Appendix B – Hydraulic Model Review

Horsham Strategic Flood Risk Assessment

Hydraulic Model Review

Horsham District Council

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Delivering a better world

Quality information

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1. Introduction

1.1 Introduction

AECOM have been commissioned to produce a Level 1 Strategic Flood Risk Assessment (SFRA) including creation of a Site Assessment Database to be used by Horsham District Council (HDC) in their application of the Sequential Test for Local Plan preparation.

The Horsham Level 1 SFRA will map Flood Zones 2, 3a and 3b (functional floodplain) in the present day and taking into account climate change. The focus of the SFRA, as identified within the Project Brief, will be on the River Arun and River Adur catchments. To assess fluvial and tidal flood risk associated with these catchments within the HDC administrative area, hydraulic models were requested from the Environment Agency and reviewed to confirm whether the outputs are suitable for use within the SFRA.

The hydraulic models provided by the Environment Agency in response to AECOM's data request on 3 April 2024 are listed below.

- Lower Tidal River Arun Strategy Model (2010)
- Adur Eastern Branch (2011)
- Horsham ABD and Hazard Mapping (2011)
- Adur Eastern Branch Climate Change Modelling (2017)
- Horsham Climate Change Flood Modelling (2017)
- Steyning Climate Change Modelling (2017)
- Upper Adur Climate Change Modelling (2017)
- Upper Arun – Arun Climate Change Modelling (2017)
- Upper Arun – Billingshurst Climate Change Modelling (2017)
- Upper Arun – Horsham Climate Change Modelling (2017)
- Upper Arun – Loxwood Climate Change Modelling (2017)
- River Adur Intertidal Model Updates (2022)

On the 5 June 2024, a meeting was held between the Environment Agency, AECOM and HDC, to discuss the models available (as listed above) and how they should be used as part of the Level 1 SFRA.

The purpose of this report is to summarise each of the models that have been provided by the Environment Agency and confirm if they were taken forward as part of the SFRA. Commentary is also provided on how the modelling results have been used and whether any modelling updates are required. This forms an appendix to the Level 1 SFRA.

1.2 Climate Change Allowances

Fluvial

For SFRAs the Environment Agency, as a statutory consultee, uses the management catchment climate change allowances from the peak river flow map as benchmarks[1]. The River Adur falls within the Adur and Ouse Management Catchment (Table 1-1) and the River Arun falls within the Arun and Western Streams Management Catchment (Table 1-2).

[1] Environment Agency (2022) Flood Risk Assessments Climate Change Allowances. Available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances (accessed May 2024)

Table 1-1: Peak river flow allowances for Adur and Ouse Management Catchment

Epoch	Central	Higher	Upper
2020s	16%	23%	40%
2050s	18%	28%	57%
2080s	37%	55%	107%

Table 1-2: Peak river flow allowances for Arun and Western Management Catchment

Epoch	Central	Higher	Upper
2020s	11%	16%	27%
2050s	13%	19%	36%
2080s	25%	36%	64%

In line with the Environment Agency's climate change guidance[1], both the central and higher allowances should be assessed as part of an SFRA. For the River Adur, the central and higher central allowances for the 2080s epoch are 37% and 55% respectively while for the River Arun they are 25% and 36%.

Tidal

There are a range of allowances for each river basin district and epoch for sea level rise. These are set out in Table 1-3 for the South East area and are based on percentiles. A percentile describes the proportion of possible scenarios that fall below an allowance level. The higher central allowance is based on the 70th percentile while the upper end allowance is based on the 95th percentile. An allowance based on the 70th percentile is exceeded by 30% of the projections in the range. At the 95th percentile it is exceeded by 5% of the projections in the range.

Table 1-3: Sea level allowances by river basin district for each epoch in mm for each year (based on 1981 to 2000 baseline) – the total sea level rise for each epoch is in brackets

Area of England	Allowance	2000 to 2035 (mm)	2036 to 2065 (mm)	2066 to 2095 (mm)	2096 to 2125 (mm)	Cumulative rise 2000 to 2125 (m)
South East	Higher Central	5.7 (200)	8.7 (261)	11.6 (348)	13.1 (393)	1.20
South East	Upper End	6.9 (242)	11.3 (339)	15.8 (474)	18.2 (546)	1.60

For SFRAs, both the higher central and upper end allowances should be assessed. There should also be consideration of the H++ scenario where deemed applicable i.e. if significant development is being proposed within areas considered to be at risk from tidal sources.

1.3 Environment Agency Liaison

A high level review of the Environment Agency's models listed in Section 1.1 was undertaken. This indicated that the majority do not have outputs which are in line with the latest climate change allowances (as presented in Section 1.2). Consequently, a meeting was held with the Environment Agency on 5 June 2024 to confirm an approach for the Level 1 SFRA.

The majority of development sites being taken forward by HDC as part of their Local Plan are located outside of Flood Zone 2 and 3, it was therefore agreed with the Environment Agency that a conservative approach will be applied where Flood Zone 2 will be combined with the latest climate change extents from the modelling available, to present a future fluvial and tidal flood extent to represent Flood Zone 3a. By combining the two datasets, whichever is greatest in extent will be reflected on the final figure.

Section 2 and 3 of this report summarises each of the models and confirms which were taken forward as part of the Level 1 SFRA. Table 2-1 provides an overview and confirms which climate change scenarios were taken forward to map future fluvial and tidal flood risk.

It was agreed with the Environment Agency and HDC that should any sites be taken forward which are located within Flood Zone 2 and 3 (and the future flood extent as detailed above), a detailed hydraulic modelling study would be required which includes the latest climate change allowances. Results from this modelling would then need to be used to inform the overall design for the type of development is proposed.

The extent of Flood Zone 3b was also discussed as the majority of the models provided by the Environment Agency did not include the 3.33% AEP event, which is now the event by definition that should be considered according to the Flood and Coastal Change Planning Practice Guidance (PPG)[2] which accompanies the National Planning Policy Framework (NPPF)[3]. It was agreed with both the Environment Agency and HDC that without this information, a conservative approach would be applied whereby the present day Flood Zone 3a would be used to represent Flood Zone 3b.

[2] Department for Levelling up, Housing and Communities (2022) Flood Risk and Coastal Change Guidance. Available at: https://www.gov.uk/guidance/flood-risk-and-coastal-change (accessed May 2024)
[3] Department for Levelling up, Housing and Communities (2023) National Planning Policy Framework. Available at: https://www.gov.uk/government/publications/national-planning-policy-framework (accessed May 2024)

2. River Adur Models

This section of the report provides an overview of the River Adur models that were provided by the Environment Agency. A brief summary of each model is provided i.e. software, model extent, climate change allowances simulated along with an overview of if/how the model has been used as part of the SFRA. Table 2-1 provides a list of all models (River Adur and River Arun) and whether they were used to inform the figures within the SFRA.

2.1 Adur Eastern Branch Model (2011 and 2017)

Model Summary: The Adur Eastern Branch Model was produced in 2011 by Hyder (now part of Arcadis). This is a 1D only model simulated using ISIS v3.4 software. The Annual Exceedance Probability (AEP) events simulated as part of this model include: 20%, 5%, 2%, 1.33%, 1%, 0.4% and 0.1%. The climate change scenario involves uplifting the 1% AEP flows by 20%.

In 2017 JBA Consulting used the 2011 Adur Eastern Branch Model and simulated the latest climate change allowances associated with the Adur and Ouse Management Catchment which were published at that time. This involved uplifting the 1% AEP flows by 35%, 45% and 70% to represent the central, higher and upper end allowances respectively. It is assumed that no other updates were made to the model or the hydrology, with exception of the software which was upgraded to Flood Modeller Pro (FMP) v4.2.

The model includes representation of the Main Rivers through Burgess Hill however this is located outside of the HDC boundary. The watercourse flows into the HDC boundary at Wineham Lane (523620, 119560) while the downstream extent is at Henfield immediately downstream of the River Adur and Chess Stream confluence (518880, 115700). Watercourses modelled include the River Adur, Herrings Stream, Pook Bourne Stream, Chess Stream, Cowfold Stream and a number of small tributaries to the River Adur (Figure A1).

Use in Level 1 SFRA: The outputs from the 2011 Adur Eastern Branch Model have been disregarded as they have been superseded by the 2017 Climate Change updates. As discussed in Section 2.2, the model extents associated with the Adur Eastern Branch model and the Upper Adur Climate Change model are very similar for the eastern branch. However, the flood extents associated with the Adur Eastern Branch model are slightly smaller than the Upper Adur Climate Change model. As a conservative approach is being applied for mapping future fluvial flood risk (see Section 1.2), the outputs from the 2017 Adur Eastern Branch model have been disregarded and instead, the outputs from the 2017 Upper Adur Climate Change modelling (Section 2.2) have been taken forward.

2.2 Upper Adur Climate Change Modelling (2017)

Model Summary: The Upper Adur Climate Change Modelling was undertaken in 2017 by JBA Consulting. This study simulated the latest climate change allowances associated with the Adur and Ouse Management Catchment which were published at that time, using an existing hydraulic model (details not provided). This involved uplifting the 1% AEP flows by 35%, 45% and 70% to represent the central, higher and upper end allowances respectively. The model was a 1D only model and was simulated using FMP v4.2. It is assumed that no other updates were made to the model or the hydrology.

The model includes representation of a similar extent as the Adur Eastern Branch model. For the eastern branch the upstream extent of the model is located at Burgess Hill (outside of the HDC boundary) while the upstream extent for the western branch is located at Coolham (512180, 123465) which is located within the HDC boundary (Figure A2). The River Arun watercourses from the Eastern and Western branches then confluence to the west of Henfield. The Upper Adur model continues to represent the River Adur downstream from this location to the A283 between Steyning and Upper Beeding (519385, 110030). This forms the downstream extent of the model.

Use in Level 1 SFRA: as discussed in Section 2.1, the outputs from the 2017 Upper Adur Climate Change modelling are larger in extent when compared to the 2017 Adur Eastern Branch model. The model also covers the western branch of the River Adur. To maintain consistency, these outputs have been taken forward within the Level 1 SFRA and have been used to map future fluvial flood risk within the upper catchment of the River Arun. It should be noted however that downstream of Henfield on the River Arun, results from the 2022 Adur Intertidal Model have been used. This model represents the latest climate change allowances but also more accurately represents this stretch of the River Adur as it is a more up to date model. These results haven’t been used in the areas upstream of Henfield as a conservative approach has been applied whereby the climate change extents that are larger in size have been used. This include the outputs from the 2017 Upper Adur Climate Change model. Furthermore, the 2022 Adur Intertidal Model does not include full representation of the eastern and western branches of the River Adur.

2.3 Steyning Climate Change Modelling (2017)

Model Summary: The Steyning Climate Change Modelling was undertaken in 2017 by JBA Consulting. This study simulated the latest climate change allowances associated with the Adur and Ouse Management Catchment which were published at that time, using an existing hydraulic model (details not provided). This involved uplifting the 1% AEP flows by 35%, 45% and 70% to represent the central, higher and upper end allowances respectively. The model was a 1D only model and was simulated using FMP v4.3. It is assumed that no other updates were made to the model or the hydrology.

The model includes representation of the Tanyard Stream through Steyning. From a review of the model results, it appears that the upstream extent of the model is located upstream of High Street (517290, 111525), while the downstream extent is located approximately where the Tanyard Stream confluences with the Black Sewer downstream of the A283 (518120, 111735) (Figure A2). This watercourse continues to flow east to the confluence with the River Adur.

Use in Level 1 SFRA: Outputs from this model have been used through the town of Steyning (i.e. from High Street to Shooting Field). However, downstream of this location (i.e. between Shooting Field and the River Adur confluence) results have been superseded by the 2022 Adur Intertidal Model.

2.4 Adur Intertidal Model (2022)

Model Summary: In 2022, JBA Consulting completed a hydraulic modelling study for the Environment Agency which involved updating an existing fluvial flood risk model of the River Adur. The model updates which included both hydrology and hydraulics, was commissioned to produce a model with improved flood risk extents and which could be confidently used to understand the sensitivity of the River Arun to changes in channel geometry and defences heights/locations. The model produced was a 1D-2D model, built using FMP v4.5 and TUFLOW version 2020-01-AB. The AEP events simulated as part of this model include: fluvial - 20%, 5%, 1.33%, 1%, 0.1% (defended and undefended) and for tidal – Mean High Water Spring (MHWS), 20%, 5%, 1.33%, 0.5% and 0.1% (defended and undefended).

When it comes to modelling climate change, three climate change scenarios were completed for the 1% AEP fluvial event. This was based on the latest Environment Agency fluvial climate change guidance (July, 2021) for the Adur and Ouse Management Catchment, using the 2080s (2070 – 2115) factors of 37% (central), 55% (higher) and 107% (upper end). For the tidal model, three climate change scenarios were completed for the 0.5% AEP tidal event. The levels and tidal curve for the downstream boundary of the model were derived from the MHWS levels for the entrance to Shoreham Harbour using the Coastal Flood Boundary Dataset (2018). An uplift to this MHWS level was then applied for climate change simulations reflecting sea-level rise allowance for central, higher and upper end scenarios.

The model includes representation of the River Adur between the A27 (Shoreham Bypass) (520650, 106370) at Shoreham (downstream extent) to a location 500m upstream of the A281 between Henfield and Shermanbury (upstream extent) (521270, 118615) (Figure A3).

Use in Level 1 SFRA: this model represents the latest climate change allowances and therefore supersedes the majority of the results from the other models in this area. The only exception is upstream of Henfield where the flood extents are greater in size for the 2017 Upper Adur Climate Change model. Furthermore, this model includes a greater representation of the River Adur, extending the full length of the eastern and western branches. Consequently, the 2017 Upper Adur Climate Change model outputs have been used within this area.

3. River Arun Models

3.1 Lower Tidal River Arun Strategy Model (2010)

Model Summary: In 2010, Atkins undertook a flood defence strategy for the Lower Tidal River Arun. This strategy required a hydrodynamic model of the River Arun catchment to assess options for managing flood risk. The Environment Agency also required detailed flood modelling of the catchment to deliver flood risk mapping. The model produced was a 1D-2D model using InfoWorks RS modelling software. The AEP events simulated as part of this model include: 5%, 1.33%, 1% and 0.1%. The climate change scenario involves uplifting the 1% AEP flows by 20%.

The 1D river channel extends from Pallingham Weir at the northern upstream end of the catchment (504735, 122965) and extends down to the A259 at Littlehampton (501575, 102382) (Figure B1). The model also includes 1D river channel representation of: the River Rother from Fittleworth (500960, 118250) to its confluence with the River Arun (503440, 118035), the River Stor from Wickford Bridge (506470, 118090) to its confluence with the River Arun (505320, 117995) and the Black Ditch through Angmering from the A280 (507635, 104790) to its confluence with the River Arun (501020, 104260). Upstream of Stopham Bridge, the River Arun is represented as 1D only. For the remainder of the catchment the majority of the floodplain has been modelled with 2D zones where it was technically appropriate and feasible.

Use in Level 1 SFRA: None of the other models provided by the Environment Agency include representation of the River Arun within the area modelled as part of the 2010 Lower Tidal River Arun Strategy Model. However, the climate change allowance applied to this model (+20%) is significantly out of date when compared to the latest climate change allowances. Consequently, a combination of this flood extent combined with the Environment Agency's Flood Zone 2 extent as a proxy has been produced which was an agreed approach with the Environment Agency during the meeting on 5 June 2024. It should be noted that this approach has been applied from the HDC boundary at South Stoke (downstream) to Pallingham Weir (upstream). This includes the settlements of Pulborough, Hardham, Coldwaltham, Amberley, Houghton and North Stoke.

3.2 Horsham ABD and Hazard Mapping (2011 and 2017)

Model Summary: The Horsham ABD and Hazard Mapping project was undertaken by JBA Consulting in 2011. This study was commissioned to produce modelling and mapping of fluvial reaches within Horsham. The model produced was a 1D-2D model using ISIS v3.3 and TUFLOW version 2009-07-AF. The AEPs simulated include: 20%, 5%, 2%, 1.33%, 1%, 0.4% and 0.1%. The climate change scenario involves uplifting the 1% AEP flows by 20%.

In 2017, JBA Consulting used the 2011 Horsham ABD and Hazard Mapping Model and simulated the latest climate change allowances associated with the Arun and Western Streams Management Catchment which were published at that time. This involved uplifting the 1% AEP flows by 35%, 45% and 105% to represent the central, higher and upper end allowances respectively. It is assumed that no other updates were made to the model or the hydrology, with exception of the software which was upgraded to ISIS v3.7 and TUFLOW 2013-12-AE.

The model includes representation of the River Arun (from the A281 (519930, 129145) to A264 New Bridge (513940, 130920)), Boldings Brook (from Station Road (516730, 134005) to its confluence with the River Arun (515450, 130220)) and Chennells Brook (from the A264 (518995, 133370) to its confluence with Warnham Mill Pond (517055, 132395)). This is shown in Figure B2.

Use in Level 1 SFRA: The outputs from the 2011 Horsham ABD and Hazard Mapping study have been disregarded as they have been superseded by the 2017 Climate Change updates. However, the extents from the 2017 Climate Change updates have also been disregarded as they have been superseded by the Upper Arun modelling for Horsham as described in Section 3.3.

3.3 Upper Arun Climate Change Modelling – Horsham, Loxwood, Billinghurst and Arun (2017)

Model Summary: In 2017, JBA Consulting undertook modelling updates on four separate hydraulic models in the areas around Horsham, Loxwood, Billinghurst and the Upper Arun catchment. This study simulated the latest climate change allowances associated with the Arun and Western Streams Management Catchment which were published at that time, using existing hydraulic models (details not provided). This involved uplifting the 1% AEP flows by 35%, 45% and 105% to represent the central, higher and upper end allowances respectively.

The models are all 1D only model and were simulated using FMP v4.3. It is assumed that no other updates were made to the model or the hydrology.

The four models include:

- Upper Arun – Horsham: same watercourse representation and upstream extents as the 2011 and 2017 Horsham ABD and Hazard Mapping Model, but this model extends further downstream to Slinfold (512410, 131520) (Figure B3).
- Upper Arun – Arun: this model includes representation of North River which flows into the HDC boundary near Bognot Road (514520, 136675), to the confluence with the River Arun (511845, 132330), River Arun from the confluence with North River (511845, 132330) to Pallingham Weir 504735, 122965), River Lox (located outside of the HDC boundary) and River Kird (outside of the HDC boundary) (Figure B4).
- Upper Arun – Loxwood: this model includes representation of the Anstead Brook outside of the HDC boundary.
- Upper Arun – Billingshurst: this model includes representation of Par Book / Brockhurst Brook through Billinghurst from an upstream location at Coneyhurst Road (509930, 124850) to the confluence with the River Arun (506485, 124705). There is also representation of a separate tributary which flows from Forge Way in Billingshurst (508295, 125535) to its confluence with Par Book / Brockhurst Brook (507230, 124735) (Figure B5).

Use in Level 1 SFRA: The Upper Arun – Loxwood model is located outside of the HDC boundary so hasn't been used within the Level 1 SFRA. With the Upper Arun – Arun model, the River Lox and River Kird are also located outside of the HDC boundary so these results have been trimmed to the HDC boundary. All other results from the Upper Arun – Horsham and Upper Arun – Billingshurst have been taken forward. As noted in Section 3.2, the 2017 Upper Arun – Horsham results supersede the 2017 Horsham Climate Change results.

Table 2-1: Summary of Hydraulic Models

Model	Date	Coverage	Climate Change Allowances	Used in Level 1 SFRA?
Adur Eastern Branch Model	2011	River Adur – Eastern branch from Burgess Hill to Henfield	+20%	No – superseded by Adur Eastern Branch Climate Change Model (2017)
Adur Eastern Branch Climate Change Model	2017	River Adur – Eastern branch from Burgess Hill to Henfield	+35%, +45% and +70%	No – superseded by Upper Adur Climate Change Model (2017)
Upper Adur Climate Change Model	2017	River Adur – Eastern and Western branch down to Steyning	+35%, +45% and +70%	Yes – the +45% climate change extent combined with the EA's Flood Zone 2
Steyning Climate Change Model	2017	Tanyard Stream through Steyning	+35%, +45% and +70%	Yes – the +45% climate change extent combined with the EA's Flood Zone 2
Adur Intertidal Model	2022	River Adur – Henfield to Shoreham	+37%, +55% and +107% Tidal uplifts for central, higher central and upper	Yes – the +55% climate change fluvial extent and the higher central tidal extent combined with the EA's Flood Zone 2
Lower Tidal River Arun Strategy Model	2010	River Arun – Pallingham Weir to Littlehampton	+20%	Yes – the +20% climate change extent combined with the EA's Flood Zone 2
Horsham ABD and Hazard Mapping	2011	River Arun (and tribs) through Horsham	+20%	No – superseded by the Horsham ABD and Hazard Mapping study in 2017
Horsham ABD and Hazard Mapping	2017	River Arun (and tribs) through Horsham	+35%, +45% and +105%	No – superseded by the Upper Arun (Horsham) Model
Upper Arun – Horsham Model	2017	River Arun (and tribs) through Horsham	+35%, +45% and +105%	Yes – conservative approach with the +45% extent combined the EA's Flood Zone 2
Upper Arun – Billingshurst Model	2017	Par Book / Brockhurst Brook through Billingshurst	+35%, +45% and +105%	Yes – conservative approach with the +45% extent combined the EA's Flood Zone 2
Upper Arun – Arun Model	2017	River Arun (and tribs) from Horsham to Pallingham Weir	+35%, +45% and +105%	Yes – conservative approach with the +45% extent combined the EA's Flood Zone 2
Upper Arun – Loxwood Model	2017	Anstead Brook	+35%, +45% and +105%	No – outside the HDC boundary

4. Conclusion

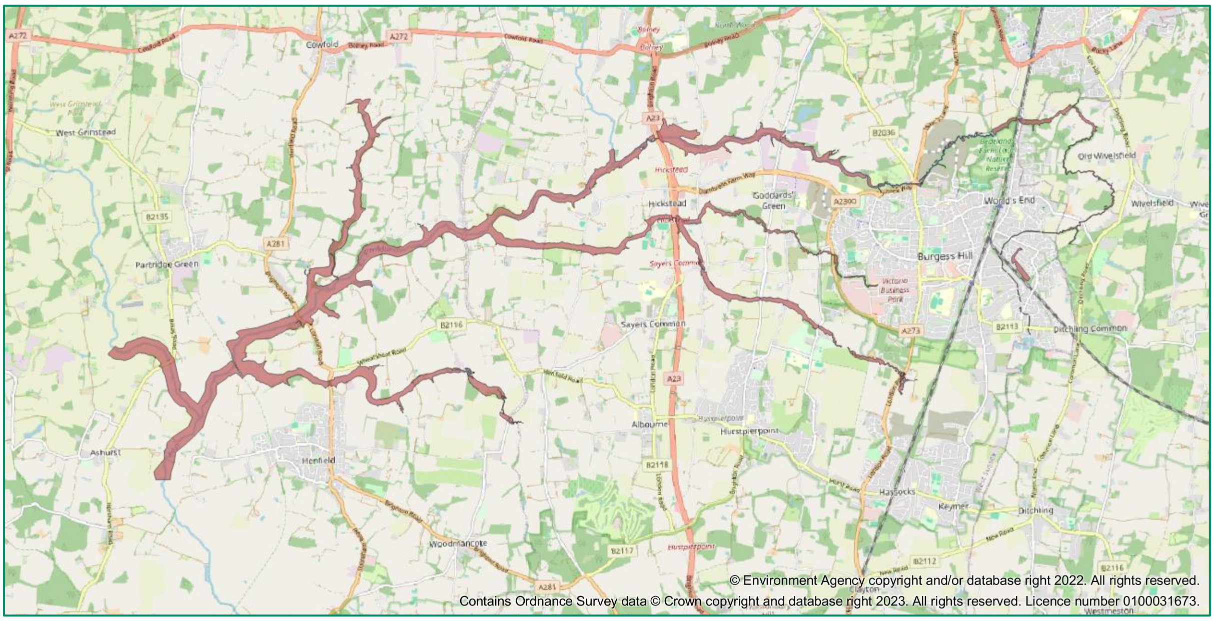
As part of the Horsham Level 1 SFRA, the Environment Agency provided a number of hydraulic models across the River Arun and River Adur catchments with results to be used to map current and future fluvial and tidal flood risk across HDC.

Following a high level review of these models, the majority did not include results which reflected the latest Environment Agency climate change allowances. A meeting was therefore held with the Environment Agency on 5 June 2024, where it was agreed that the latest climate change flood extents available would be combined with the Environment Agency's Flood Zone 2 (as a proxy) to map future fluvial and tidal flood risk. This was considered a suitable approach as the majority of development sites being taken forward by HDC, are located outside of Flood Zone 2 and 3.

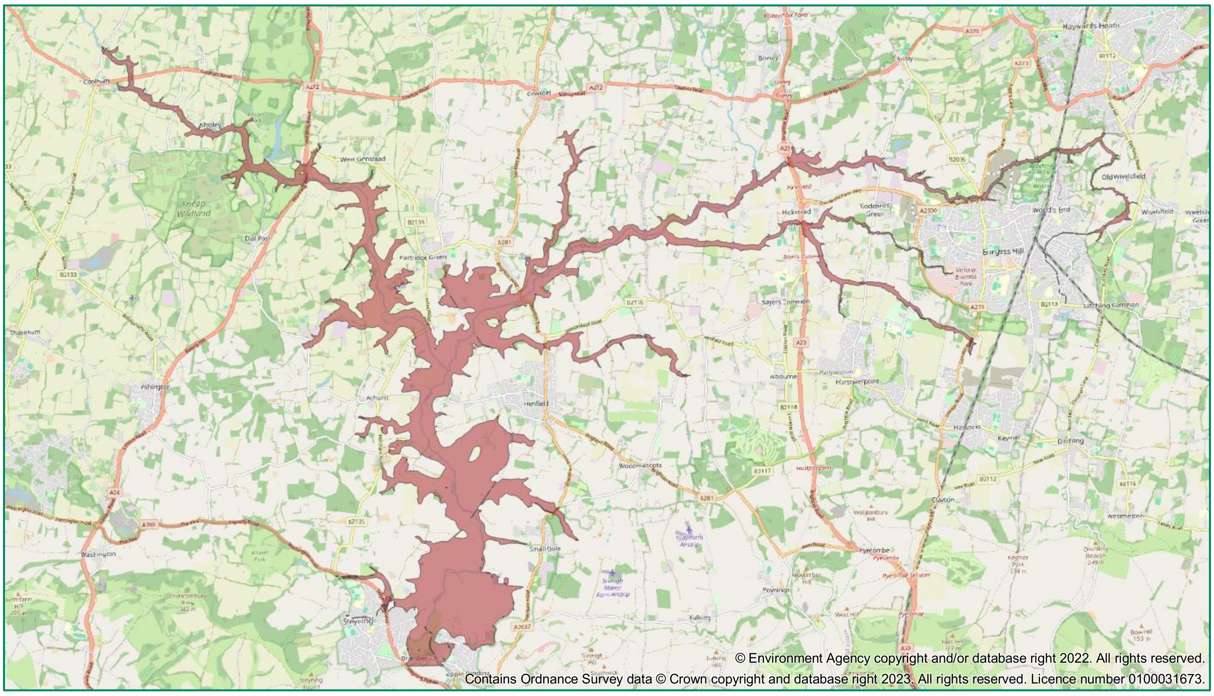
It was agreed with the Environment Agency and HDC that should any sites be taken forward which are located within Flood Zone 2 and 3 (and the future flood extent as detailed in Section 1.3), a detailed hydraulic modelling study would be required which includes the latest climate change allowances as part of a Level 2 SFRA. Results from this modelling would then need to be used to inform the overall design of the development proposed.

It was also agreed with both the Environment Agency and HDC that a conservative approach would be applied when mapping the functional floodplain with Flood Zone 3a used as a proxy for Flood Zone 3b.

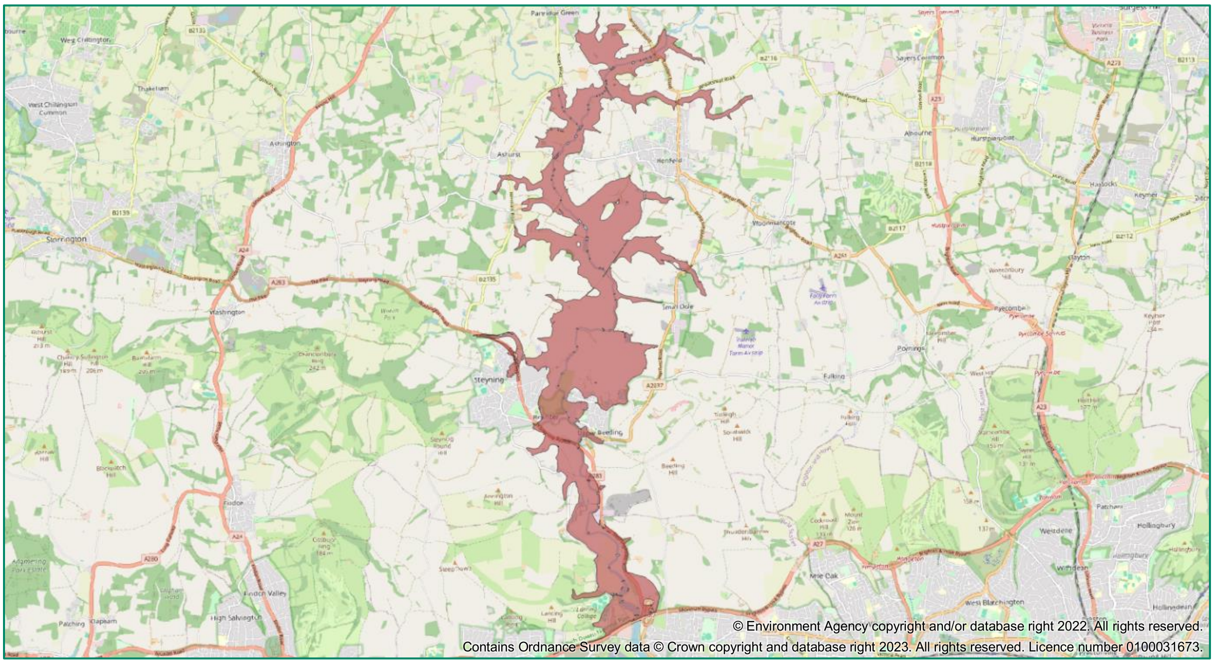
Appendix A – River Adur Model Extents



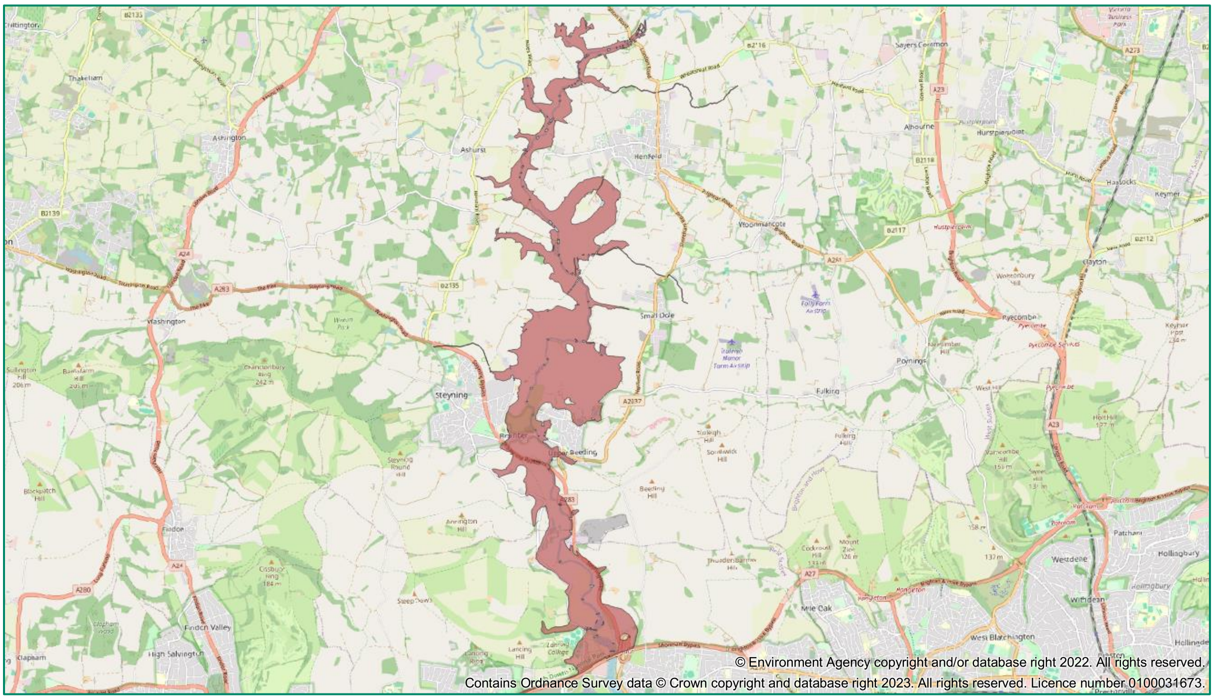
A1. Adur Eastern Branch Model (2017) – 1% AEP plus 45% Climate Change (undefended)



A2. Upper Adur and Steyning Model (2017) - 1% AEP plus 45% Climate Change (undefended)

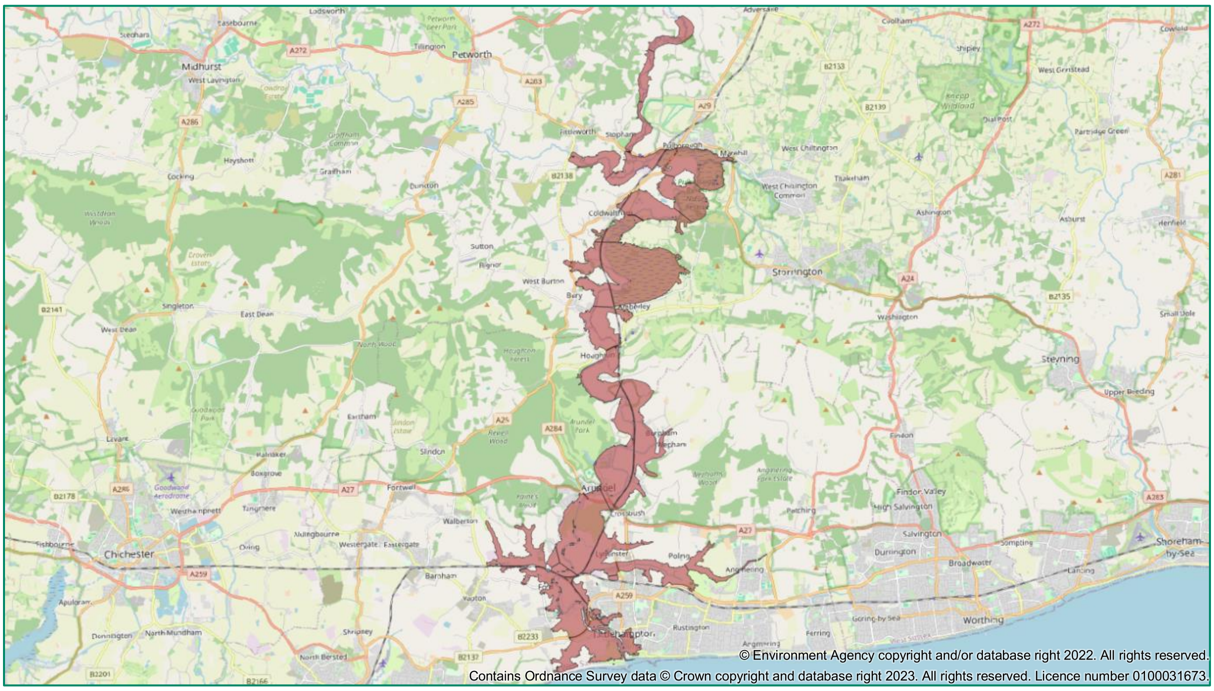


A3. Adur Intertidal Model (2022) – 1% AEP plus 55% climate change (undefended)

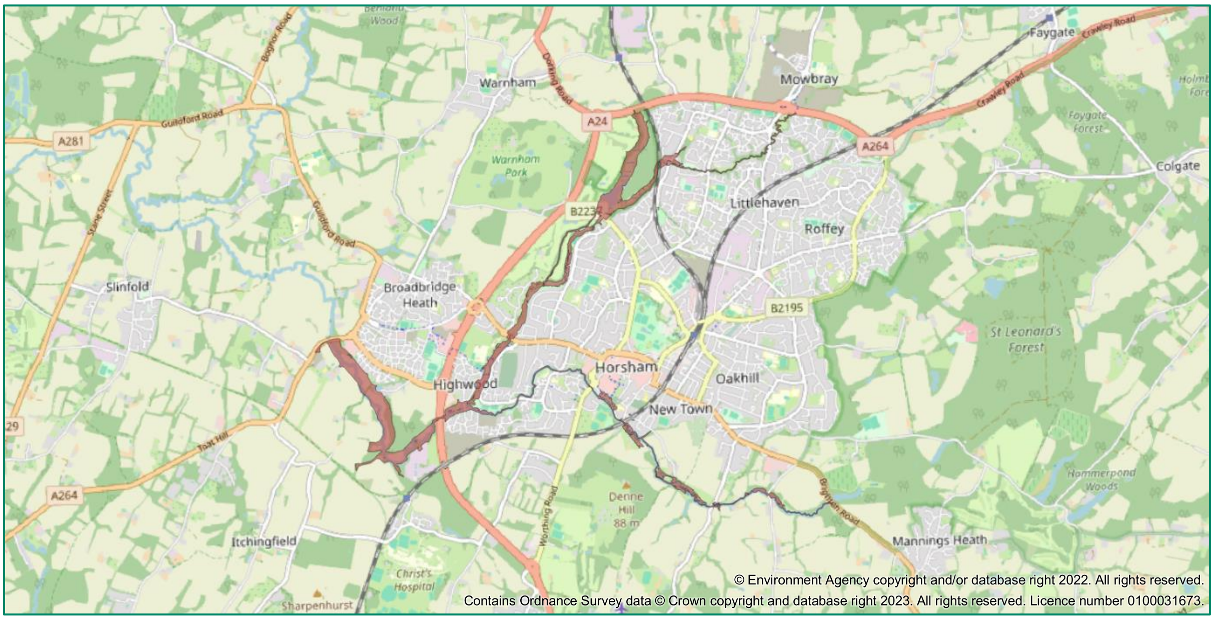


A4. Adur Intertidal Model (2022) – 0.5% AEP, Higher Central Climate Change 2080s (undefended)

Appendix B – River Arun Model Extents

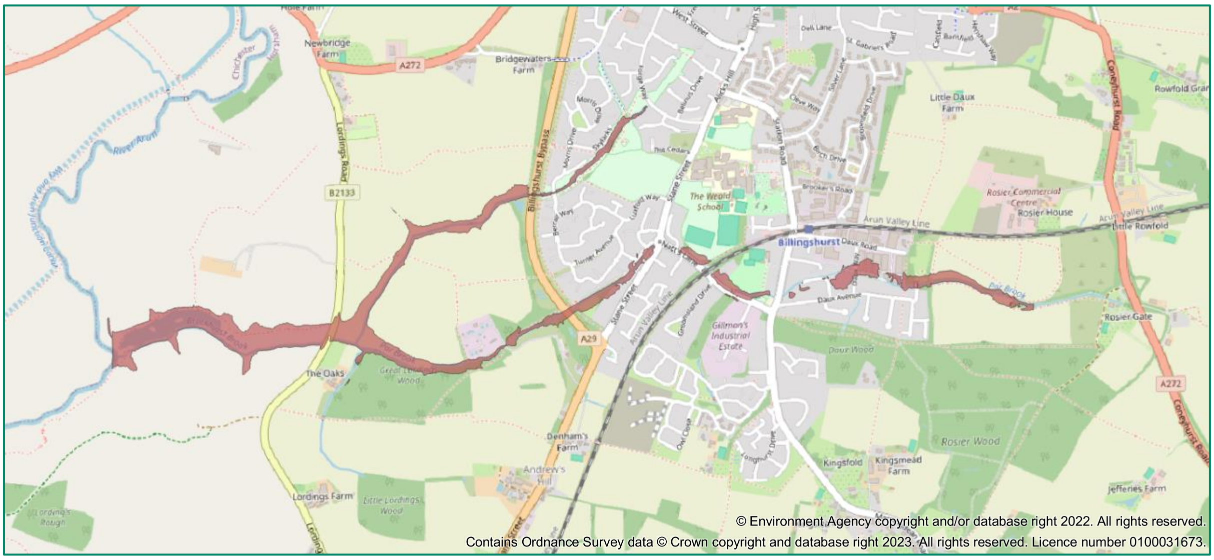


B1. Lower Tidal River Arun Strategy Model (2010) – 1% AEP +20% climate change (undefended)

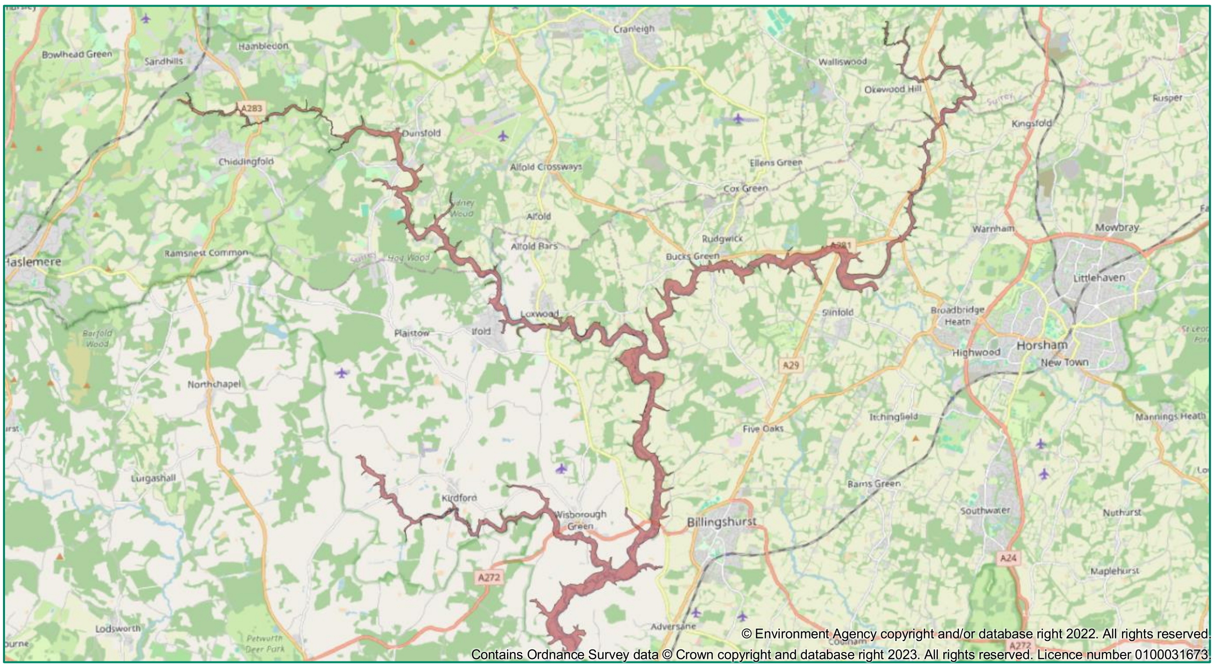


B2. Horsham ABD and Hazard Mapping Model (2011) – 1% AEP plus 45% climate change (undefended)

B3. Upper Arun (Horsham) Model (2017) - 1% AEP plus 45% climate change (undefended)



B4. Upper Arun (Billingshurst) Model (2017) - 1% AEP plus 45% climate change (undefended)



B5. Upper Arun (Arun) Model (2017) - 1% AEP plus 45% climate change (undefended)

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