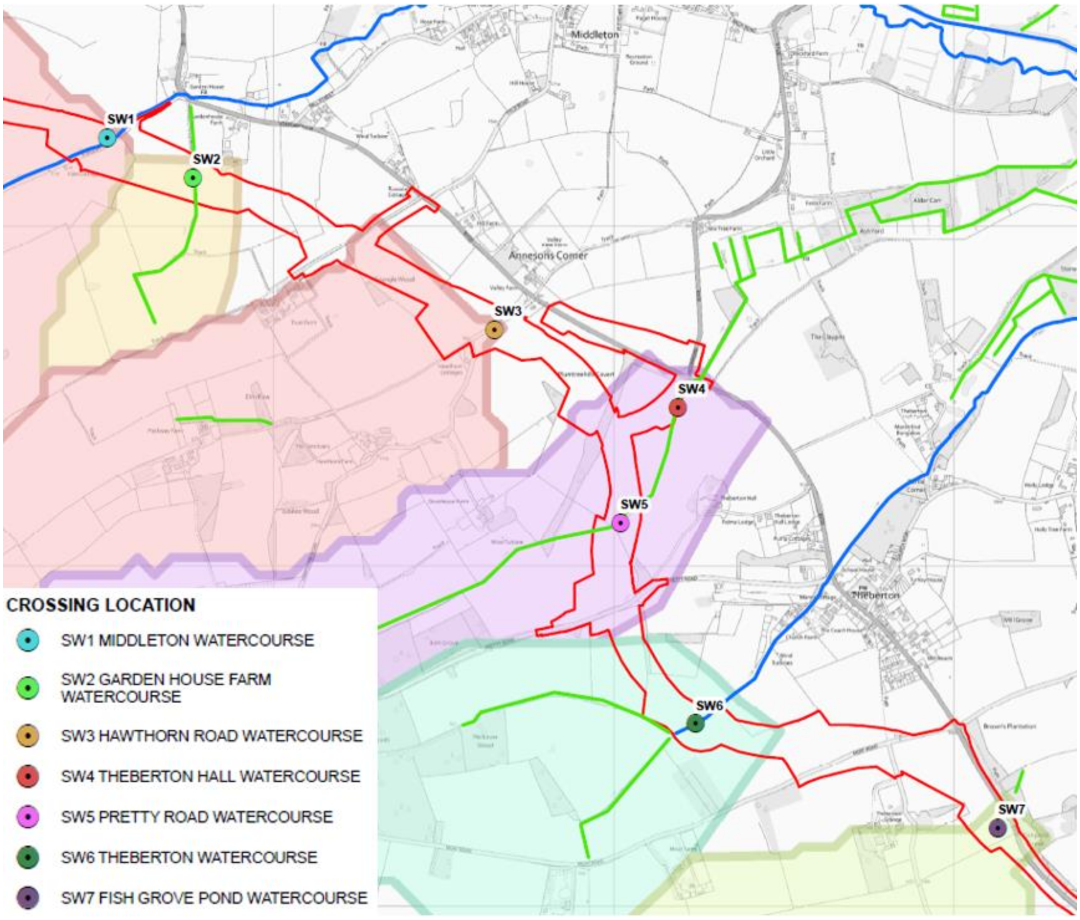
SW1. Fordley Road (Main River)
SW2. Garden House Farm Watercourse (Ordinary Watercourse)
SW3. Hawthorn Road Watercourse (Ordinary Watercourse)
SW4. Theberton Hall (Ordinary Watercourse)

SW5. Pretty Road Watercourse (Ordinary Watercourse)
SW6. Moat Road (Main River)
SW7. Fish Grove Pond Watercourse (Ordinary Watercourse).

2.1.4. The design includes for watercourse relief basins, if required, adjacent to each of the six watercourses, located upstream of crossings SW1, SW2, SW3, SW5, SW6 and SW7. No design details were available during this assessment and therefore these have not been included in the hydraulic modelling. The modelling results therefore present a conservative approach.

2.1.5. There are two Environment Agency Main Rivers which intersect the proposed road layout, both tributaries of the Minsmere Old River. The first is at Fordley Road and the second is adjacent to an unnamed track to the south-west of Theberton (herein Moat Road). The remaining four watercourses are Ordinary Watercourses.

Plate 2.1. Extract from Figure 1: Sizewell link road watercourse crossing locations.



2.1.6. In addition to the seven crossings listed above, there are two other crossings where existing roads would tie into the new link road. These are located upstream of crossings SW1 at Fordley Road and upstream of SW3 at Hawthorn Road. As these crossings could potentially impact flow regime and flood extents, they are included in the hydraulic modelling.

2.1.7. Modelling was not undertaken at crossing SW4 (Theberton Hall), as further details on the road layout design confirmed that the existing culvert would not be altered during the proposed construction and the proposed road levels would be very close to the existing levels tying in with the surrounding elevations. Since no changes to the flow regime or floodplain extents would be made, no impact on flood risk was assumed. This does assume that flow toward the culvert will remain the same as the current baseline scenario, once the link road is constructed.

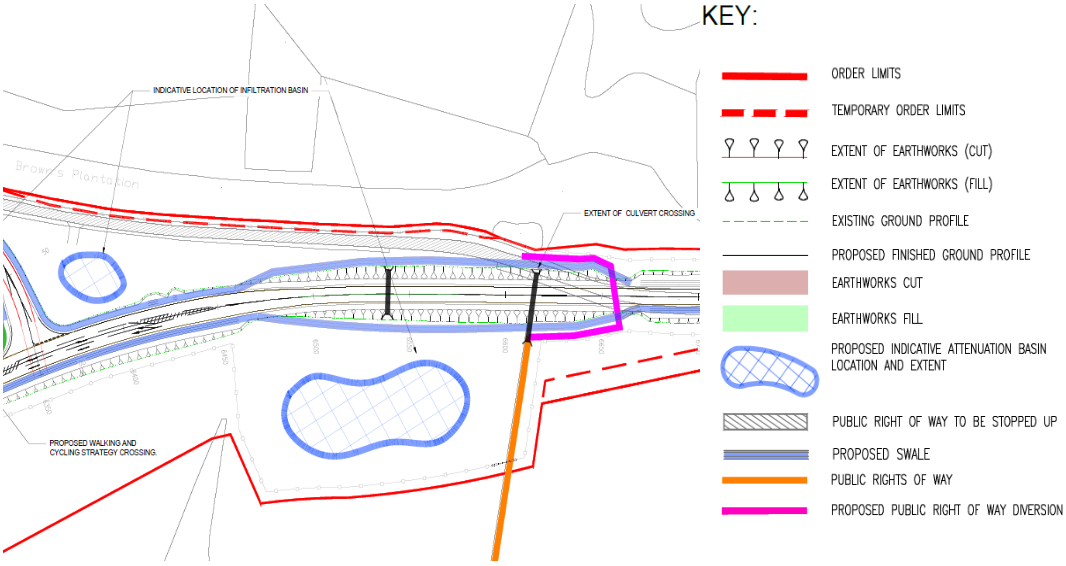
2.1.8. Hydraulic modelling was also not undertaken for crossing SW7 (Fish Grove Pond). At this location there is an existing drain that runs along a public right of way, which then passes through a piped culvert underneath the B1122. It has not been possible to confirm the culvert's precise location, invert and soffit levels at this stage of works.

2.1.9. Review of the Environment Agency Risk of Surface Water Flooding data (see **Figure 2** attached to this report) indicates that surface water accumulates to the north of the culvert and overflows the existing B1122 where the road is at its lowest point. Since the surface water mapping does not take into account the hydraulic influence of the local culvert, it is likely that the accumulation and any overflow are overestimated.

2.1.10. The lack of data and assumptions that would have to be made to represent the watercourse and the structure to capture the hydraulic behaviour meant that the modelling could not be carried out to a sufficient quality. Further assessment and appropriate modelling would be undertaken at the detailed design stage of the Sizewell C project when further details and survey information would be available.

2.1.11. The current design for the SW7 crossing location is to include a retention pond and flood relief culvert, north-west of the crossing location where the water is identified to currently pond during flood events (**Plate 2.2**). These hydraulic structures would be sized sufficiently at detailed design stage, based on the outcome of the detailed survey and modelling, to mitigate the impact of the crossing.

Plate 2.2. Extract from EDF Energy link road drawing: SZC-SZ0204-XX-000-DRW-100067 P09 SLR B1122-Theberton Junction Highway Layout.

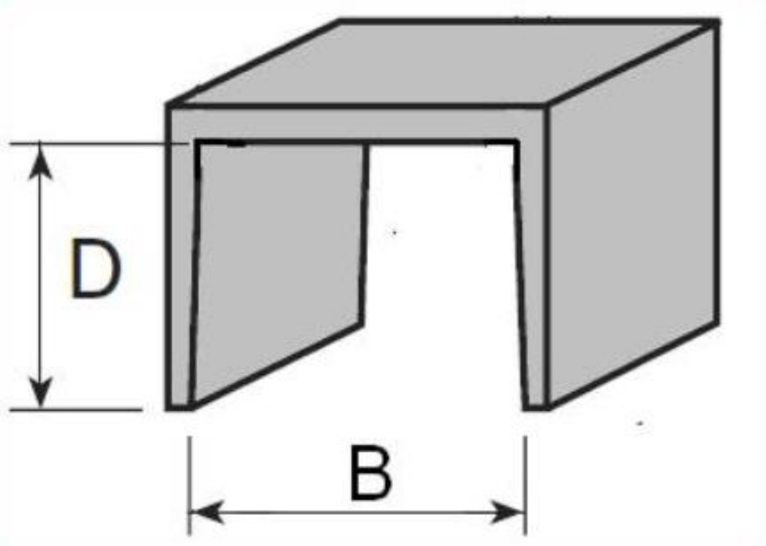


2.1.12. Outline design details for the remaining five crossings were sufficient to carry out the hydraulic modelling. Initial design assumed the use of reasonably sized standard box culverts on all of the crossings. However, this option was found insufficient to fulfil flood risk and environmental requirements. That was especially the case at crossings SW1 and SW3 where the double crossings (connection road and the link road) were introducing too much flow constriction. Also, the culverts would be very dark due to their lengths (between 30m and 50m) and therefore not attractive for animal passage.

2.1.13. Based on the above factors the design was revised. The current proposed outline design for all the watercourses crossings assumes 3-sided portal culverts (**Plate 2.3**), 5.4m wide (B) by 1.2m high (D). Portal culverts were chosen over widely used box culverts as they are placed on top of the existing banks allowing more height and removing the need for re-profiling of the natural river channel. These are presented further in this section in **Plate 2.8** – **Plate 2.12** for each of the crossings respectively.

2.1.14. The retained river banks also act as ledges to allow mammal passage beneath the link road. The 5.4m width for culverts was selected to optimise conveyance and allow as much natural light through as possible given the required length of the culverts. This was the maximum width of manufactured culvert blocks that could be transported to the site considering current road width and weight restrictions.

Plate 2.3. Portal culvert concept.



2.1.15. In addition to the revised type of the culverts, further changes were made to the design at the connection road crossings at Fordley Road and Hawthorn Road. At Fordley Road the decision has been made to propose a diversion of the watercourse in order to avoid crossing under the connection road, as illustrated in **Plate 2.4**. This solution results in the requirement for only one portal culvert that would provide a relatively wide opening and sufficient height. However, diversion of the watercourse would require construction of a new section of the river channel (**Plate 2.5**).

2.1.16. The current design of the diverted watercourse assumes keeping the Fordley Road junction at the same position to test the impact of the worst-case hydraulic scenario where the watercourse would be diverted the furthest. The alignment of the watercourse would be refined at the detailed design stage including the opportunity to move the junction further eastwards which would reduce the length of the diversion channel and its bed elevation so that it would be situated at a lower topography than currently proposed. On this basis, the current design and the current modelling tests a more conservative scenario for the purposes of the FRA.

2.1.17. Due to the constriction of the width of the portal culvert, the diverted channel with a 1 in 3 side slopes would not fit. On that basis, the current design proposed a T-shaped concrete cross-section through the culvert (**Plate 2.6**) with natural material placed at the channel bed and bank ledges.

Plate 2.4. Extract from EDF Energy link road drawing: SZC-SZ0204-XX-000-DRW-100137 P05 SLR Fordley Road Highway Junction Layout and Profile.

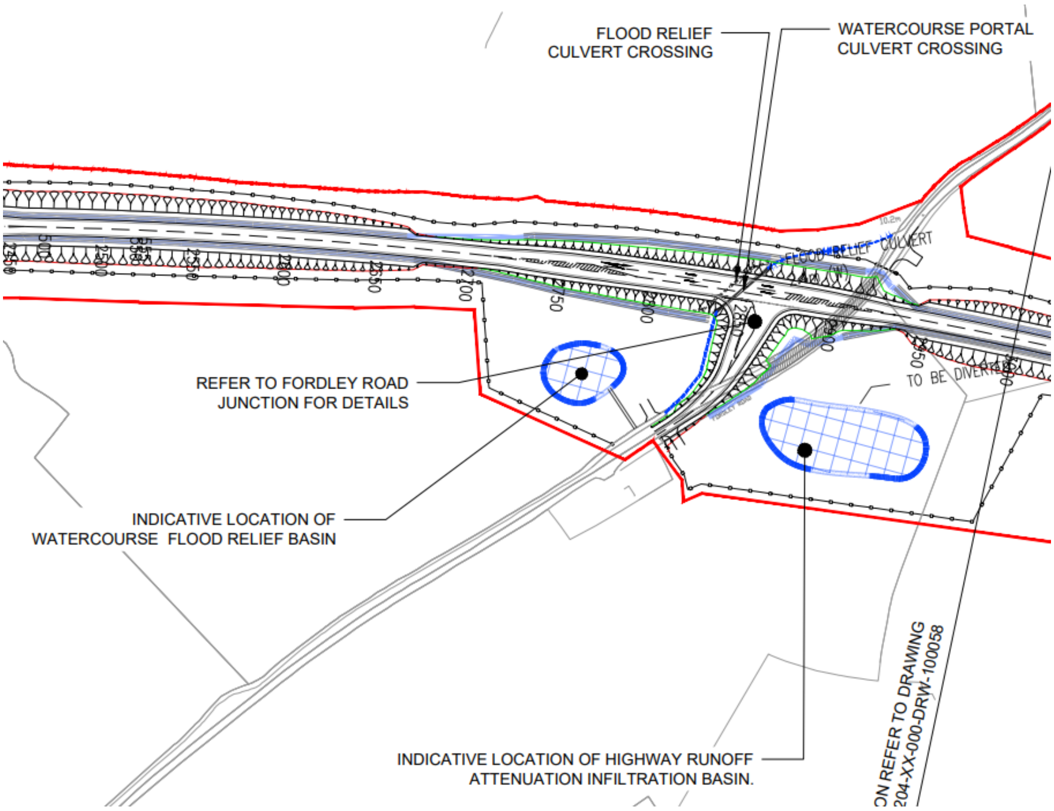


Plate 2.5. Proposed cross-section of the diverted channel at crossing SW1.

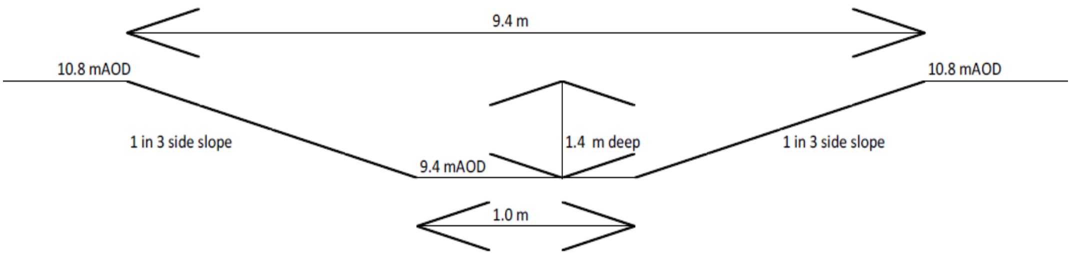
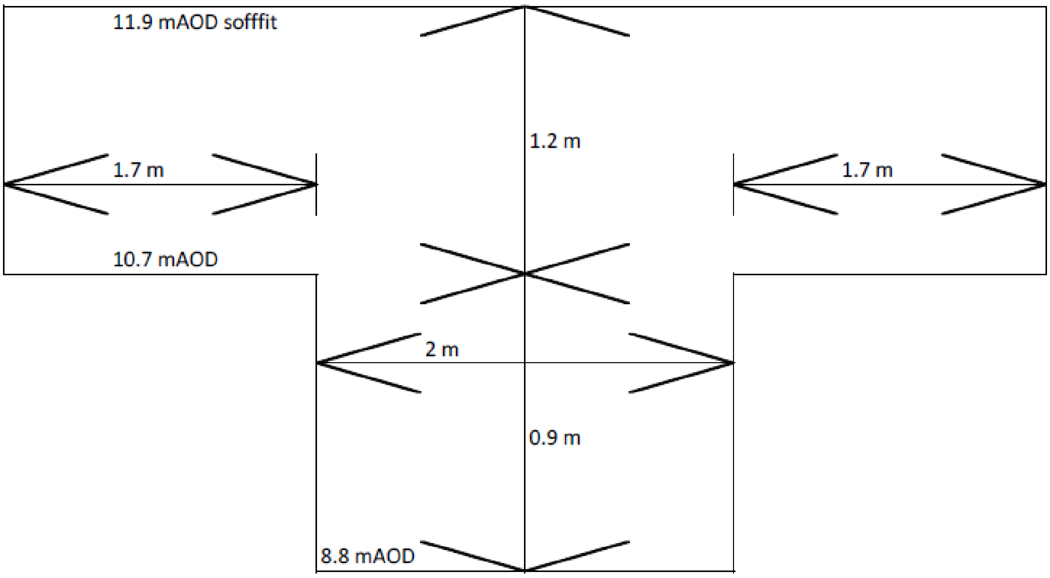


Plate 2.6. Proposed cross-section through the portal culvert at crossing SW1.



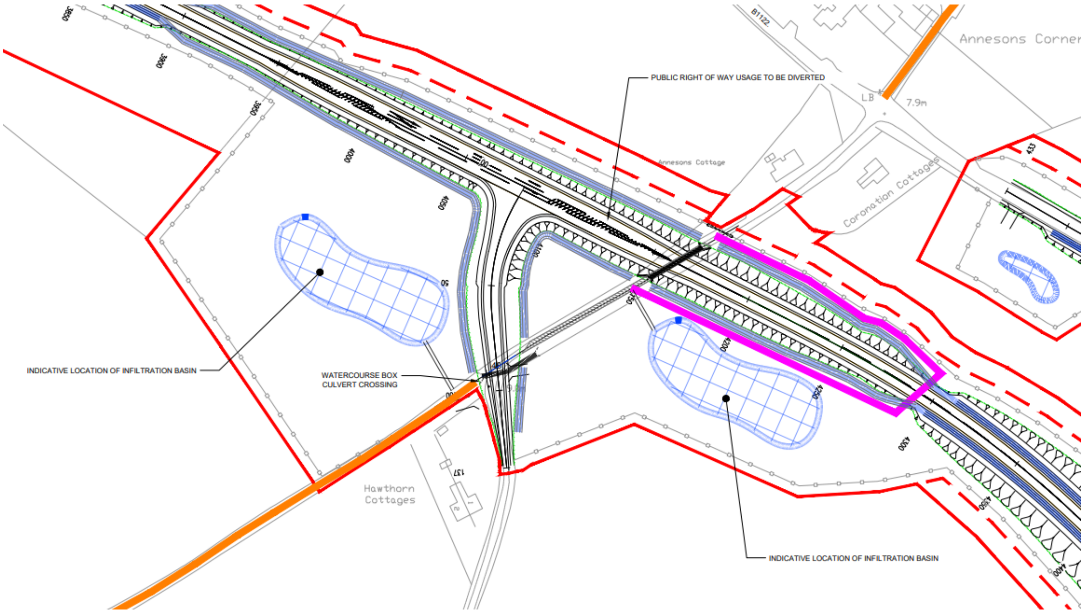
2.1.18. The levels within **Plate 2.6** is further explained here. At the upstream face of the SW1 culvert the model retains the 11.9m AOD soffit, and 10.7m AOD bank level. Setting the upstream bed level to 8.8m AOD (in line with the drawing) would cause the overall gradient within the culvert to be extremely flat. Instead the bed level at the downstream end has been set to 8.8m AOD, whereas 9.2m AOD level was set upstream in order to adopt a reasonable gradient of 1:100 (closer to the gradient derived from LiDAR).

2.1.19. A further design revision involves changed alignment of the connection road tying in the Hawthorn Road to the new link road such that it would be closer to the main link road. As a result, the existing Hawthorn Road culvert (upstream of the proposed link road location) would remain unchanged and a new crossing under the connection road would be constructed as a portal culvert with no disruption to the natural river channel (**Plate 2.10**).

2.1.20. The hydraulic modelling of this crossing doesn't account for the presence of the existing Hawthorne Road culvert upstream of the proposed development, assuming that all flow from the catchment upstream of this point would reach the new crossing. This creates a worst-case scenario for the modelling and the potential impact of the proposed crossing and ensures that should the existing culvert ever be removed the design of the new crossing would be resilient for potentially increased flows.

2.1.21. In **Plate 2.7** the blue outline shows how the initial proposed road layout would interact with the watercourse. This was then amended with the black dotted line which illustrates the revised alignment of the connection road.

Plate 2.7. Extract from EDF Energy link road drawing: SZC-SZ0204-XX-000-DRW-100140 P05 SLR Hawthorn Road Highway Junction Layout and Profile.



2.1.22. **Plate 2.8** – **Plate 2.12** illustrate the proposed portal culvert crossings for each considered location respectively. The top of each culvert is more than a metre below the surface of the SLR at all locations.

Plate 2.8. Proposed revised layout at crossing SW1.

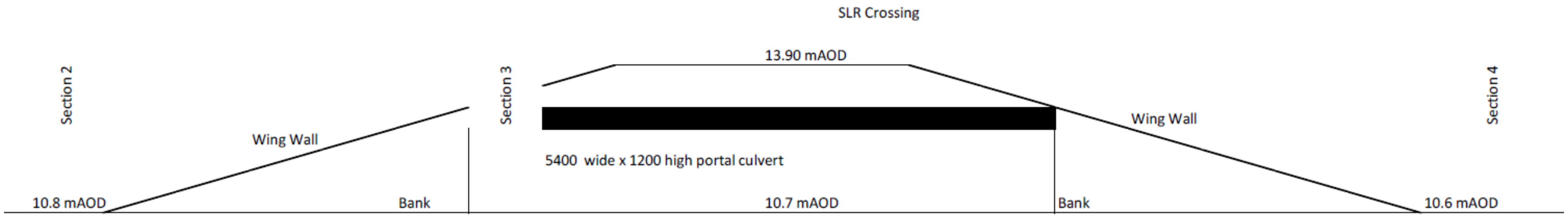


Plate 2.9. Proposed layout at crossing SW2.

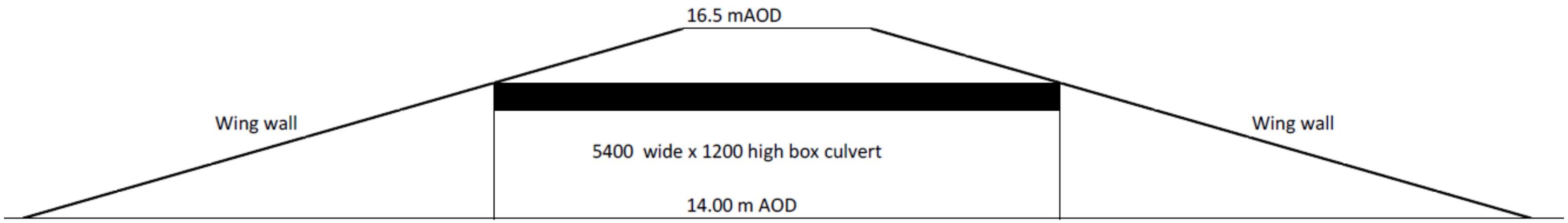


Plate 2.10. Proposed revised layout at crossing SW3 (Hawthorn Road).

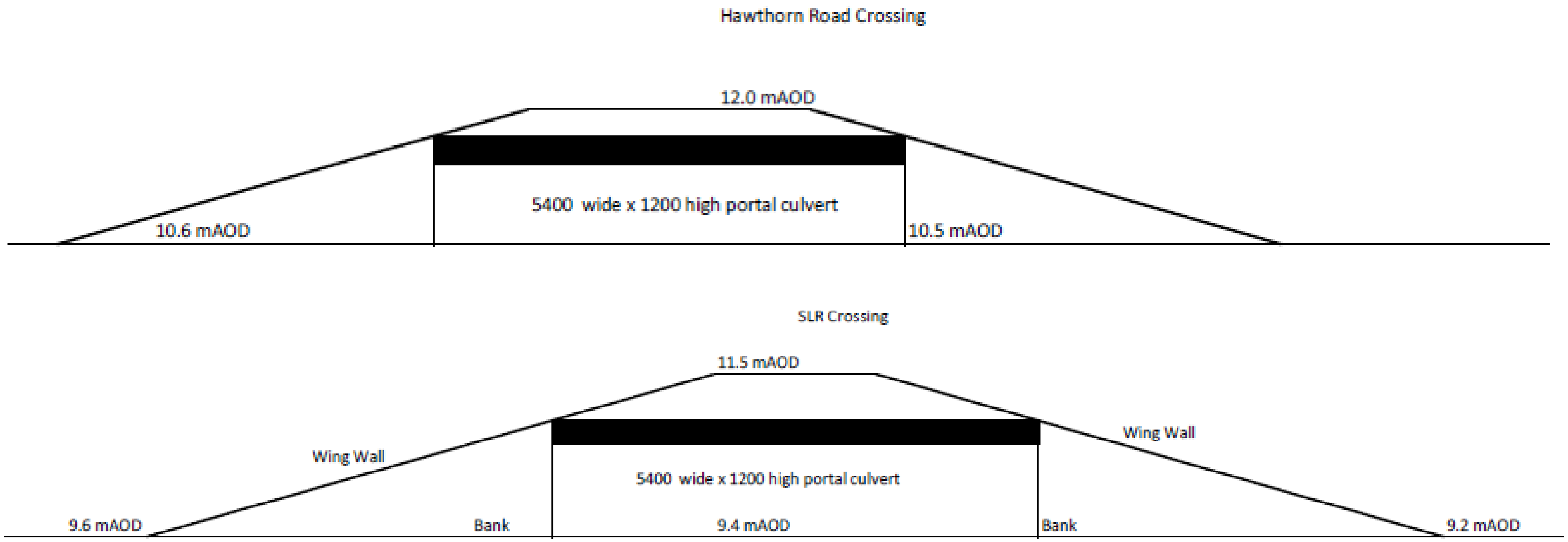


Plate 2.11. Proposed layout at crossing SW5.

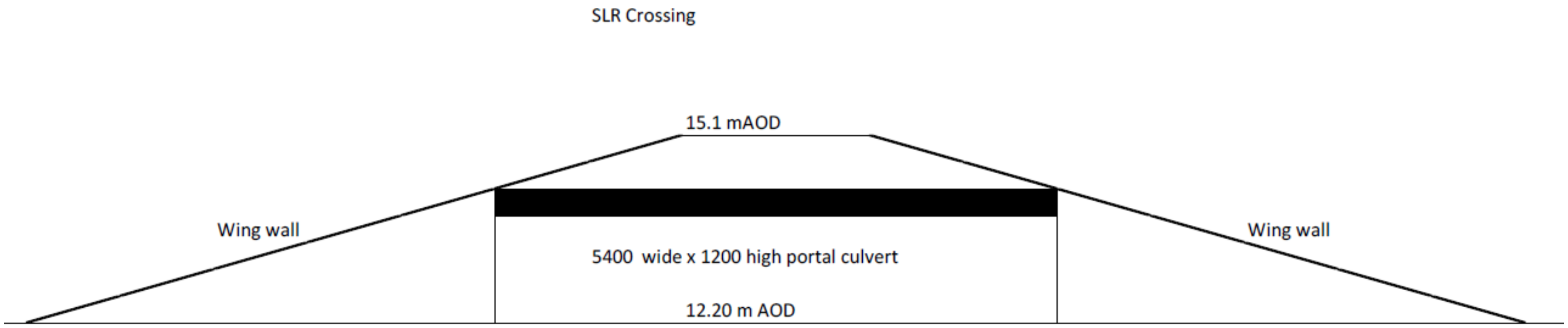
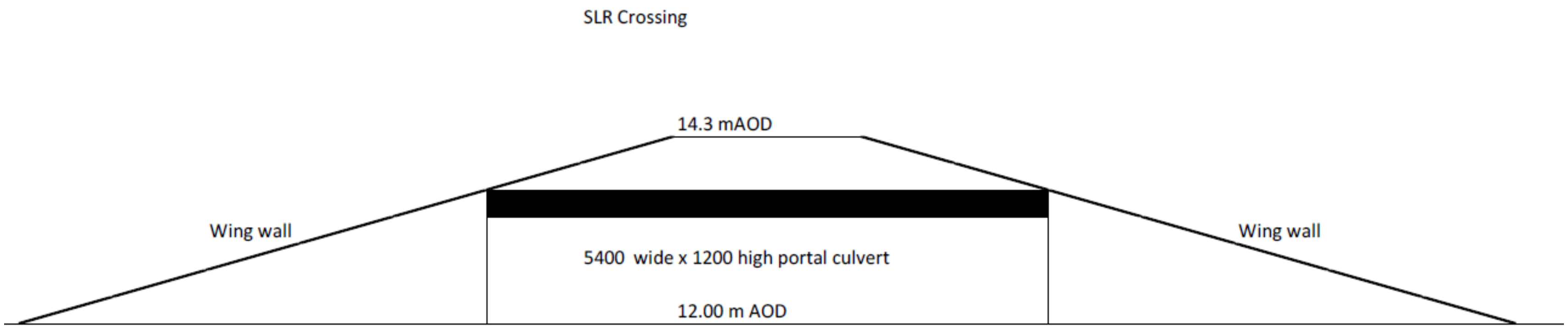


Plate 2.12. Proposed layout at crossing SW6.



2.1.23. Initial model testing revealed that at crossings SW1 and SW3 during high-flow events the existing roads, Fordley Road and Hawthorn Road respectively, act as flow paths. In order to help alleviate high flows, additional flood relief culverts were added alongside the portal culverts. These are designed standard box culverts, 2.4m wide and 1m high. There are no mammal ledges included within those box culverts as dry passage would be provided through the bigger, more open portal culverts and natural material lined bank ledges.

2.1.24. Since there are two portal culverts proposed at crossing SW3 (at the link road and the Hawthorn Road), two flood relief box culverts were also included, one alongside each of the portal culverts.

3 Methodology

3.1 Overview

3.1.1. To inform the FRA, hydraulic models were developed using industry standard hydraulic modelling software Flood Modeller Pro.

3.1.2. As each of the crossings would only introduce localised changes, a simplified approach was adopted whereby a relatively small 1D model was constructed for each watercourse with a crossing to allow assessment of the relative hydraulic performance of the design and determine the impact of the development on flood risk.

3.1.3. For all watercourses with crossings at Sizewell link road, relevant catchment information was obtained from the Centre for Ecology and Hydrology (CEH) Flood Estimation Handbook (FEH) web service (**Ref 2**) and used to derive flow hydrographs for input into the model, further details are discussed in **section 3.2**.

3.1.4. To construct the baseline model, cross-section survey data was used, where available, and supplemented with LiDAR data as required to create extended cross sections upstream and downstream. The baseline model was then amended to represent the link road design (as described in **section 2**) and derive the comparative results required for the assessment. Details related to the model development are discussed in **section 3.3**.

3.2 Hydrology

3.2.1. To derive the flow hydrographs, for use within the hydraulic model, catchment descriptors were first obtained from the CEH FEH web service (Ref 2) for each of the defined catchments, as presented in **Figure 1** attached to this report. All of these are relatively small in nature and collect water from the primarily undeveloped upper catchment.

3.2.2. The downloaded FEH catchment outlines were compared with the latest available Environment Agency 1m resolution LiDAR elevation data and it was identified that the FEH catchments did not realistically capture the catchment areas in relation to each crossing location. Each catchment outline was therefore manually reviewed and modified based upon the LiDAR data to correctly capture the catchment extents.

3.2.3. Although crossings SW4 and SW7 were not subsequently included within the hydraulic modelling, a hydrological boundary was derived for all seven initially identified crossings. Crossings SW4 and SW5 are located on the same watercourse, with SW5 located approximately 250m upstream of SW4, and therefore the same derived flow hydrograph was used for both locations.

3.2.4. **Table 3.1** presents the obtained key catchment descriptors for the six identified sub-catchments. All of these are relatively small in nature and a review of the catchment descriptors was carried out to ensure they were representative of the sub-catchment.

3.2.5. For the catchment at crossing SW2, FEH was not able to generate catchment descriptor information due to the small size of the catchment and size of the watercourse itself (this watercourse is a small tributary to main river at crossing SW1). Therefore, descriptors for the catchment at crossing SW3 were adopted as the most hydrologically similar with area adjusted for catchment SW2. The area for the SW2 catchment was based on an assessment of LiDAR and the boundaries of the adjacent catchments, with the resulting area taken as $0.25km^2$.

Table 3.1. Obtained catchment descriptors.

Area	SW1	SW3	SW4/SW5	SW6	SW7
AREA	2.935	1.1275	0.74	0.97	0.54
ALTBAR	28	22	19	22	16
ASPBAR	81	71	58	71	34
ASPVAR	0.48	0.51	0.52	0.49	0.76
BFIHOST	0.327	0.456	0.551	0.483	0.608
DPLBAR	1.59	1.1	1.1	1.11	0.75
DPSBAR	22.4	16.7	17	9.8	14.2
FARL	1	1	1	1	1
FPEXT	0.043	0.118	0.172	0.227	0.107
FPDBAR	0.252	0.47	0.659	0.858	0.361
FPLOC	1.055	0.915	1.054	0.995	0.513

Area	SW1	SW3	SW4/SW5	SW6	SW7
LDP	3.09	2.52	2.56	2.02	1.59
PROPWET	0.26	0.26	0.26	0.26	0.26
SAAR	595	597	598	596	596
SAAR4170	600	600	599	600	599
SPRHOST	43.83	39.03	33.39	36.08	31.29
URBEXT1990	0	0	0	0	0
URBEXT2000	0	0	0.0017	0	0

3.2.6. A review of the catchment characteristics was carried out for each of the catchments to understand the similarity between catchments and to ensure that the descriptors are representative.

3.2.7. The area value for each catchment was modified to the area of the updated catchment outlines from LiDAR, as previously discussed. Urban Extent (URBEXT) values were checked to ensure the descriptors accurately captured the rural characteristic of each catchment. FARL values were also checked to ensure the descriptors captured the lack of water storage within each catchment.

3.2.8. A summary of the contributing catchment characteristics for each of the crossings is set out in **Table 3.2**. With the exception of the catchment at crossing SW1, the other catchments are relatively long and narrow. All of the catchments are predominantly rural and collect water mostly from agricultural land.

Table 3.2: Summary of catchment characteristics.

Crossing	Catchment Summary
SW1	Collects water primarily from agricultural land. Upper catchment is intersected by the Ipswich to Lowestoft railway line (East Suffolk Line). Watercourse flows adjacent to a number of buildings / residences at Littlemoor Road / Fordley Road. In the lower parts of the catchment the watercourse flows to the north and adjacent to Fordley Road. Watercourse passes under Littlemoor Road approximately 500m upstream of the B1122.
SW2	Small catchment located between the catchments for SW1 and SW3. Catchment area derived from LiDAR. Catchment contains no properties. Land use is agricultural / rural only.
SW3	Collects water primarily from agricultural land. There are a number of farm buildings and residences within the catchment.

Crossing	Catchment Summary
	Watercourse is primarily adjacent to field boundaries prior to Hawthorn Road. At Hawthorn Road the watercourse flows to the north and adjacent to the road. Watercourse passes under Hawthorn Road approximately 100m upstream of the proposed crossing location.
SW4	Crossing is located in the same catchment as SW5. Approximately 250m downstream of SW5. Intervening area between SW5 and SW4 is solely agricultural land
SW5	Crossing is located in the same catchment as SW4. Land use is primarily agricultural / rural land. Some areas of woodland adjacent to the watercourse. Southern boundary of catchment defined by Pretty Road.
SW6	Upper catchment includes areas of woodland. Limited buildings / residences present within the catchment. Two watercourses combine to become one watercourse draining towards Theberton.
SW7	Collects water primarily from agricultural land. There are some buildings in the lower catchment but none in the upper catchment. Watercourse is primarily adjacent to field boundaries. Watercourse passes under a road approximately 300m upstream of the B1122.

3.2.9. When selecting hydrological methods, it is important to note that the FEH Rainfall-Runoff method has largely been superseded by the Revitalised Flood Hydrograph (ReFH) method, and subsequently the Revitalised Flood Hydrograph Version 2.2 (ReFH2). Guidance from the Environment Agency (Ref 3) on the application of the FEH Rainfall-Runoff method indicates that for the catchments in this study it would not warrant the application of the FEH Rainfall-Runoff method over the updated ReFH methods.

3.2.10. Two hydrological approaches were assessed for comparison and their suitability for the derivation of flows and accompanying flood hydrographs for each of the catchments. Initial flow hydrographs were derived based on the ReFH model and the ReFH2 model in line with the Environment Agency guidance for peak flow estimation (Ref 3). A summary of the derived 1 in 100-year peak flows for each catchment, using the ReFH and ReFH2 methods is provided in **Table 3.3**.

Table 3.3: 1 in 100-year peak flow comparison using ReFH and ReFH2

Crossing	ReFH (m^3/s)	ReFH2 (m^3/s)
SW1	2.60	3.68

Crossing	ReFH (m^3/s)	ReFH2 (m^3/s)
SW2	0.19	0.21
SW3	0.81	0.90
SW4	0.59	0.60
SW5	0.59	0.60
SW6	0.63	0.68
SW7	0.44	0.42

3.2.11. Results from each of the methods are comparable for most of the catchments, with the greatest variation observed for SW1.

3.2.12. The descriptors for each of the catchments are applicable for both the ReFH and the ReFH2 methods. Based on current guidance from the Environment Agency the ReFH2 method was used in this study based on the BFIHOST, URBEXT, PROPWET values, critical storm duration and size of catchment as well as the revised underlying equations which concluded that ReFH2 is suitable for rural settings, where the use of an “Alpha factor” effectively reduces initial soil moisture for the more extreme rainfall events, thus reducing runoff volume and peak flow simulated in the model (Ref 4).

3.2.13. In addition, as can be seen in **Table 3.3**, by applying the ReFH2 method within the study a conservative approach has been taken with regard to the use of the maximum peak flow hydrographs and, as a result, the potential maximum impact of the proposed development.

3.2.14. For the hydraulic modelling, four return period events were considered, namely 1 in 5-year, 1 in 20-year, 1 in 100-year and 1 in 1,000-year. For each of the catchments the critical storm duration was calculated based on the 1 in 100-year event using ReFH2, as considered most relevant for the study. Derived storm durations and peak flows for the considered return period events are presented in **Table 3.4**.

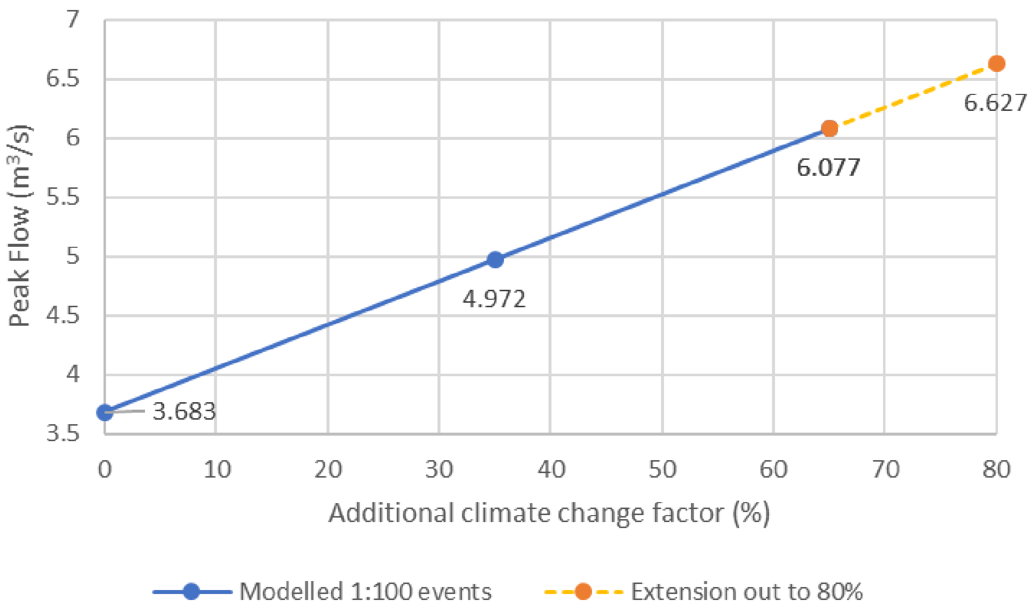
Table 3.4: Catchment area, critical duration, and peak flow

Catchment	Area (km^2)	Return Period (years)	Critical Storm Duration (hours)	Peak Flow (m^3/s)
SW1	2.89	5	9.5	1.61
		20		2.29
		100		3.68
		1,000		6.67
SW2	0.25	5	10.5	0.09
		20		0.13
		100		0.21
		1,000		0.39
SW3	1.05	5	11.5	0.38

Catchment	Area (km^2)	Return Period (years)	Critical Storm Duration (hours)	Peak Flow (m^3/s)
		20		0.54
		100		0.90
		1,000		1.65
SW4 / SW5	1.00	5	12.5	0.25
		20		0.35
		100		0.60
		1,000		1.11
SW6	0.98	5	12.5	0.29
		20		0.41
		100		0.68
		1,000		1.26
SW7	0.81	5	10.5	0.18
		20		0.25
		100		0.42
		1,000		0.81

3.2.15. In order to demonstrate that all eventualities were considered for the hydrology, **Plate 3.1** shows that the peak flow at catchment SW1 for the 1 in 100-year event with 80% climate change allowance has lower peak than the 1 in 1,000-year event. This allows confidence in using the 1 in 1,000-year event to examine the worst-case scenario.

Plate 3.1. Extension of 1:100-year climate change events out to 80%.



3.2.16. Further review of the sensitivity of the modelling to the hydrology has been carried out by assessing a 20% increase in flow. Results of that sensitivity are presented in **section 7.2** of this report.

3.3 Model build

3.3.1. To construct the models for each of the crossings and respective catchments, a topographical cross-section survey (Ref 5) was used. Only one cross-section at each proposed crossing location was surveyed. Due to access restrictions, surveying was not undertaken at crossing SW5. At this location LiDAR data was used instead.

3.3.2. The latest available 1m resolution LiDAR data was obtained from the Environment Agency Open Source Data Portal (Ref 6). This data was used to derive extended cross-sections upstream and downstream of the proposed crossing locations to enable sufficient number of cross-sections and lengths of the river channel within the simplified hydraulic models.

3.3.3. A review of the cross-sections obtained from the LiDAR data and compared to the surveyed cross section was carried out to ensure that cross sections within the hydraulic model were as representative as possible.

3.3.4. Due to the limited LiDAR resolution considering size of the channel of the watercourses, some details of the channels and banks were not captured by the LiDAR data. As a result of the review the cross-sections were adjusted, with priority given to the information from the surveyed cross-section, where possible. Therefore, at some of the crossings the downstream LiDAR data was adjusted to ensure that it reasonably matched the levels within the surveyed channel cross-sections and the slope of the bed of the watercourse along the length of the model. Details of these changes have been included as comments within the respective Flood Modeller Pro 1D model nodes.

3.3.5. The cross-section levels from the LiDAR data were found to generally have a varied representation of the channel and bed levels when compared to the survey. This error was up to 1m difference as illustrated in **Plate 3.2** and **Plate 3.3** for cross-sections at crossings SW1 and SW2 respectively.

3.3.6. To determine potential impact of variations in the cross-sections geometry on the model results and the overall conclusions on changes in flood risk due to proposed Sizewell link road, sensitivity testing was carried out and is further discussed in **section 7.3**.

3.3.7. Note that outputs on the following pages may refer to Above Ordnance Datum (AOD) as “AD” or “AoD”, due to default settings in the software.

Plate 3.2. Comparison between the LiDAR and Surveyed cross-section at crossing SW1

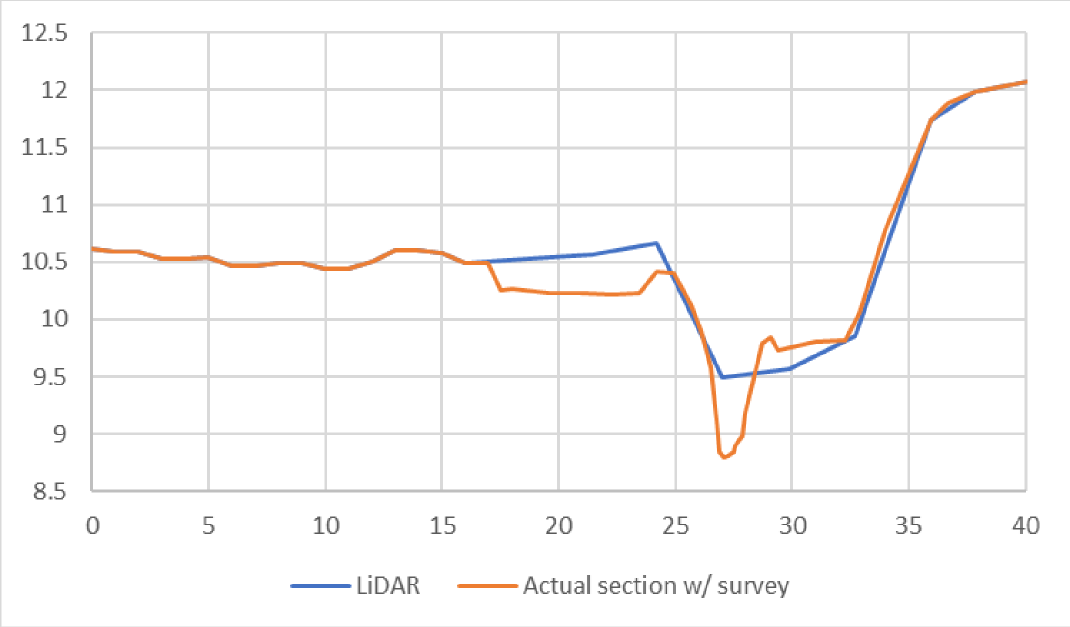
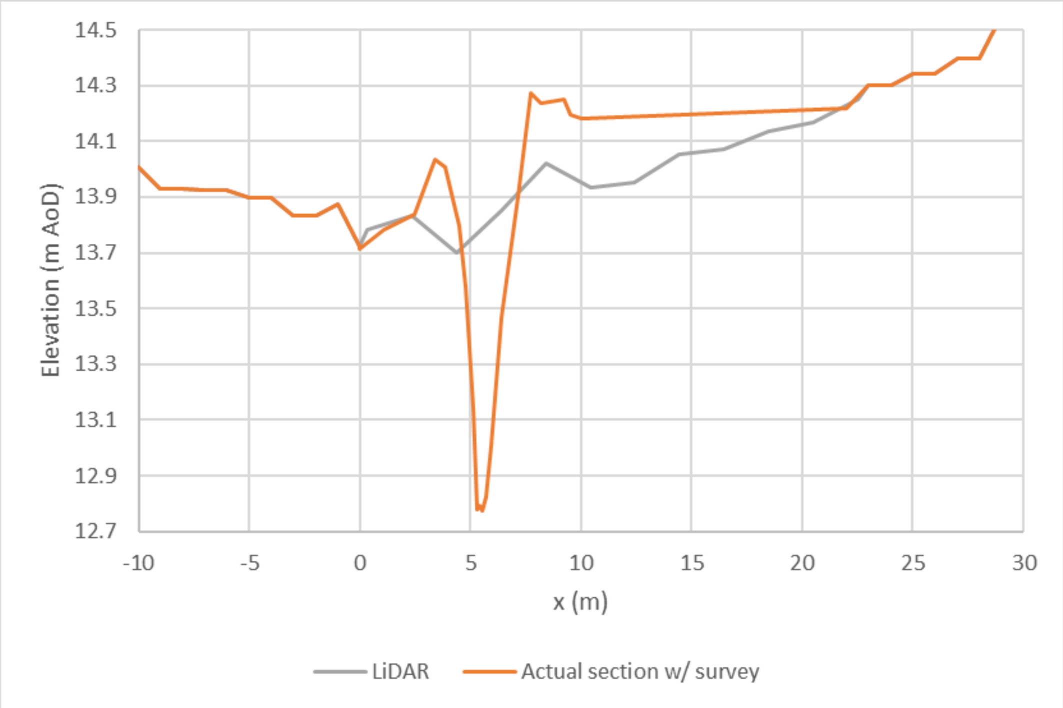


Plate 3.3. Comparison between the LiDAR and Surveyed cross-section at crossing SW2



3.3.8. For the purpose of this flood risk assessment, the derived cross-sections were applied in both the baseline and 'with scheme' model schematisations and therefore the relative change in water levels, as a result of the proposed development at each of the crossing locations has been assessed.

3.3.9. For the 'with scheme' scenario, for each of the reaches the crossing was represented as per the details of the design options described in **section 2**. Since both the model cross-sections and the design levels are based on limited surveyed data and LiDAR topography, there are some small discrepancies in the assumed bank levels. In such cases, for consistency, the levels obtained and used in the baseline model were retained, whilst keeping the principles of the design.

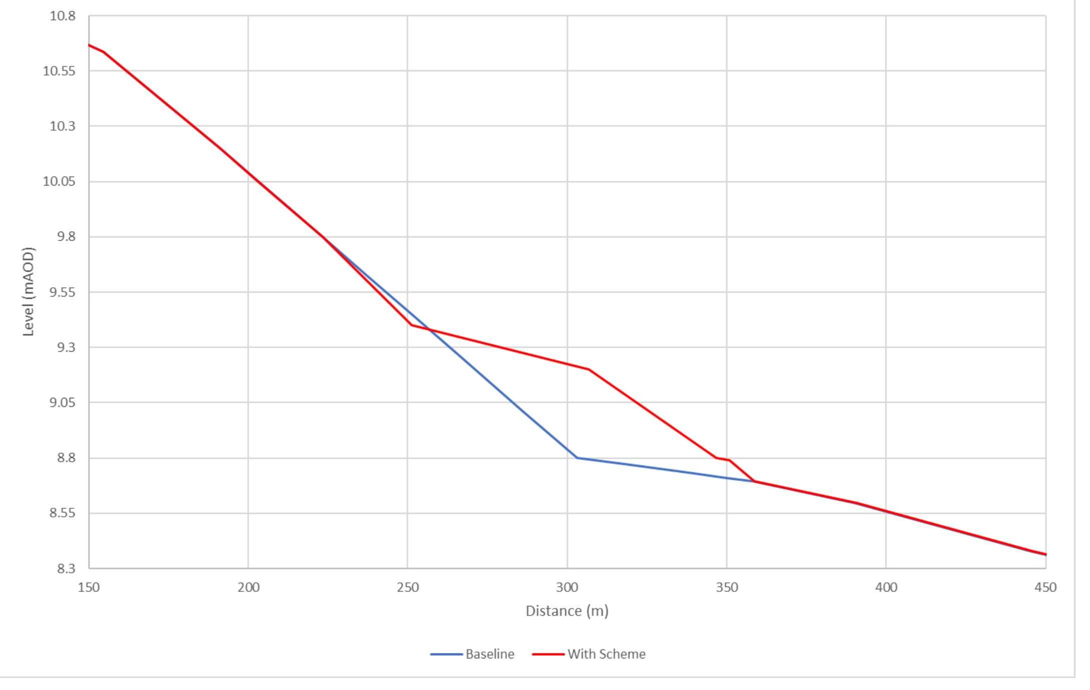
3.3.10. As discussed in **section 2**, the initial design was updated to improve overall hydraulic performance and alleviate flood risk. The flood relief culverts were added at crossings SW1 and SW3 (including the Hawthorn Road connection road crossing). These were placed adjacent to the portal culverts with the invert level set to the road level to mimic baseline flooding mechanism and ensure its effectiveness in high flow conveyance.

3.3.11. Additionally, the design update moved the connection road culvert on the Hawthorn Road closer to the link road in comparison to the initial placement. Due to lack of more detailed data, the new culvert bed levels were applied using the gradient derived for the baseline model.

3.3.12. The revised design for crossing SW1 and connection at Fordley road includes a diverted section of the river channel which bypasses the connection road from Fordley Road to the new link road thereby avoiding the need for a second crossing. The re-aligned channel would be set at a higher ground levels than the original watercourse and therefore, the long-section gradient would be slightly different (**Plate 3.4** chainage between approximately 250m and 360m).

3.3.13. As presented in **Plate 3.4**, in the 'with Scheme' model schematisation the diversion of the channel results in flattening of gradient. This then would result in a steeper gradient within the culvert itself. At the downstream end of the culvert the fairly steep portion in the graph is simply an artefact of condensing the extra chainage (where the proposed new channel re-joins the existing channel) in a shorter distance in order to display both Baseline and 'with scheme' schematisations on the same graph.

Plate 3.4. Comparison of long-section slope at crossing SW1 between the baseline and 'with Scheme' model schematisations.



3.3.14. The surveyed cross-section at crossing SW1 is not directly comparable to the design option with the diverted channel. Bed levels have been set according to the final issued design. Adjustment to the design had to be made in order to ensure that the model is hydraulically stable. This is detailed in **section 2**.

3.3.15. It is acknowledged that the cross sections and bank levels used within the hydraulic models have limitations. These would be reviewed and refined further during the detailed design stage of the Sizewell C project

3.4 Model scenarios

3.4.1. The hydraulic model has been used to assess the relative change as a result of the proposed development and therefore provide an understanding of the suitability of the proposed design in terms of flood risk to the proposed scheme itself as well as the impact on flood risk to any off-site receptors upstream or downstream of the crossings.

3.4.2. For that purpose, two model scenarios were considered as follows:

- **Baseline**: pre-development / existing ground levels; and
- **'With scheme'**: post implementation of the portal culverts, box culverts and channel diversions as described in the design details (**section 2**).

3.4.3. These two model schematisations were run for the three return period events as presented in **section 3.2**. In addition, future climate change scenarios were assessed. Details on the adopted climate change allowances are discussed in **section 4.2**.

4 Boundary Conditions

4.1 Fluvial flows

4.1.1. The 1D hydraulic models developed for this FRA study required two boundary conditions to be defined, i.e. the upstream boundary that specifies flow in the watercourse and downstream boundary that drives the flow-stage relationship.

4.1.2. For the upstream inflow boundary conditions, the derived flow hydrographs were used in accordance with the methodology discussed in **section 3.2**. Flow hydrographs for the modelled catchments for the 1 in 100-year return period event are presented in **Plate 4.1.**

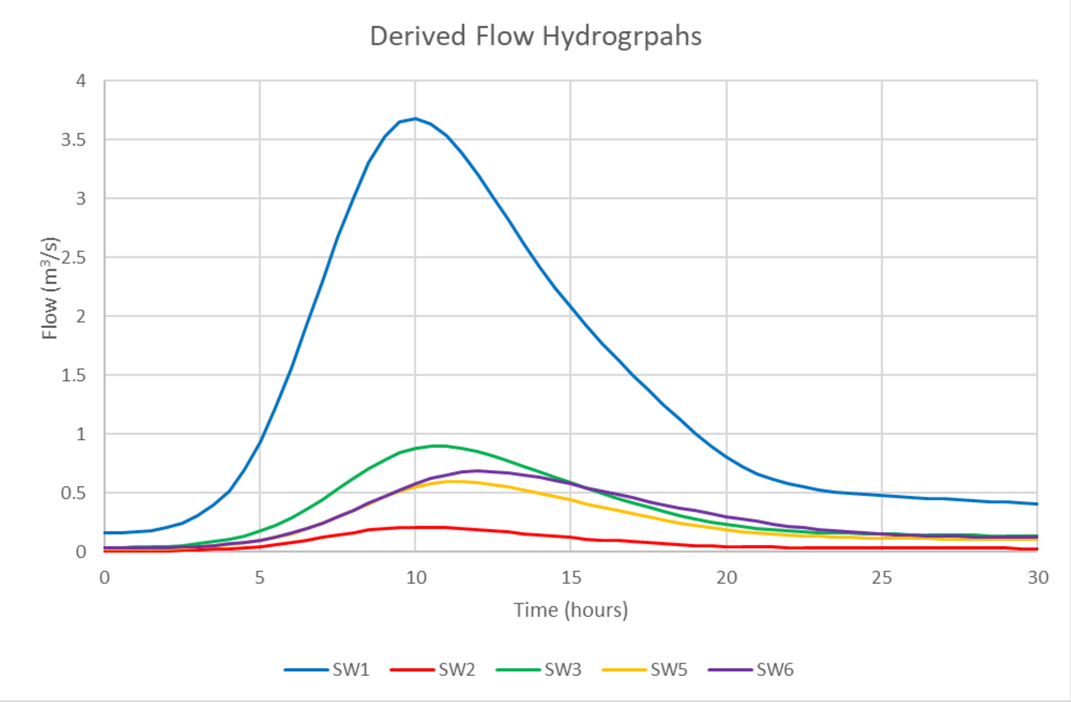
4.1.3. Each model reach has a Flow/Time boundary linked to the appropriate flow timeseries for the considered events that were defined in the ied event files.

4.1.4. The downstream boundary of each model reach was defined as a Normal Depth boundary. This was due to the lack of any stage or flow data close to the model boundary. This was considered appropriate given the overall simplified approach adopted in this modelling exercise.

4.1.5. In order to improve model stability, the first several hours of flow hydrographs for models SW1, SW2, SW5, and SW6 have an increased sweetening flow. This is significantly below peak flow and doesn't impact the final model results.

4.1.6. Initial conditions were generated using a steady state direct method within the 1D Flood Modeller Pro simulation.

Plate 4.1. Derived flow hydrograph for the 1 in 100-year return period event for each of the modelled catchments.



4.2 Climate change

4.2.1. For the purpose of this Sizewell link road modelling study it was assumed that the construction period would commence in 2022 and would last for 2 years, and that the design life of the link road would be 100-years. Considering a simplified modelling approach with limited data availability was adopted, the climate change allowances were assessed only for the more conservative end of the development lifetime scenario, i.e. up to 2124 epoch.

4.2.2. In line with the Environment Agency guidance (Ref 7) allowances for increase in fluvial flows were considered for the Higher Central and Upper End scenarios for the Anglian river basin district. The adopted allowances for the end of the development lifetime epoch comprise a 35% and 65% increase in fluvial flow for the two scenarios respectively.

4.2.3. No further extrapolation was applied for the epoch beyond 2115 as advised in the Environment Agency guidance for flood risk management authorities (Ref 8). Climate change epochs were only assessed for the 1 in 100-year return period event as considered most relevant to the study.

4.2.4. The 1 in 100-year return period with 65% climate change allowance was considered as the basis of design scenarios, whereas the 1 in 100-year return period with 35% climate change allowance was assessed for used to assess any potential off-site impact on flood risk as a result of the proposed road scheme. This was agreed with the Environment Agency.

4.2.5. The two climate change scenarios were generated by applying a scaling factor of 1.35 and 1.65 to the 1 in 100-year ReFH2 model unit at each upstream model boundary, for the 35% and 65% uplift for climate change scenarios respectively.

5 Model parameters and stability

5.1 Run parameters

5.1.1. All simulations were run using Flood Modeller version 4.4.6. Each model was run for 18 hours, allowing sufficient time for the flood hydrograph to pass through the model.

5.1.2. Roughness coefficients of 0.04 and 0.07, were applied within the channels and floodplains respectively. These were based on relevant literature and available photographic evidence collected during the channel cross-sections survey (see **Plate 5.1**). In addition, sensitivity testing was carried out by adjusting the roughness (Mannings 'n') values used within the model by 20%. Further information related to the sensitivity testing and results is summarised in **section 7.3**.

5.1.3. Due to the relative steepness of the model, a number of alterations have been made to the default model parameters in order to improve model stability. These are as follows:

- fixed time-step of 5 seconds was applied;
- automated Preissmann slots have been enabled;
- theta coefficient has been set to 0.95 (from the default of 0.7) to boost the effectiveness of the Preissmann slots;
- dflood has been set to 5m (from the default 3m) to help the generation of suitable initial conditions.

5.1.4. All other model parameters were set to the suggested default values.

Plate 5.1. Photograph of a typical channel section.

5.2 Model stability

5.2.1. The mass balance errors for the baseline and 'with scheme' model runs are shown in **Table 5.1**. Usually a model is considered to have a good convergence if the cumulative mass balance error is within +/- 1%.

Table 5.1. Mass balance error (%) for the baseline and 'with scheme' model runs for all considered scenarios.

Return period	Baseline	'With scheme' – portal culvert only	'With scheme' – portal and flood relief culvert
5-year	-1.48	-0.09	-1.46
20-year	-1.47	-2.74	-1.78
100-year	-2.05	-2.75	-1.7
100-year + 35%CC	-1.57	-1.75	-0.48
100-year + 65%CC	-1.92	-1.52	-0.42

Return period	Baseline	'With scheme' – portal culvert only	'With scheme' – portal and flood relief culvert
1,000-year	-1.89	-1.34	-0.39

5.2.2. It is acknowledged that the mass balance errors are relatively high, however given the fairly course resolution of the available information used to construct the channel cross-sections and the subsequent rapid inter cross-section changes, this is deemed acceptable at this stage. Following further work at the detailed design stage, the model would be revised accordingly, and mass balance errors improved.

6 Model results

6.1 Overview

6.1.1. Model outputs were assessed to determine the peak flood levels for the baseline and 'with scheme' models for all considered return period events and climate change scenarios. Also, the difference between them has been examined to determine potential impact of the proposed Sizewell link road scheme on flood risk.

6.1.2. The peak flood levels were assessed at key locations in each model reach, such as the crossing location and upstream and downstream cross-sections to determine extent of the potential impact of the crossing

6.1.3. Results for crossings SW2, SW5 and SW6 are discussed in **section 6.2.11**, whereas crossings SW1 and SW3 are presented separately in **section 6.2** and **section 6.4** respectively as these two crossings have more complex design with the connection roads and need for flood relief box culverts.

6.2 Crossing SW1 (Fordley road)

6.2.1. For the crossing SW1, due to the proposed channel diversion, results at the sections immediately upstream and downstream of the portal culvert couldn't be directly compared between the baseline and 'with scheme' scenarios as they represent a different geometry of the cross-sections and different chainages along the watercourse. Instead results for the nearest sections, upstream and downstream of the crossing, which are common in both models have been compared.

6.2.2. Results of peak water levels for crossing SW1 for all considered events are presented in **Table 6.1**. The 'with scheme' model schematisation includes both the main portal culvert and the flood relief box culvert.

Table 6.1. Modelled peak water levels for crossing SW1.

Node	Return period (years)	Baseline level (m AOD)	'With scheme' level (m AOD)	Difference in level (m)
Approx. 60m upstream of the diversion channel (SW1_378)	5	11.10	11.12	0.02
	20	11.18	11.22	0.04
	100	11.33	11.36	0.03
	100 + 35%CC	11.41	11.45	0.04
	100 + 65%CC	11.47	11.46	-0.01
	1,000	11.51	11.48	-0.03
Beginning of diversion channel (SW1_310)	5	10.29	10.36	0.07
	20	10.36	10.46	0.10
	100	10.49	10.61	0.12
	100 + 35%CC	10.58	10.71	0.13
	100 + 65%CC	10.65	10.79	0.14
	1,000	10.68	10.81	0.13
End of diversion channel (SW1_175)	5	9.54	9.54	0.00
	20	9.64	9.64	0.00
	100	9.82	9.82	0.00
	100 + 35%CC	9.89	9.89	0.00
	100 + 65%CC	9.95	9.95	0.00
	1,000	9.98	9.98	0.00

6.2.3. As mentioned at the beginning of this section, the comparison against the baseline at the culvert face is not informative at crossing SW1 due to the new channel geometry. The channel is slightly shifted north (up the valley side) which causes a raise in bed levels and subsequently a rise in bank level, which results in a deeper channel that is incised into the floodplain in order to accommodate the new watercourse alignment.

6.2.4. Maximum afflux at the model node nearest to the residential property on the right floodplain, adjacent to the Fordley road, is approximately 40mm (**Table 6.1**). This is primarily due to the change in gradient between the two model schematisations that results in different water level profile, as illustrated in **Plate 6.1** and **Plate 6.2** for the 1 in 100-year event with 35% and 65% climate change allowance respectively. The impact of change in gradient is also confirmed with the peak levels in the 'with scheme' scenario being 44mm below the baseline level at model node SW1_342 (the intermediate node between SW1_378 and SW1_310).

Plate 6.1. Comparison of peak water levels for long-section at crossing SW1 for the 1 in 100-year return period event with 35% climate change allowance

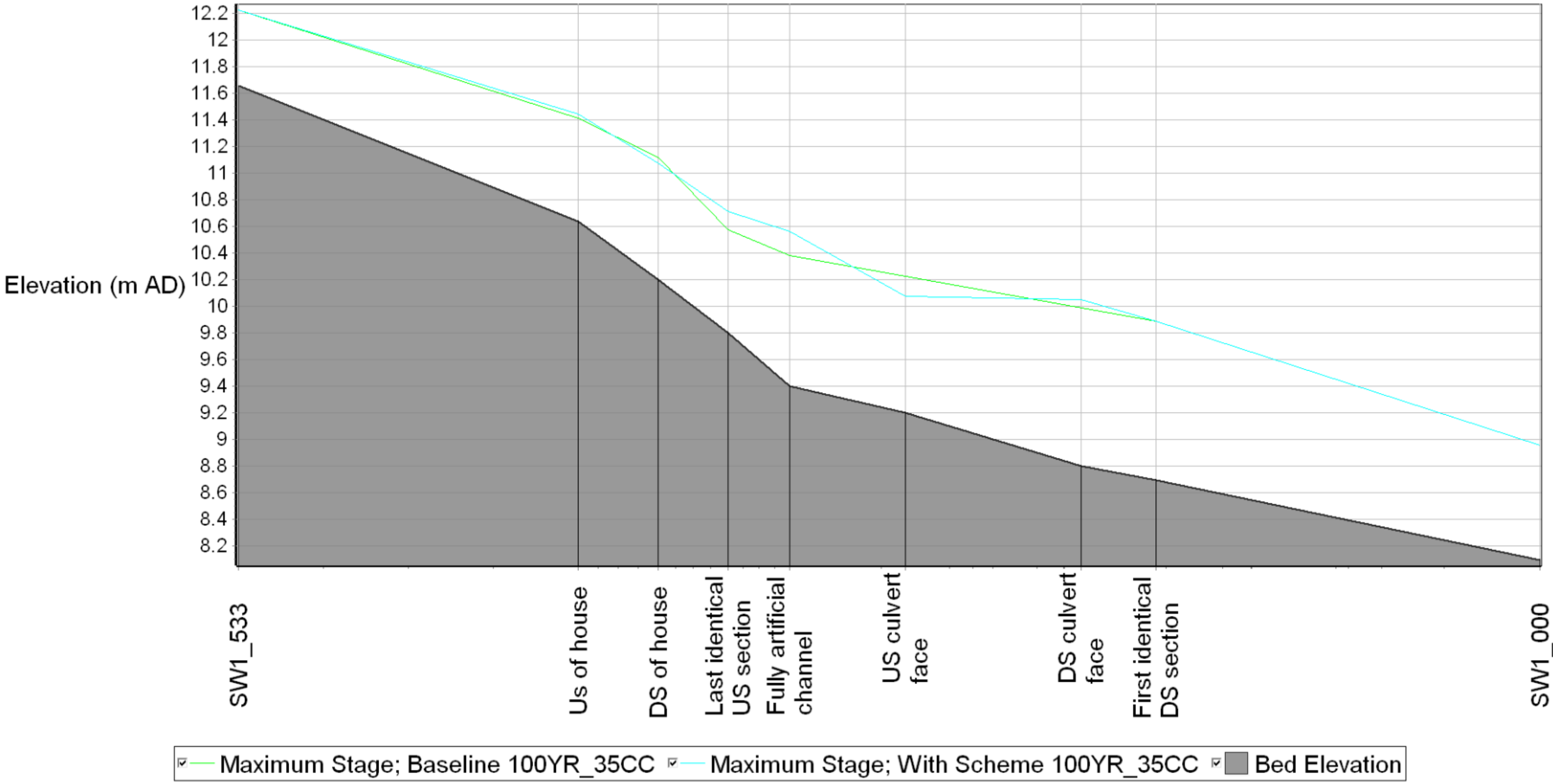
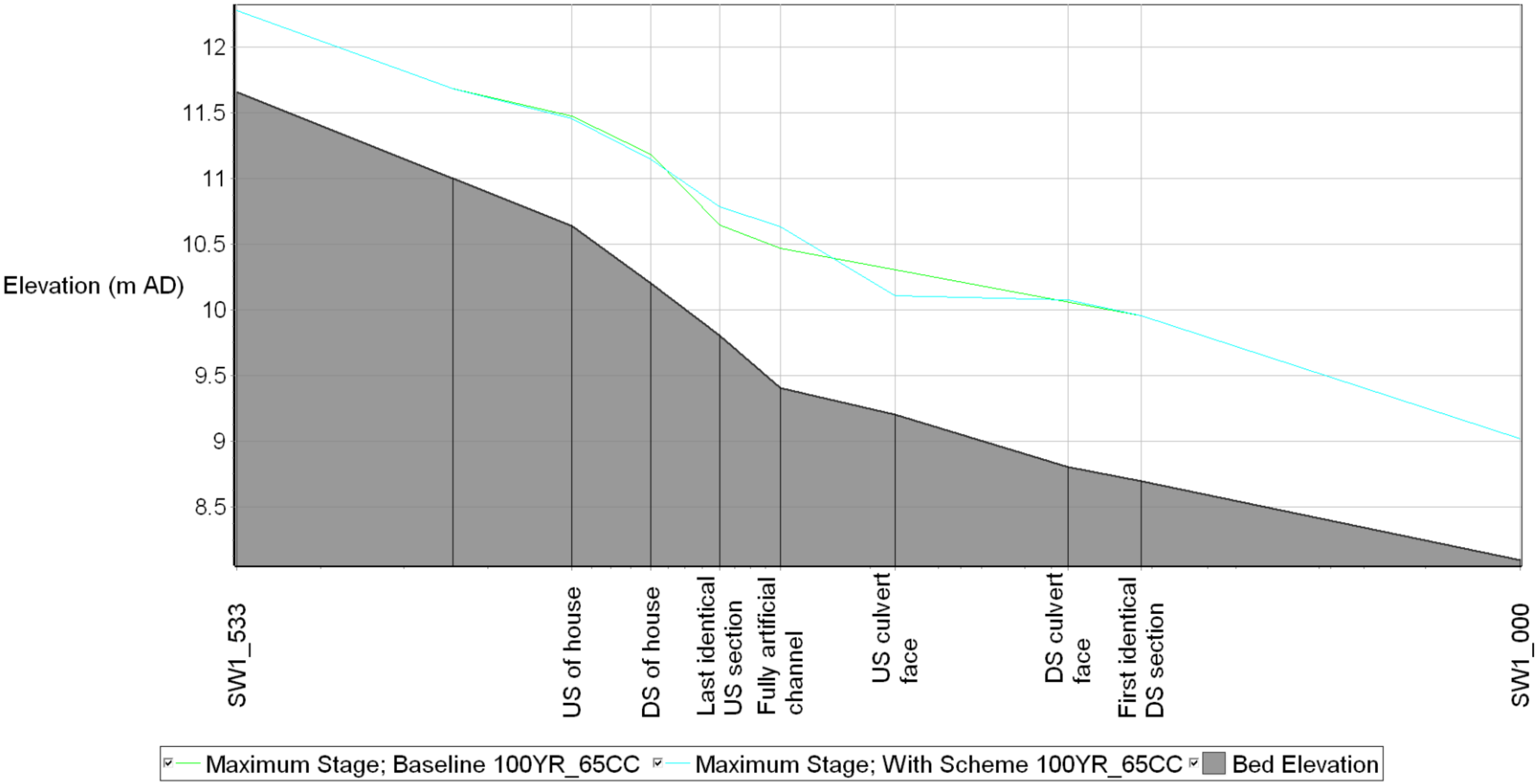


Plate 6.2. Comparison of peak water levels for long-section at crossing SW1 for the 1 in 100-year return period event with 65% climate change allowance



6.2.5. The residential property mentioned above would not be at risk of flooding in the considered scenarios as it is located on higher ground (minimum 0.5m above the right bank level) and around 10m away from the river channel (**Plate 6.3**), with the Fordley road in between the channel and the property.

6.2.6. The difference in peak level of 130mm upstream of the crossing (at the start of the diversion channel) at model node SW1_310 inundates the Fordley road itself but does not flood the fields on the left bank (**Plate 6.4**). This increase is mostly due to raised downstream bed levels as a result of the watercourse re-alignment up the valley profile.

6.2.7. Further upstream of the model node SW1_378 and downstream of the node SW1_175 where the river returns to its natural course, there is no significant difference in peak flood levels as a result of the scheme (as illustrated in **Plate 6.1** and **Plate 6.2**).

6.2.8. **Plate 6.5** shows peak water levels at the upstream face of the portal culvert and the box culvert to illustrate flood levels at the crossing itself in the 'with scheme' scenario. These results show that maximum water levels are well below the road levels and therefore do not pose risk of flooding to the crossing. Also, the water levels within the portal culvert are within the channel allowing dry mammal passage on both banks.

6.2.9. To assess the benefit of the flood relief culvert, a long-section plot for the 1 in 100-year return period event with 35% climate change allowance illustrating comparison of maximum water levels for crossing SW1 for model scenarios with and without the additional box culvert is presented in **Plate 6.6**. Results show that the flood relief box culvert reduces afflux at the crossing location by approximately 100mm, which in return lowers water levels below the bank levels within the portal culvert and also helps reduce difference in peak flood levels upstream of the crossing.

6.2.10. **Plate 6.6** also shows the short area upstream of the SW1 crossing where there is out of bank flooding (maximum water level lines are above the left and right bank elevation lines). This flooding is focused around model node SW1_282 and has a maximum extent of approximately 20 metres within the floodplain affecting only agricultural fields.

6.2.11. Overall the results for crossing SW1 show limited impact on water levels immediately upstream of the diversion channel, with very limited impact on the adjacent land, and no impact on buildings or residential properties. There is no impact downstream of the diverted channel. The final details on the alignment of the diversion channel would be confirmed during the detailed design and further hydraulic modelling may be carried out at this stage of the Sizewell C project.

Plate 6.3. Comparison of peak water levels for crossing SW1 for the 1 in 100-year event with 35%CC, 65%CC and 1 in 1,000-year event – cross-section at model node approximately 60m upstream of the diversion channel (SW1_378)

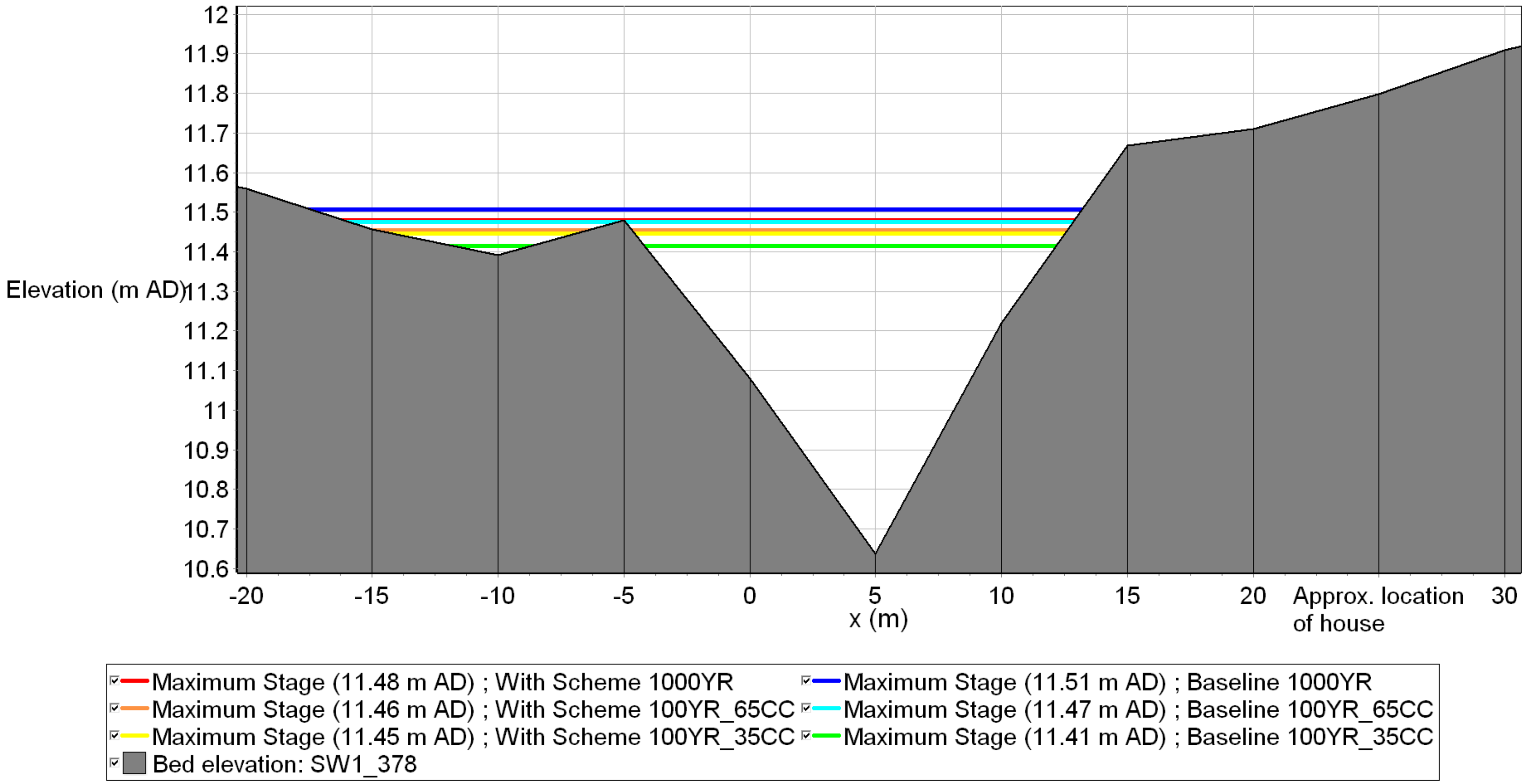


Plate 6.4. Comparison of peak water levels for crossing SW1 for the 1 in 100-year event with 35%CC, 65%CC and 1 in 1,000-year event – cross-section at beginning of the diversion channel (SW1_310)

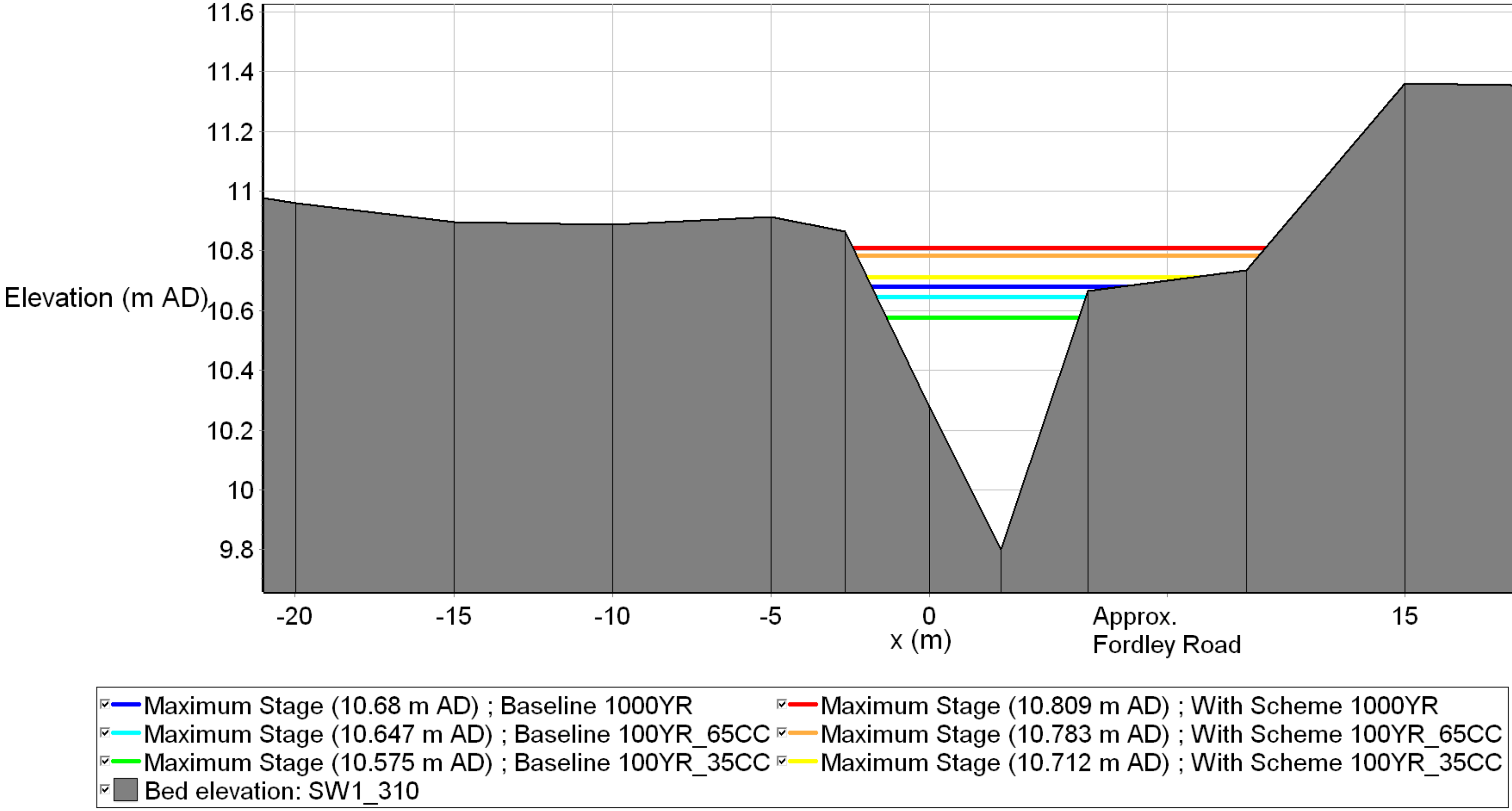


Plate 6.5. Peak water levels for crossing SW1 for the 1 in 100-year event with 35%CC, 65%CC and 1 in 1,000-year event – cross-section at entrance to the portal and box culverts (SW1_USface)

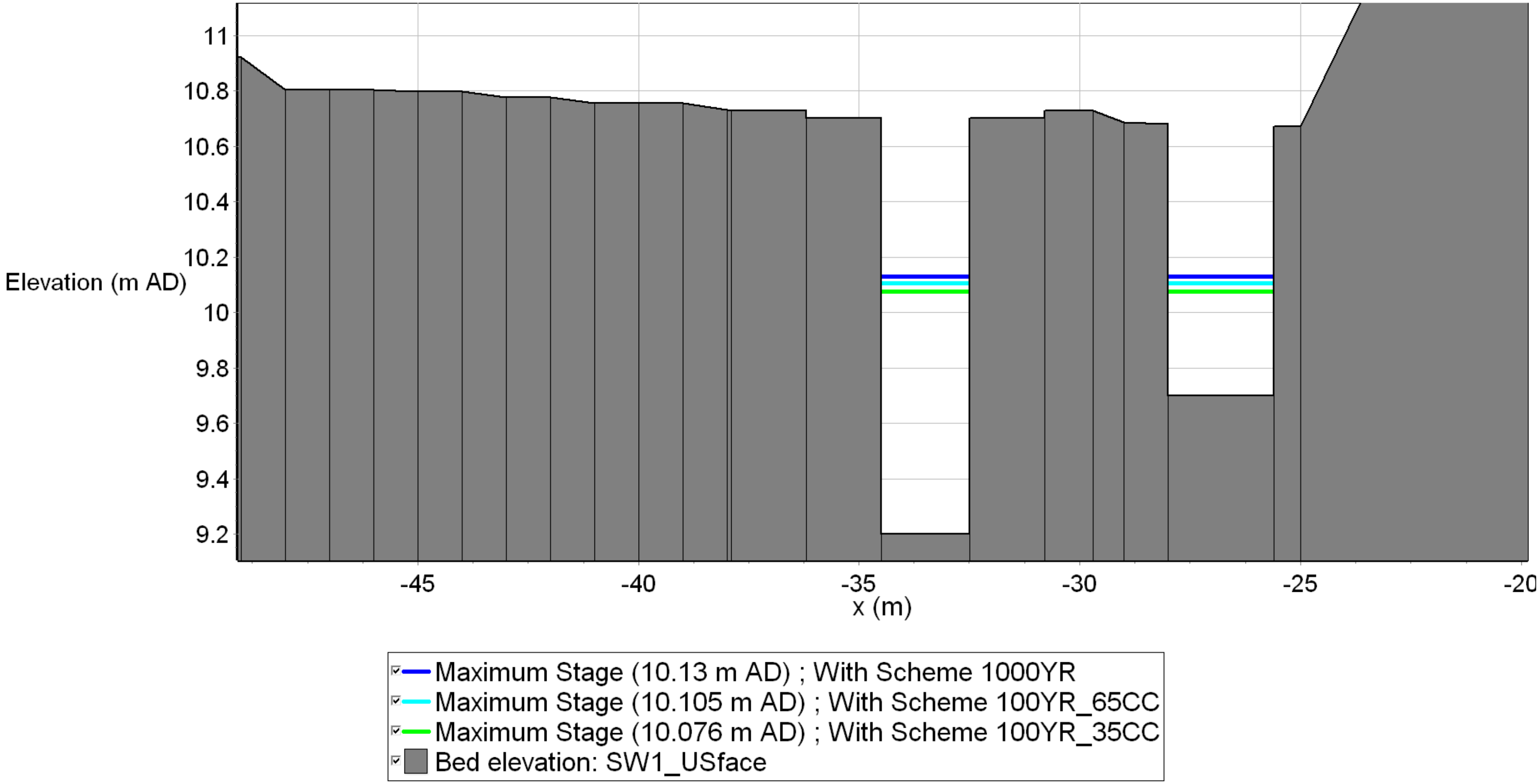
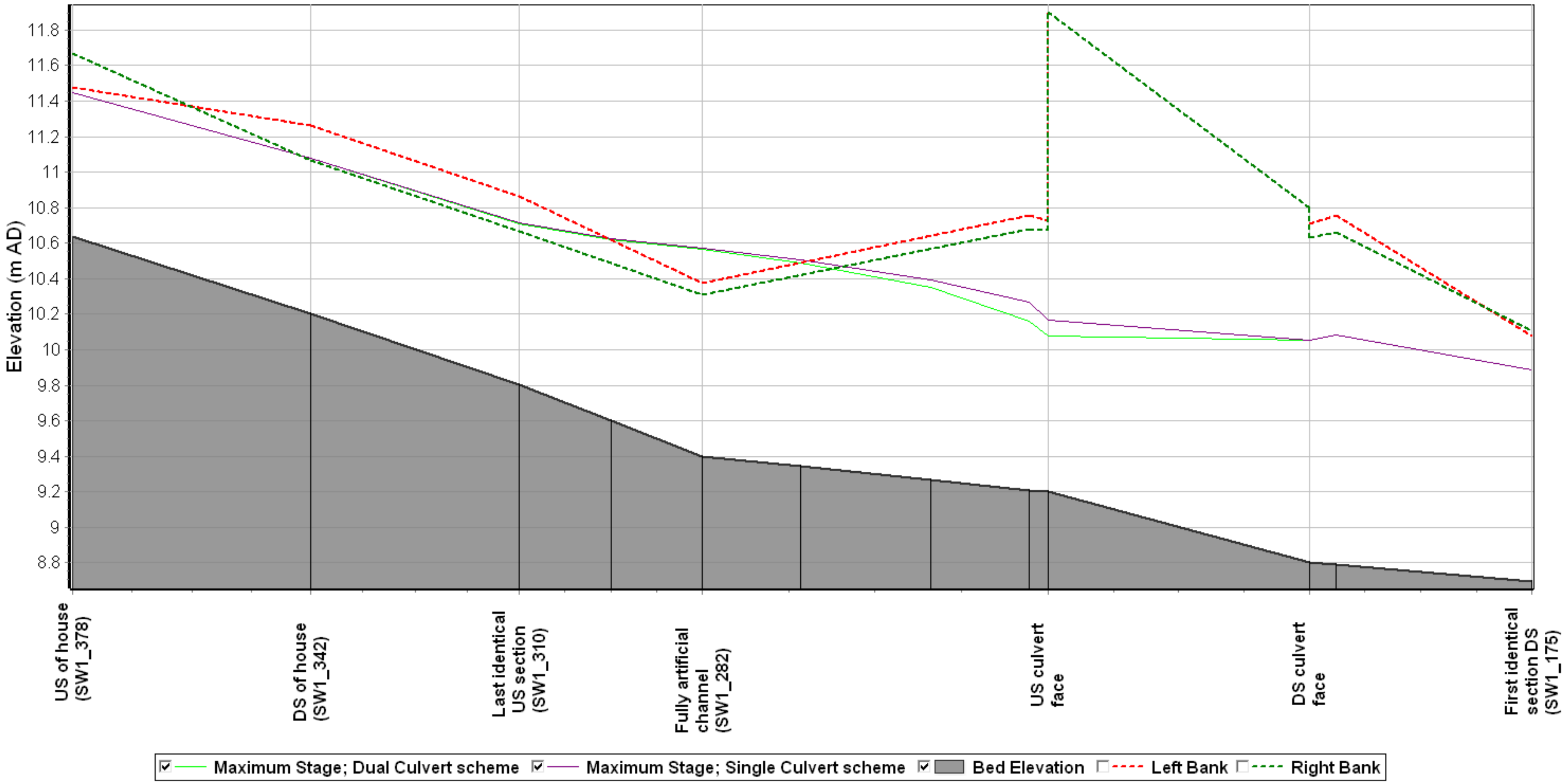


Plate 6.6. Comparison of peak water levels for long-section at crossing SW1 for 1 in 100-year return period event with 35% climate change scenario - 'with scheme' model with and without the flood relief culvert



6.3 Crossing SW2, SW5 and SW6

6.3.1. The modelled peak water levels for crossings SW2, SW5 and SW6 are presented in **Table 6.2** for the upstream and downstream faces of the proposed portal culverts with the appropriate model node labels presented.

6.3.2. Since the flood levels do not reach the bank levels at these crossing, the proposed portal culverts do not pose flow restriction, as illustrated in **Plate 6.7**, **Plate 6.8**, and **Plate 6.9** for the three crossings respectively. Also, dry mammal passage would be possible on both sides of the river channel for all three of the crossings and all considered return period events and climate change scenarios.

Table 6.2. Modelled peak water levels for crossings SW2, SW5 and SW6.

Node	Return period (years)	Baseline level (m AOD)	'With scheme' level (m AOD)	Difference in level (m)
Upstream face of SW2 culvert (SW2_177)	5	13.02	13.03	0.01
	20	13.07	13.08	0.01
	100	13.16	13.16	0.00
	100 + 35%CC	13.22	13.23	0.01
	100 + 65%CC	13.28	13.28	0.00
	1,000	13.30	13.30	0.00
Upstream face of SW5 culvert (SW5_583)	5	11.20	11.20	0.00
	20	11.22	11.23	0.01
	100	11.27	11.28	0.01
	100 + 35%CC	11.31	11.32	0.01
	100 + 65%CC	11.34	11.35	0.01
	1,000	11.37	11.37	0.00
Upstream face of SW6 culvert (SW6_110)	5	11.88	11.88	0.00
	20	11.94	11.94	0.00
	100	12.06	12.04	-0.02
	100 + 35%CC	12.12	12.11	-0.01
	100 + 65%CC	12.16	12.17	0.01
	1,000	12.19	12.19	0.00

6.3.3. The adjacent areas on both banks upstream and downstream of the SW2, SW5 and SW6 crossings are mainly agricultural land with small scattering of deciduous woodland near crossing SW5. There are no residential or non-residential properties in the vicinity of the three crossings.

6.3.4. Overall, modelling results show that crossings SW2, SW5 and SW6 would not be at risk of flooding from any of the considered return period events and climate change scenarios and they do not significantly impact flood risk to receptors or areas upstream or downstream of the proposed crossings.

Plate 6.7. Comparison of peak water levels for crossing SW2 for the 1 in 100-year event with 35%CC, 65%CC – cross-section at entrance to the portal culvert (SW2_177)

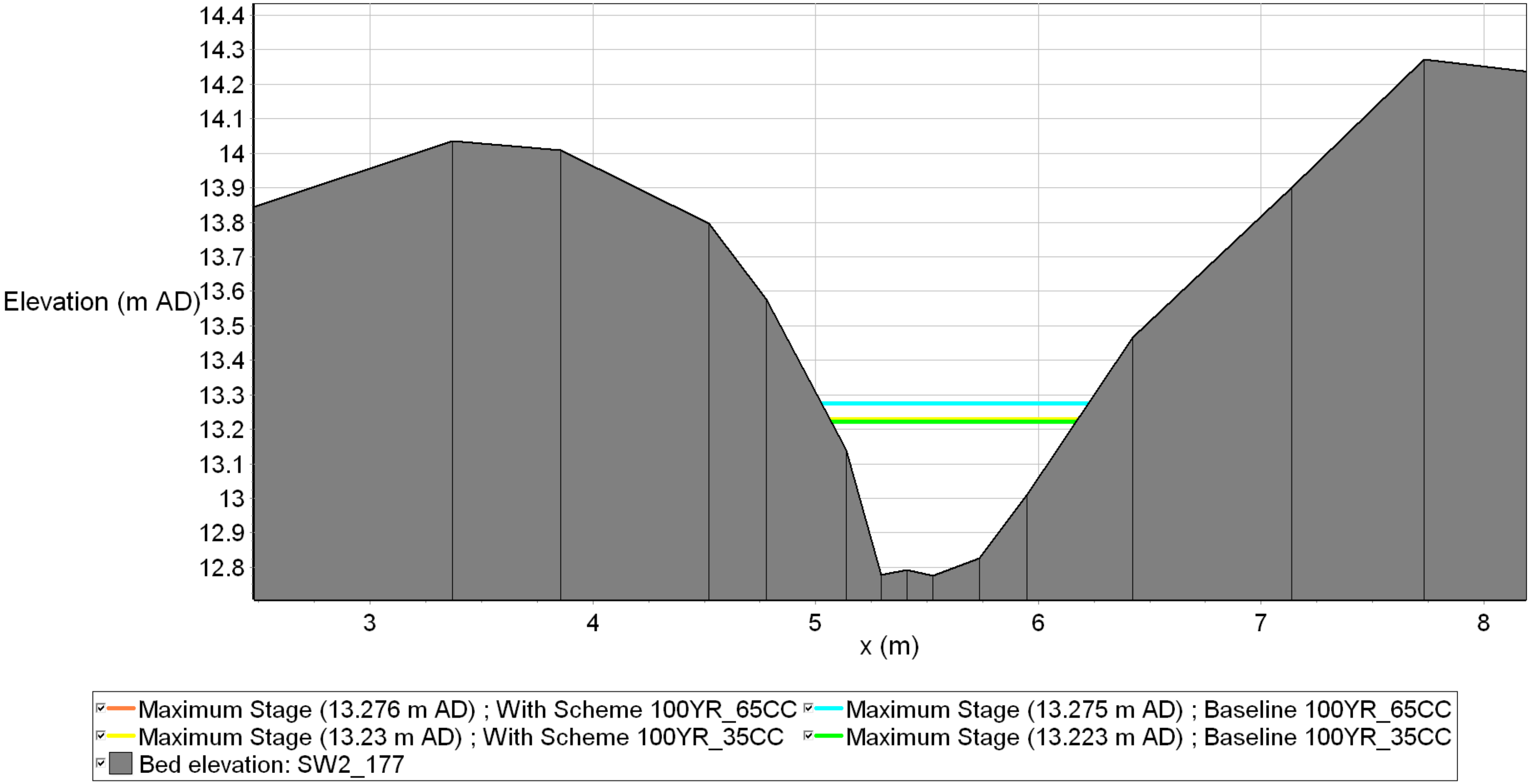


Plate 6.8. Comparison of peak water levels for crossing SW5 for the 1 in 100-year event with 35%CC, 65%CC – cross-section at entrance to the portal culvert (SW5_583)

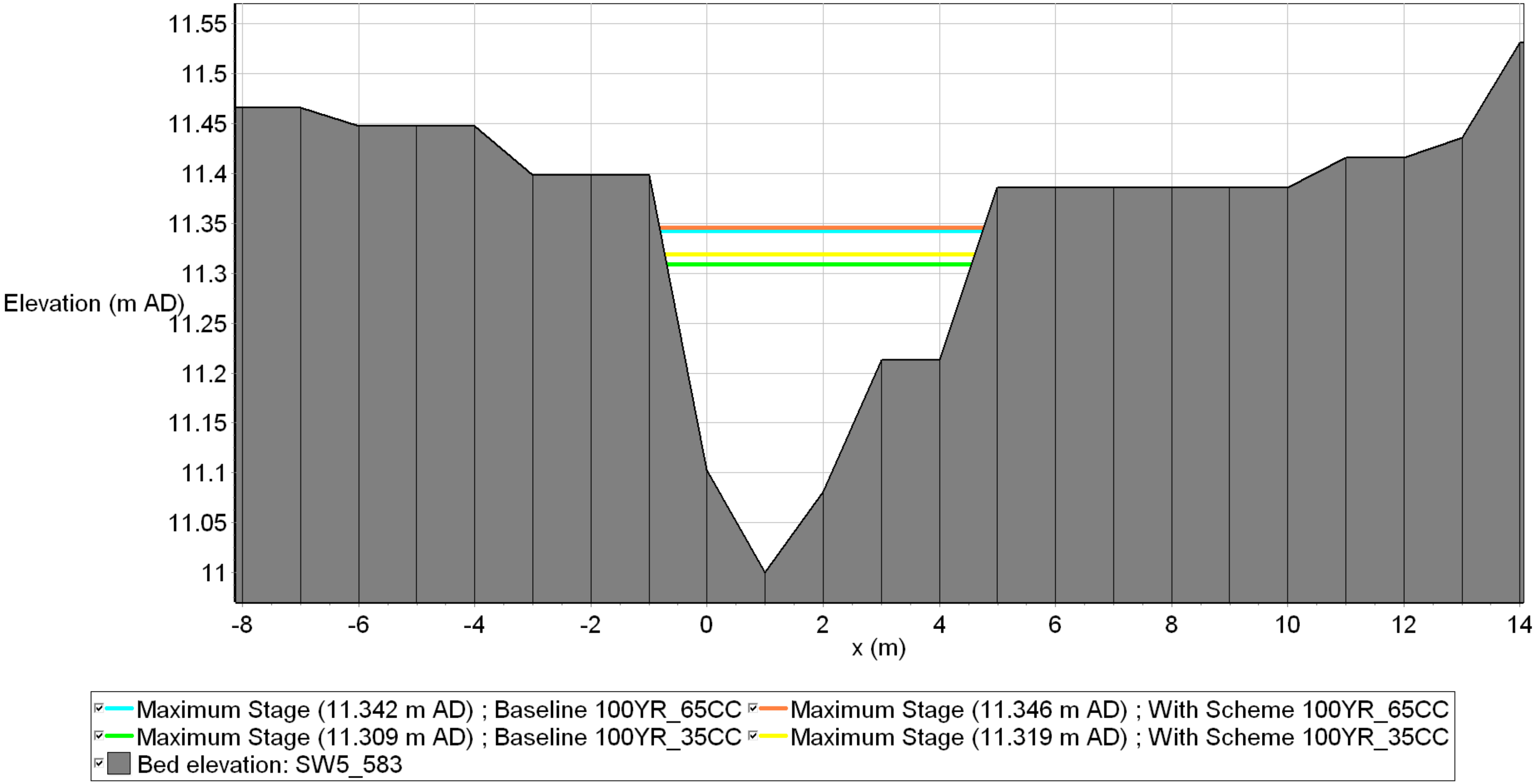
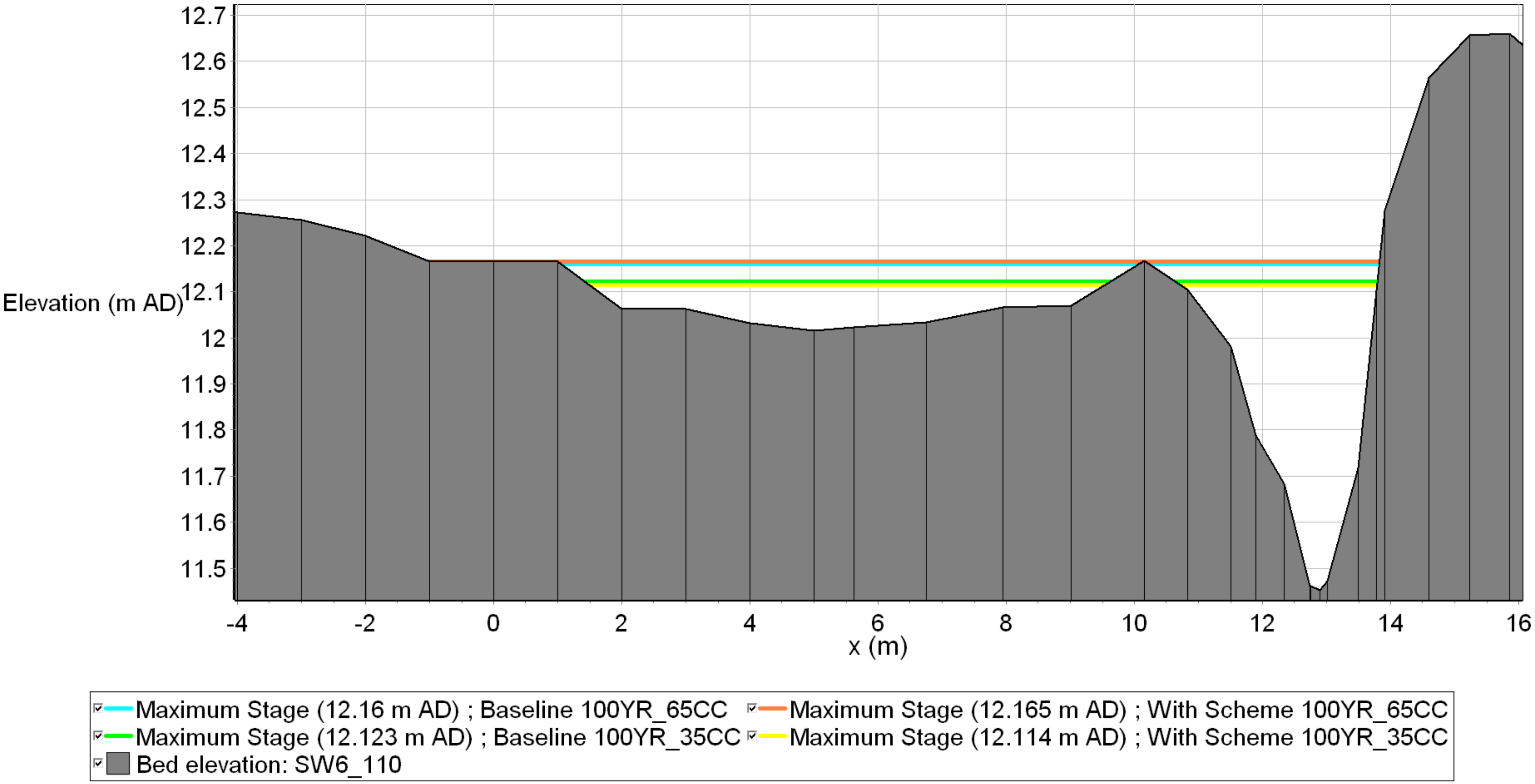


Plate 6.9. Comparison of peak water levels for crossing SW6 for the 1 in 100-year event with 35%CC, 65%CC – cross-section at entrance to the portal culvert (SW6_110)



6.4 Crossing SW3 (Hawthorn road)

6.4.1. Results of the peak water levels for crossing SW3 and the connection to Hawthorn road are presented in **Table 6.3**. The 'with scheme' model schematisation includes both the main portal culvert and the flood relief box culvert at both connection road and link road locations.

Table 6.3. Modelled peak water levels for crossing SW3.

Node	Return period (years)	Baseline level (m AOD)	'With scheme' level (m AOD)	Difference in level (m)
Upstream of Hawthorn Road portal culvert (SW3_245)	5	8.46	8.49	0.03
	20	8.55	8.54	-0.01
	100	8.64	8.60	-0.04
	100 + 35%CC	8.69	8.64	-0.05
	100 + 65%CC	8.73	8.67	-0.06
	1,000	8.75	8.69	-0.07
Downstream Hawthorn Road portal culvert (SW3_223)	5	8.22	8.23	0.02
	20	8.30	8.32	0.02
	100	8.39	8.41	0.02
	100 + 35%CC	8.44	8.46	0.02
	100 + 65%CC	8.48	8.50	0.02
	1,000	8.50	8.52	0.02
Upstream of link road portal culvert (SW3_176)	5	7.90	7.89	-0.01
	20	7.96	7.94	-0.02
	100	8.06	8.02	-0.04
	100 + 35%CC	8.12	8.08	-0.04
	100 + 65%CC	8.16	8.14	-0.02
	1,000	8.18	8.18	-0.01
Downstream of link road portal culvert (SW3_146)	5	7.57	7.56	-0.01
	20	7.62	7.63	0.01
	100	7.73	7.76	0.03
	100 + 35%CC	7.79	7.79	0.00
	100 + 65%CC	7.82	7.82	0.00
	1,000	7.83	7.83	0.00

6.4.2. Long-section plots for the 1 in 100-year return period event with 35% and 65% climate change allowances illustrating the comparison of maximum water levels for crossing SW3 between the baseline and 'with scheme' scenarios are presented in **Plate 6.10** and **Plate 6.11** respectively.

Plate 6.10. Comparison of peak water levels for long-section at crossing SW3 for the 1 in 100-year return period event with 35% climate change allowance

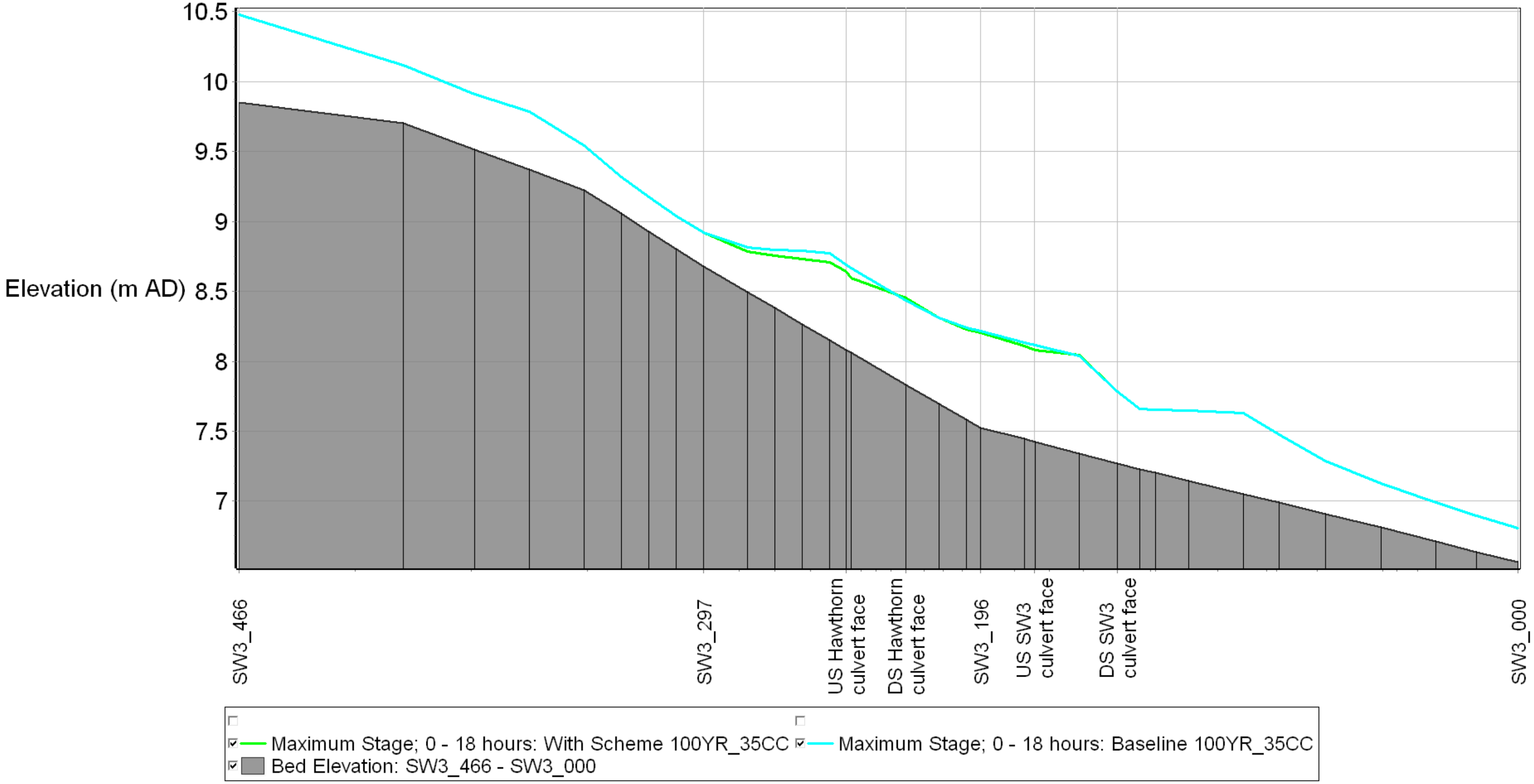
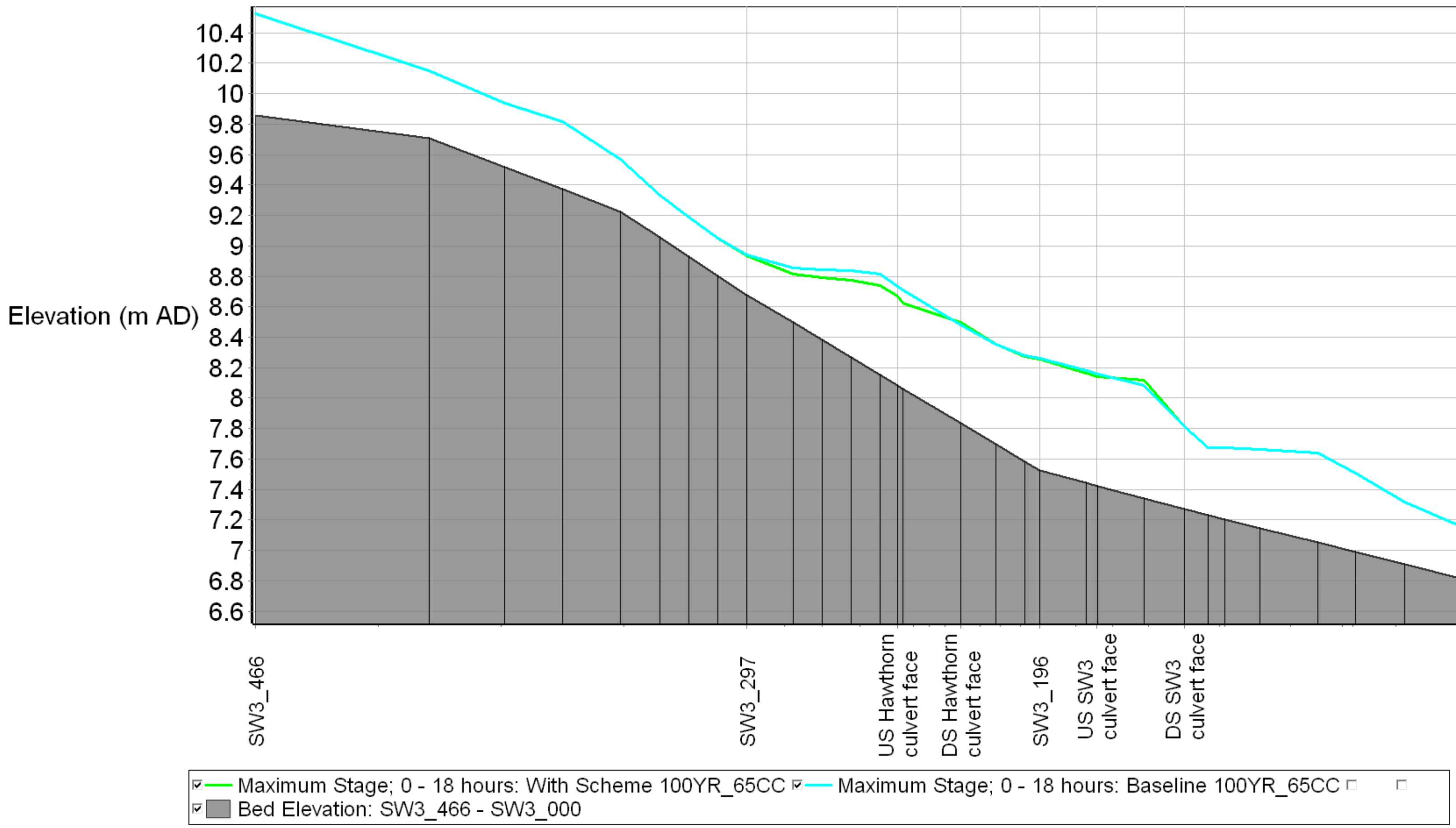


Plate 6.11. Comparison of peak water levels for long-section at crossing SW3 for the 1 in 100-year return period event with 65% climate change allowance



6.4.3. The modelling results for all considered events (**Table 6.3**) show that the peak water levels at portal culverts and associated flood relief culverts results are similar when compared to the baseline scenario. The maximum increase is approximately 20mm, and this only occurs for a short extent between the two proposed culverts (**Plate 6.13**).

6.4.4. Further upstream and downstream of the crossings, the model results show no increase in flood levels as a result of the proposed road scheme and therefore is considered not to substantially change the pattern of flooding in the area, with a very limited localised impact (small increase in water level) to the adjacent agricultural land (**Plate 6.10**, **Plate 6.11, Plate 6.12, Plate 6.14** and **Plate 6.15**).

6.4.5. The nearest residential property is located immediately upstream of the existing culvert. The closest model node to the property is SW3_297. The proposed development does not increase peak water levels for all the assessed return period events at this location. Therefore, the scheme is considered to have no impact on the flood risk to the property (**Plate 6.15**). There are no other properties in the vicinity of the proposed crossings.

6.4.6. To assess the benefit of the flood relief culvert, a long-section plot for the 1 in 100-year return period event with 35% climate change allowance illustrating comparison of maximum water levels for crossing SW3 and the connection road crossing at Hawthorn Road for model scenarios with and without the additional box culverts is presented in **Plate 6.16**. The results show that the two flood relief box culverts added to the proposed portal culverts reduce afflux at the crossing locations by approximately 130mm and 150mm for the link road and the connection road crossing respectively and by 40mm and 50mm respectively when compared to the baseline water levels.

6.4.7. Overall the results for crossing SW3 and the Hawthorn road crossing show no increase in water levels for most of the watercourse extent and very local afflux that result in negligible impacts to agricultural land but no impact to any properties.

6.4.8. The hydraulic modelling for the Hawthorn Road and SW3 crossings has not included the existing culvert that is upstream of the proposed road crossing. In the model, it is assumed that all flow would arrive at the portal culvert at Hawthorn road and subsequently at the link road crossing. However, it is likely that the existing culvert upstream of the proposed crossings would introduce some constriction of flow. Therefore, the model has adopted more conservative approach and the presented results are likely to slightly overestimate peak water levels.

Plate 6.12. Comparison of peak water levels for crossing SW3 for the 1 in 100-year event with 35%CC, 65%CC and 1 in 1,000-year event – cross-section at model node immediately upstream of Hawthorn Road portal culvert (SW3_245)

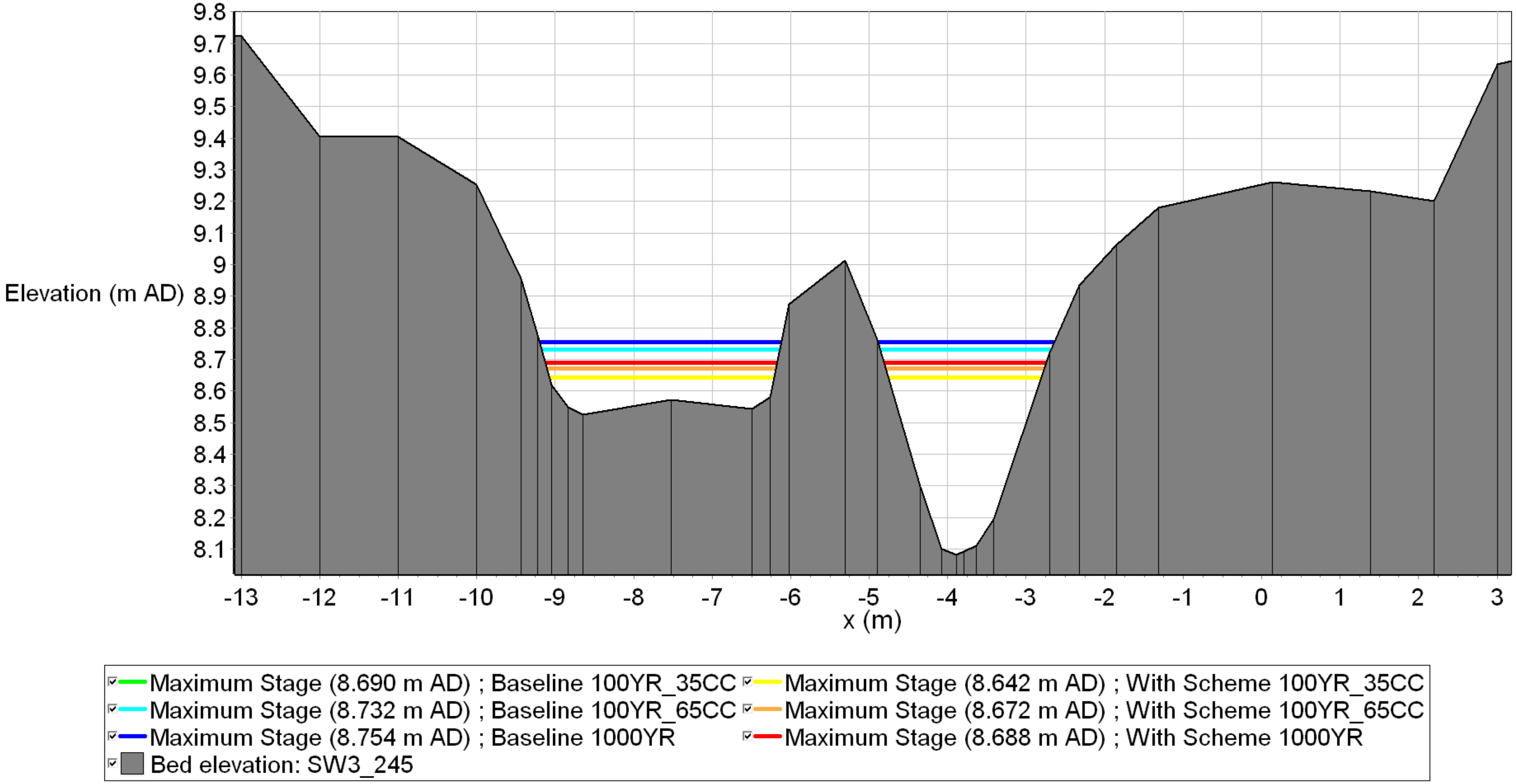


Plate 6.13. Comparison of peak water levels for crossing SW3 for the 1 in 100-year event with 35%CC, 65%CC – cross-section at model node immediately downstream of Hawthorn Road portal culvert (SW3_223)

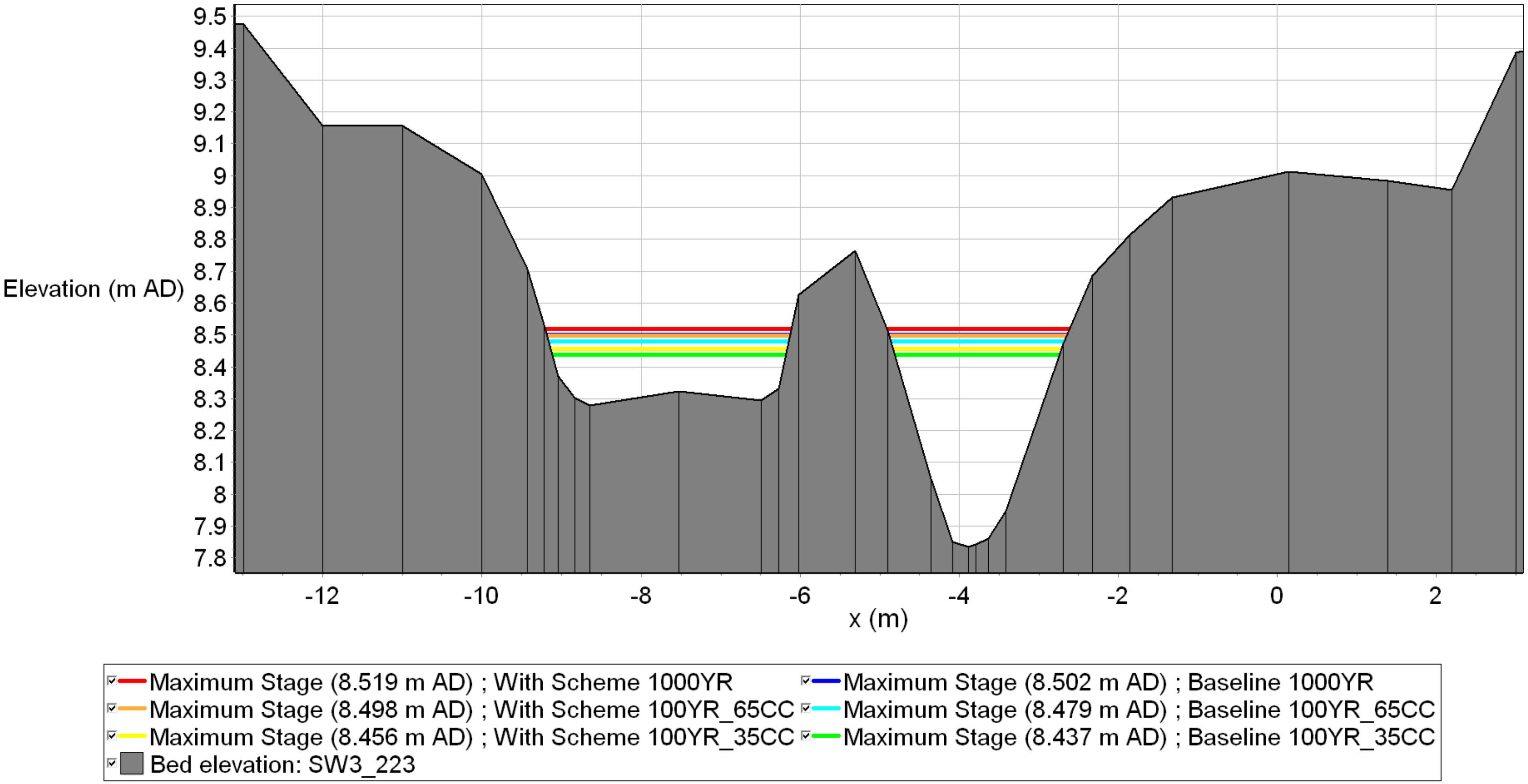


Plate 6.14. Comparison of peak water levels for crossing SW3 for the 1 in 100-year event with 35%CC, 65%CC and 1 in 1,000-year event – cross-section at model node immediately upstream of link road portal culvert (SW3_176)

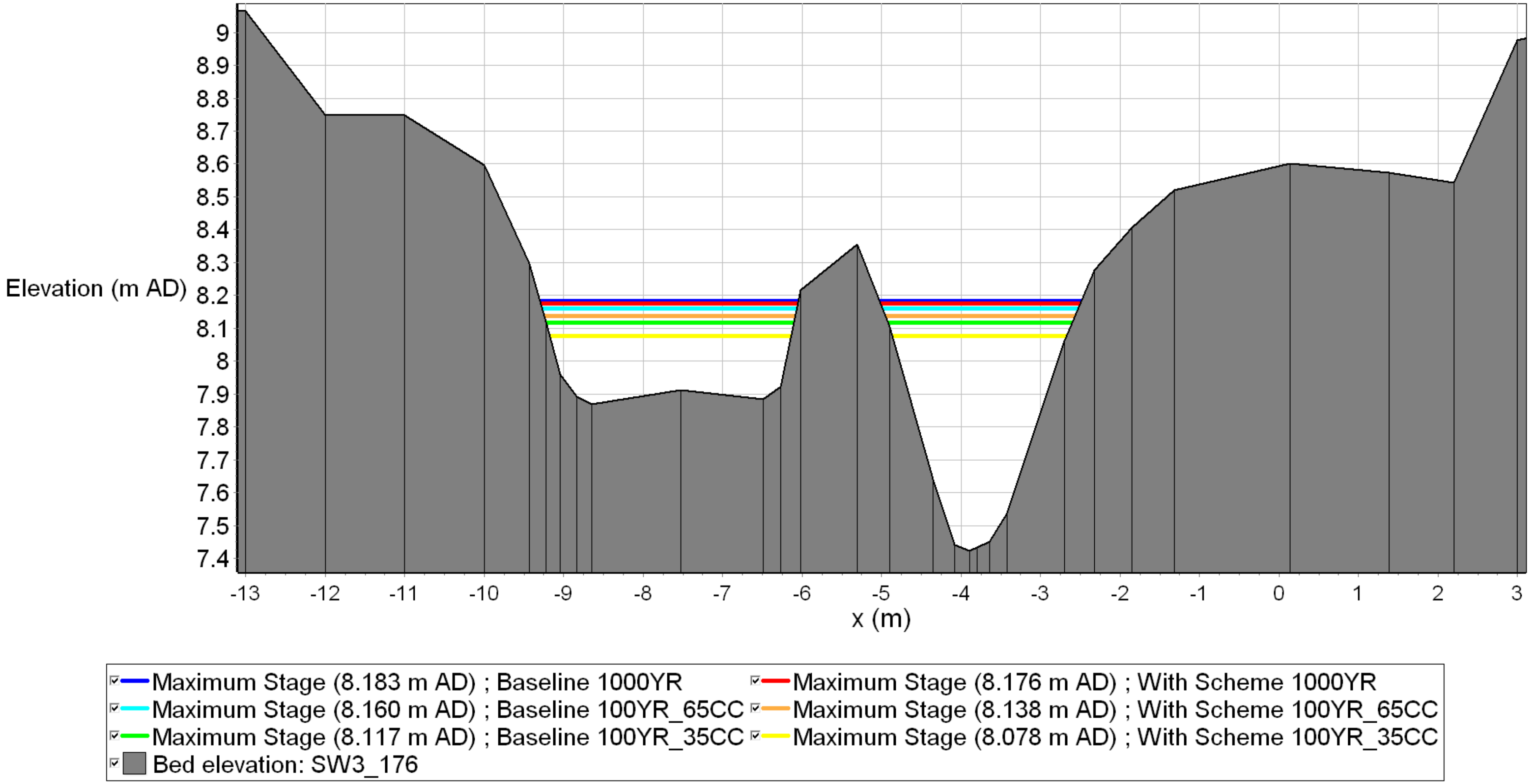


Plate 6.15. Comparison of peak water levels for crossing SW3 for the 1 in 100-year event with 35%CC, 65%CC and 1 in 1,000-year event – cross-section at model node approximately 60m upstream of the crossings (SW3_297)

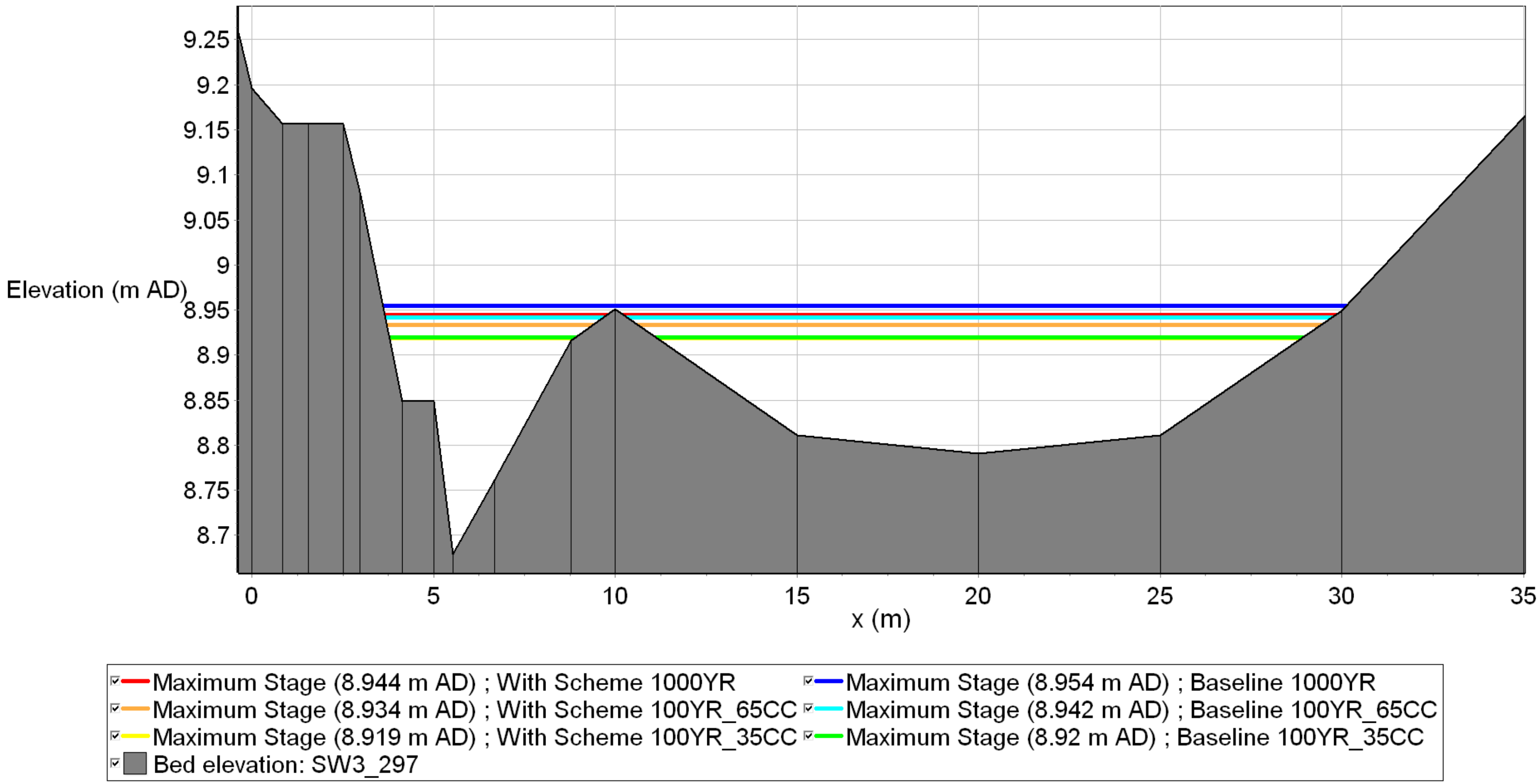
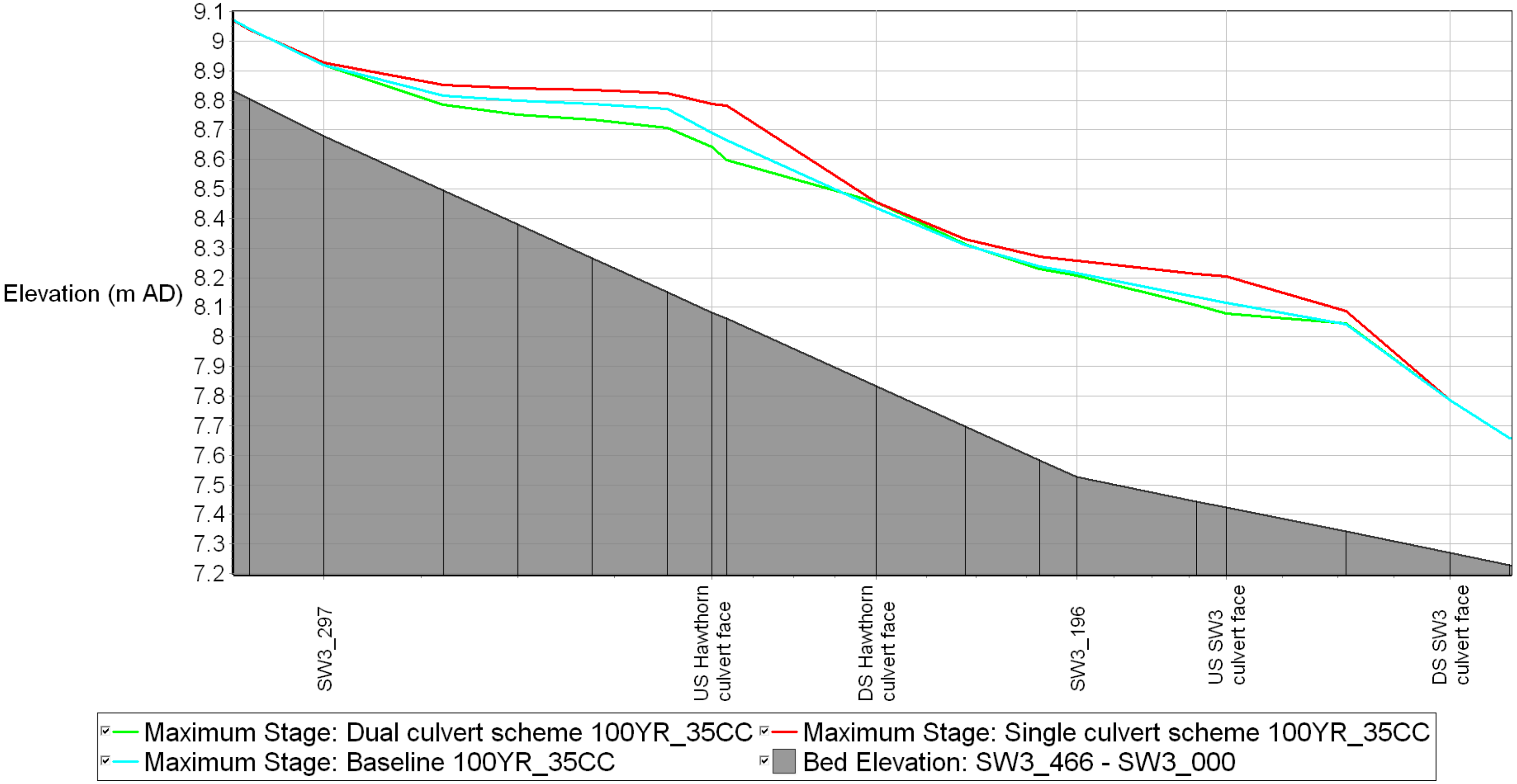


Plate 6.16. Comparison of peak water levels for long-section at crossing SW3 and the connection road crossing at Hawthorn Road for the 1 in 100-year return period with 35% climate change event for baseline and 'with scheme' scenarios with (dual culvert) and without (single culvert) the flood relief culvert



7 Sensitivity tests

7.1 Overview

7.1.1. As set out previously, the modelling was based on very limited information available at the time of the assessment. To address the concerns related to the limitations, a series of sensitivity tests were carried out to determine the potential impacts of the limitations on the model results and subsequently on flood risk to and from the proposed development, as follows:

- 20% increase in fluvial flows;
- 20% increase in roughness coefficient; and
- Suitability of LiDAR data in representing channel geometry and floodplain levels for the small watercourses

7.1.2. These were the three key parameters within the hydraulic model that were considered to have potentially the greatest impact on change in flood risk.

7.1.3. The increase in fluvial flow test was carried out for all considered return period events, while the increased roughness test and channel geometry tests were carried out for the 1 in 100-year event with 35% climate change only for time efficiency.

7.1.4. The sensitivity test results are discussed in detail in the following sub-sections.

7.2 Increase in flow

7.2.1. Potential uncertainties in the hydrology and flow assessments were assessed by model scenario with an increase of 20% in the peak flow hydrograph.

7.2.2. The results of this sensitivity testing show minor change to the water levels as a result of the proposed development, in the order of 48mm and 1mm for the 1 in 100-year event with 65% allowance for climate change at crossing SW1 and SW3 respectively, as illustrated in **Plate 7.1** and **Plate 7.3**. However, the differences between the baseline and 'with scheme' scenarios are lower for this sensitivity test. This shows that the relative impact of the development is less with higher flows.

7.2.3. For the other crossing locations (SW2, SW5 and SW6), the impact of increased flows on peak water levels is less pronounced as the water would remain within the watercourse channels, as illustrated in **Plate 7.2**, **Plate 7.4** and **Plate 7.5** for the three crossings respectively.

Plate 7.1. Comparison of peak water levels at crossing SW1 (node SW1_378) – sensitivity test: +20% in flow

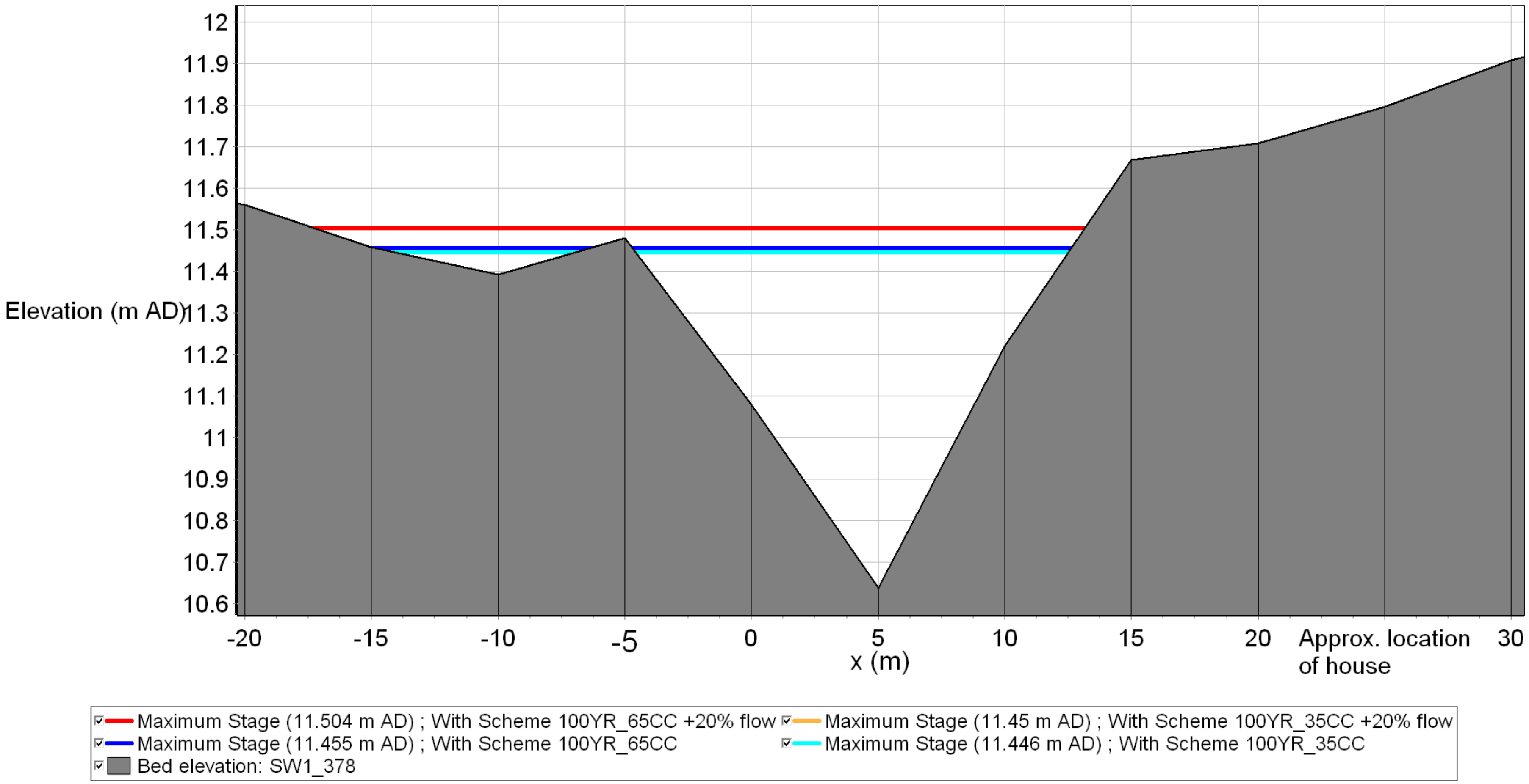


Plate 7.2. Comparison of peak water levels at crossing SW2 (node SW2_177) – sensitivity test: +20% in flow

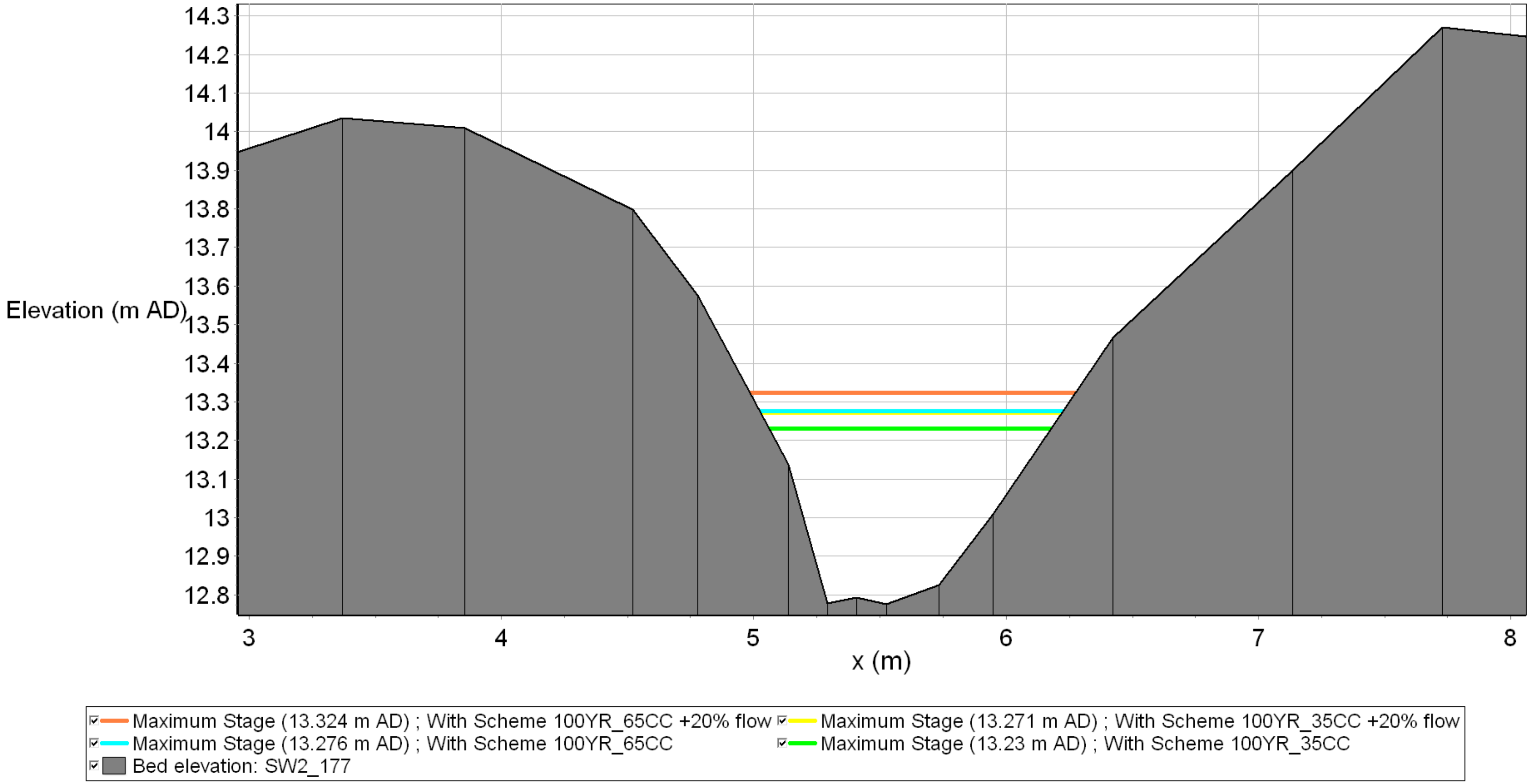


Plate 7.3. Comparison of peak water levels at crossing SW3 (node SW3_176) – sensitivity test: +20% in flow

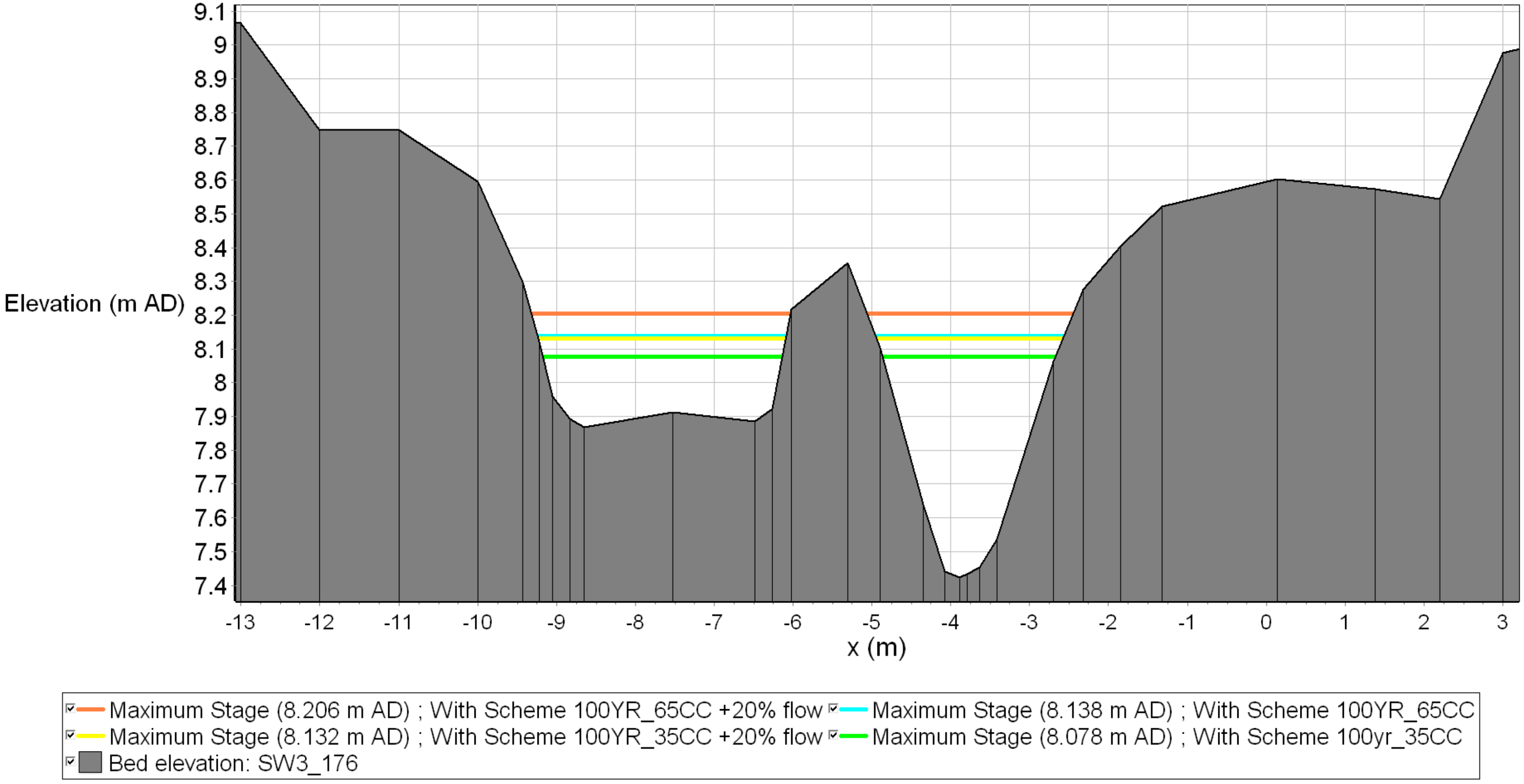


Plate 7.4. Comparison of peak water levels at crossing SW5 (node SW5_583) – sensitivity test: +20% in flow

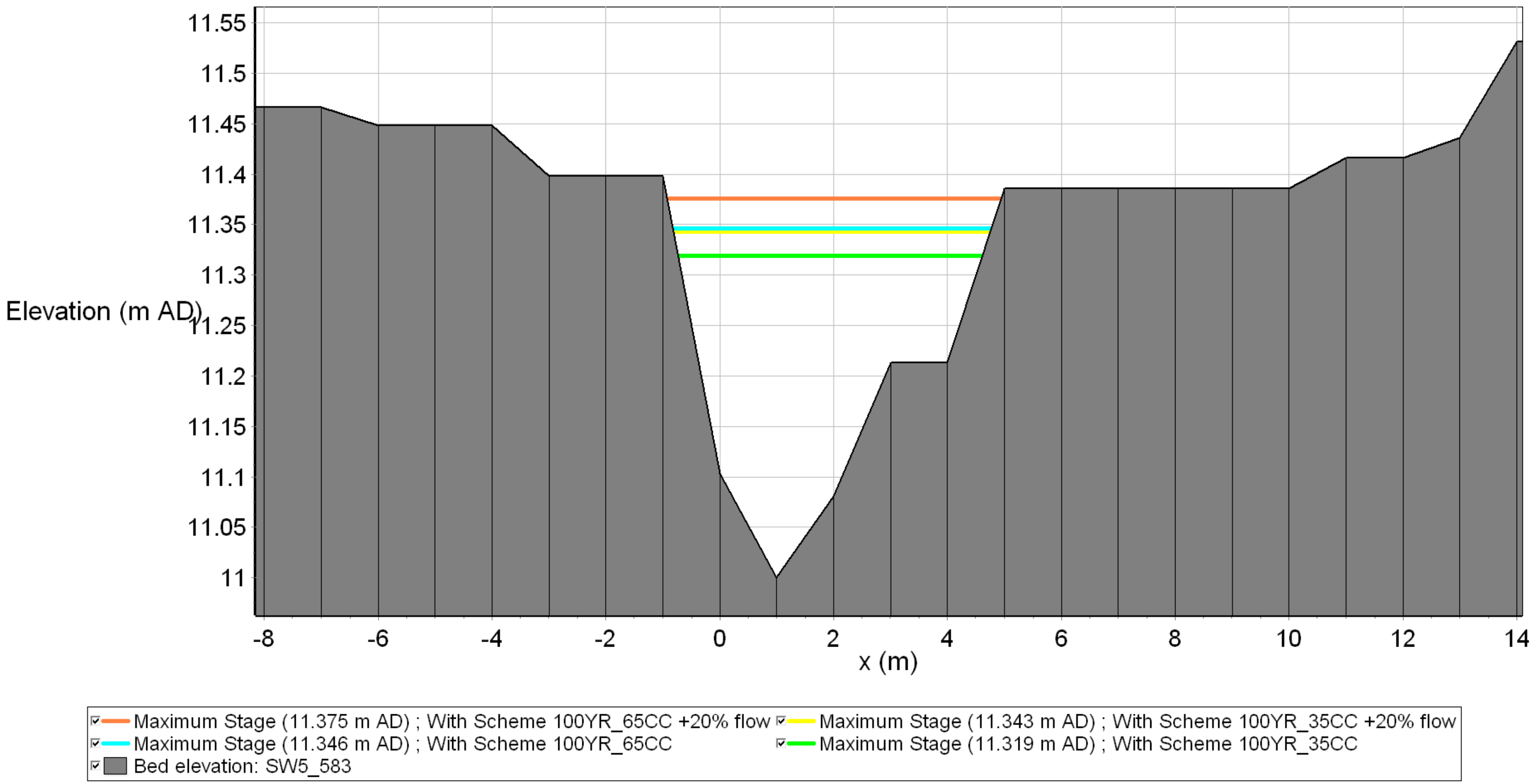
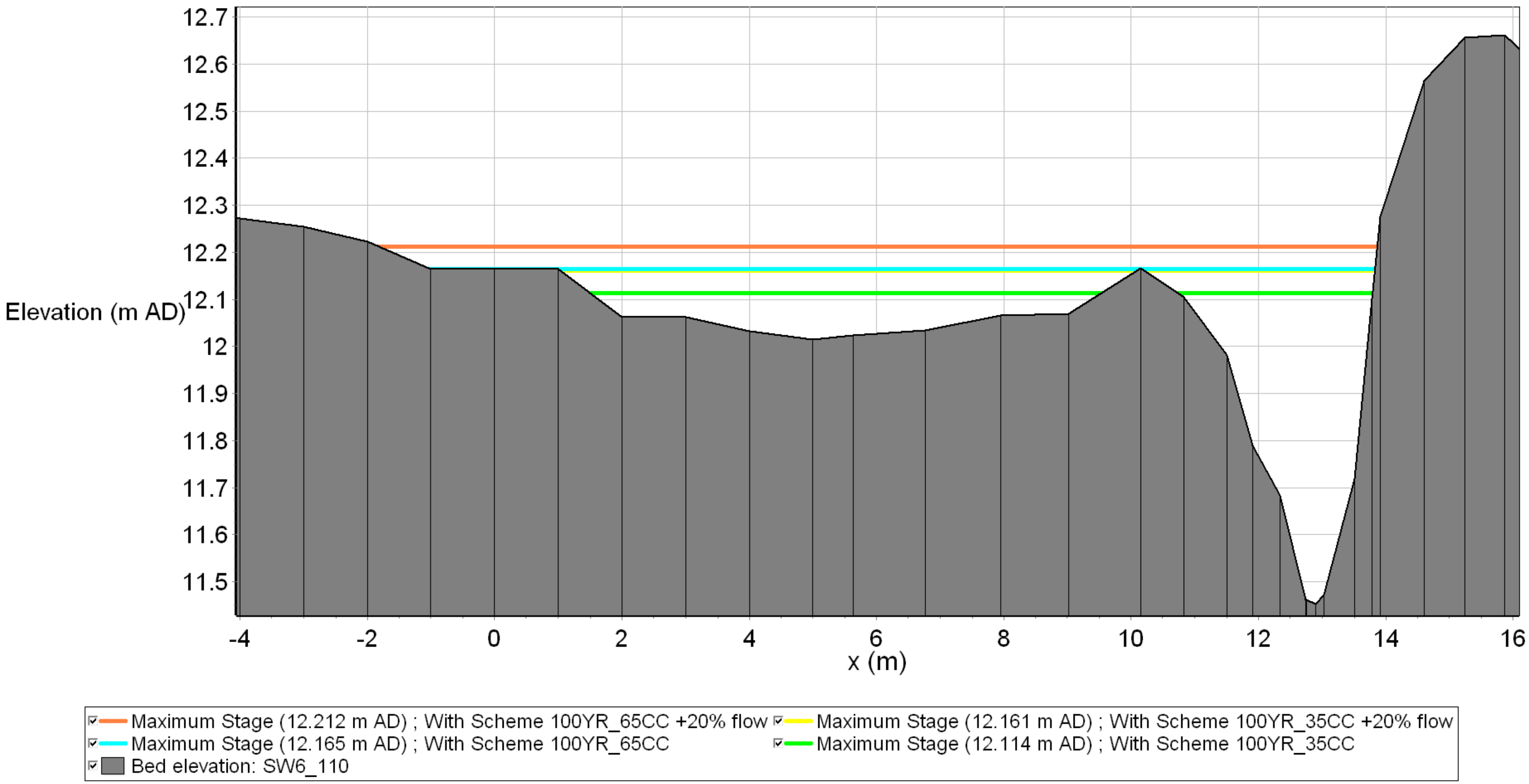


Plate 7.5. Comparison of peak water levels at crossing SW6 (node SW6_110) – sensitivity test: +20% in flow



7.2.4. Results show that at crossing SW1 the increase in water levels would cause slightly wider flood extent that would only affect approximately 2m of agricultural land on the left bank of the watercourse during the 1 in 100-year event with 35% climate change allowance (**Plate 7.1**). However, the residential property located on the right bank of the watercourse would not be affected by the slightly increased water levels.

7.2.5. At crossing SW3 there are two proposed culverts. The increase in water levels results in slightly more water within the floodplain in the area located between the two proposed culverts. At this location only agricultural land would be affected, which is also affected in the scenario without uplift to flows. However, there are no additional areas flooded and no properties at risk in the vicinity of the development. The difference in peak flood levels between the baseline and 'with scheme' is lower with the increased flows.

7.2.6. On this basis, the sensitivity testing indicates that increased flow is likely to result in slightly higher water levels but limited localised impact on flood risk off-site. Flood risk to the proposed crossings is negligible.

7.3 Increase in roughness

7.3.1. The second parameter that was tested was the Mannings 'n' roughness value to consider the potential seasonal variations in vegetation or other localised differences in roughness and its impact on the model results.

7.3.2. The roughness coefficient was increased by 20% for model cross-sections, with values set to 0.084 at the floodplains and 0.048 within the watercourse channels. This sensitivity was assessed only for the SW1 crossing, as the preliminary model results indicated the greatest potential for negative impacts at this reach.

7.3.3. The results show that the peak water levels increased by approximately 0.05m along the long sectional profile due to the increased roughness (**Plate 7.6**). The increase in the peak water levels is minor and does not result in any flood risk impacts to either the proposed development or to any off-site receptors. The increased water level does result in a minor increase in the floodplain flood extent by approximately 1m (**Plate 7.7**).

7.3.4. However, this increase is not the same along the watercourses. At the location just upstream of the residential property near crossing SW1 (SW1_378) the slight increase in water levels results in less afflux from 32mm (in the ordinary model) to 19mm (in the roughness sensitivity test) when compared to the baseline results.

7.3.5. Overall the results from the increase in roughness sensitivity test were similar results to the increased flow test.

Plate 7.6. Comparison of peak water levels at crossing SW1 (long-section) – sensitivity test: +20% in roughness

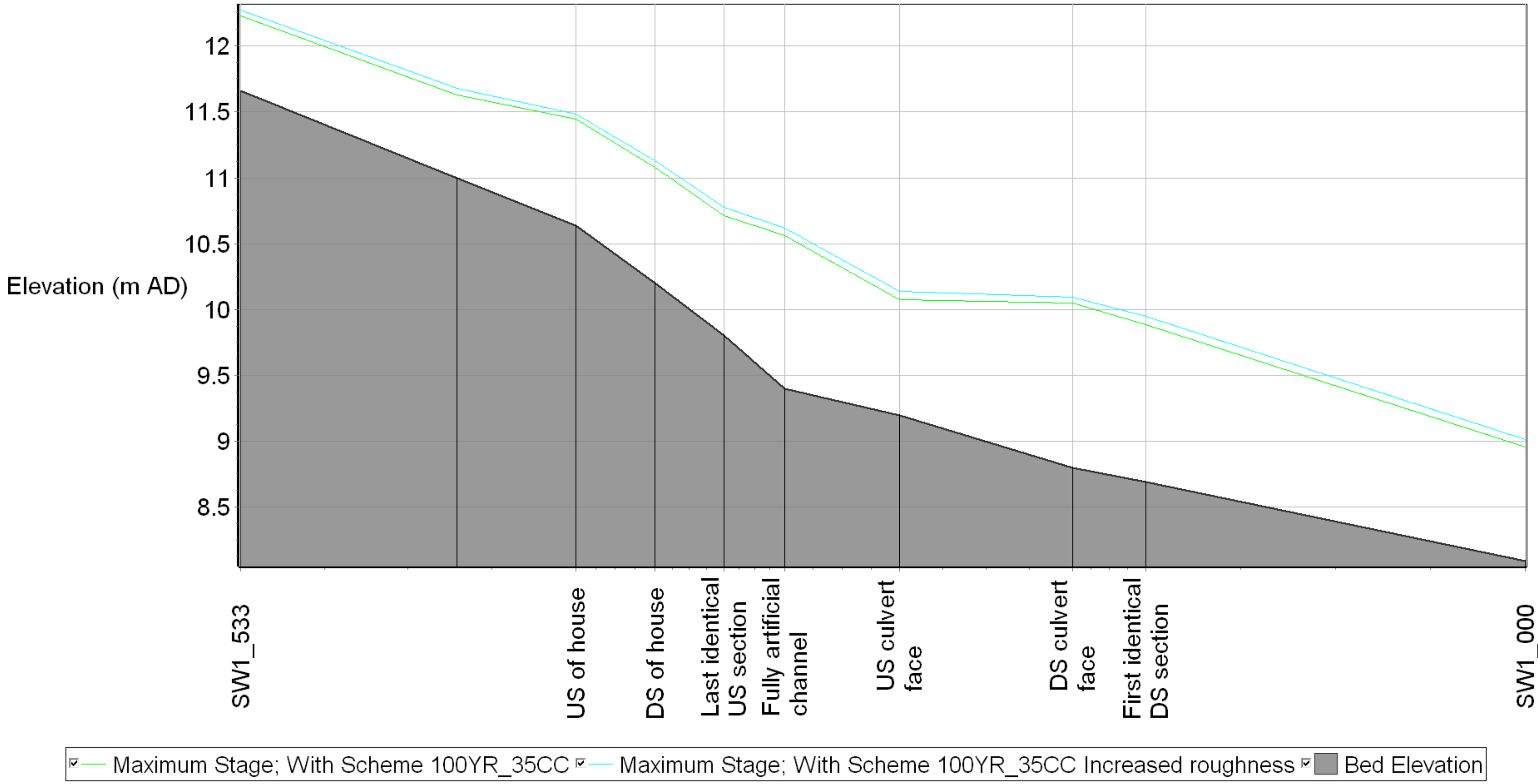
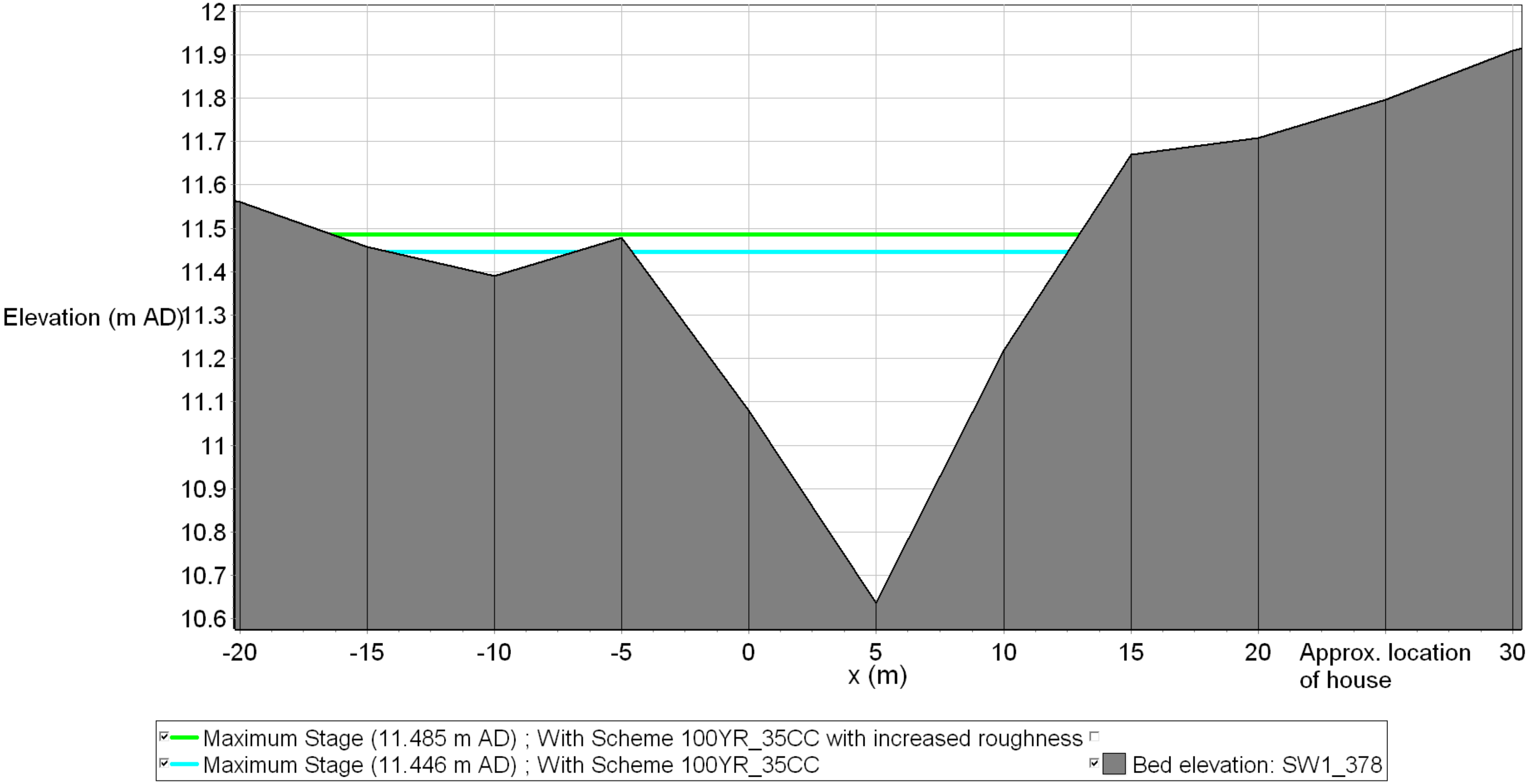


Plate 7.7. Comparison of peak water levels at crossing SW1 (node SW1_378) – sensitivity test: +20% in roughness



7.4 Cross-section geometry

7.4.1. The third sensitivity test was carried out on channel geometry to assess how the differences in channel geometry could potentially impact model results and overall study conclusions, as the LiDAR dataset was used to inform cross-sections upstream and downstream of the proposed crossings where no survey data was available (as discussed in **section 3.3**).

7.4.2. The LiDAR was found to generally have a varied representation of the channel and of bed levels when compared to the surveyed cross-sections. The highest difference was observed at crossing SW2, where the surveyed bed level was approximately 1m lower than that from the LIDAR. This is potentially due to SW2 being one of the narrowest assessed watercourses, hence a challenge for 1m LIDAR to accurately pick up channel geometry (**Plate 3.3**). Due to crossing SW1 being the crossing with relative largest impact (identified from preliminary results), it was also included in the channel geometry sensitivity test. The difference in bed level of about 0.6m was observed at crossing SW1 (**Plate 3.2**)

7.4.3. The test was conducted by lowering the channel in the cross-sections derived from LiDAR in line with the difference between surveyed and LiDAR sections, without changing the bank levels or overall gradient of the watercourse.

7.4.4. The model run showed that water levels in the channel upstream of the SW2 crossing decreased by an average of 0.06m. There were locations where the water level increased, but these were assessed to be the result of a significant flattening of gradient caused by lowering of the bed level upstream of the survey location.

7.4.5. Results of this testing showed that for crossing SW1, the maximum water levels in the channel upstream of the crossing decreased by an average of 0.06m (**Plate 7.8** and **Plate 7.9**). These results were confirmed by performing a similar appropriate reduction to the reach at crossing SW2 (**Plate 7.10** and **Plate 7.11**). The water levels at crossing SW1 decreased by a similar amount to SW2 even though the crossing at SW1 has a larger channel, where a reduction in bed represents a larger increase in in-channel storage.

7.4.6. The overall conclusion from this sensitivity testing is that currently adopted approach resulted in more conservative maximum water levels. Following more extensive topographical survey that would be undertaken at detailed design stage of the Sizewell C project, the hydraulic models would be improved by better representation of the various watercourses however the relative impact of the scheme is unlikely to change.

Plate 7.8. Comparison of peak water levels at crossing SW1 (node SW1_378) – sensitivity test: channel geometry

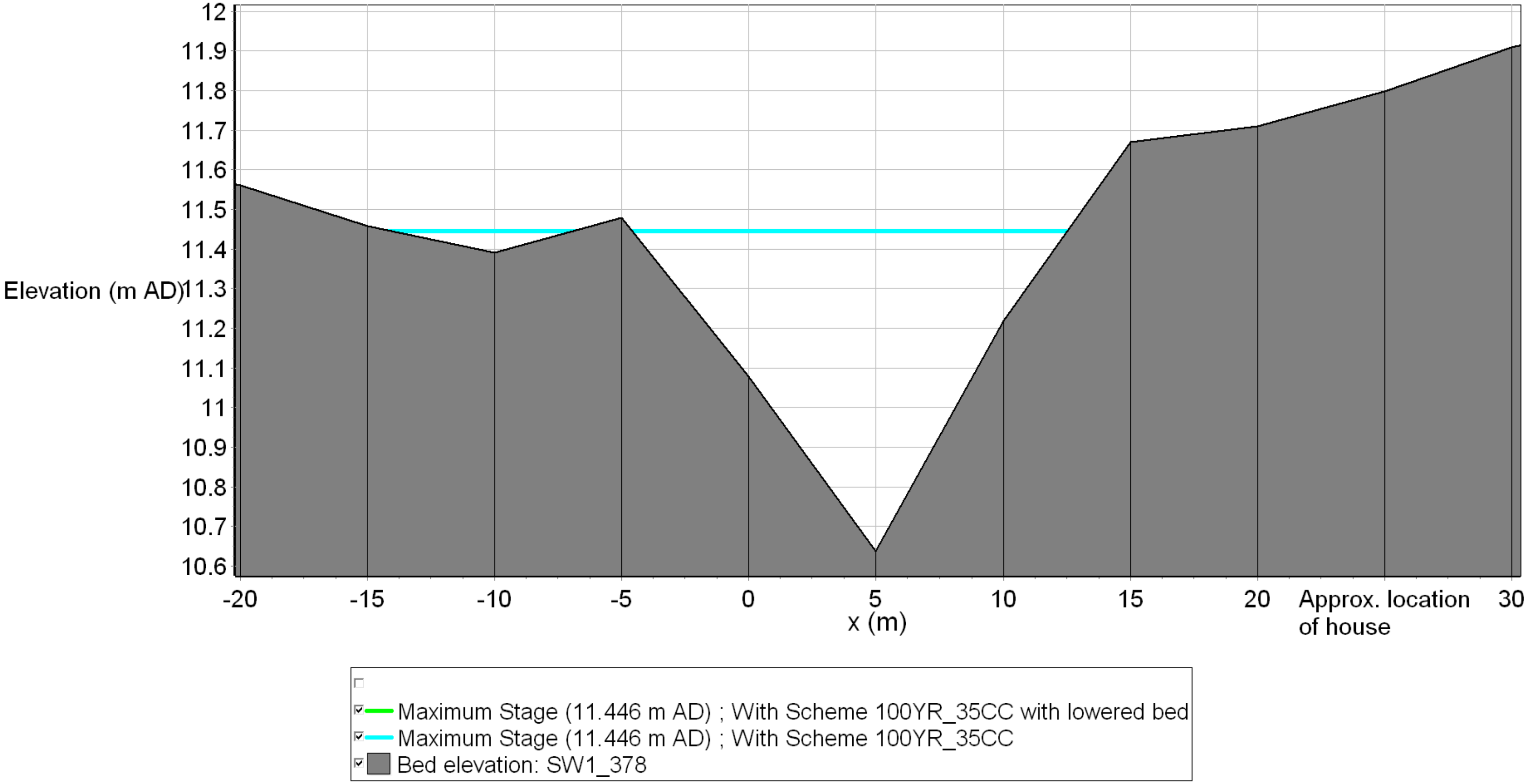


Plate 7.9. Comparison of peak water levels at crossing SW1 (long-section) – sensitivity test: channel geometry

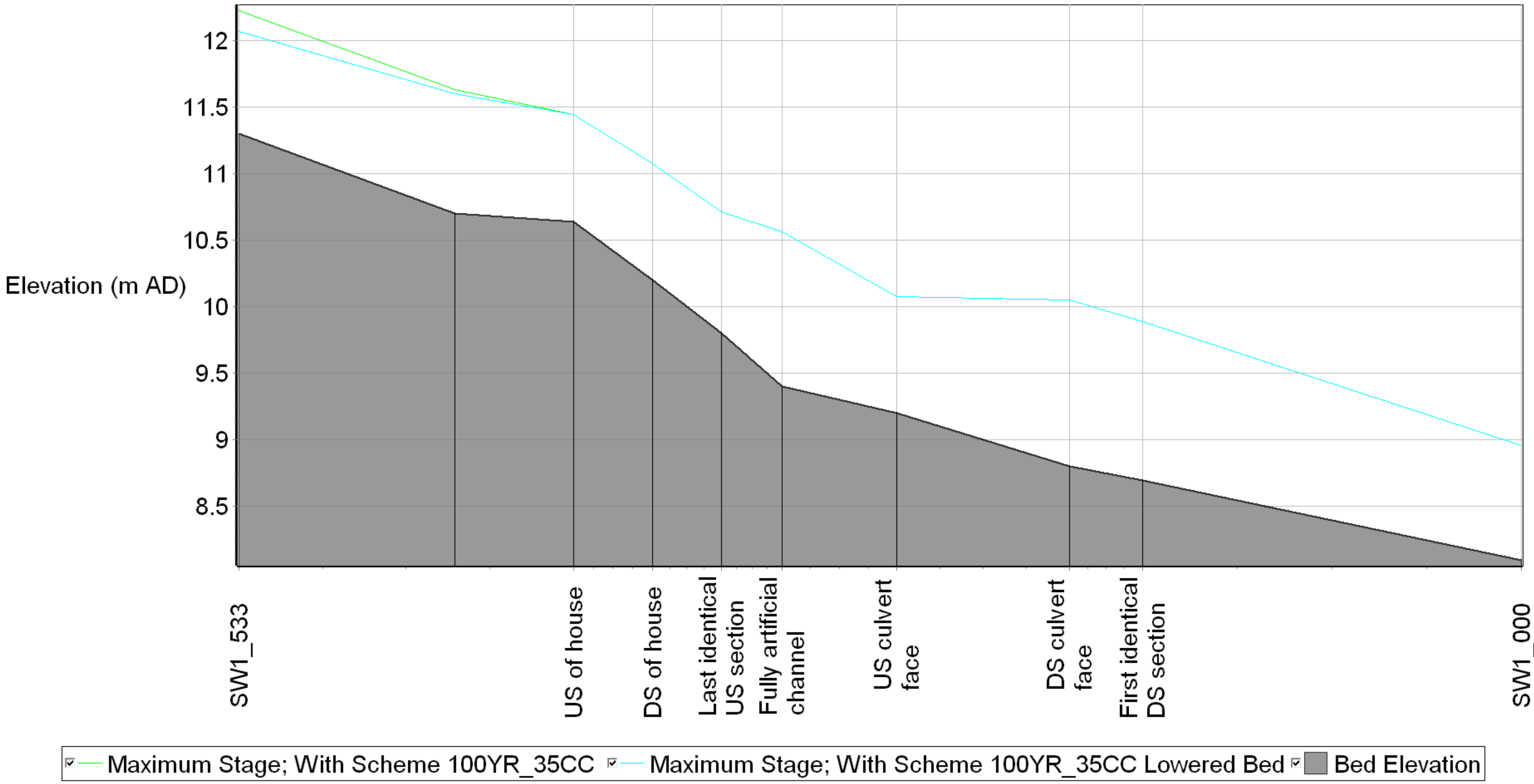


Plate 7.10. Comparison of peak water levels at crossing SW2 (node SW2_177) – sensitivity test: channel geometry

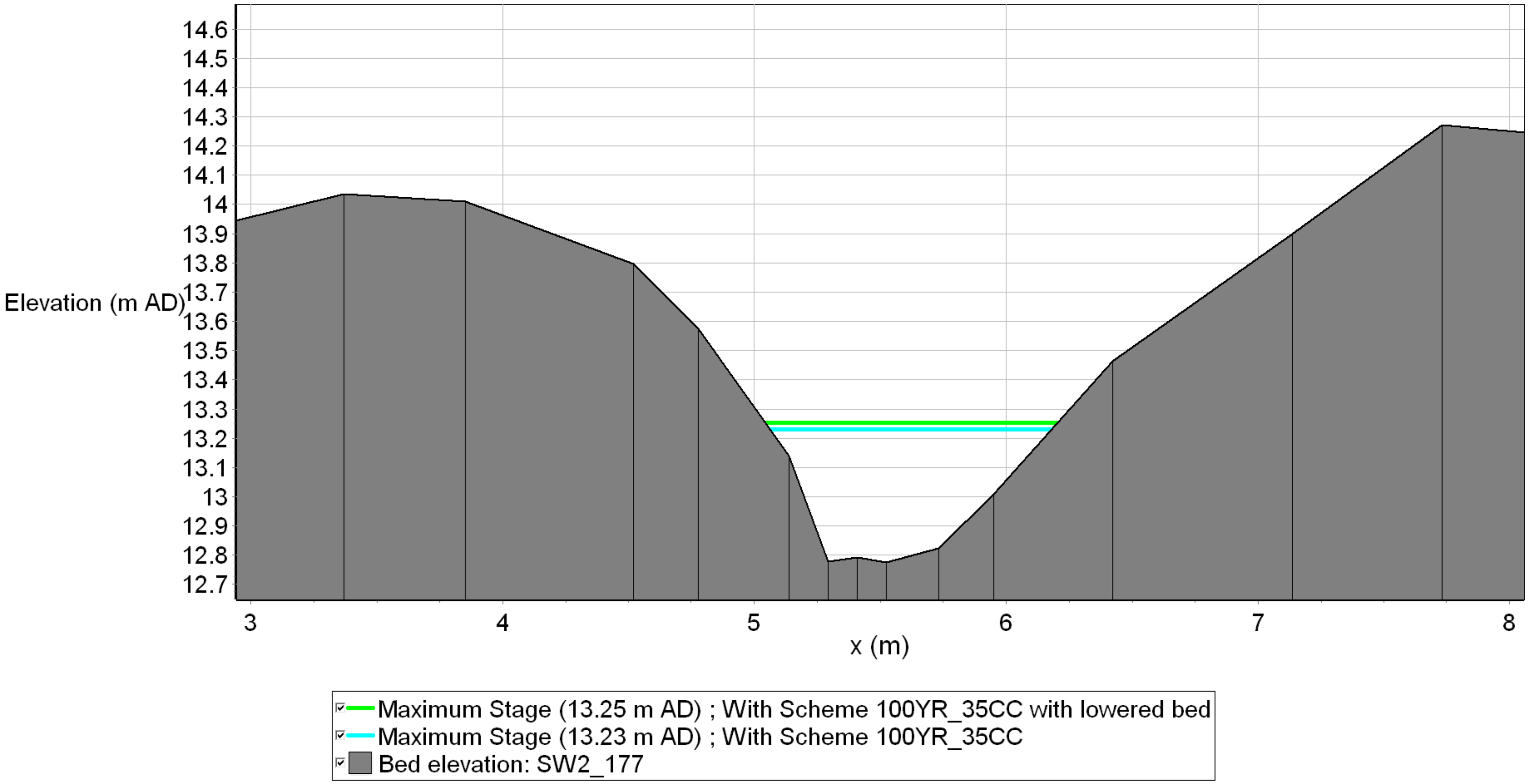
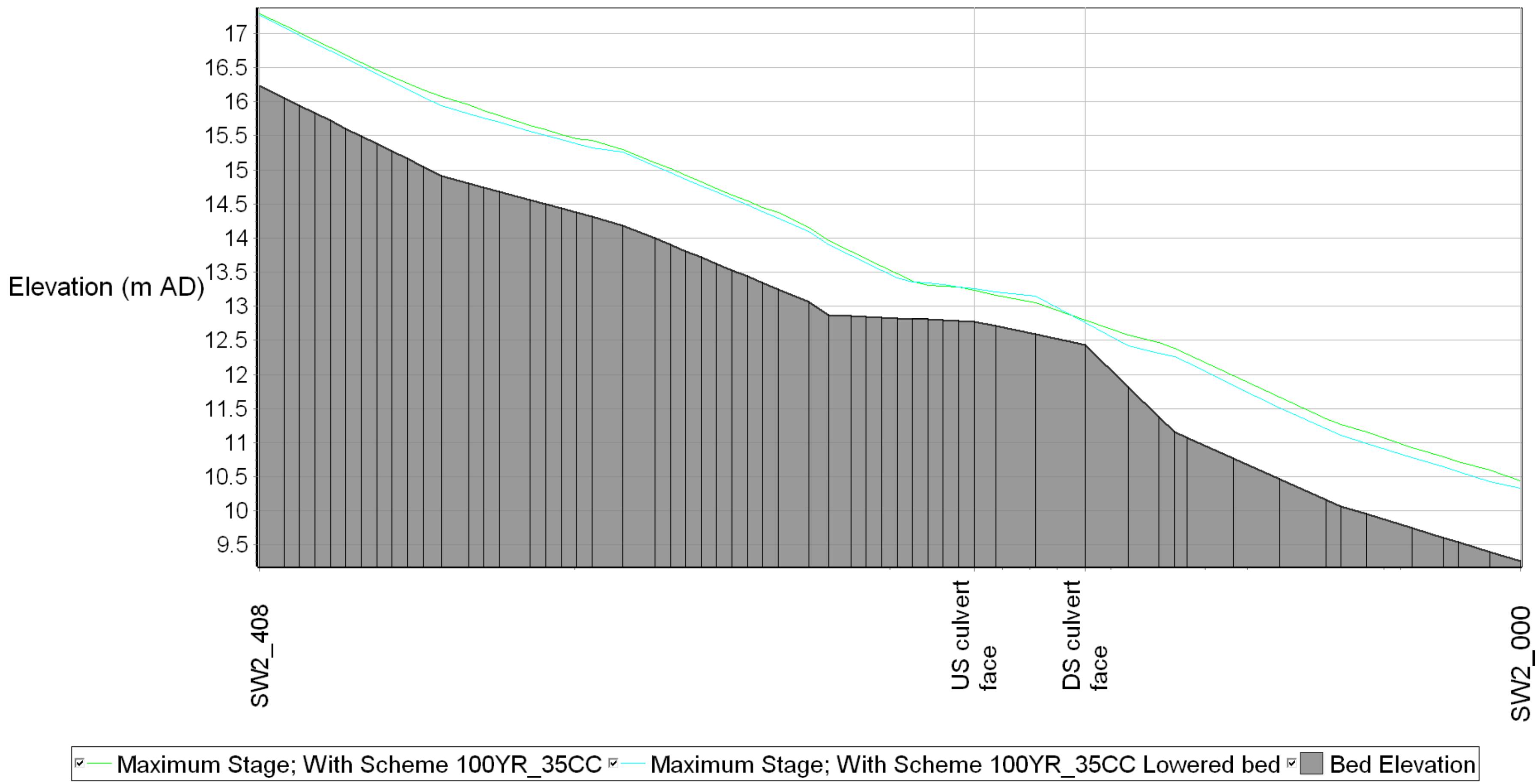


Plate 7.11. Comparison of peak water levels at crossing SW2 (long-section) – sensitivity test: channel geometry



8 Limitations

8.1.1. For this Sizewell link road FRA, a 1D only hydraulic modelling approach has been used. The model is generally stable however some numerical non-convergence does arise, and mass error is relatively high. However, this was assumed as being acceptable for this stage of the project, given the simplified approach, very limited information, the use of sensitivity testing to explore areas of potential uncertainties and the focus of the assessment being on relative changes between baseline and 'with scheme', as opposed to absolute values.

8.1.2. 1m resolution LiDAR data has been used to generate most cross-sections and in some cases the channel has not been picked up in sufficient detail. Therefore, manual adjustments have been made in order to improve the channel geometry and slope to provide reasonable representation of the watercourses.

8.1.3. Flood Modeller Pro (used in this study) does not provide a 3-sided culvert unit option. In order to maintain the natural river channel (as portal culverts allow), ordinary river units were used with adjusted bank levels to represent the culverts. Bridge units were initially considered, however these do not have any length in the model and therefore would not appropriately account for losses through the culverts.

8.1.4. Although appropriate geometry of the portal culverts was represented within the river units (by rising the embankments), the river units do not account for all energy losses, i.e. entry and exit losses into the structure. Additional loss units were not added due to uncertainties about loss coefficients to be applied. This limitation is not considered significant as in most cases the water levels are within the channels and therefore are not confined by the proposed portal culverts.

8.1.5. Due to proposed river channel re-alignment at the crossing SW1, there were a number of assumptions made in order to maintain a stable, positively graded hydraulic model. These are as follows:

- Despite the stated gradient within the design of the SW1 crossing being 1:60, it has instead been set to 1:100. This is due to the proposed 1:60 slope causing either the upstream section to be effectively flat, or alternatively causing the downstream section to be negatively graded back to the existing channel;
- As a result of this gradient change, the bed level of the upstream face of the portal culvert was set to 9.2m AOD. The design specifies 8.8m AOD and so this has been used as the downstream level which, then ties into the existing levels at the connection back to the existing channel.

9 Conclusions

9.1.1. Sizewell link road scheme is proposed as associated development to the main Sizewell C new nuclear build project. 1D Flood Modeller hydraulic models were developed to assess the flood risk to the proposed link road crossings and their potential impact on change in flood risk.

9.1.2. The proposed link road would require seven watercourse crossings (SW1 – SW7), five of which were modelled in this assessment. In addition, a connection road crossing at Hawthorn Road, upstream of crossing SW3 was considered. A second connection road is included in the scheme at Fordley road (upstream of crossing SW1), however the current proposed design assumes diversion of the watercourse to bypass this connection road and therefore crossing at this location would not be required.

9.1.3. The proposed design assumes portal culverts at all modelled crossing locations, with additional flood relief box culverts at crossings SW1 and SW3 (including the connection road crossing at Hawthorn Road).

9.1.4. For crossings SW2, SW5 and SW6, the modelling results show that peak flood levels are within the bank levels and therefore the proposed portal culverts design does not pose any flow constriction for the 1 in 100-year event with 35% and 65% climate change allowances.

9.1.5. Also, there are no receptors near these crossings apart from agricultural land. On that basis, it is concluded that these crossings would have a negligible impact on change in flood risk in the area.

9.1.6. Preliminary results at crossings SW1 and SW3 were showing relatively significant afflux, when compared to the baseline scenario. For that reason, the flood relief culverts were added to alleviate the flow constriction.

9.1.7. For crossing SW1, due to channel diversion it was not possible to directly compare results for the baseline and 'with scheme' scenarios. Instead the results were compared at the closest common river sections, showing only limited and very localised impact on peak flood levels which does not affect any residential or non-residential properties. The out of bank flow upstream of crossing SW1 is limited in its extent, flooding approximately 20 metres of the left bank.

9.1.8. The proposed SW3 crossing also does not increase flood risk to any residential receptors, either upstream or downstream of its location. The nearest residential property is located immediately upstream of the existing culvert (further upstream from the Hawthorn road crossing) but the proposed development does not increase peak water levels for all the assessed return period events at this location.

9.1.9. In addition to the assessed design options for a number of return period events and climate change scenarios, sensitivity testing was carried out to understand the potential impact of key model parameters on modelled water levels and the overall conclusions of this FRA study.

9.1.10. A total of three sensitivity testing scenarios were carried out. These comprised an increase in flow by 20%, an increase in roughness coefficient by 20% (by altering the Mannings n' value) and adjustment (lowering) of the watercourse channel geometry derived from LiDAR data.

9.1.11. The results of the increase in peak flow sensitivity test show a slight increase in flood levels with no additional impacts on flood risk, whilst the differences between the baseline and 'with scheme' scenarios reduced. This shows that the relative impact of the development is less with higher flows.

9.1.12. The results of the increase in roughness sensitivity testing are very similar to those of increase in flow, with water levels raised by approximately 0.05m for crossing SW1 (only crossing assessed with this sensitivity test). Therefore, the flood risk from the proposed development was relatively localised with flooding affecting only agricultural land and there is no flood risk to the development itself.

9.1.13. The sensitivity test with channel geometry showed that differences between the baseline and the 'with scheme' scenarios remained broadly the same as in the unaltered model, with overall reduction in peak water levels as a result of greater 'in-channel' capacity. On that basis, the adopted model approach and obtained results are more conservative.

9.1.14. Overall, hydraulic modelling undertaken shows that the proposed Sizewell link road scheme would not be at risk of flooding under all assessed return period events and climate change scenarios. The relative impacts of the watercourse crossings on flood risk are very limited and localised and affect mainly agricultural land. There are only two residential properties located in the vicinity of the crossings, one upstream of crossing SW1 at Fordley road and second upstream of crossing SW3 and Hawthorn road crossing. For both of these properties there is no change in flood risk. Therefore, it is concluded that the proposed development does not adversely impact flood risk to any surrounding receptors.

9.1.15. It is acknowledged that the modelling undertaken incorporates some assumptions and is based on limited information. In the event that more extensive topographical survey is undertaken at detailed design stage of the Sizewell C project, the hydraulic models could be improved by better representation of the various watercourses, however the relative impact of the scheme is unlikely to change.

References

Ref 1 Environment Agency. Catchment Data Explorer: https://environment.data.gov.uk/catchment-planning/ (Accessed 8 December 2019)

Ref 2 Centre for Ecology and Hydrology (CEH). Flood Estimation Handbook (FEH) web service: https://fehweb.ceh.ac.uk/ (accessed on 16.04.2019)

Ref 3 Environment Agency, Flood estimation guidelines, Environment Agency, Operational Instruction197_08. 2017

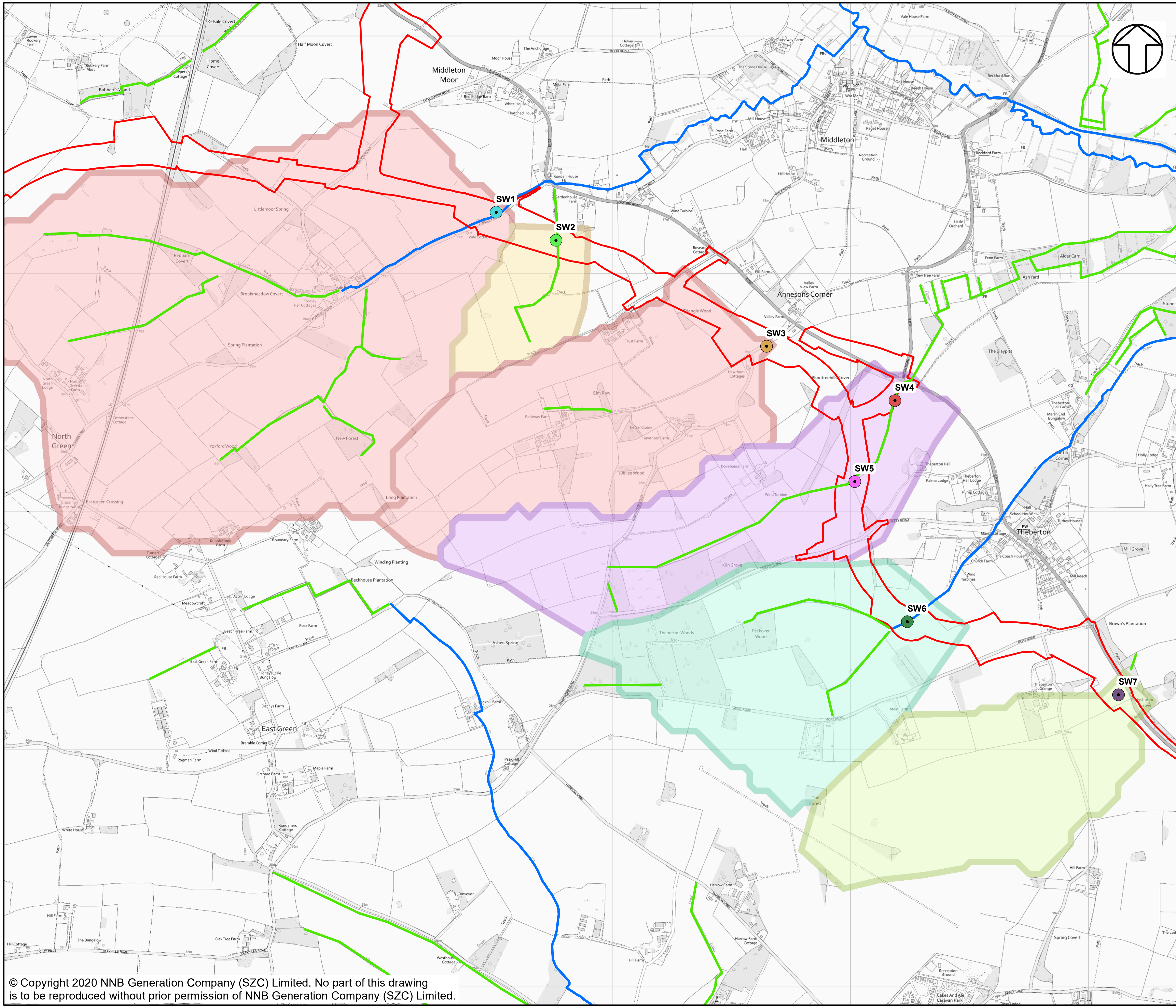
Ref 4 Centre for Ecology and Hydrology (CEH). The Revitalised Flood Hydrograph Model REFH 2.2: Technical Guidance. Wallingford Hydrosolutions Ltd. 2016

Ref 5 EDI Surveys Ltd, River Alde & Link Road Channel Survey. May 2019

Ref 6 Department for Environment Food and Rural Affairs, Defra Data Services Platform: Defra Survey Data Download. https://environment.data.gov.uk/DefraDataDownload/?Mode=survey (accessed 29/05/2019)

Ref 7 Environment Agency. Flood Risk Assessments: Climate Change Allowances. London, December 2019. https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

Ref 8 Environment Agency – Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities, April 2016: https://www.gov.uk/government/publications/adapting-to-climate-change-for-risk-management-authorities



NOTES

KEY

SIZEWELL LINK ROAD DEVELOPMENT SITE BOUNDARY

CROSSING LOCATION

- SW1 MIDDLETON WATERCOURSE
- SW2 GARDEN HOUSE FARM WATERCOURSE
- SW3 HAWTHORN ROAD WATERCOURSE
- SW4 THEBERTON HALL WATERCOURSE
- SW5 PRETTY ROAD WATERCOURSE
- SW6 THEBERTON WATERCOURSE
- SW7 FISH GROVE POND WATERCOURSE
- ENVIRONMENT AGENCY MAIN
- ORDINARY WATERCOURSE

MODEL CATCHMENTS

- SW1, SW3
- SW2
- SW4, SW5
- SW6
- SW7

NOT PROTECTIVELY MARKED

DOCUMENT:
SIZEWELL C
SIZEWELL LINK ROAD
FLOOD RISK ASSESSMENT

DRAWING TITLE:
SIZEWELL LINK ROAD
WATERCOURSE CROSSING LOCATIONS

DRAWING NO:
FIGURE 1

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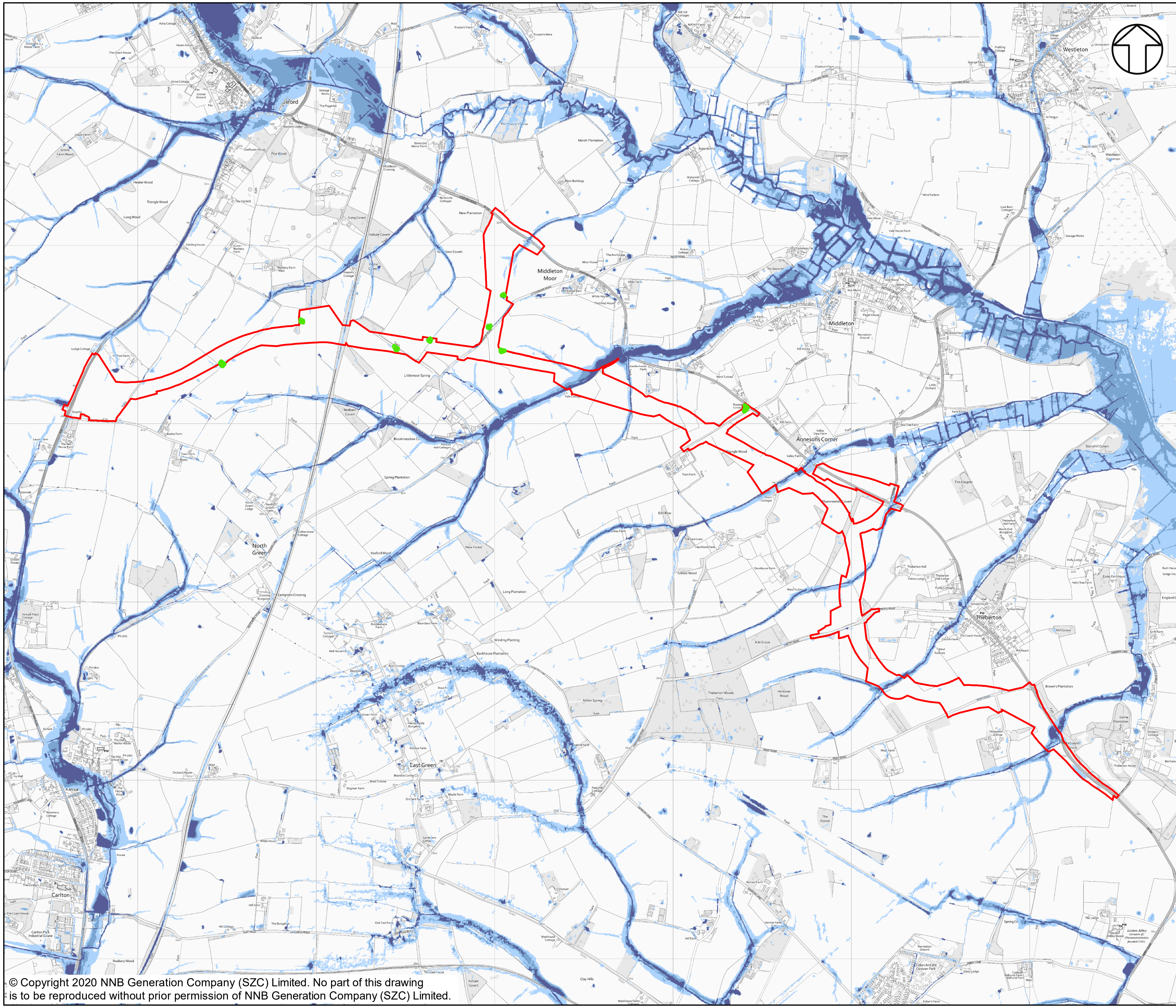

NOTES

KEY

SIZEWELL LINK ROAD DEVELOPMENT SITE BOUNDARY

PONDS WITHIN SITE BOUNDARY

ENVIRONMENT AGENCY RISK OF SURFACE WATER FLOODING

HIGH RISK (GREATER THAN 1 IN 30 ANNUAL PROBABILITY OF FLOODING)

MEDIUM RISK (BETWEEN 1 IN 100 AND 1 IN 30 ANNUAL PROBABILITY OF FLOODING)

LOW RISK (BETWEEN 1 IN 1,000 AND 1 IN 100 ANNUAL PROBABILITY OF FLOODING)

VERY LOW RISK (LESS THAN 1 IN 1,000 ANNUAL PROBABILITY OF FLOODING)

NOT PROTECTIVELY MARKED

DOCUMENT:
SIZEWELL C
SIZEWELL LINK ROAD
FLOOD RISK ASSESSMENT

DRAWING TITLE:
ENVIRONMENT AGENCY
RISK OF SURFACE WATER FLOODING MAP

DRAWING NO:
FIGURE 2

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JAN 2020	P.S.	1:20,000 @A3

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