Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects

Environmental Statement

Volume 3

Appendix 18.2 - Annex 18.2.2: Onshore Substation Hydraulic Modelling Technical Note

August 2022
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equinor

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Glossary of Acronyms

AOD	Above Ordnance Datum
BFIHOST	Base flow index by Soil Types (HOST) classification
DDF	Depth Duration Frequency
DEP	Dudgeon Offshore Wind Farm Extension Project
DSM	Digital Surface Model
DTM	Digital Terrain Model
FEH	Flood Estimation Handbook
LLFA	Lead Local Flood Authority
LiDAR	Light Detection and Ranging
NPPF	National Planning Policy Framework
OnSS	Onshore Substation
PEIR	Preliminary Environmental Information Report
PPG	Planning Practice Guidance
SEP	Sheringham Offshore Wind Farm Extension Project
SPRHOST	Standard Percentage Runoff associated with each (HOST) soil class

Glossary of Terms

Order Limits	The area subject to the application for development consent, including all permanent and temporary works for SEP and DEP.
Dudgeon Offshore Wind Farm Extension Project (DEP)	The Dudgeon Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
DEP onshore site	The Dudgeon Offshore Wind Farm Extension onshore area consisting of the DEP onshore substation site, onshore cable corridor, construction compounds, temporary working areas and onshore landfall area.
Landfall	The point at the coastline at which the offshore export cables are brought onshore, connecting to the onshore cables at the transition joint bay above mean high water
Onshore cable corridor	The area between the landfall and the onshore substation sites, within which the onshore cable circuits will be installed along with other temporary works for construction.
Onshore export cables	The cables which would bring electricity from the landfall to the onshore substation. 220 – 230kV.
Onshore Substation	Compound containing electrical equipment to enable connection to the National Grid.
PEIR boundary	The area subject to survey and preliminary impact assessment to inform the PEIR.
Sheringham Shoal Offshore Wind Farm Extension Project (SEP)	The Sheringham Shoal Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
SEP onshore site	The Sheringham Shoal Wind Farm Extension onshore area consisting of the SEP onshore substation site, onshore cable corridor, construction compounds, temporary working areas and onshore landfall area.
Study area	Area where potential impacts from the project could occur, as defined for each individual Environmental Impact Assessment (EIA) topic.
The Applicant	Equinor New Energy Limited

ANNEX 18.2.2: ONSHORE SUBSTATION HYDRAULIC MODELLING TECHNICAL NOTE

1 Introduction

1. This annex provides a technical note with regards to the hydraulic modelling on the onshore substation for the Sheringham Shoal Offshore Wind Farm Extension Project (SEP) and Dudgeon Offshore Wind Farm Extension Project (DEP).

1.1 Background

2. A review of the Environment Agency online surface water flood risk mapping was undertaken to inform the understanding of surface water flood risk at the proposed Onshore Substation (OnSS) site to the south-west of Norwich.

3. Reference to the Environment Agency's online surface water mapping indicates an overland flow path crosses the proposed OnSS site with water pooling against the railway embankment in the proposed location of the sub-station platform, as shown in **Figure 1**. As such, it was considered necessary to investigate this potential flood mechanism further.

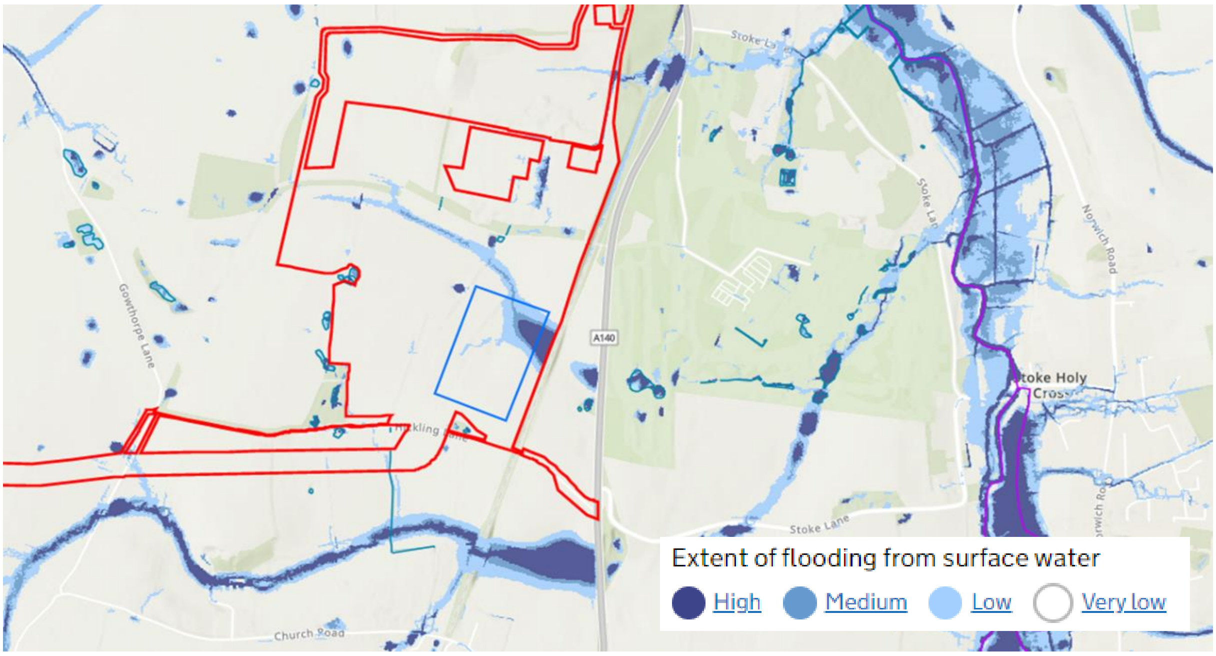

Figure 1: Extract of Environment Agency Surface Water Flood Risk Mapping in Comparison with the OnSS Platform

4. To understand the above flood risk in greater detail, a 2D direct rainfall model has been constructed, covering the site of the proposed new OnSS platform to be located in an existing agricultural field to the west of Ipswich Road and the railway embankment and to the north of Hickling Lane (approximate grid reference: 621847, 301820).

5. This Technical Note provides a summary of the modelling exercise undertaken and the subsequent results which have been reviewed to provide a greater understanding of surface water flood risk in this location.

2 Hydrological Analysis

6. A review of the British Geological Survey online mapping ([redacted]) indicated the OnSS site to be located above a bedrock of chalk with deposits of diamicton.

7. In addition, a review of the Flood Estimation Handbook (FEH) catchment descriptors obtained from the FEH Web Service [redacted] showed the catchment to have a very high base flow index (BFIHOST)19 value of 0.795 which suggests high permeability and relatively low standard percentage runoff associated with each host soil class (SPRHOST) with a value of 23.86% which indicates relatively low surface water runoff, based on the soil classification.

8. However, onsite soakaway testing carried out, as part of a series of borehole and trial pit investigations, in September 2021 indicated that there was very low infiltration across the OnSS site. The soakaway tests were abandoned due to a lack of infiltration into the ground over the time period that was monitored (180 – 300 minutes) because water levels had not dropped below 75% of the starting head in the majority of the test locations. As a result, infiltration rates could not be calculated because they require water level data at 75% and 25% of the starting head.

9. Therefore, there is uncertainty in the infiltration potential of the catchment which may be hindered by the presence of other sub-surface layers above the chalk, such that surface water runoff is unlikely to infiltrate into the ground.

10. In addition, a review of the hydrological catchment was undertaken to ensure that the contributing area was aligned with that expected based on the local topography, the hydrological catchment has been reproduced in **Figure 2**.

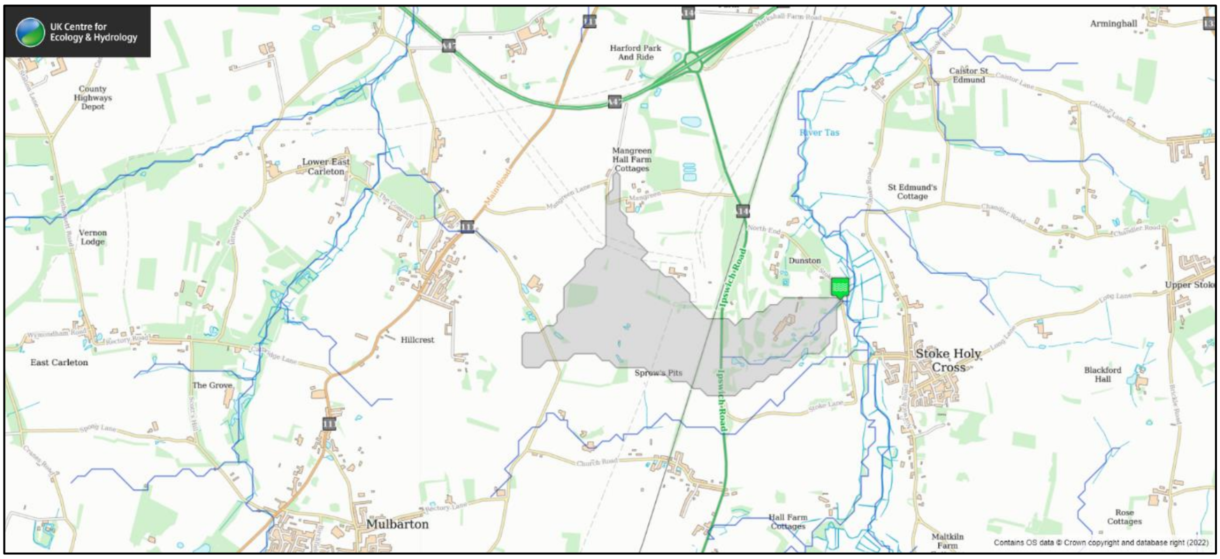

Figure 2: Extract from the FEH Web Service Showing Contributing Hydrological Catchment

11. Following review of the hydrological catchment, the ReFH2 software was used to generate direct rainfall hyetographs based on the FEH13 Depth-Duration-Frequency (DDF) estimates. Following FEH guidelines, the winter storm profile was used, in line with best practice guidance, on the basis that the URBEXT2000 value for the catchment was less than 0.30.

12. Given the poor infiltration potential, a conservative approach to the hydrological analysis was initially adopted whereby the gross rainfall hyetographs were applied as a direct rainfall boundary, rather than the net rainfall. This meant that no losses to the ground were included in the rainfall runoff model.

13. A review of the critical storm duration found that the critical storm (i.e. duration of the rainfall event) for this catchment is 7.5 hours. Therefore, the model was subsequently run for a total of 12 hours to allow time for surface water to flow through the catchment following the storm and to ensure that maximum depths were modelled in the areas where ponding would occur.

14. For the hydrological inputs to the model, rainfall hyetographs were prepared for the 1 in 10 year, 1 in 30 year, 1 in 100 year, 1 in 100 year (plus 20% for climate change) and 1 in 100 year (plus 40% for climate change) events.

3 Hydraulic Model Construction

15. The model was built using the TUFLOW 2D modelling software which is benchmarked by the Environment Agency and is considered suitable for predicting flood levels, depths, flow velocities and flood hazard ratings across floodplains.

16. The Environment Agency open source LiDAR comprising the Digital Terrain Model (DTM) at 0.5m resolution was used to create the digital elevation model i.e. the ground profile over which the rainfall is distributed.

17. This data was also cross referenced with survey data flown for the Project in August 2021 and the equivalent Digital Surface Model (DSM), i.e. unfiltered LiDAR, for validation. The digital elevation model was checked prior to running the modelling scenarios to ensure the railway embankment, drainage ditches and other features within the study area were sufficiently picked up.

18. Within the model a cell size of 2m was considered suitable for the study, to capture the flow paths while still allowing a reasonable model simulation time.

19. Mannings roughness values as defined by Chow (1959) in the publication '*Open Channel Hydraulics'* were used to define the surface roughness. As much of the modelled catchment comprises fields then roughness values of between 0.035 and 0.045 were typically applied. Where there were areas of denser woodland these were assigned a value of 0.08, to reflect the greater roughness and slowing of flow that they are likely to represent.

20. Where there were known ground features, for example field boundaries and hedgerows these were not only reviewed within the ground elevation model to ensure they had been appropriately represented but also, where necessary, modifications were made to the roughness values in these locations to be representative of the vegetation.

21. The rainfall boundary was applied, within the model, as a single 'RF' polygon which covered the whole of the contributing catchment. A 'HT' boundary was applied to the catchment boundary with a constant outflow of -50 to enable any water reaching the edge of the model to flow out and not cause spurious results at the model boundary. As the contributing catchment extends to the north, west and south of the OnSS site it is considered to be far enough from the edge of the model so as not to affect either the results at the OnSS site or the outflow boundary.

4 Modelling Results

4.1 Initial Baseline Modelling

22. The model was run for the baseline scenario (i.e. with no platform included) for the 1 in 100 year event to test the stability. A review of the cumulative error was noted as being 0% and there were no negative depths, which is an indication of a stable model.

23. Following review, the model was subsequently run for all of the return period events identified in **Section 2** above to provide a baseline understanding of the existing surface water flood risk in this location. The resulting depth maps are included as **Figure 3** – **Figure 6**.

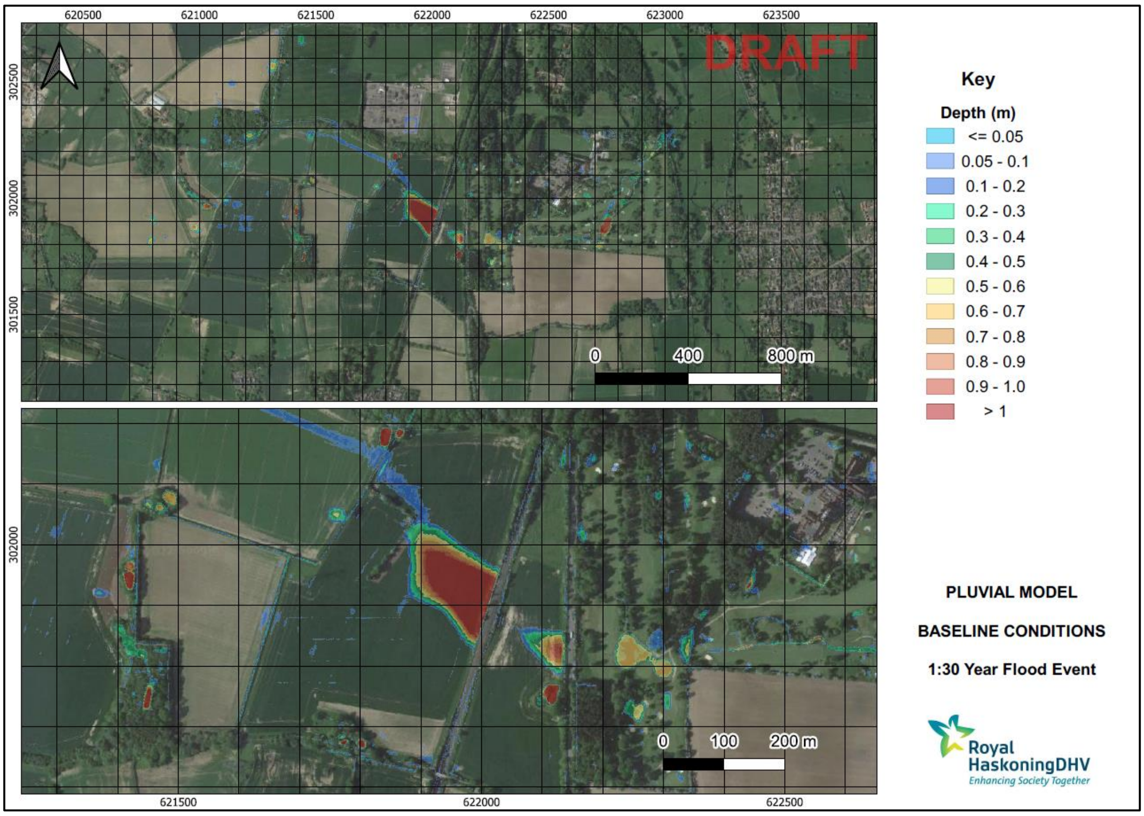

Figure 3: 1 in 30 Year Baseline (Existing Scenario) Flood Depth

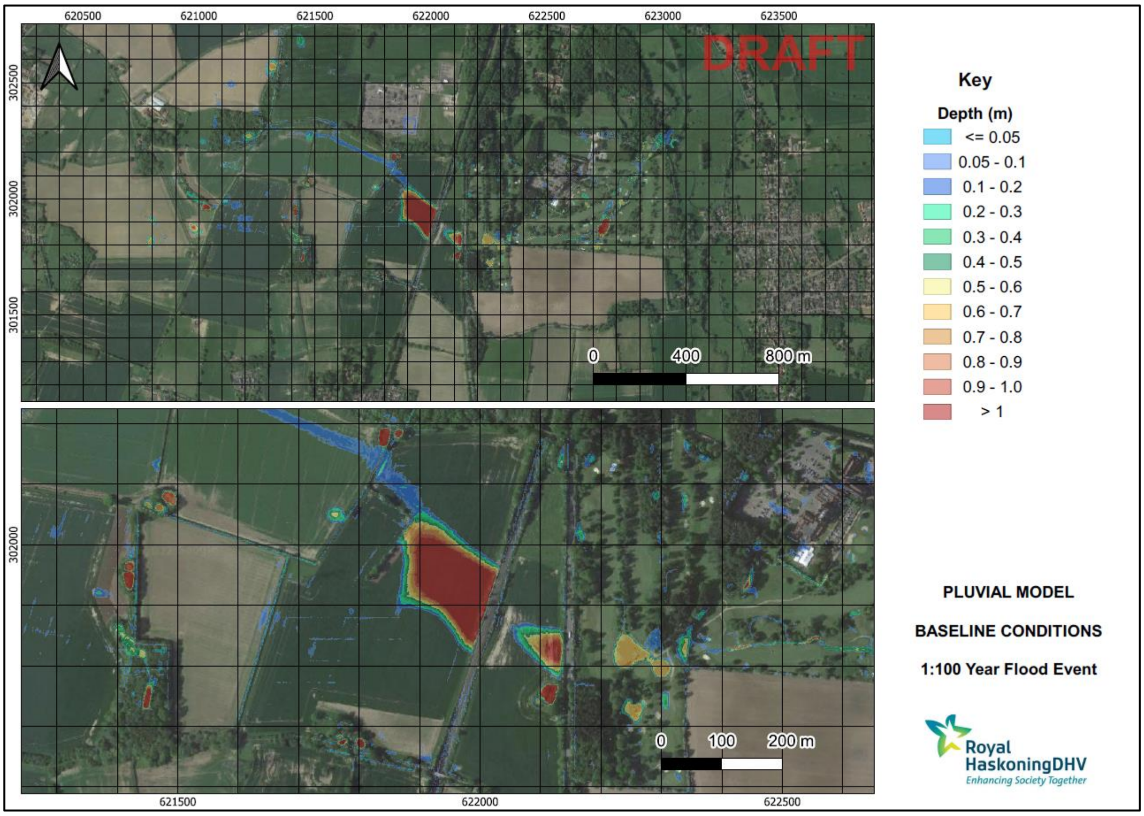

Figure 4: 1 in 100 Year Baseline (Existing Scenario) Flood Depth

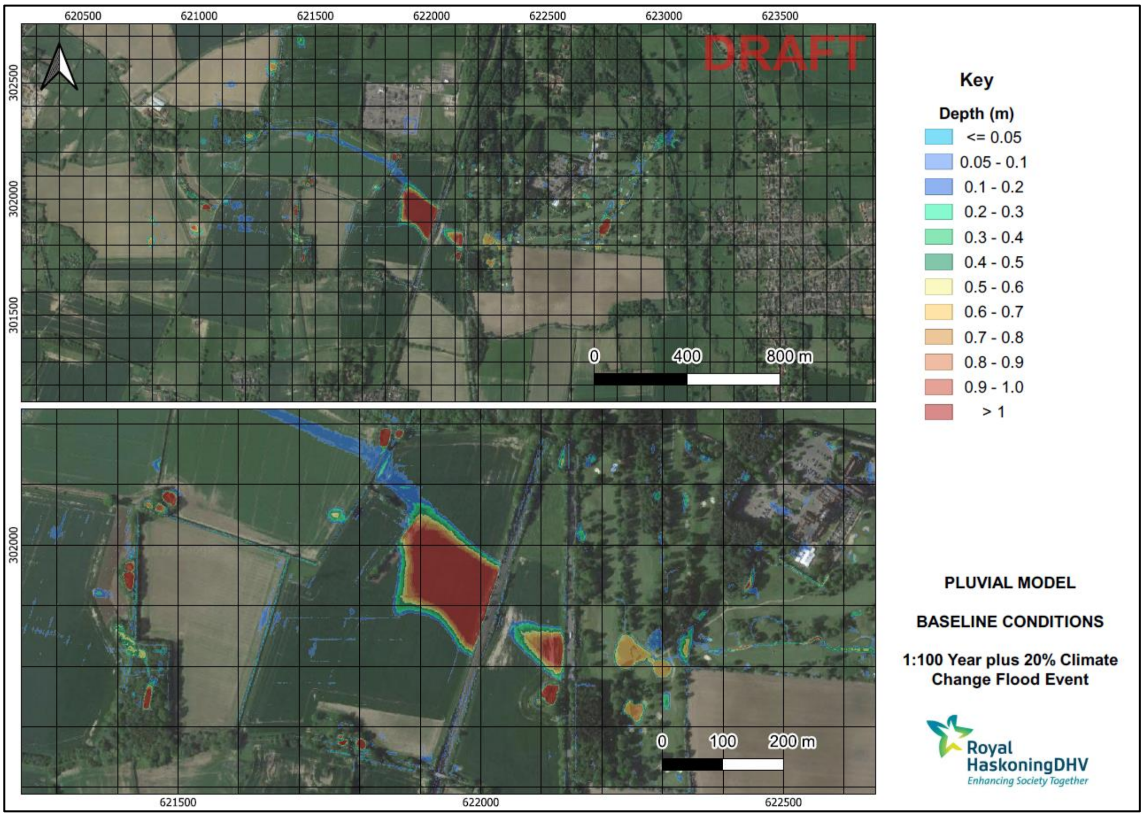

Figure 5: 1 in 100 Year Plus 20% for Climate Change Baseline (Existing Scenario) Flood Depth

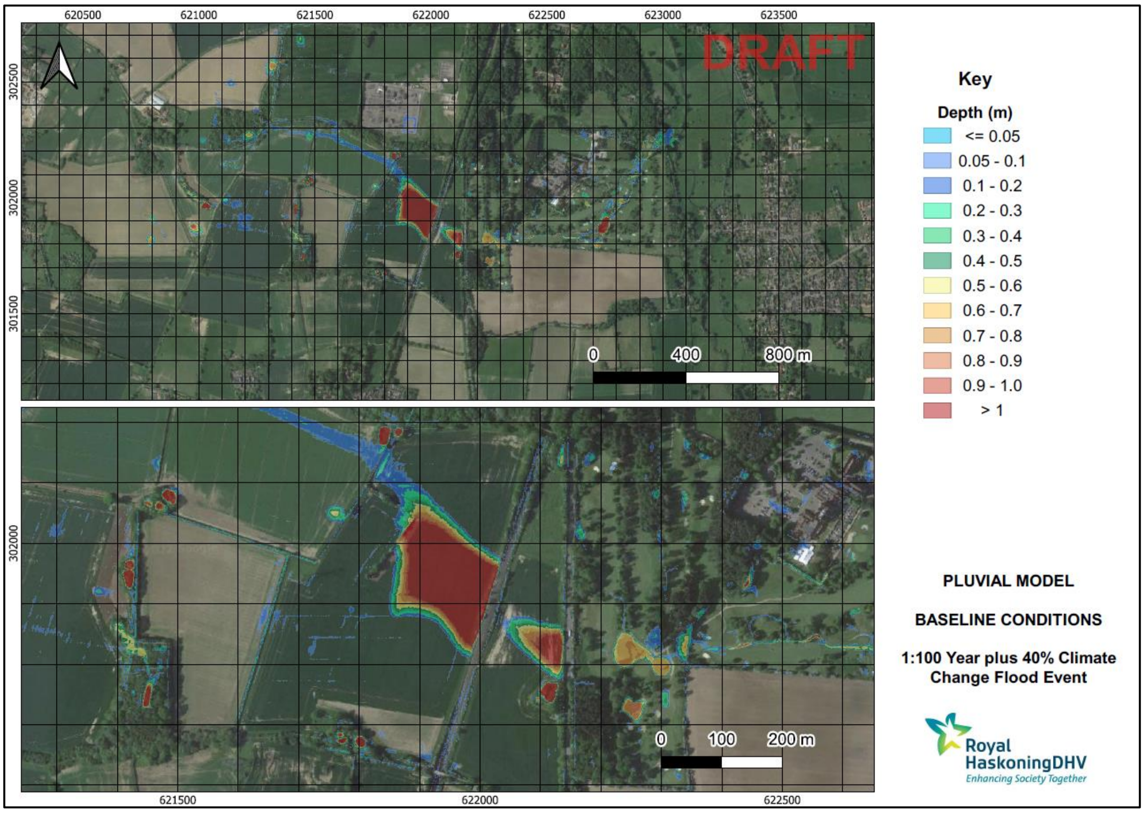

Figure 6: 1 in 100 Year Plus 40% for Climate Change Baseline (Existing Scenario) Flood Depth

24. The results of the modelling show that the baseline model broadly matches the Environment Agency's surface water mapping, with an overland surface water flow path through the OnSS site which is obstructed by the railway embankment in the location of the proposed OnSS platform.

25. However, the results of the initial baseline modelling indicated that the extent of flood depth produced by the modelling exercise appears to be larger than the Environment Agency's surface water flood map.

26. An assessment of the results for the 1 in 100 year (plus 40% for climate change) extent has been undertaken as this comprises the most conservative i.e. worst-case scenario. In this event it is noted that:

- There may be up to 3.40m depth of water which would occur adjacent to the railway embankment
- This would comprise a maximum water level of around 25.76m Above Ordnance Datum (AOD).

27. In addition, a review of less extreme events has been undertaken as follows:

- 1 in 30 year event indicates there may be up to 2.53m flood depth (comprising a maximum water level of 25m AOD).
- 1 in 100 year event indicates there may be up to 2.97m flood depth (comprising a maximum water level of 25.30m AOD).

28. From the results of the initial baseline modelling exercise, it was noted that the railway embankment appears to be impounding or holding water back resulting in ponding to the lower lying area immediately to the west.

29. In this scenario the flood depths against the embankment would be relatively significant during an extreme event, with no clear route for water to exit this area.

30. A Network Rail buried services request highlighted culverts north and south of the study area and did not indicate any additional culverts beneath the railway embankment in the location shown to be at high risk of surface water flooding on the EIA mapping.

31. On the basis of anecdotal evidence from the local farmer, noting the lack of overland flow in heavy rainfall events, and following discussions with the Lead Local Flood Authority (LLFA) regarding surface water drainage and flood risk in this location, a series of amendments to the initial baseline model were undertaken, as set out in the following section.

4.2 Amendments to the Baseline Model

32. Although the initial baseline modelling for the OnSS site broadly matched the Environment Agency's surface water flood mapping, a review of the results indicated that it may be overestimating the flood extent and depth in places, particularly adjacent to the railway embankment. As such, it was considered likely that there could be losses to the ground by way of infiltration elsewhere in the catchment, despite the results of the on-site infiltration tests. This was supported by the results of geophysical surveys caried out in April 2022, which indicated there may be some key areas within the OnSS site which have greater infiltration potential, although there remain areas which were identified as having limited potential for infiltration.

33. It was therefore decided to re-run the direct rainfall model using the net rainfall hyetograph, rather than the gross rainfall hyetograph, to determine the influence of the losses. This approach is in accordance with the best practice adopted for 2D direct rainfall modelling.

34. In addition, during discussions with the LLFA it was noted that climate change allowances may be subject to change, which in this area is likely to result in a reduction in the allowance to be applied.

35. On the basis, the 1 in 100 year plus 20% for climate change and 1 in 100 year plus 40% for climate change had already been modelled, additionally the 1 in 100 year plus 30% for climate change was also modelled.

36. The resulting depth maps are shown in **Figure 7** – **Figure 11** which also show the flood extents for the net rainfall model simulations.

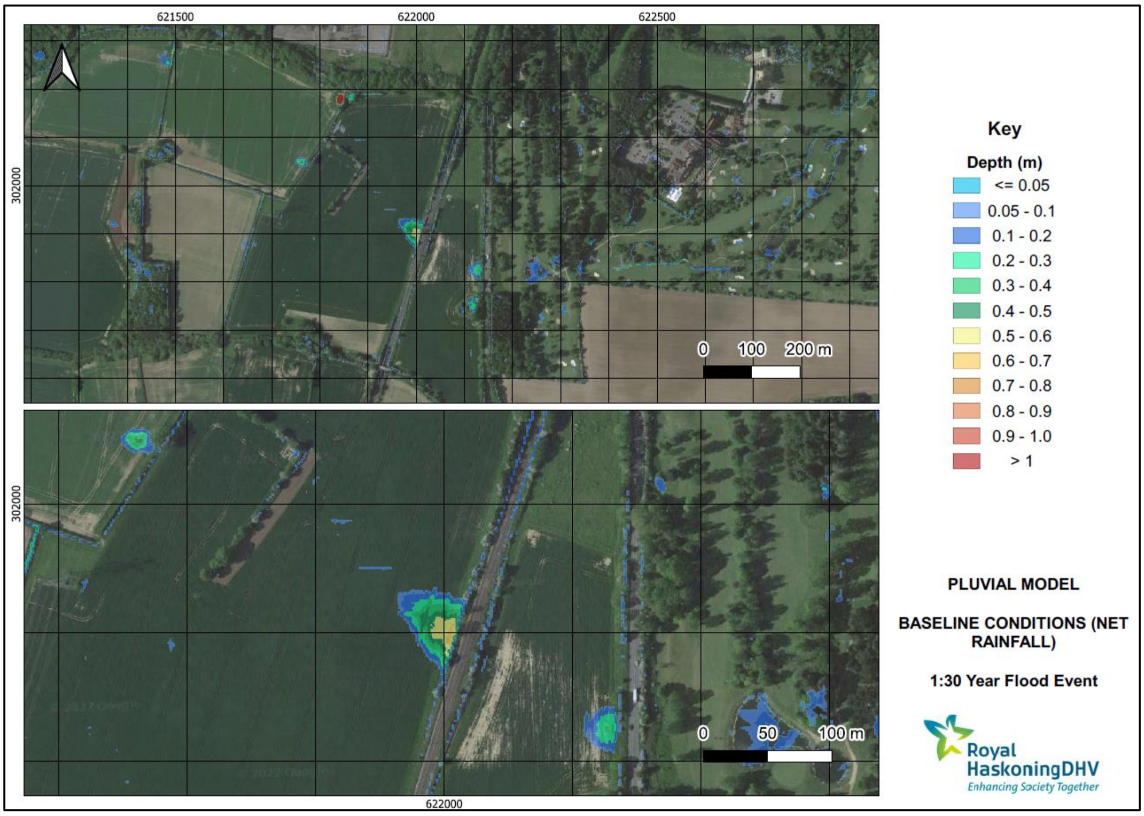

Figure 7: 1 in 30 Year Baseline (Existing Scenario) Using Net Rainfall Hyetograph

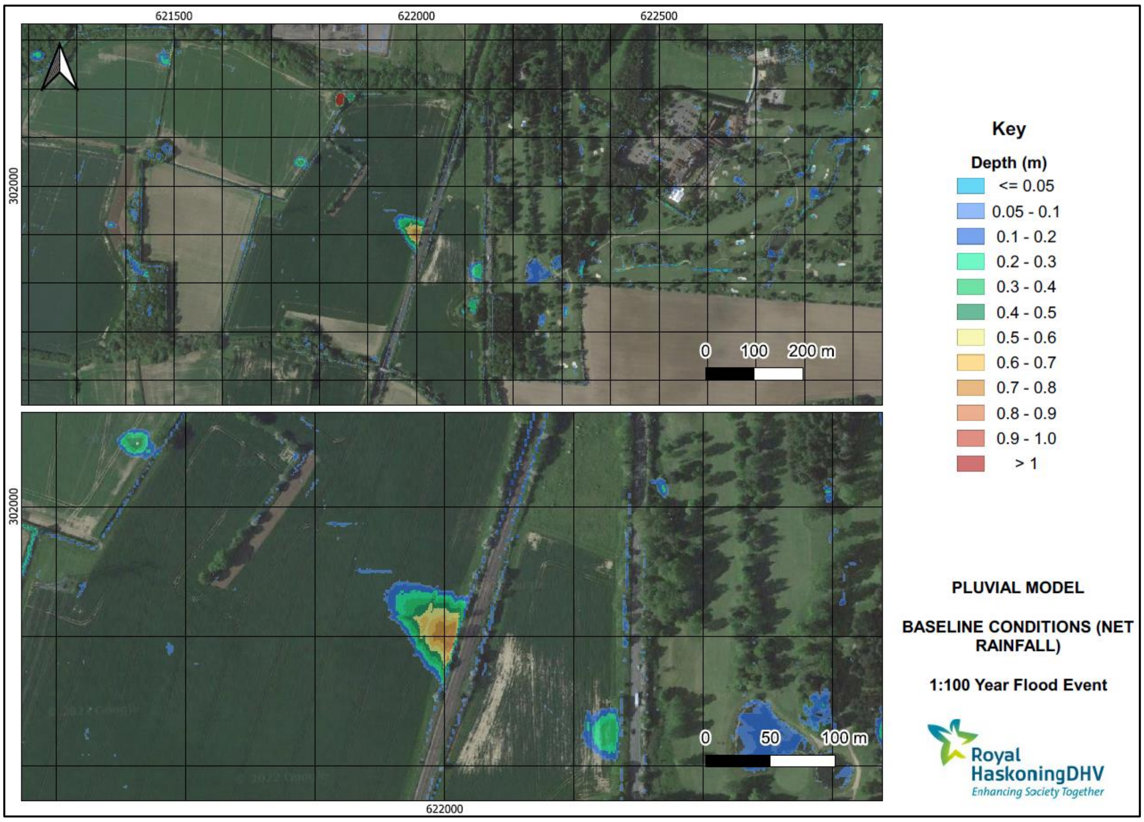

Figure 8: 1 in 100 Year Baseline (Existing Scenario) Using Net Rainfall Hyetograph

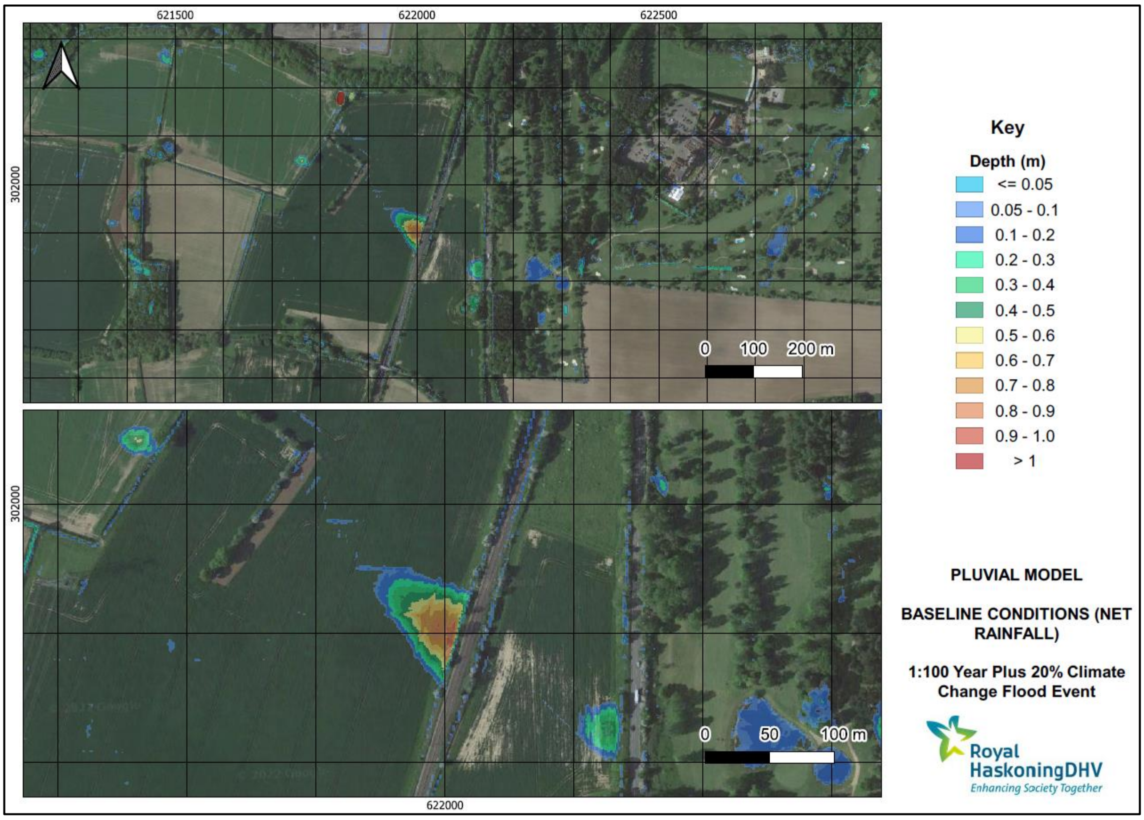

Figure 9: 1 in 100 Year Plus 20% for Climate Change Baseline (Existing Scenario)- Net Rainfall Hyetograph

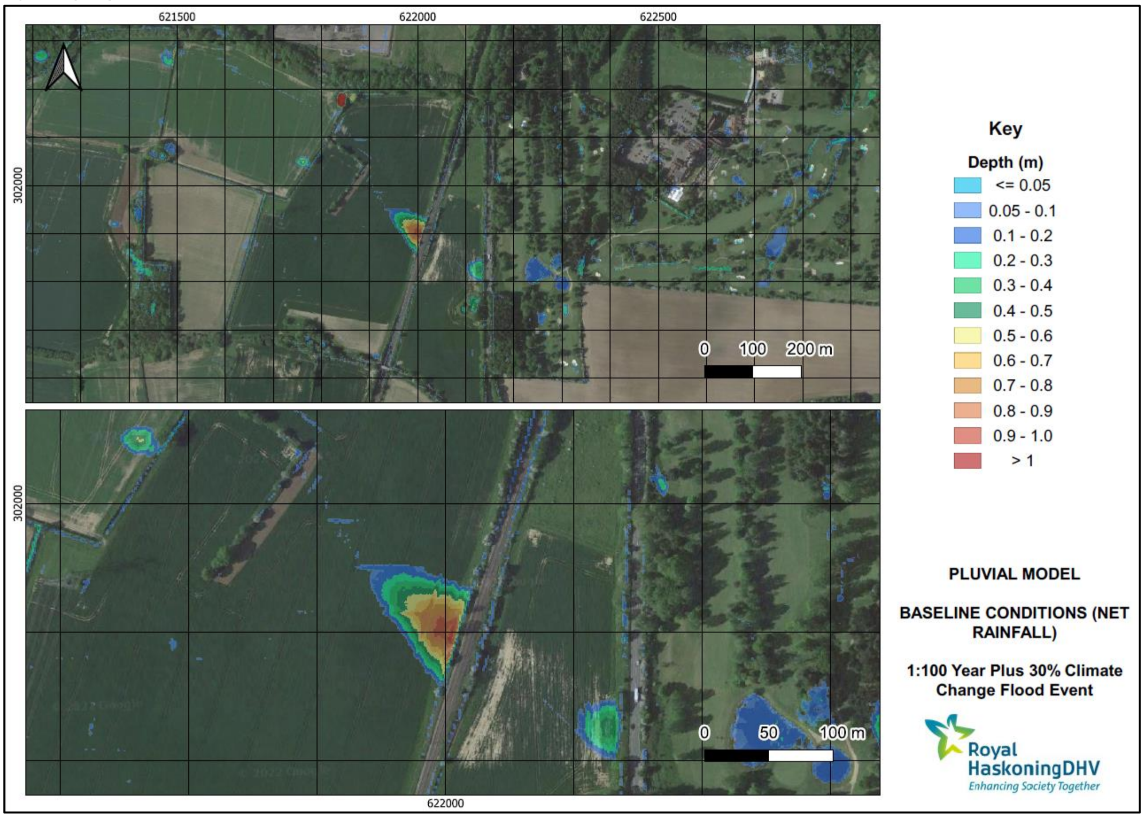

Figure 10: 1 in 100 Year Plus 30% for Climate Change Baseline (Existing Scenario) - Net Rainfall Hyetograph

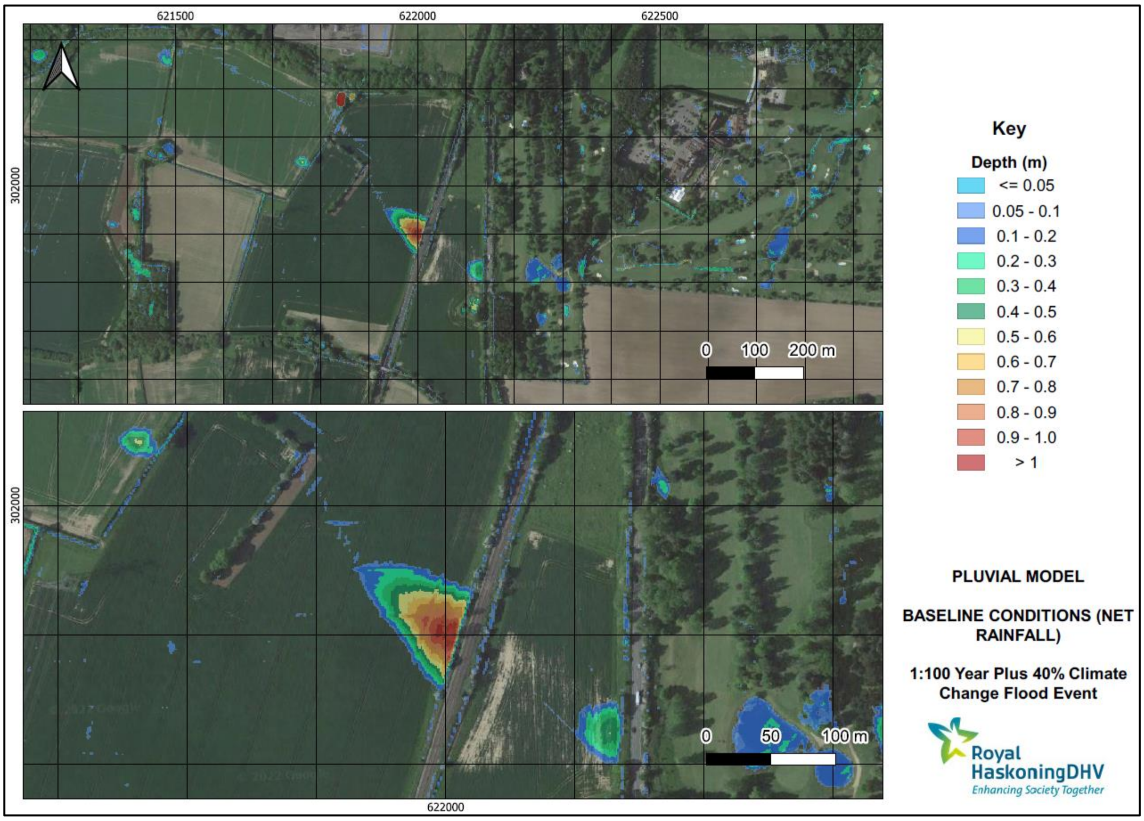

Figure 11: 1 in 100 Year Plus 40% for Climate Change Baseline (Existing Scenario) Using Net Rainfall Hyetograph

37. The results of the modelling using the net rainfall hyetograph shows a significant reduction in the flood extents and depths. Furthermore, a comparison with the Environment Agency surface water mapping, as shown in **Figure 1** indicates the net rainfall hyetographs results are more closely aligned with the Environment Agency's mapping than the gross rainfall results.

38. This validation exercise indicates that the net rainfall hyetographs, which account for potential losses elsewhere in the catchment, should be used to represent the baseline and proposed scenarios rather than the gross hyetographs.

4.3 Review of Higher Resolution LiDAR

39. Within the initial baseline modelling exercise the LiDAR data used was 0.5m resolution, which meant that ground levels were taken at 0.5m intervals across the catchment.

40. To aid in the refinement of the model, higher resolution 0.25m LiDAR data was obtained for the catchment. The model was re-run for the 1 in 100 year (plus 40% for climate change) rainfall event using the 0.25m LiDAR and the resulting depth map is shown in **Figure 12**.

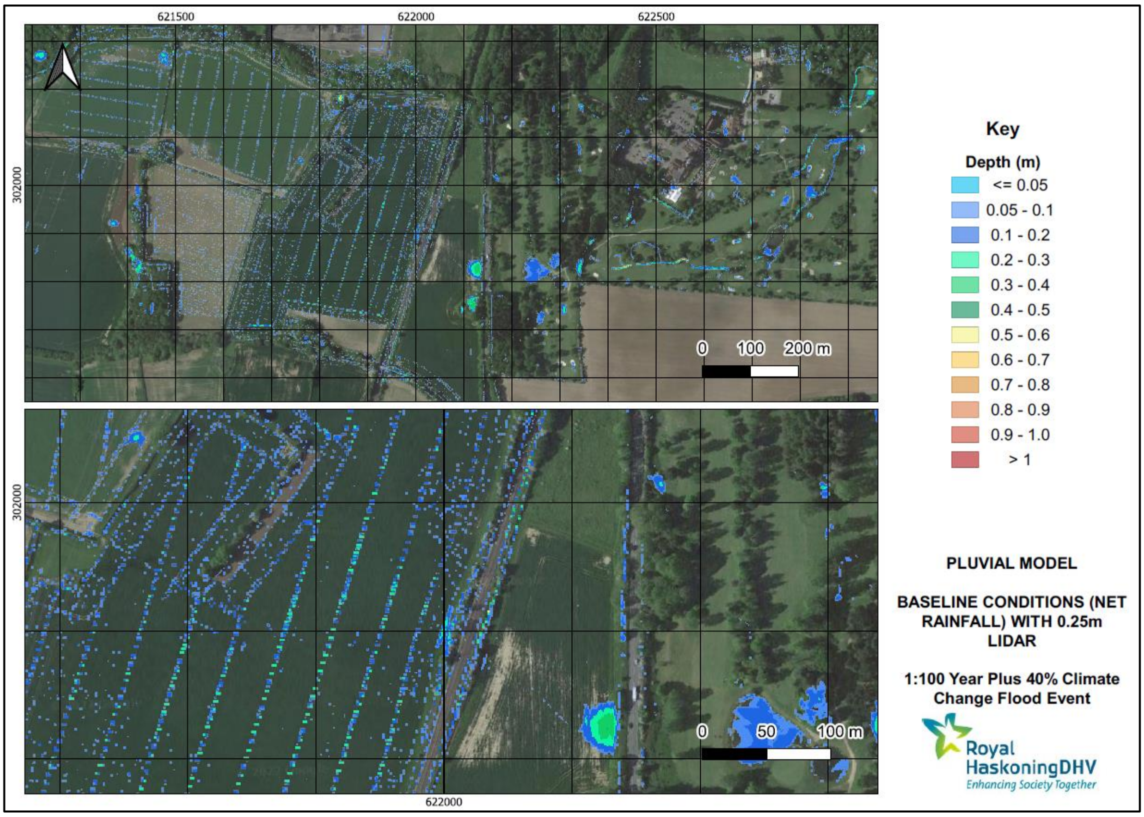

Figure 12: 1 in 100 Year Plus 40% for Climate Change Baseline (Existing Scenario) Using Net Rainfall Hyetograph and 0.25m LiDAR

41. It is clear from **Figure 12** that the surface water in this modelling scenario is not pooling in the low point adjacent to the railway embankment, but instead is being held back within the plough lines of the fields to the west and north-west of the OnSS site. This is likely to be reflective of the time of year that the 0.25m resolution LiDAR was captured i.e. prior to crop growth.

42. This significantly reduces the flood depth adjacent to the railway line. However, this is not considered to be representative of the typical surface water flooding scenario and is very different to the Environment Agency surface water mapping as well as the previous modelling results.

43. While it may be the case that some surface water is held back within the plough lines at certain times of the year (i.e. when the fields have recently been ploughed), for significant periods of the year the plough lines may not be there.

44. On this basis and taking a conservative approach, whereby water is able to reach the low point adjacent to the railway line, the 0.25m resolution LiDAR has not been used for the purposes of the remainder of this modelling exercise, and the 0.5m resolution LiDAR has been used instead.

45. It is within the context of this existing surface water flood risk that the consideration of potential options for the layout and location of the OnSS platform has been assessed.

4.4 Scenario Modelling

46. Following on from the baseline modelling exercise, a number of options have been considered for the layout and location of the proposed OnSS platform. These have been subject to an iterative approach and all options have been considered with respect to the net rainfall model results.

4.4.1 Option 1

47. Option 1 comprises a simple raised rectangular platform, similar to that presented at the Preliminary Environmental Information Report (PEIR) stage, which is located adjacent to the railway embankment. The results of the baseline surface water model have been overlain with the Option 1 location to understand the interaction the OnSS platform may have with the surface water flood extent for various events, as shown in **Figure 13** – **Figure 17**.

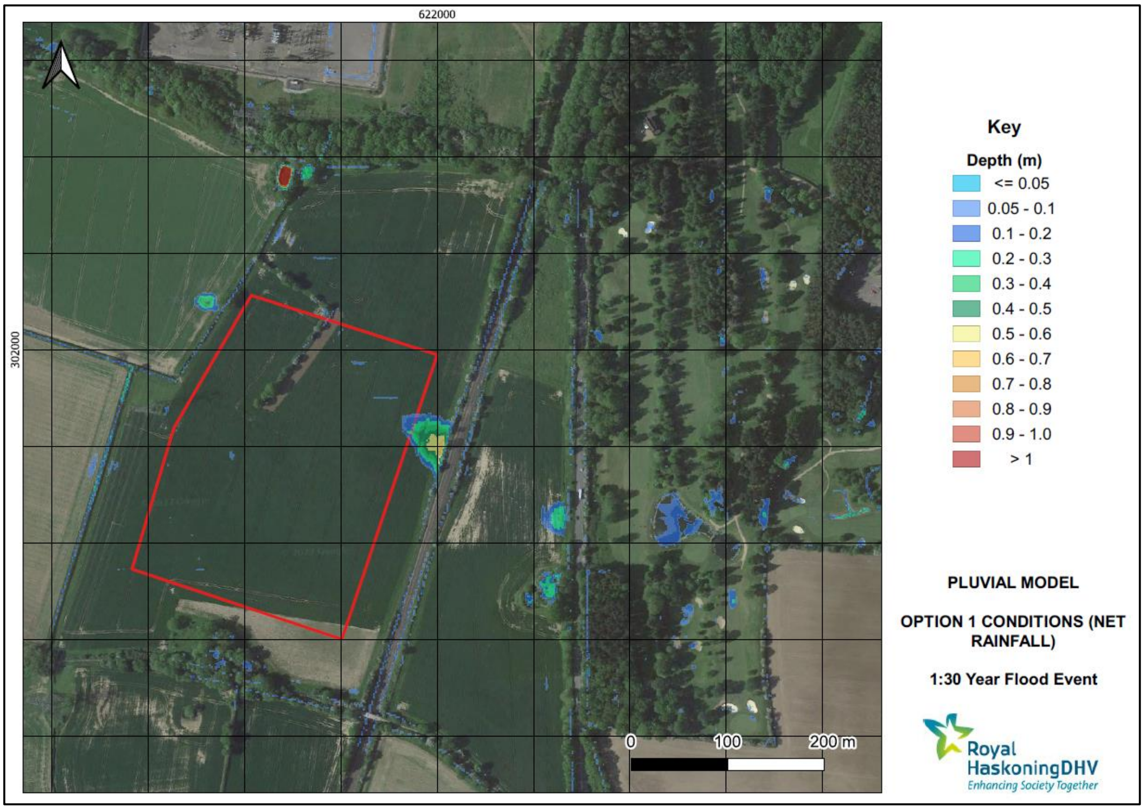

Figure 13: 1 in 30 Year Extent in Comparison with the Option 1 Layout Using Net Rainfall Hyetograph

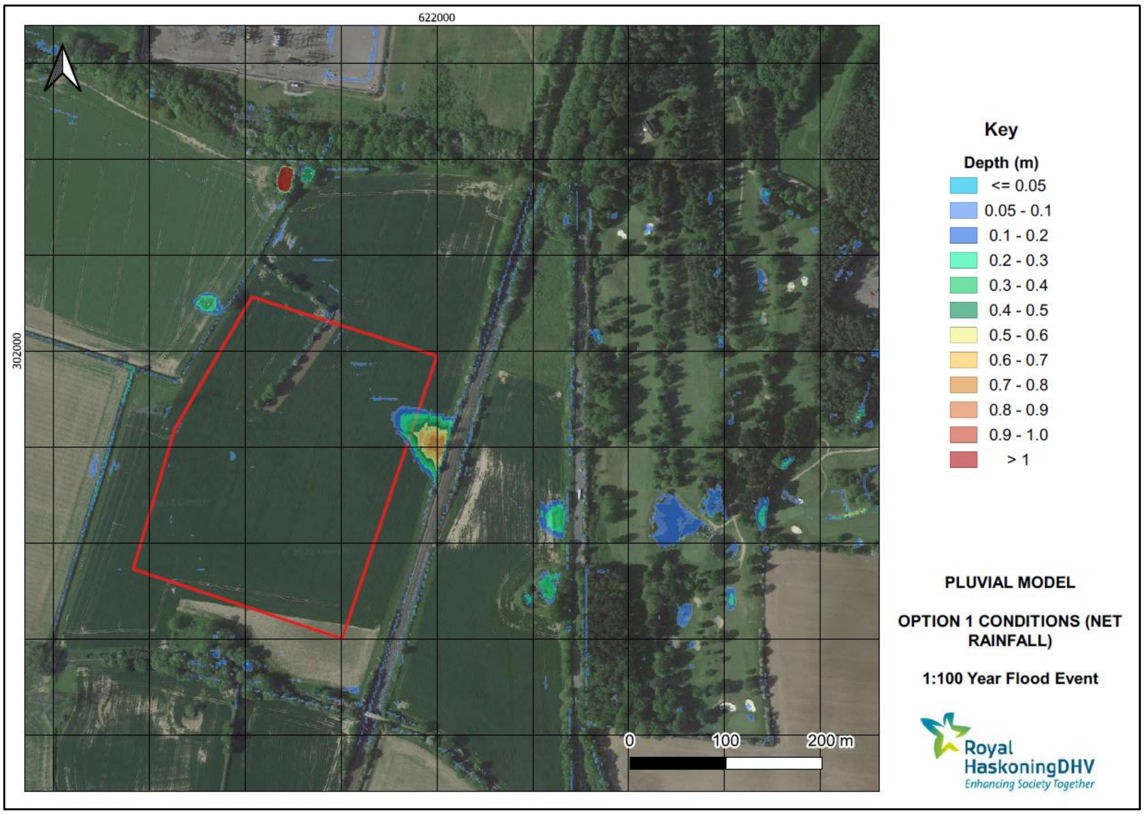

Figure 14:1 in 100 Year Extent in Comparison with the Option 1 Layout Using Net Rainfall Hyetograph

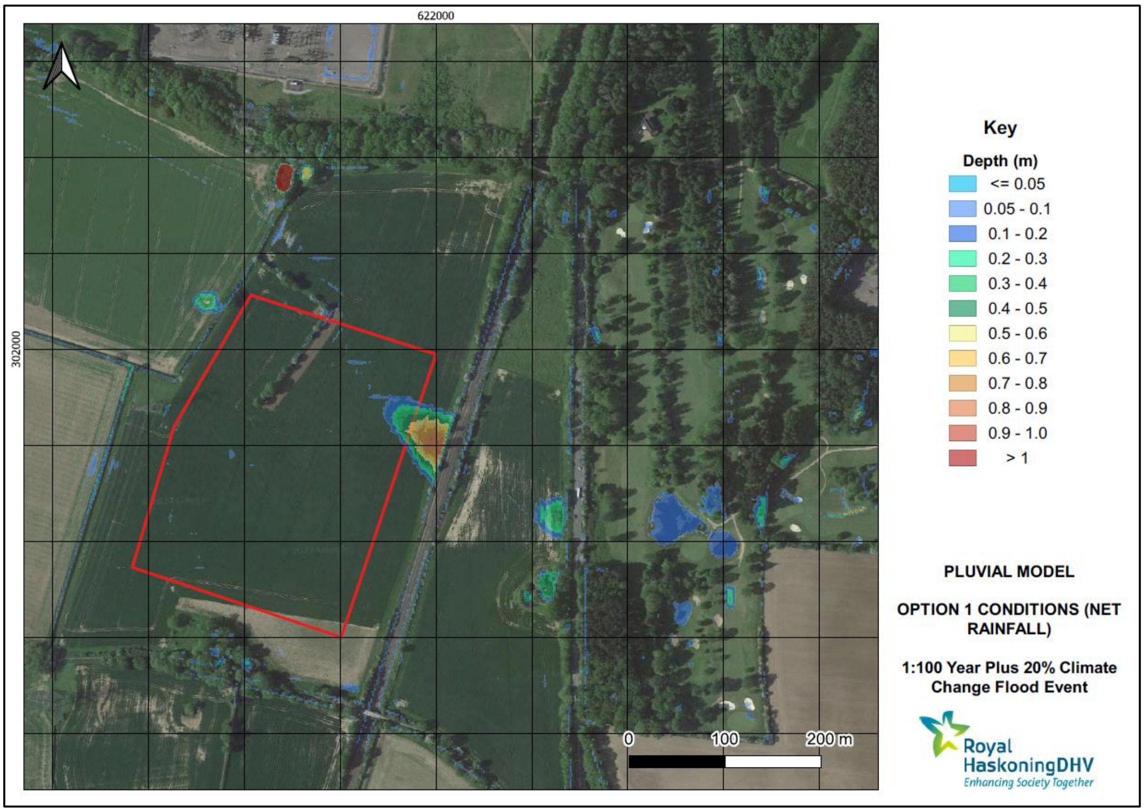

Figure 15: 1 in 100 Year Plus 20% for Climate Change Extent in Comparison with the Option 1 Layout Using Net Rainfall Hyetograph

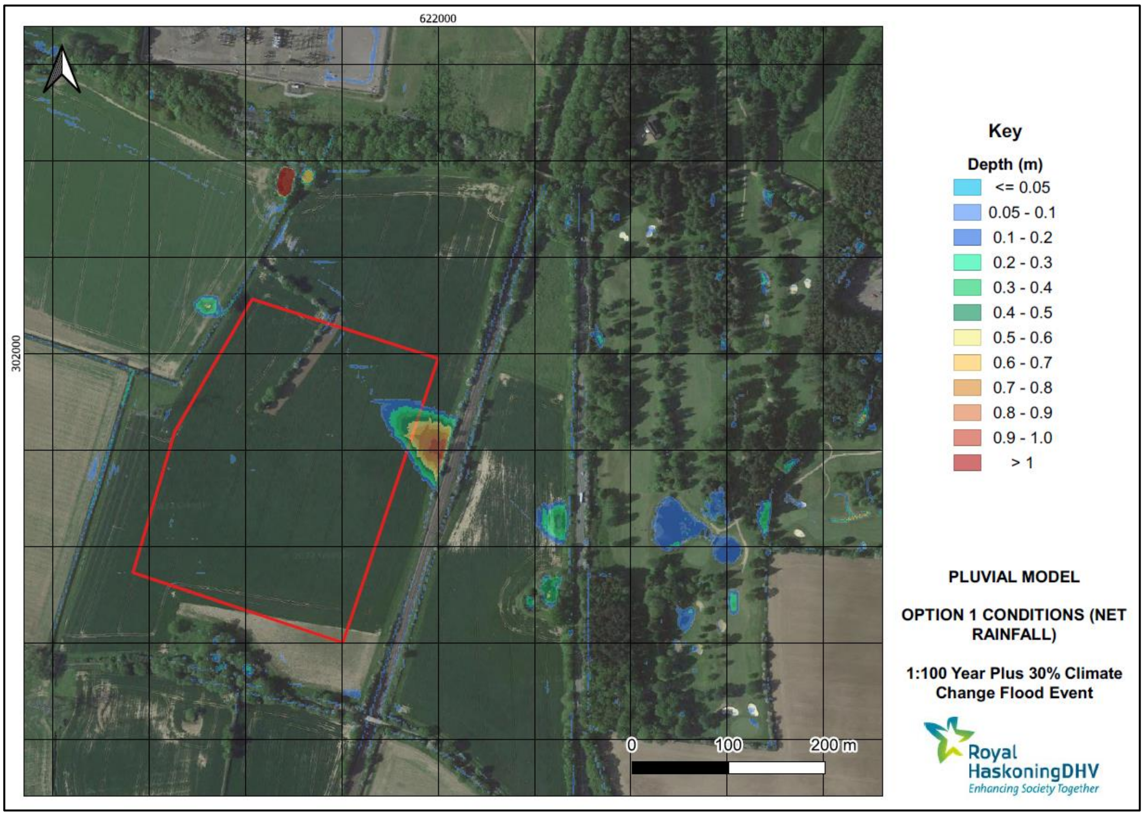

Figure 16: 1 in 100 Year Plus 30% for Climate Change Extent in Comparison with the Option 1 Layout Using Net Rainfall Hyetograph

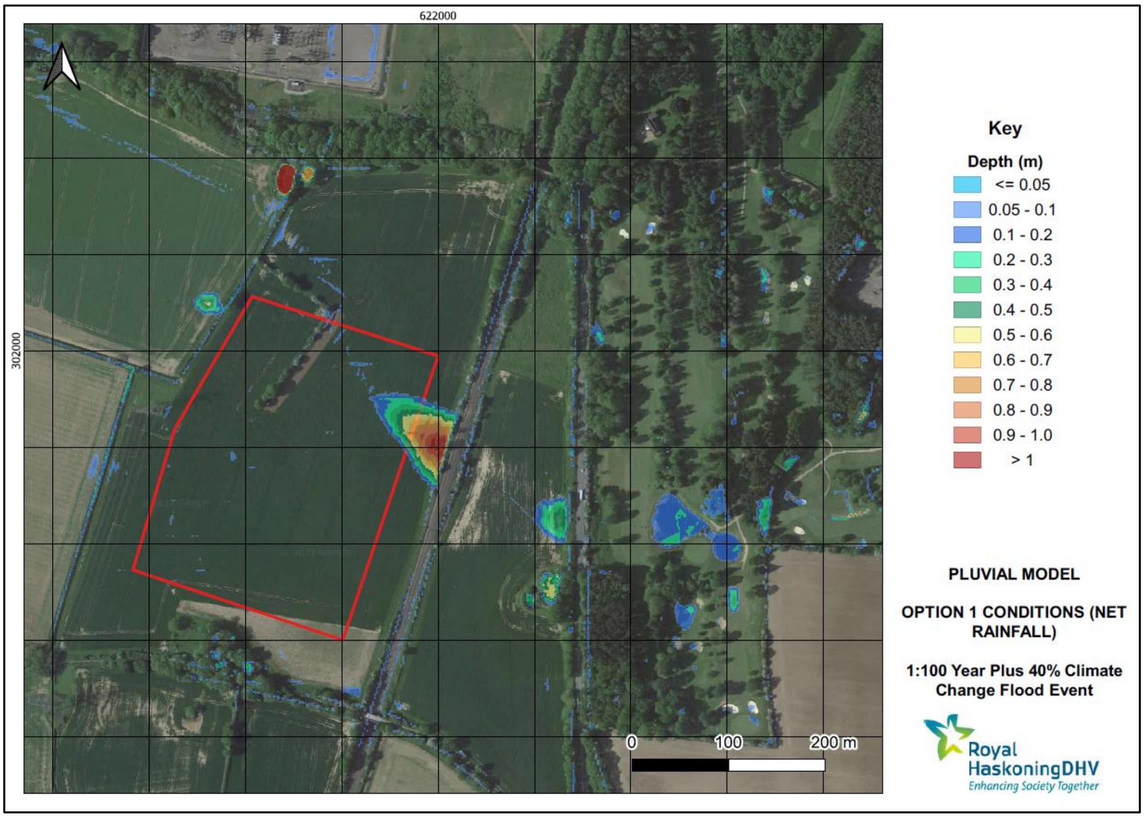

Figure 17: 1 in 100 Year Plus 40% for Climate Change Extent in Comparison with the Option 1 Layout Using Net Rainfall Hyetograph

48. The results of the model show that there is a small amount of surface water within the footprint of the OnSS platform during the 1 in 30 year event. In the higher return period events, this increases quite significantly with the results of the modelling suggesting up to 0.6m depth within the OnSS platform footprint.

49. As the OnSS platform will be raised above ground level, this would result in displacement of surface water. In addition, there will be an access road leading up to the platform which could also obstruct surface water flow paths.

50. If Option 1 was to be selected, the displaced volume of surface water for the 1 in 100 year (plus 40% for climate change) event would need to be quantified and accounted for elsewhere. In addition, measures to enable the existing surface water flow paths to continue beneath the new access road would need to be considered, for example, by including appropriately sized culverts beneath the access road or raising it above the ground on pillars.

4.4.2 Option 2

51. Following an initial design iteration process, Option 2 was developed comprising a slightly smaller, irregular shaped platform which is also located adjacent to the railway embankment. This shape has been developed to enable either a north to south orientation for the OnSS or an east to west orientation. On this basis, the area required is likely to be smaller than the shape shown; however, as this would need to be subject to further design refinement the largest conservative shape has been assessed.

52. The results of the baseline surface water model have been overlain with the Option 2 location to understand the interaction the OnSS platform may have with the surface water flood extent for various events, as shown in **Figure 18** – **Figure 22**.

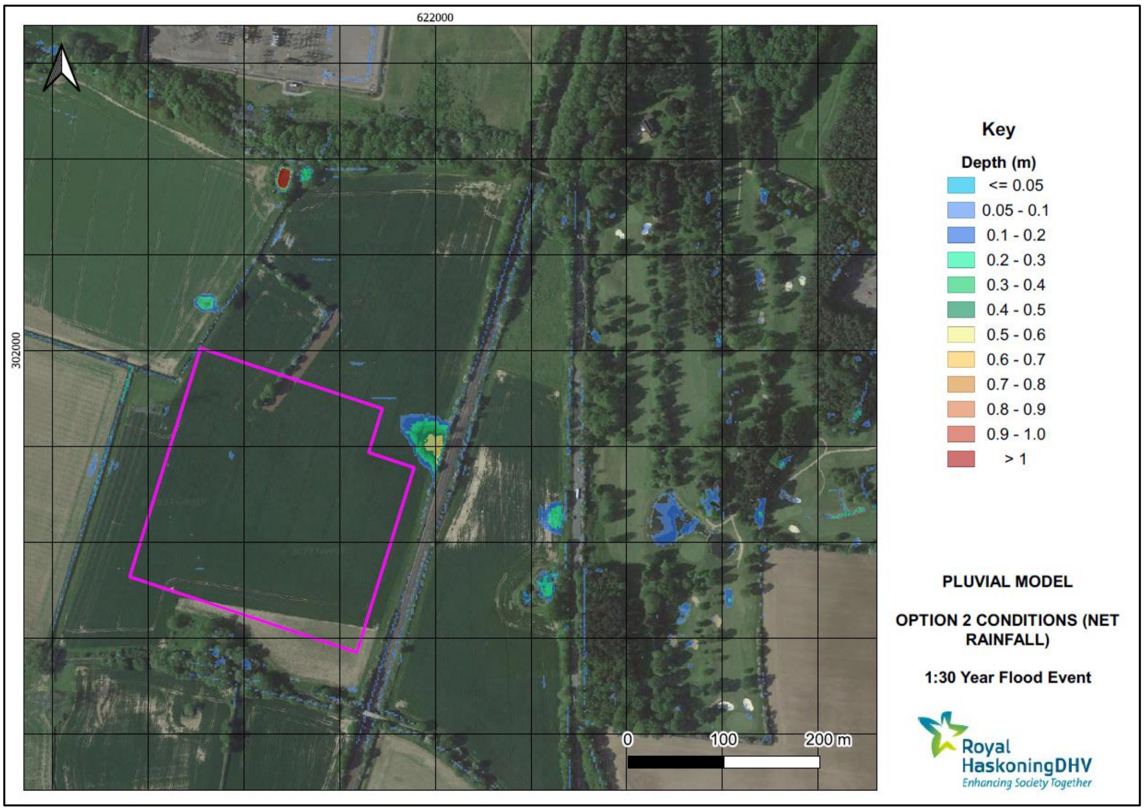

Figure 18: 1 in 30 Year Extent in Comparison with the Option 2 Layout Using net Rainfall Hyetograph

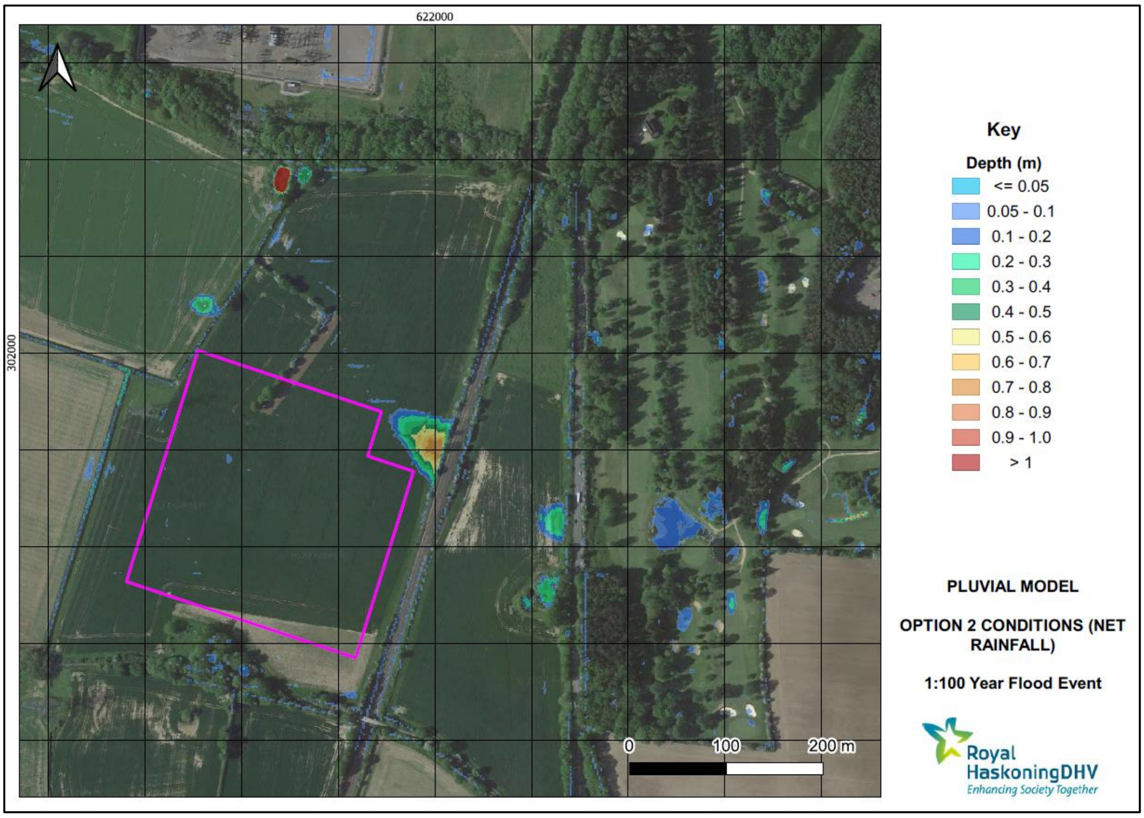

Figure 19: 1 in 100 Year Extent in Comparison with the Option 2 Layout Using net Rainfall Hyetograph

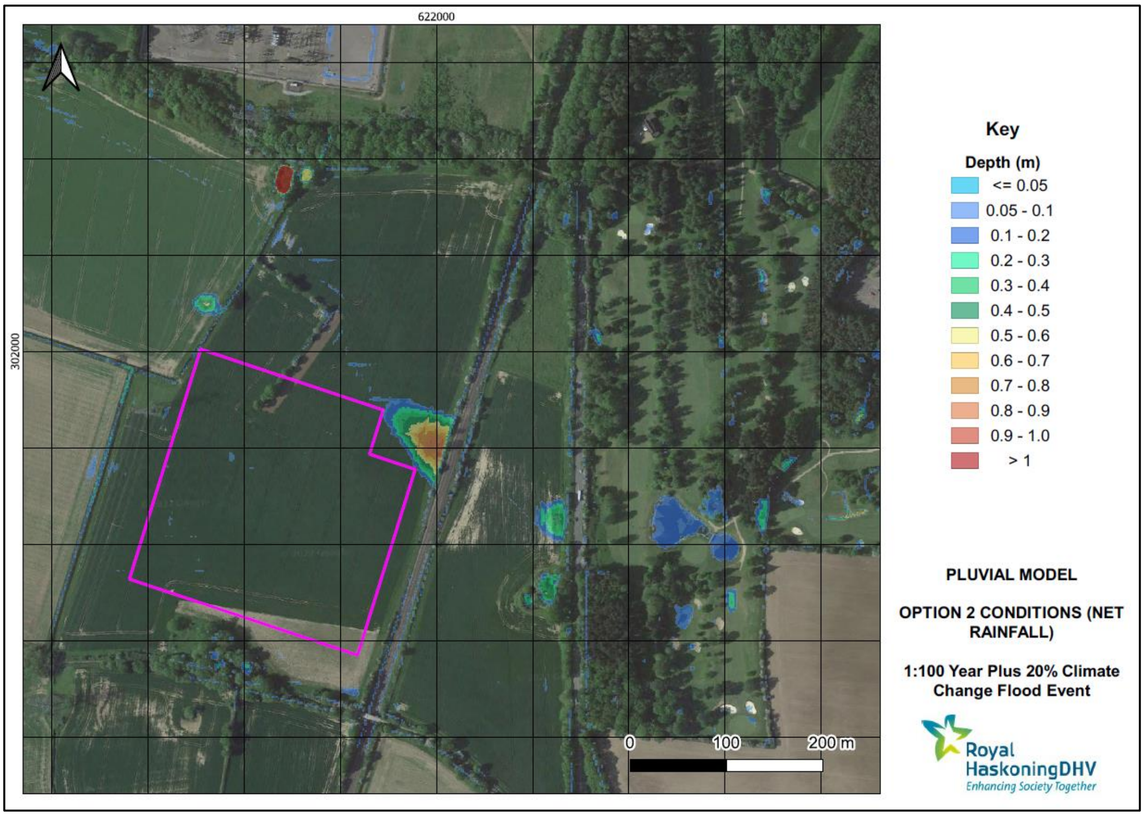

Figure 20: 1 in 100 Year Plus 20% for Climate Change Extent in Comparison with the Option 2 Layout Using Net Rainfall Hyetograph

[redacted]

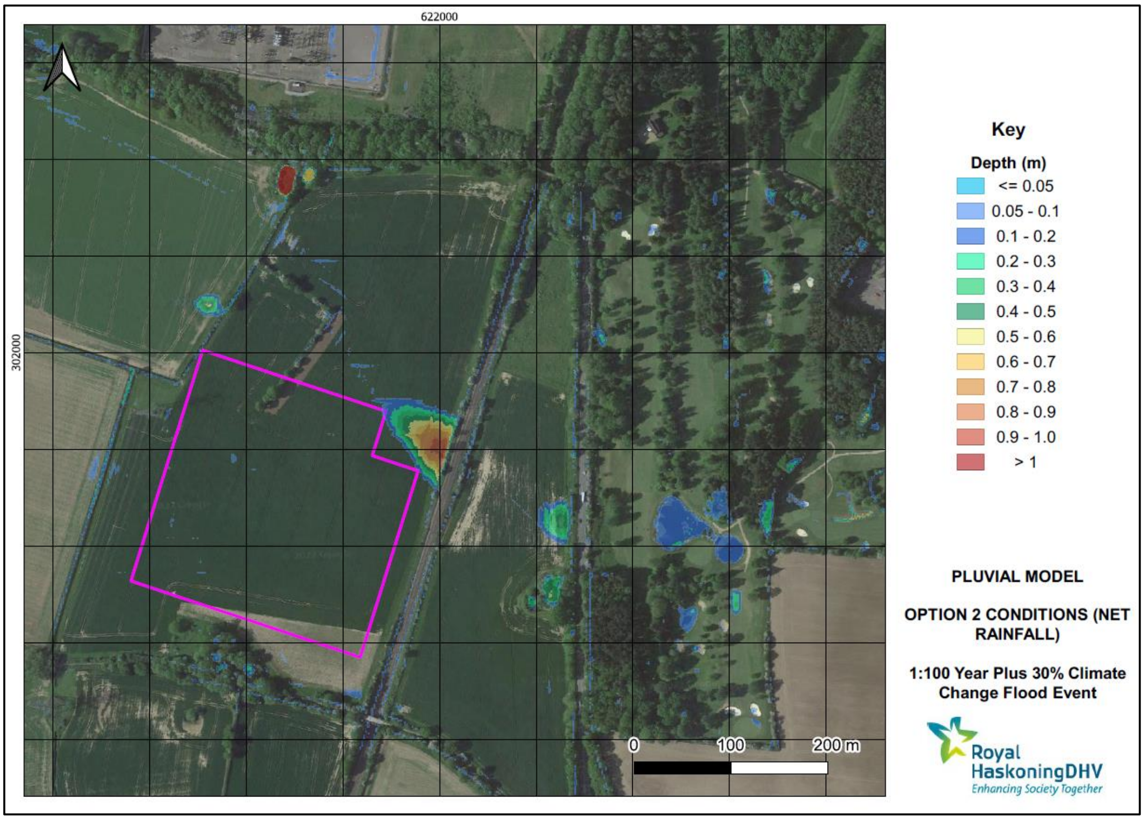

Figure 21: 1 in 100 Year Plus 30% for Climate Change Extent in Comparison with the Option 2 Layout Using Net Rainfall Hyetograph

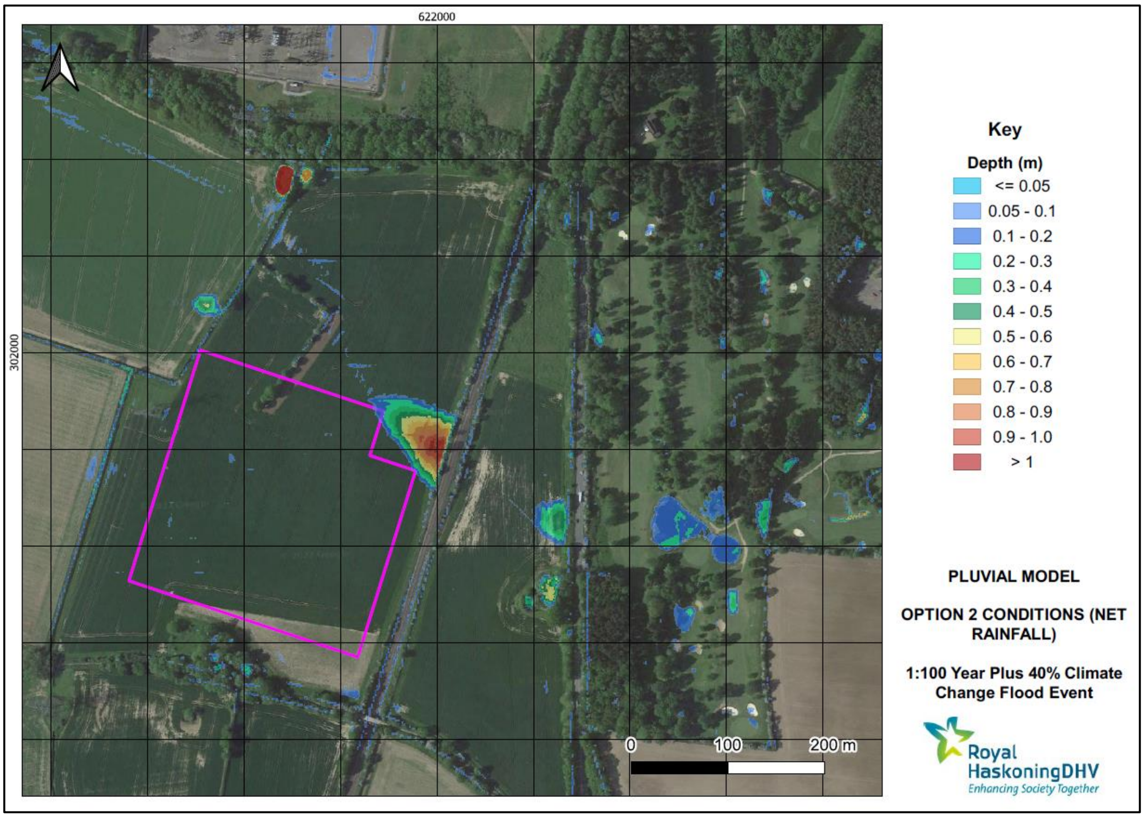

Figure 22: 1 in 100 Year Plus 40% for Climate Change Extent in Comparison with the Option 2 Layout Using Net Rainfall Hyetograph

53. The results of the model show that for the majority of the Option 2 scenarios, the flood extent doesn’t extend into the footprint of the OnSS platform. In the most extreme scenario, the 1 in 100 year (plus 40% for climate change) surface water event, there is a small area where the flood extent is within the corner of the OnSS platform footprint, with the maximum flood depth being up to 0.2m.

54. Although the OnSS platform will be raised above ground level, it is noted that the Option 2 arrangement is unlikely to displace as much surface water as the Option 1 arrangement. For some events the Option 2 arrangement would be entirely located outside the surface water flood extent, therefore the appropriate climate change allowances should be reviewed to understand the implication this may have on the OnSS design.

55. In addition, depending on the proposed orientation of the OnSS the new access road, is still likely to result in some displacement of water or obstruction to the overland flow path. Therefore, some mitigation measures should be included to manage this, such as including appropriately sized culverts beneath the access road or building it as a clear span connection.

4.4.3 Option 2 with Embankment

56. Following a review of the design iteration proposed in Option 2 it has been identified that the platform is likely to incorporate sloped sides rather than a vertical edge. To assess the potential flood risk to the OnSS, the area required for the platform with sloped sides has been compared with the relevant flood extents. This has been undertaken by overlaying the results of the baseline surface water model, as used in the Option 2 comparison (i.e. with net rainfall hyetograph), with the outline for the Option 2 with embankments. This is to understand the interaction the OnSS platform may have with the surface water flood extent for various events, as shown in **Figure 23 – Figure 27**.

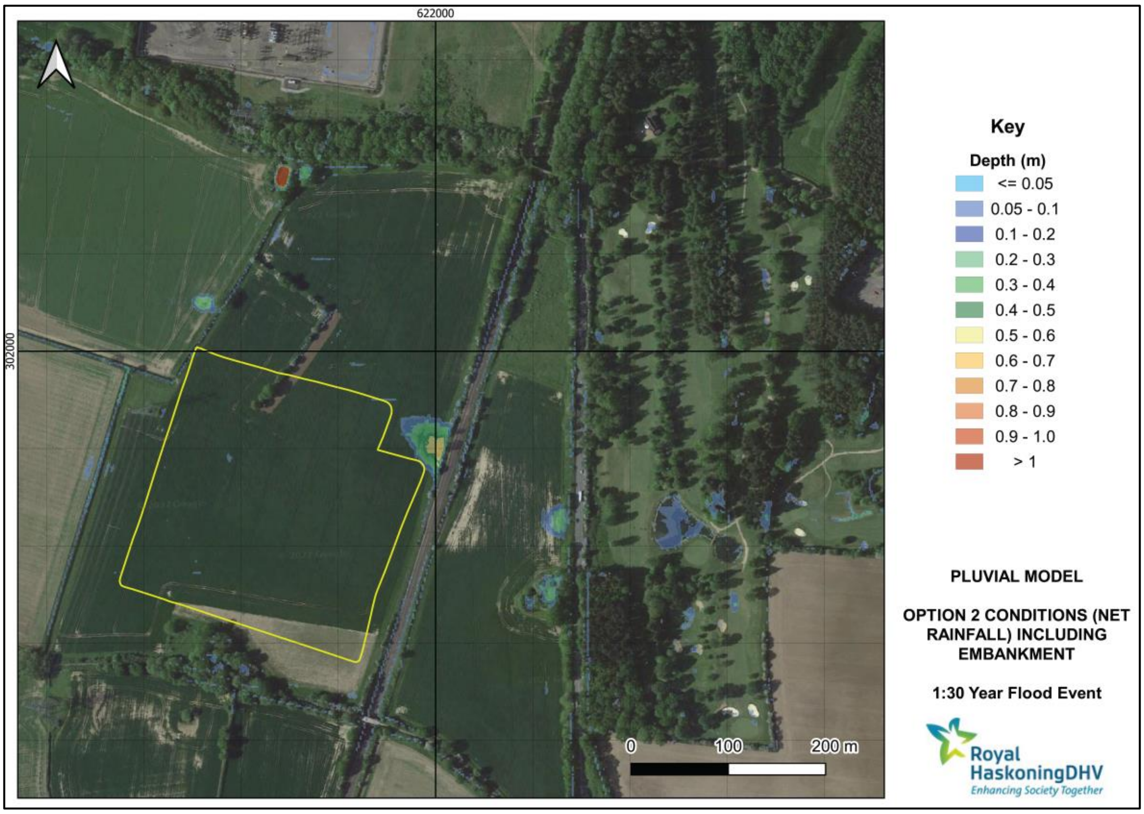

Figure 23: 1 in 30 Year Extent in Comparison with the Option 2 with Embankments Layout

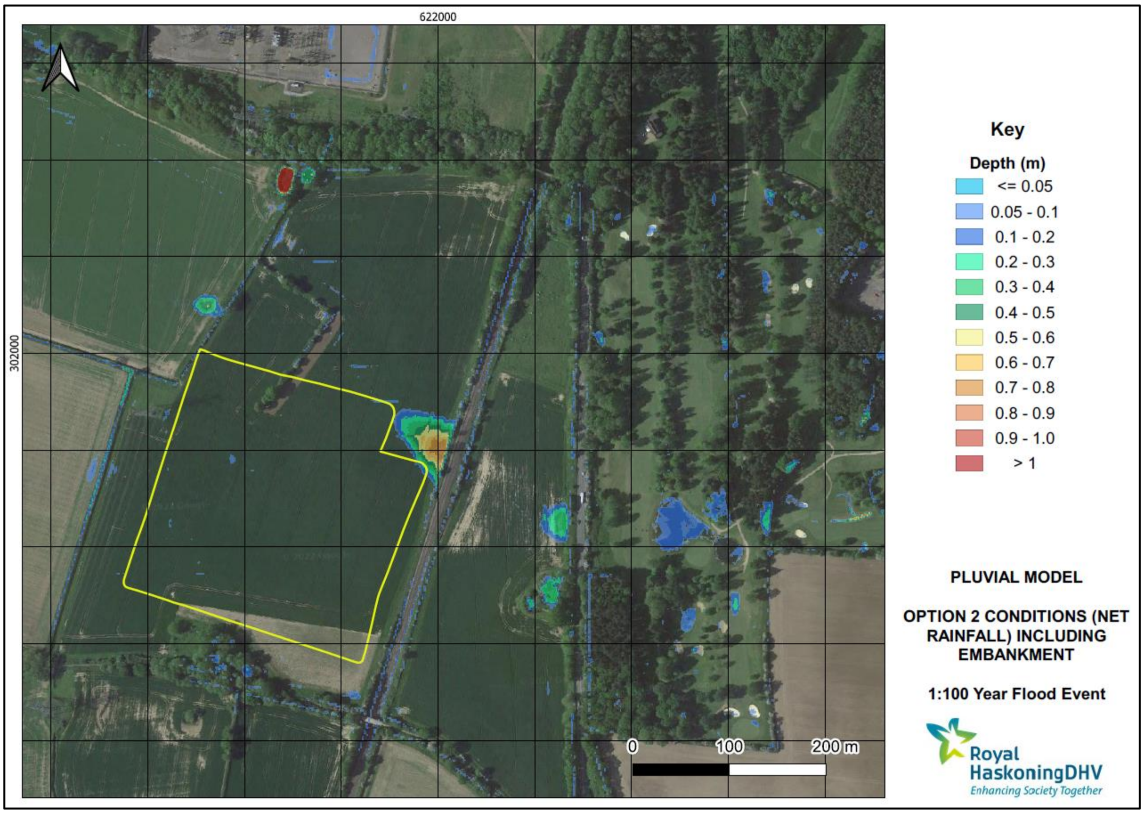

Figure 24: 1 in 100 Year Extent in Comparison with the Option 2 with Embankments Layout

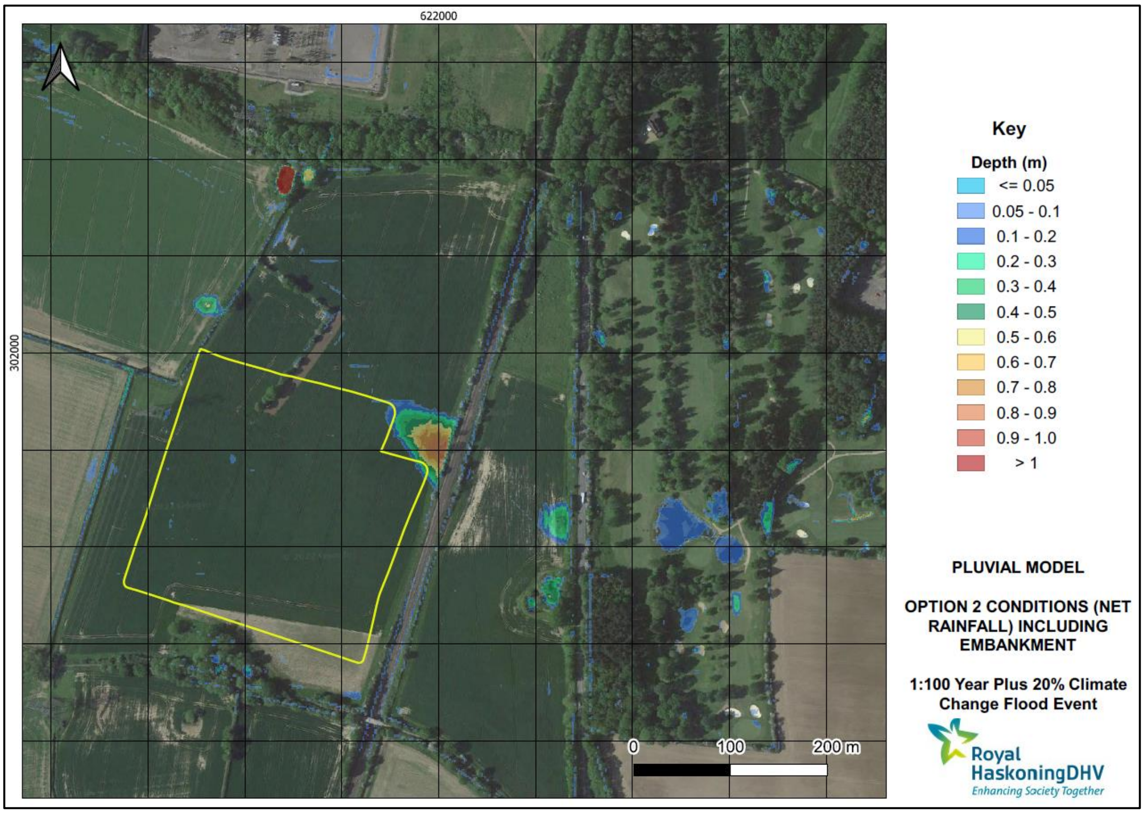

Figure 25: 1 in 100 Year Plus 20% for Climate Change Extent in Comparison with the Option 2 Embankments Layout

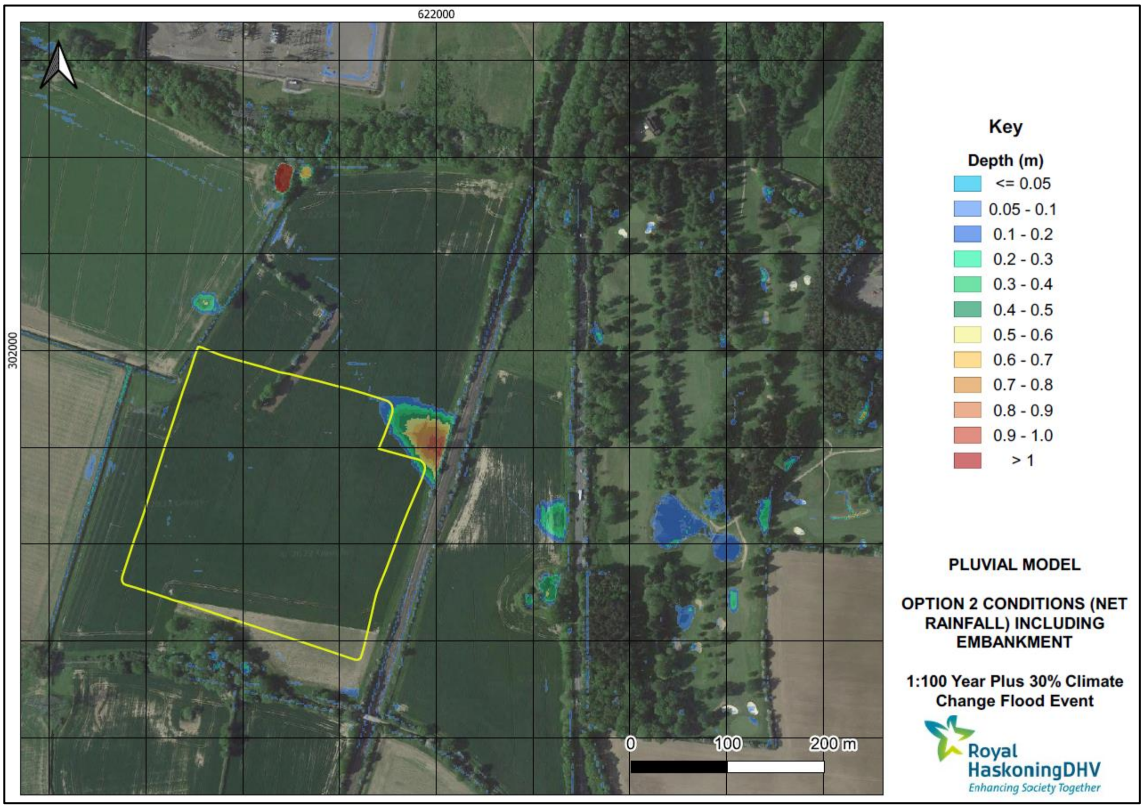

Figure 26: 1 in 100 Year Plus 30% for Climate Change Extent in Comparison with the Option 2 Embankments Layout

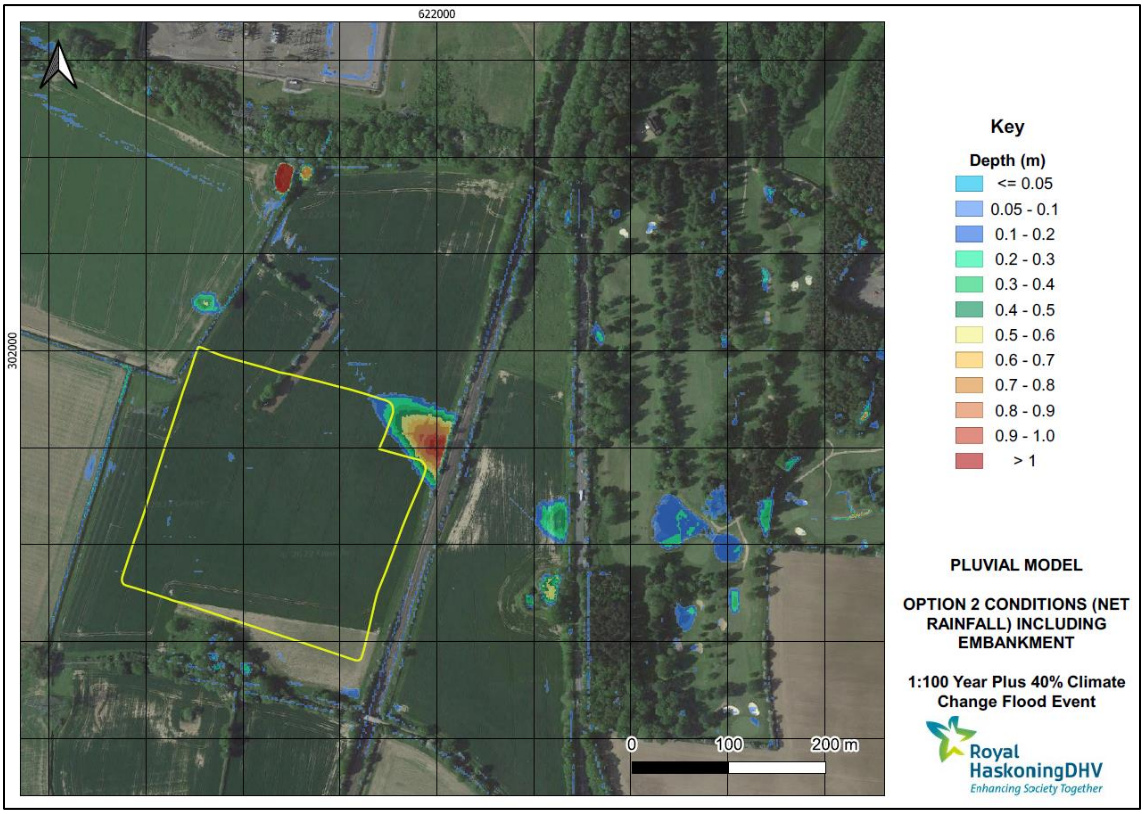

Figure 27: 1 in 100 Year Plus 40% for Climate Change Extent in Comparison with the Option 2 Embankments Layout

4.4.4 Option 2 with Embankment and North-West Access Road

57. Following the process of assessing the potential flood risk to the OnSS by overlaying the baseline modelling results with the platform outline, in accordance with the guidance set out in the National Planning Policy Framework (NPPF) and its supporting Planning Practice Guidance (PPG) it is necessary to consider any potential change in off site flood risk as a result of the displacement of flood water during an event.

58. In order to assess the above, the OnSS platform was included within the model, and it was re-run for the worst-case scenarios. Based on the information presented in the Outline Operational Drainage Plan (onshore substation) (document reference 9.2), the OnSS platform level was set at 28.23m AOD.

59. **Figure 28** and **Figure 29** show the results of the 1 in 100 year (plus 20% for climate change) and 1 in 100 year (plus 40% for climate change) events with the platform and embankments included within the model. The results of this modelling exercise were compared with the results presented in **Figure 25** and **Figure 27** to understand the potential impact as a result of the displacement of surface water.

60. Following review of these results it was noted that both the surface water flood extent and maximum flood depths are slightly reduced compared with the results from the baseline modelling. This reduction can be attributed to the incorporation of the OnSS platform in the model. By including the OnSS platform within the model, rainfall falling on the platform during an event does not contribute to the flooding as it is assumed this will be collected by the surface water drainage system to be implemented as part of the project.

61. As such there is a small reduction in surface water flood depth and extent in the area of potential flooding close to the OnSS platform. In addition, there is no change in the wider off site flood risk as the surface water flooding is contained in an area within the OnSS site.

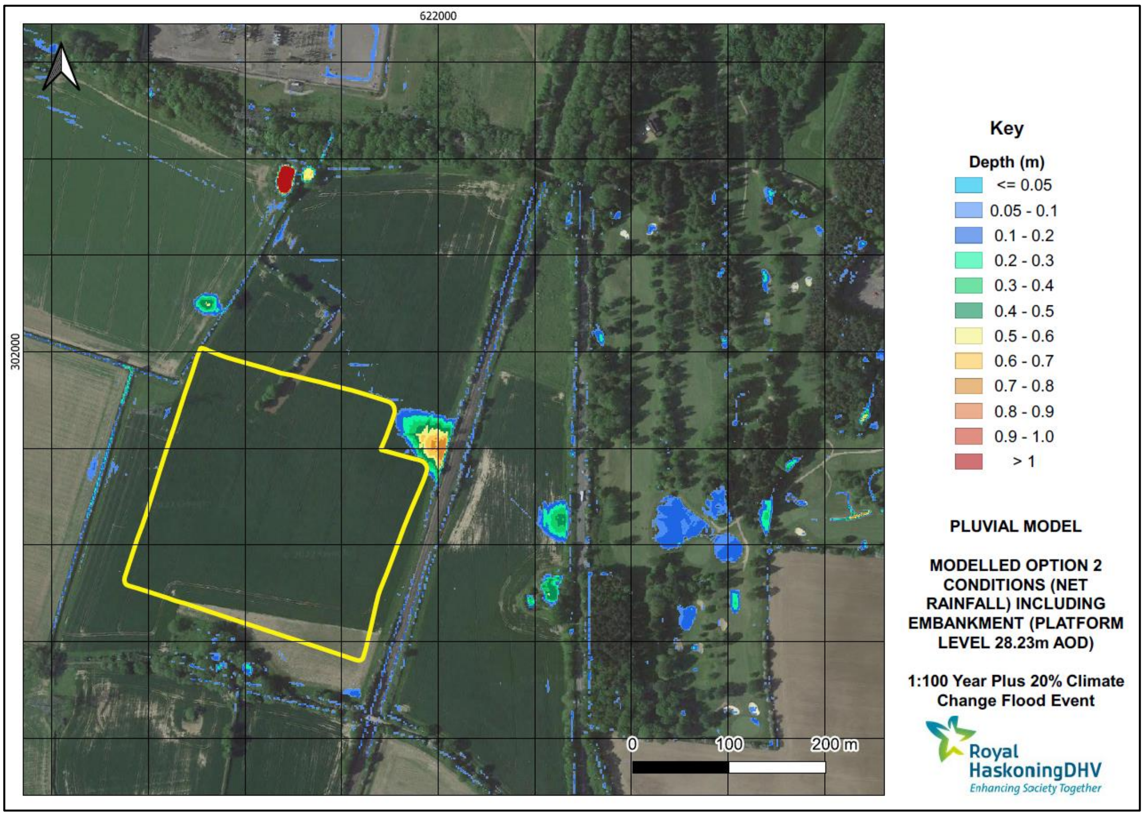

Figure 28: 1 in 100 Year Plus 20% for Climate Change with OnSS Platform Level Set at 28.23m AOD

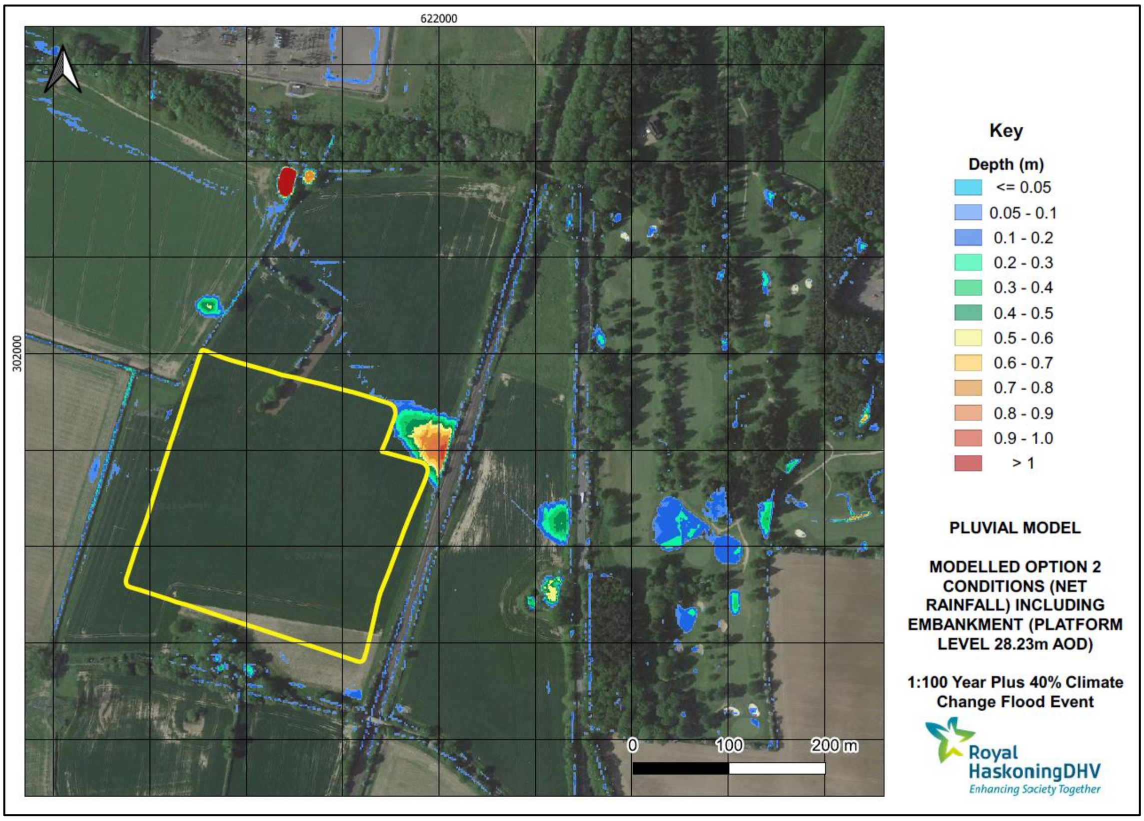

Figure 29: 1 in 100 Year Plus 40% for Climate Change with OnSS Platform Level Set at 28.23m AOD

62. Following consideration of the impact of the OnSS platform a further scenario was modelled which included the access road to the OnSS platform which it is proposed will tie into the north-west corner of the OnSS platform (referred to as the north-west access road).

63. Similar to the level used for the OnSS platform, the north-west access road was set at 28.23m AOD for the section adjacent to the platform using the 'MAX' flag in the TUFLOW software. This means that any ground levels below the proposed North-west access road which are lower than 28.23m AOD were raised to this level.

64. In addition, a large rectangular culvert with the dimensions 25m x 2.2m high was located under the north-west access road in the location of the existing overland surface water flow path. The culvert was included as a section of 1D network and modelled in the ESTRY software. A Manning's roughness value of 0.025 was applied to the culvert, which was considered to be a suitable as it is likely to be less vegetated than the surrounding land.

65. It is likely that this culvert would in reality be a bridge or other similar crossing over the lower-lying land, which will be confirmed during the detailed design, however for the purposes of this modelling exercise it was included as a culvert to enable the continued conveyance of the overland flow path beneath the proposed north-west access road.

66. **Figure 30** and **Figure 31** show the results of the 1 in 100 year (plus 20% for climate change) and 1 in 100 year (plus 40% for climate change) events which include the OnSS platform with embankments and the North West access road.

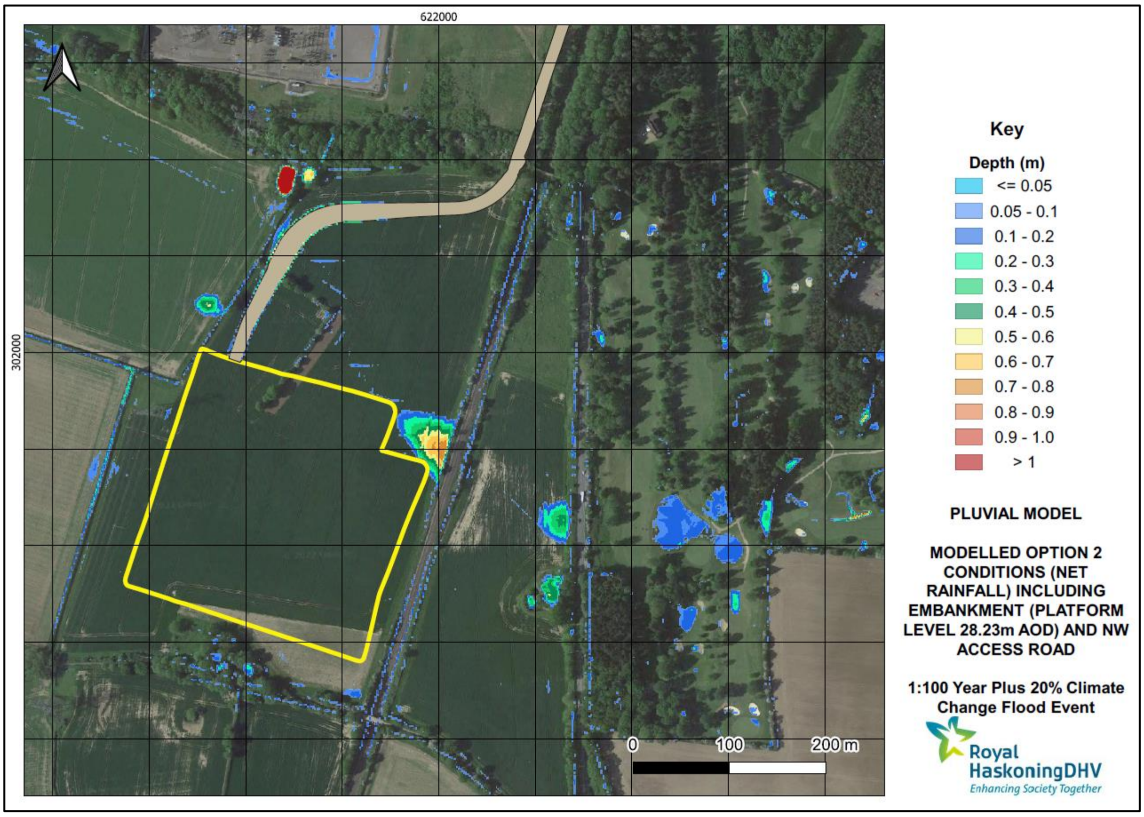

Figure 30: 1 in 100 Year Plus 20% for Climate Change with OnSS Platform Level Set at 28.23m AOD and North-West Access Road

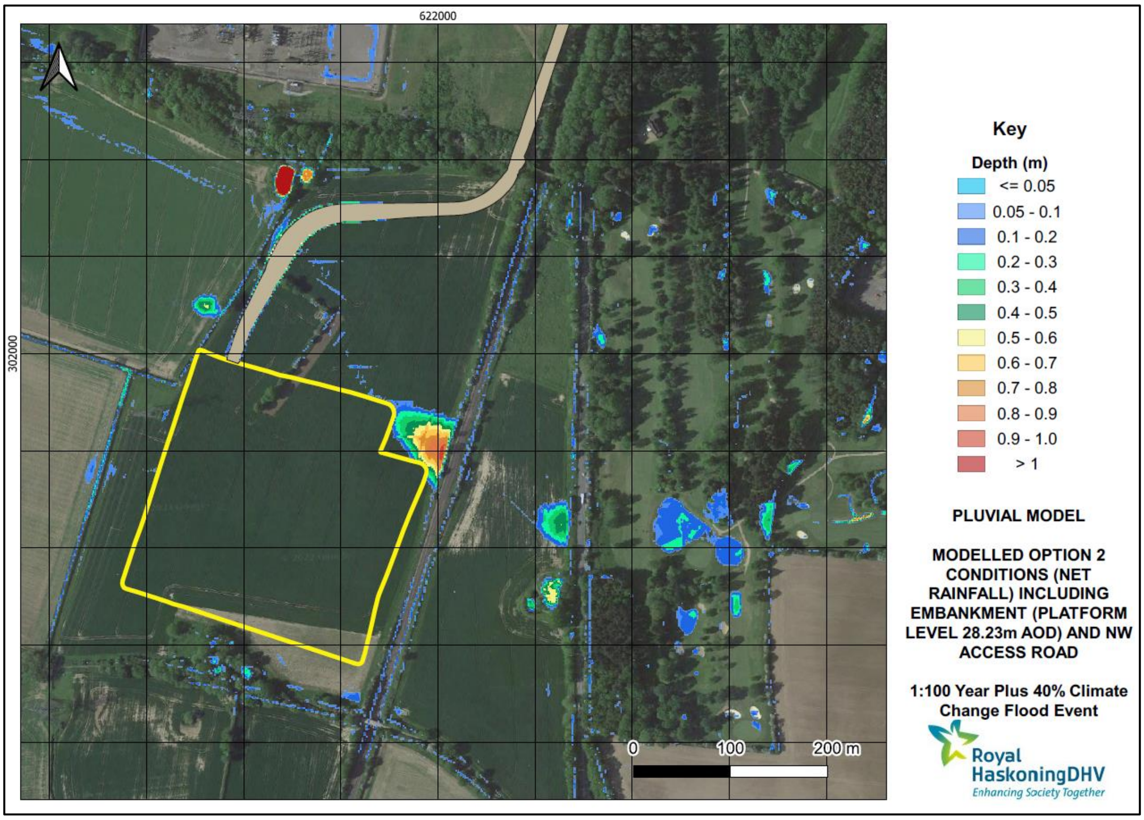

Figure 31: 1 in 100 Year Plus 40% for Climate Change with OnSS Platform Level Set at 28.23m AOD and North-West Access Road

67. The results of this modelling exercise confirm that the north-west access road can be designed such that there is continued conveyance beneath it. On this basis neither the OnSS platform nor the north-west access road will result in displacement of surface water flooding such that there would be an off-site impact on surface water flood risk as a result of the project.

5 Climate Change Considerations

68. When considering surface water flood risk, the Norfolk LLFA Statutory Consultee Guidance Document (Version 4, updated 2021) requires an assessment of the lifetime of the development, the vulnerability of the proposed land use and a justification related to the choice of allowance.

69. Further to the above guidance the Environment Agency issued updated climate change allowance guidance, specifically with regard to the application of peak rainfall allowances on 10th May 2022 (Environment Agency, 2022).

70. The surface water climate change allowances are determined by the predicted increase in peak rainfall intensity. These are determined by regional variations, which are based on management catchments, which are sub-catchments of river basin districts.

71. The OnSS site is located within the Broadland Rivers Management Catchment and therefore the allowances for this Management Catchment have been considered further within the surface water modelling.

72. A review of the updated guidance noted that for the OnSS site, assuming 40 years of operation with commencement of operation in 2028, the required allowance to be considered comprises an increase of 20% for the 1 in 100 (1%) year event applying the central allowance, as shown in **Table 1**.

Table 1: Peak Rainfall Intensity Allowance for the Broadland Rivers Management Catchment

Broadland Rivers Management Catchment	Central 1 in 30 year (3.3%)	Upper end 1 in 30 year (3.3%)	Central 1 in 100 year (1%)	Upper end 1 in 100 year (1%)
2050s	20%	40%	20%	45%
2070s	20%	40%	20%	40%

73. As noted in **Section 4.4.3** the flood extents for the 1 in 100 year plus 20% for climate change and 1 in 100 year plus 40% for climate change events have been considered alongside the layout of the OnSS platform, as shown in **Figure 25** and **Figure 27** respectively. This has confirmed that there is minimal interaction with the surface water flood extent up to and including the 1 in 100 year plus 40% for climate change event.

6 Summary

74. The modelling exercise undertaken to date has identified that the net rainfall hyetographs and the use of the 0.5m resolution LiDAR is likely to provide the best representation of the study area. Whilst the direct rainfall model was undertaken for comparison with the Environment Agency's surface water mapping, based on anecdotal information, best practice application of modelling approaches and the results of the geophysical surveys this method was considered to be an unlikely representation of the catchment. Therefore, the use of the net rainfall hyetographs was adopted within the modelling exercise.

75. Following development of the baseline / existing model, two options for the layout and location of the OnSS platform have been considered as part of the design iteration process.

76. Option 1, comprising a large rectangular shape, overlaps the baseline surface water flood extent in all modelled scenarios. In this scenario, this would result in the displacement of surface water, which would requirement mitigation / management within the site boundary.

77. Option 2, comprising an irregular polygon shape to allow for either a N-S or E-W orientation for the OnSS, does not appear to overlap with the baseline surface water flood extent in any scenario except for the 1 in 100 year (plus 40% for climate change) event. On this basis, the volume of displaced water would be much reduced compared with the Option 1 scenario and would require less mitigation / management of surface water within the site boundary.

78. Furthermore, modelling of Option 2 with the side slopes / embankments for the OnSS platform did not show any significant impacts to the flood extent when compared to the baseline results. This scenario also demonstrates a significant reduction in surface water displacement compared with the Option 1 scenario.

79. Both of the Option 2 orientations also require the provision of an access road to connect the higher ground to the north with the OnSS platform. As a result, this means the southern end of the access road (at the OnSS platform) would be raised above the existing ground level. The access road would need to pass over existing overland flow paths, and could potentially block them, which would result in water pooling adjacent to the road and the OnSS platform.

80. Therefore, it was noted that measures will be required to enable the existing surface water flow paths to continue to pass below the access road. Methods such as including culverts, raising the road on pillars or creating an open span solution would need to be considered during the detailed design.

81. To understand the impact the OnSS platform and access road may have on surface water flood risk and to consider the potential for an increase in off site flood risk, the Option 2 embankment scenario was modelled with the north-west access road included, tying in to the OnSS platform level of 28.23m AOD at the southern end.

82. A large culvert / bridge was included within the model beneath the north-west access road to allow the continued conveyance of the existing flow path beneath it. The results of this modelling demonstrated very little impact from the north-west access road on the overland flow path, with the water continuing to reach the low-lying area adjacent to the railway embankment, as is the existing situation.

83. Furthermore, the results of this scenario show that both the surface water flood extent and maximum flood depths are slightly reduced compared with the results from the baseline modelling. This reduction can be attributed to the incorporation of the OnSS platform in the model. By including the OnSS platform within the model, rainfall falling on the platform during an event does not contribute to the flooding as it is assumed this will be collected by the surface water drainage system to be implemented as part of the project.

84. As such there is a small reduction in surface water flood depth and extent in the area of potential flooding close to the OnSS platform. In addition, there is no change in the wider off site flood risk as the surface water flooding is contained in an area within the OnSS site.