

Executive Summary

Royal HaskoningDHV (RHDHV) was commissioned to undertake a numerical hydraulic flood modelling and mapping study of Havant Thicket.

The aim of the study was to demonstrate that there would be no uncontrolled release of surface water runoff from the site during at least a 3.3% AEP storm event (1:30 year storm).

This report details the methodology used in developing the model, including the hydrological analysis and hydraulic approaches, and presents the results and sensitivity analysis, as well as providing conclusions, limitations, and recommendations.

Hydrology

Rainfall catchment data was obtained from the FEH Web Service. The Flood Estimation Handbook (FEH) Web Service provides standardised catchment descriptors for the UK, which enables the national dataset to be used to predict the catchment run-off characteristics for most of the UK.

In line with best practice, hydrological assessments should be based on catchment-wide design rainfall as this provides the best representation of the response of the wider catchment to a rainfall design event.

The hybridised modelling approach requires an estimation of the net rainfall to be applied as rainfall hyetographs to the upper catchments of the hydraulic model. These hyetographs are to be extracted for each return period and storm duration. Various storm durations have been assessed to determine the critical storm event.

Hydraulic Modelling

The hydraulic model is a combined 1D-2D ESTRY-TUFLOW model (TUFLOW Solver Build: 2023-03-AC-iSP-w64). The 1D domain is restricted to just the pipe and pump network connecting through topographical constrictions and leading into sedimentation basins. The 2D extent covers the study area and utilises the latest LiDAR data to represent the general surface.

The sedimentation basins were initially modelled to align with specific designs and gradients but following discussions with the Client the model was adapted to remove most of the connections between the various basins and to contain the surface water runoff in the uppermost basins. This removes any uncertainty on the speed at which the flocculant solutions need to work.

The hydraulic modelling conducted demonstrates that the site, provided it creates suitably sized basins, can contain all of the runoff associated with the 3.3% AEP storm.

Impact on Flood Risk

As noted above, the hydraulic modelling confirmed the site, provided it creates suitably sized basins, can contain 3.3% AEP storm entirely within the site boundary. Therefore, it is concluded that the adaptations identified for the sedimentation basins would not result in an increase in flood risk and that water can continue to be stored in the upstream basins with no off-site impact.

As such, there is no change in the conclusions related to the potential flood risk impact compared with the flood risk assessment previously undertaken and presented in the 2020 ES.

Table of Contents

Revision History	ii
Executive Summary	iii
1 Introduction	1
1.1 Project Aims	1
1.2 Study Area Overview	1
1.3 About This Report	2
2 Input Data Plan	3
2.1 Previous Studies	3
2.2 GIS Datasets	3
3 Methodology	4
3.1 Choice of Approach	4
3.2 Hydrological Approach	5
3.3 Hydraulic Modelling Approach	5
4 Hydrology	6
4.1 Overview	6
4.2 Hydrological Setting	6
4.3 Net Rainfall Hyetographs	6
4.4 Storm Seasonality	7
5 Model Build	8
5.1 Overview	8
5.2 Model Schematisation	8
5.3 1D Domains	8
5.4 2D Domains	9
5.5 Boundaries	10
5.6 Initial Conditions	11
5.7 Infiltration Parameters	11
6 Model Simulation Summary	12
6.1 Model Scenarios and Events	12
6.2 Model Results	12
7 Model Condition	15
7.1 Overview	15

7.2	Running The Model	15
7.3	Run Performance	15
7.4	Significant Issues	17
7.5	Model Condition Conclusion	17
8	Assumptions and Limitations	18
8.1	Data Limitations	18
9	Recommendations & Conclusions	20
9.1	Recommendations	20
9.2	Conclusions	20
9.3	Impact on flood risk	20
10	Bibliography	21

Table of Tables

Table 3-1: Design Fluvial Flood Events	4
Table 5-1: Definition of Surface Roughness Values with respect to Ordnance Survey Vector Map data [3] and Chow [4].	10
Table 6-1: Summary of Modelled Scenarios and Events	12
Table 6-1: Maximum water level within the basins (3.3% AEP event)	13
Table 6-2: Maximum water volume within the 'Upper' basins (3.3% AEP event)	13
Table 8-1: Data type and sources	18

Table of Figures

Figure 1-1: Site overview	1
Figure 3-1: Methodology Overview	4
Figure 4-1: Environment Agency LiDAR and Detailed River Network Relative to active site area (black outline) and future wetland area (blue shading)	6
Figure 4-1: Rainfall at time-step applied to the drainage model	7
Figure 5-1: Drainage layout	9
Figure 5-2: Boundary Location Map	10
Figure 6-1: Outline 3.3% AEP Maximum Flood Depth Map	12
Figure 6-2: Outline 3.3% AEP Flood Depth Map at the end of the simulation	14
Figure 7-1: 2D Mass Error Graph	15
Figure 7-2: Havant Thicket dVol graph	16
Figure 7-3: HPC Timestep Graph	16

Glossary & Acronyms

Term / Acronym	Description
OBC	Outline Business Case
AEP	Annual Exceedance Probability is the probability of a rainfall or tidal event occurring within any one year. For example an event of a 100 year return period has an AEP of 1:100 or 1%.
Critical Storm Duration	The duration of a specific storm event which creates the largest volume or highest rate of net storm water runoff for typical durations up to and including the 10 day duration event.
ESTRY	Dynamic flow program suitable for mathematic modelling floods and tides (and/or surges) in a virtually unlimited number of combinations.
FEP	Flood Estimation Point
Flood Defences	Artificial structures maintained to a set operational level designed to protect land people and property from Tidal and Fluvial flood sources to an established AEP threshold.
Flood Source: Fluvial	When flows within watercourses exceed the capacity of the watercourse causing out of bank flows.
Flood Source: Pluvial	When rainfall causes overland flows which exceed the capacity of the drainage network, causing flooding to land that is normally dry.
Flood Source: Tidal	When high tide events overtop the shoreline to cause flooding to land behind.
Flood Zone 1	Low Probability. Land defined as having a less than 1:1000 AEP of flooding from tidal and fluvial sources.
Flood Zone 2	Medium Probability. Land defined as having a risk of fluvial flooding between 1:100 AEP and 1:1000 AEP. Or Land defined as having a risk of tidal flooding between 1:200 AEP and 1:1000 AEP.
Flood Zone 3 (A)	High Probability. Land defined as having a fluvial risk of 1:100 AEP or greater. Or a tidal risk of 1:200 AEP or greater.
Flood Zone 3 (B)	Functional Floodplain. Defined by SFRA's as areas where floodwater is stored during lower AEP events, typically the 1:20 AEP.
Flood Zone Map	The Environment Agency has produced a mapping data set which covers England and provides the general extents of Flood Zones 1, 2, and 3. However the national data set available online does not differentiate between Flood Zone 3 (A) and 3 (B)
LiDAR	Light Detection And Ranging is an accurate ground terrain model obtained by aerial survey. The typical vertical accuracy is +/- 150 mm, the horizontal spacing of survey points (resolution) is normally 0.5m in city centres, 1m in urban areas and 2m in rural areas.
Main River	Defined on the Main River map and relate to rivers on which the Environment Agency have powers to carry out flood defence works
Model Event	The Model Event is the AEP storm or flow profile used within each Model Scenario
Model Scenario	Each Model Scenarios considers a range of Model Events to assess the impact of the Scenario, typical Model Scenarios are; base case, post development, post mitigation.
m AOD	Metres Above Ordnance Datum
OS	Ordnance Survey.
Ordinary Watercourse	A watercourse which does not form part of a Main River
TUFLOW	TUFLOW is one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software. It simulates the complex hydrodynamics of floods and tides using the full 1D St Venant equations and the full 2D free-surface shallow water equations.

1 Introduction

Royal HaskoningDHV (RHDHV) was commissioned to undertake a numerical hydraulic flood modelling and mapping study of the proposed Havant Thicket Reservoir. This note covers the initial drainage investigations related to sedimentation modelling.

Due to site preparation work for the planned reservoir the current site has been scraped, exposing the underlying clay surface. This could potentially result in a lot of sediment pollution escaping into downstream rivers due to surface runoff. The proposed solution to this is to implement a series of basins which will capture that sediment and treat it, reducing the suspended clay particles until that water reaches an acceptable level whereupon the water will be released down to the rivers below.

This report details the methodology used in developing the model, including the hydrological analysis and hydraulic approaches, and presents the results and sensitivity analysis, as well as providing conclusions, limitations, and recommendations.

1.1 Project Aims

The aim of the study was to understand the surface water flow paths within the site and thereby the locations and sizing of sedimentation basins. The overall objective was to demonstrate that the runoff (and therefore any sediment pollution) from the 3.3% Annual Exceedance Probability (AEP) storm was contained on site.

1.2 Study Area Overview

The site lies north of the town of Havant and drains down into the Riders Lane Stream. The hydraulic model includes the area of the proposed reservoir as well as some of the upstream catchment. The model area and key features are presented in the **Figure 1-1** below and indicates locations of the storage basins as well as the overground bunds which assist in controlling the flow of surface water.

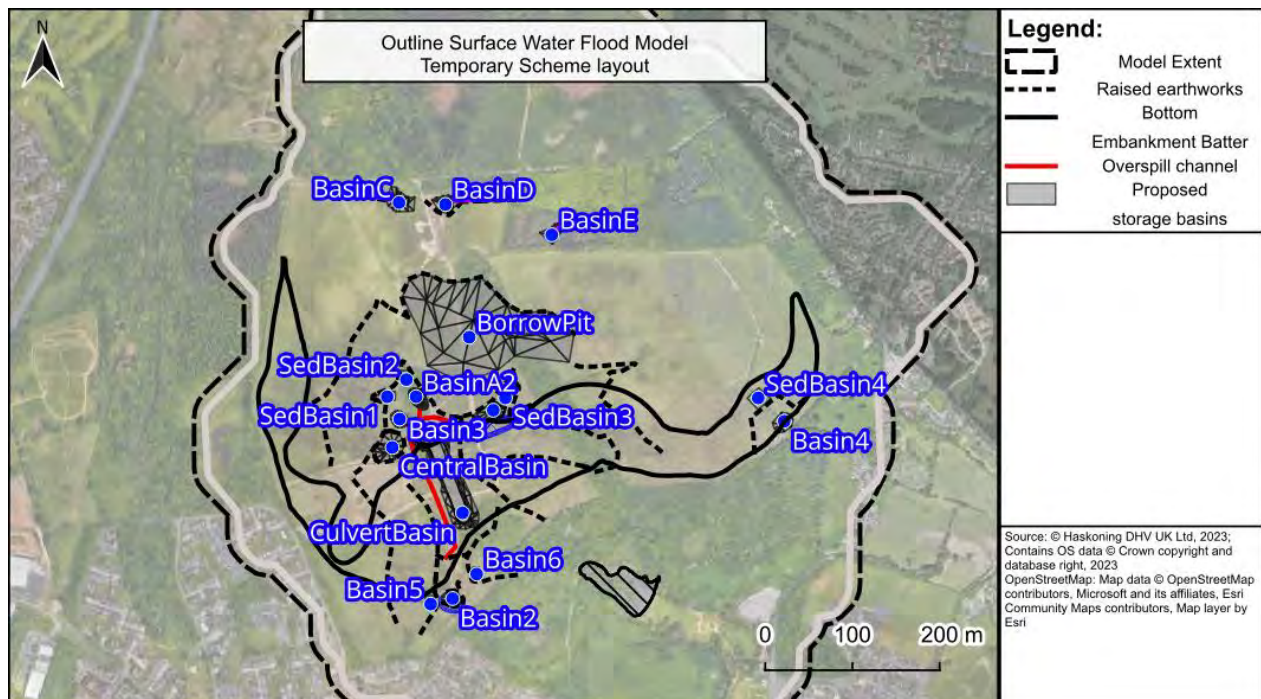


Figure 1-1: Site overview

1.3 About This Report

This report details the methodology used in developing the hydraulic model, including the hydrological analysis and hydraulic approaches, and presents the results and sensitivity analysis, as well as providing conclusions, limitations, and recommendations.

2 Input Data Plan

2.1 Previous Studies

A previous Infoworks ICM hydraulic model exists which covered the town of Havant, south of the site, however this model was not suitable for modelling the reservoir or any pre-construction phases without very significant alterations.

2.2 GIS Datasets

2.2.1 Vector Data

2.2.1.1 Ordnance Survey (OS) Zoomstack Data

OS Zoomstack data was downloaded from the Ordnance Survey website¹. This formed the basis of assigning 2D roughness values and building representation in the 2D flow areas.

2.2.2 Raster Data

2.2.2.1 Environment Agency LiDAR Data (2022)

The latest composite, one metre grid resolution EA LiDAR data sets have been retrieved from the DEFRA Data Services Platform open-source web portal² and merged to cover the model extent. The model extent has full coverage by 2022 LiDAR data. A review of the LiDAR dataset did not highlight any issues, therefore this dataset was used for the model build.

¹ OS Data Hub, <https://osdatahub.os.uk/downloads/open/OpenZoomstack>

² DEFRA Data Services Platform, <https://environment.data.gov.uk/survey>

3 Methodology

3.1 Choice of Approach

The model is a combined 1D-2D ESTRY-TUFLOW model. The use of this software enables both 1D in-channel flows as well as varied 2D floodplain dynamics to be modelled accurately. This is both an industry standard and Environment Agency benchmarked software. Through utilising advances in Graphic Processing Unit (GPU) modelling capabilities it was possible to construct a high-resolution model without negatively impacting model simulation times.

The 1D domain consists solely of various pipe and pumping units. The 2D extent covers the study area identified by the Environment Agency and utilises the latest LiDAR data. The 2D model extent is shown in Figure 1-1 above.

A suite of return period events have been determined. These events are listed in Table 3-1 below:

Table 3-1: Design Fluvial Flood Events

Annual Exceedance Probability (AEP)	Return Period (RP)
50% AEP	2 Year
3.3% AEP	30 Year
1% AEP	100 Year
0.1% AEP	1,000 Year

As a summary, **Figure 3-1** provides an overview of the modelling methodology based on the agreed approach. The numerical flood model has been developed using a systematic approach of identifying data, determining hydrological conditions, and then construction of a numerical flood model.

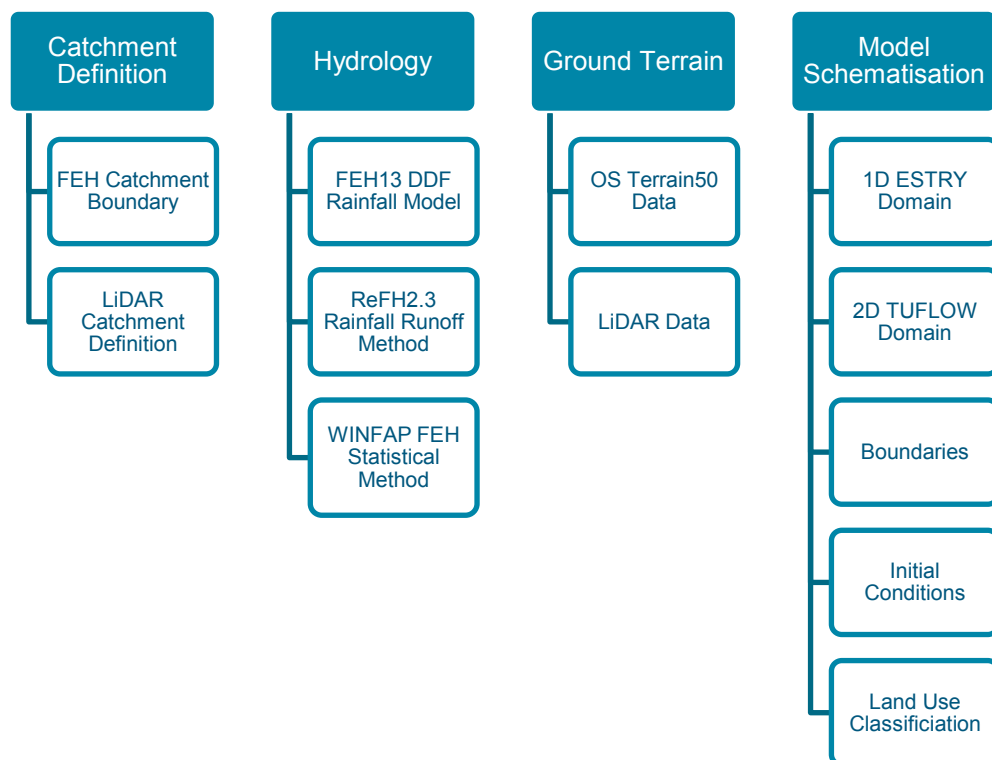


Figure 3-1: Methodology Overview

3.2 Hydrological Approach

For the hydraulic model, it was necessary to derive inflow hydrographs through utilising the FEH Catchment Descriptors as extracted from the FEH Web Service, and evaluated using the ReFH2 Rainfall-Runoff software. This enables design hydrographs with appropriate losses to be extracted and applied to the hydraulic model.

3.3 Hydraulic Modelling Approach

Based on the study area, and the type of flood dynamics expected within the model, it is considered appropriate to implement a 2D³ flood modelling regime, using the TUFLOW computational engine.

The TUFLOW computational engine has been benchmarked by the Environment Agency, and is suitable for predicting flood levels, flood depths, flow velocities, and flood hazard ratings, associated with tidal and fluvial flood inundation.

Based on experience of development of 2D numerical flood models for assessment of catchment-specific flood risks, the TUFLOW solver is appropriate for the simulation of the baseline scenario, and for testing of potential future mitigation options.

³ A 2D solver enables an estimation of water level and flow rates in a dual vector direction, usually forwards and backwards along a channel, and perpendicular to the channel. These solvers are usually slower than 1D solvers, and can encounter problems when dealing with small channel widths (less than 3 model cell widths).

4 Hydrology

4.1 Overview

Rainfall catchment data was obtained from the FEH Web Service. The Flood Estimation Handbook (FEH) Web Service provides standardised catchment descriptors for the UK, which enables the national dataset to be used to predict the catchment run-off characteristics for most of the UK.

In line with best practice, hydrological assessments should be based on catchment-wide design rainfall as this provides the best representation of the response of the wider catchment to a rainfall design event.

4.2 Hydrological Setting

Based on a comparison of LiDAR data and the Environment Agency's Detailed River Network information, the pre-construction setting of the site is summarised in **Figure 4-1**. This indicates that there are three main channels (Channels A – C) that enter the site from the north, combine within the active works area, and discharge to a single channel (Riders Lane Stream) downstream of the works area.

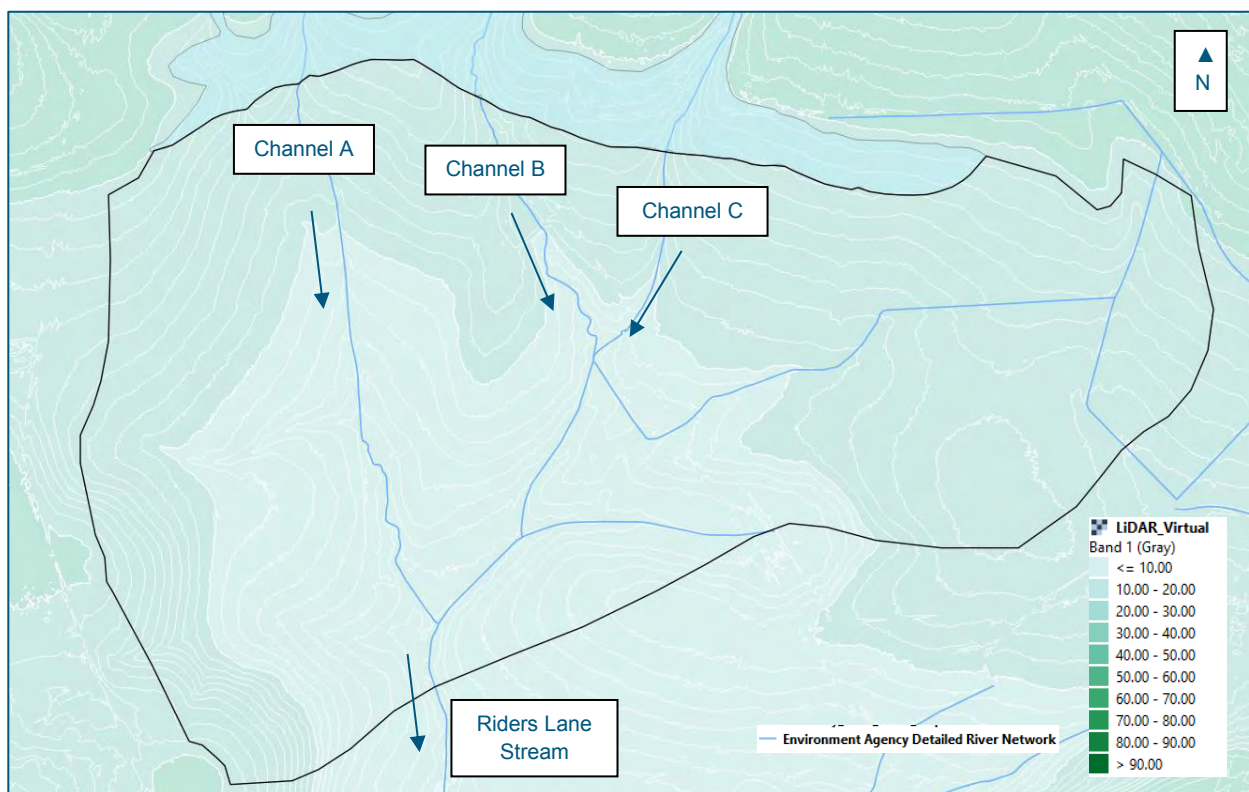


Figure 4-1: Environment Agency LiDAR and Detailed River Network Relative to active site area (black outline) and future wetland area (blue shading)

4.3 Net Rainfall Hyetographs

The hybridised modelling approach requires an estimation of the net rainfall to be applied as rainfall hyetographs to the upper catchments of the hydraulic model. These hyetographs are to be extracted for each return period and storm duration. Various storm durations have been assessed to determine the critical storm event. The critical storm duration for the design catchment was 5.5 hours / 330 minutes.

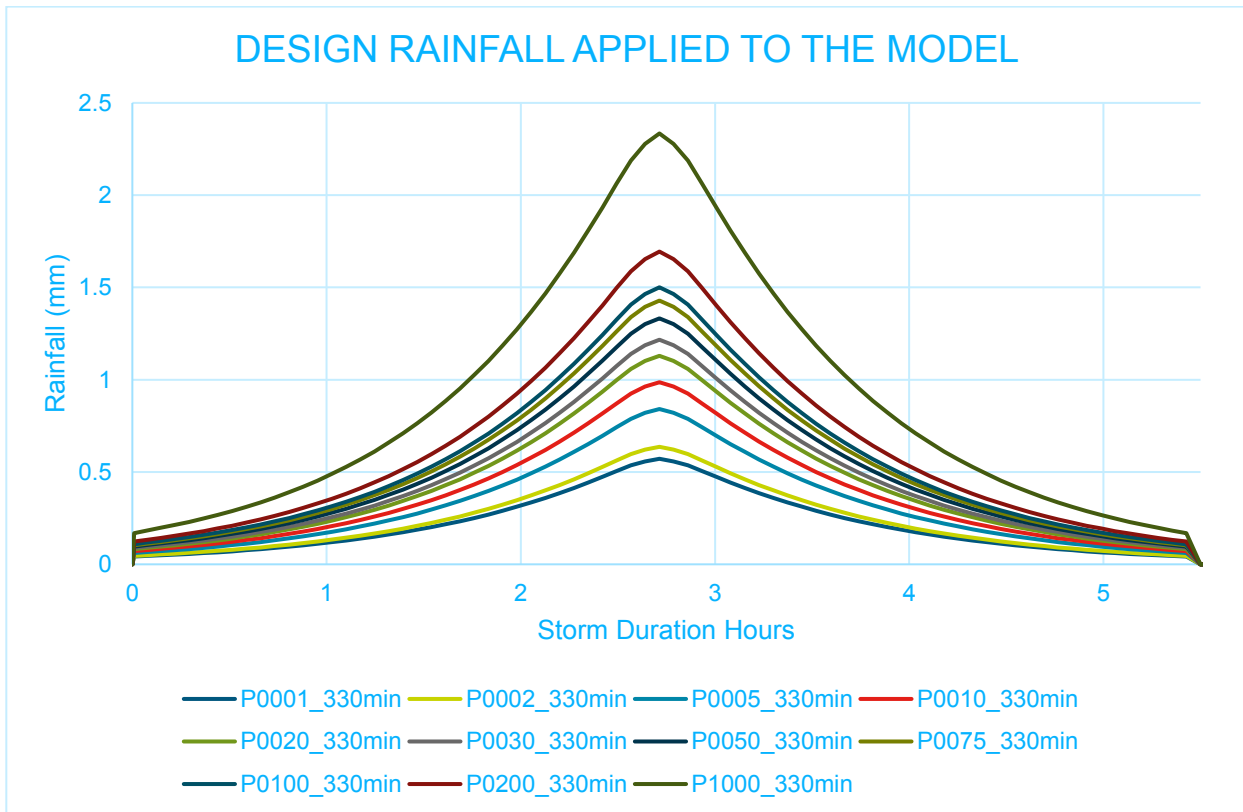


Figure 4-2: Rainfall at time-step applied to the drainage model

4.4 Storm Seasonality

Selection of storm seasonality is subjective and can be dependent but not limited to several key catchment characteristics including geographical location, land gradient, land use and urban coverage. The storm seasonality was investigated as part of the hydrological assessment, and Winter seasonality was deemed to be critical.

5 Model Build

5.1 Overview

This section of the report refers to the baseline definition of flood risk across the Catchment. This definition is based on the current geometric and hydrological parameters. A hydraulic model of the catchment was constructed using the specialist flood modelling software ESTRY/TUFLOW. The use of this software for studies of this nature has been benchmarked by the Environment Agency [2], and is considered appropriate for use.

The 1D/2D linked modelling approach represents the different hydraulic characteristics of the catchment in a digital model suited to the type and extent of the available data and is proportionate to the scale and nature of the study. The pipe network including the pumping units were captured using 1D model elements, based on the data provided by FROG Environmental Ltd and the Client. Meanwhile, the study area has been represented using a 2D model domain, utilising the detailed coverage of the Environment Agency LiDAR DTM data.

5.2 Model Schematisation

The hydraulic model schematisation was based on a desktop inspection of the hydrological characteristics and hydraulic features. This model has evolved significantly from the initial design with numerous additions:

- improving bund heights throughout the model to ensure no overtopping occurs from surface water ponding behind the bund;
- isolating key basins such as the Central Basin and Basin 2 via complete bund encirclement;
- extension of some bunds to ensure capture of surface water runoff which might otherwise have escaped the site boundary;
- introduction of the Culvert Basin pit and pumping;
- removing pumped connections between basins to assess the storage requirements for just the uppermost basins.

The cumulative effect of these changes is to produce a conservative estimate for the storage requirements in the uppermost basins (Basin C, Basin D, Basin E, Sed Basin 1, Sed Basin 2, Sed Basin 3, Sed Basin 4, Basin 5, and Basin 6).

5.3 1D Domains

The 1D Domain represents the pipe network within the model domain. There are no 1D open channel sections. The information below discusses the approach undertaken to model this.

Culvert invert and soffit levels have been taken from the survey data where available. Where culvert dimensions were not surveyed, the sizes of the culverts were estimated through aerial imagery and consideration of the size of the channel flowing into the structure. The flow routes over structures (under high flow conditions) have been represented within the 2D domain.

The various pumps within the catchment help reduce the amount of surface water ponding which might otherwise occur on the uphill face of raised embankments. Frog Environmental has confirmed that its Pipe Reactor have a maximum throughput of 1,800 litres per minute. This flow rate has been used for every modelled pumping unit. The latest layout does not have pumping or connections between the various basins. The only exception to this is that the Culvert Basin and Borrow Pit both pump into Sed Basin 3. The reason that there are no connections between the basins is to ensure that the uppermost basins in their respective chains would have sufficient capacity to hold the 3.3% AEP storm water and allow that to settle out.

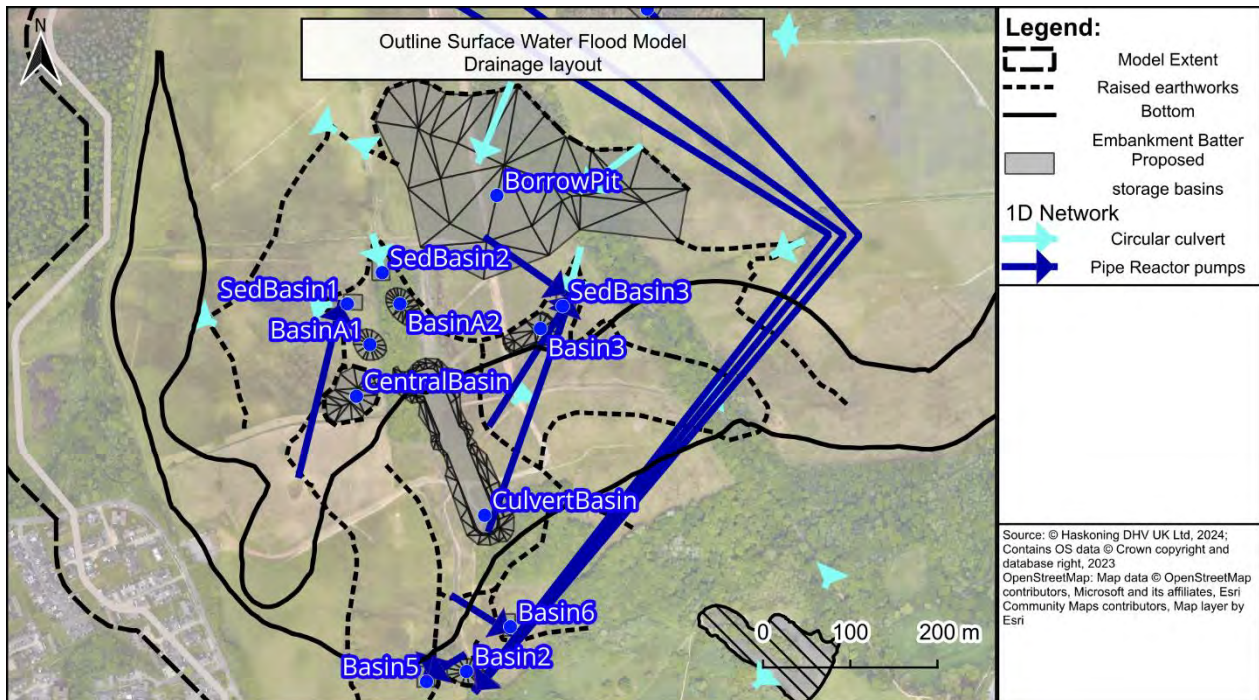


Figure 5-1: Drainage layout

5.4 2D Domains

The basis of the 2D domain has been developed using Environment Agency LiDAR DTM data. The 2D domain covers the entire study area. A 2 metre cell size has been utilised for the 2D domain.

5.4.1 Digital Elevation Model

The Digital Elevation Model has been developed from Environment Agency LiDAR data (1m resolution). The latest composite, one metre grid resolution LiDAR data set has been retrieved from the Environment Agency open-source web portal. The 2D model domain has full coverage by 2022 LiDAR data. A review of the LiDAR did not highlight any issues, therefore this dataset was used for the model domain.

It should be noted that some areas within the 2D model domain are heavily vegetated and as such, the reliability of LiDAR data in these areas may be limited.

5.4.2 Sedimentation Basins

The sedimentation basins were initially developed based around specific guidance and designs from the Client. Many of these same designs have remained in the model however in order to better produce advice regarding maximum required volume storages, Sed Basin 1, Sed Basin 2, Sed Basin 3, Sed Basin 4, Basin 5, and Basin 6 have been digitised as large pits within the 2D domain. These pits have a bed level of 1mAOD with sheer sides and are rectangular in form. This allows for quick calculation of final volume requirements and reduces the potential for having to rework the model if one of them were to overtop by making it functionally impossible for that to happen.

5.4.3 Surface Roughness

Definition of surface roughness within the floodplain is important, especially for areas of shallow flow, where the roughness factor of the ground can have an impact on the flow velocity, due to the impacts of friction.

The land use classification was determined using Ordnance Survey ZoomStack dataset. It provides a detailed view of Great Britain's landscape, including roads, fields, buildings, and woodland giving a sufficient level of detail for the study area and the scale of the model. Table 5-1 provides the surface roughness values (as Manning's n values) that have been applied in the updated model for each land use classification. Buildings were represented with high roughness, rather than the "stubby building" approach.

Table 5-1: Definition of Surface Roughness Values with respect to Ordnance Survey Vector Map data [3] and Chow [4].

Material Code	Manning's n	Land Cover
999	0.045	Default Roughness
101	0.060	Urban Areas
102	0.035	Greenspace
103	0.080	Woodland
104	0.020	Surface Water
105	0.050	Foreshore
106	0.020	Waterlines
107	0.300	Buildings
108	0.022	Roads
201	0.020	Stripped Soil Locations

5.5 Boundaries

The boundary conditions represent the inflow and outflow conditions of the model and at any external model connections. The purpose of the boundary conditions is to provide a realistic simulation of the way in which water flows in and out of the modelled domain. For this model the following conditions have been used:

- Inflow area; and
- Normal Depth boundaries.

A map detailing the location of the various model conditions can be found in **Figure 5-2**.

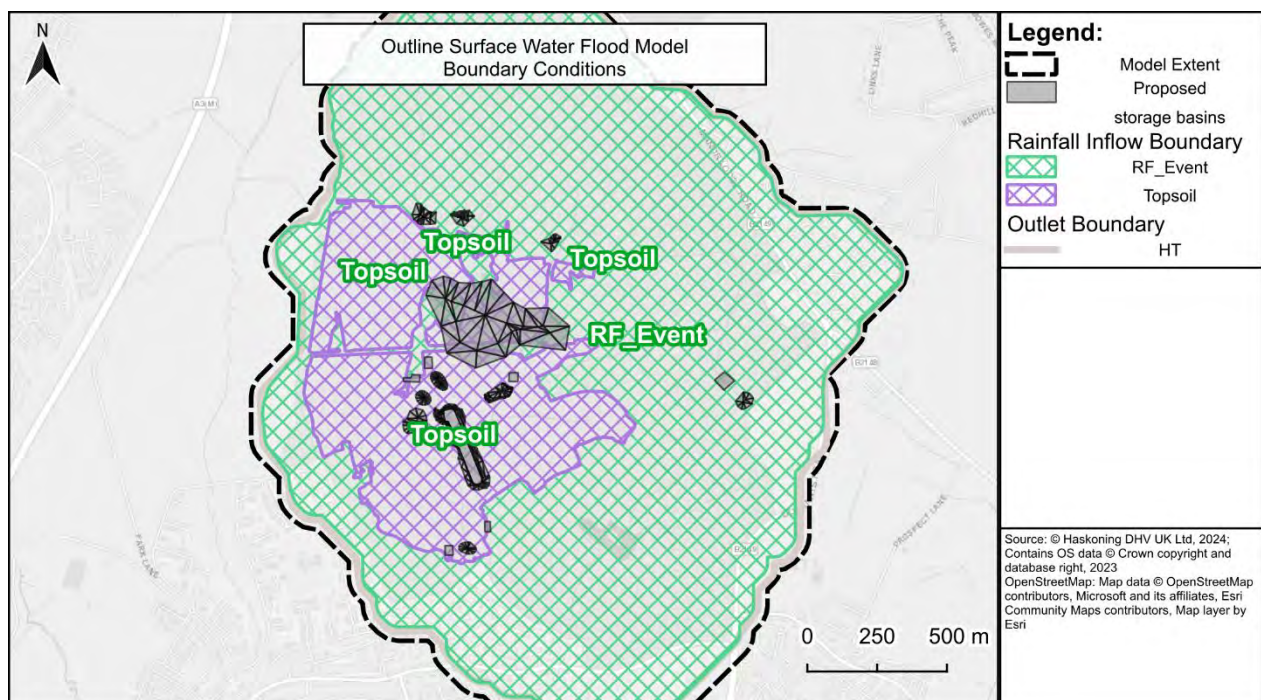


Figure 5-2: Boundary Location Map

5.5.1 Rainfall Area Inflow Boundaries

The hydrological inflows derived from the hydrological assessment were applied across the entire modelled catchment.

The model has two different inflow rates;

- (1) at a normal greenfield runoff rate, as defined in the “RF_Event” area, and;
- (2) at an increased inflow rate in the areas where the topsoil has been stripped.

The increased rate for the Topsoil areas is designed to mimic the reduced infiltration, and thereby the increased runoff, which would be produced in these areas.

5.5.2 Outlet Boundary Conditions

The edge of the model is surrounded by a HT boundary set to -50mAOD. This is designed to extract any water which might touch it. Given that the boundary is set on the far side of the watershed for the main study area, and that there is no consistent gradient around the edge of the model, this was deemed appropriate.

5.6 Initial Conditions

The initial water levels represent the antecedent conditions of the study area prior to a storm event. There is a small area to the south of the study site which is an existing pond and as such contains water. This was represented via a 2D initial water level patch set to 22.75mAOD. There are no other initial water levels within the model.

5.7 Infiltration Parameters

Infiltration parameters (i.e. to represent losses to sewers or infiltration to the ground) were not explicitly included within the ESTRY-TUFLOW hydraulic model as the effect of infiltration is included within the hydrological assessment.

6 Model Simulation Summary

6.1 Model Scenarios and Events

The modelling project has run 4 different simulations (scenario and event combinations). Given the iterative process required to reach this final scenario, a coded naming convention was applied to the model run files, summarised in Table 6-1. The following key should be used to understand the nomenclature:

- *HavantThicket* – Model Identifier
- *Outline* – ‘Initial Outline’
- *P* – Pluvial Return Period
- *330min* – Storm Duration
- *019* – Run Version

Table 6-1: Summary of Modelled Scenarios and Events

Name [.tcf] and Results File	Scenario	AEP (%)	Storm Duration	Version
Design Runs				
HavantThicket_Outline_P0002_330min_019	Initial Outline	50	330 Minute	019
HavantThicket_Outline_P0030_330min_019	Initial Outline	3.3	330 Minute	019
HavantThicket_Outline_P0100_330min_019	Initial Outline	1	330 Minute	019
HavantThicket_Outline_P1000_330min_019	Initial Outline	0.1	330 Minute	019

6.2 Model Results

The hydraulic modelling conducted is designed to understand the volume requirements for the various basins within the model, assuming that a 3.3% AEP storm would need to be fully contained on site.

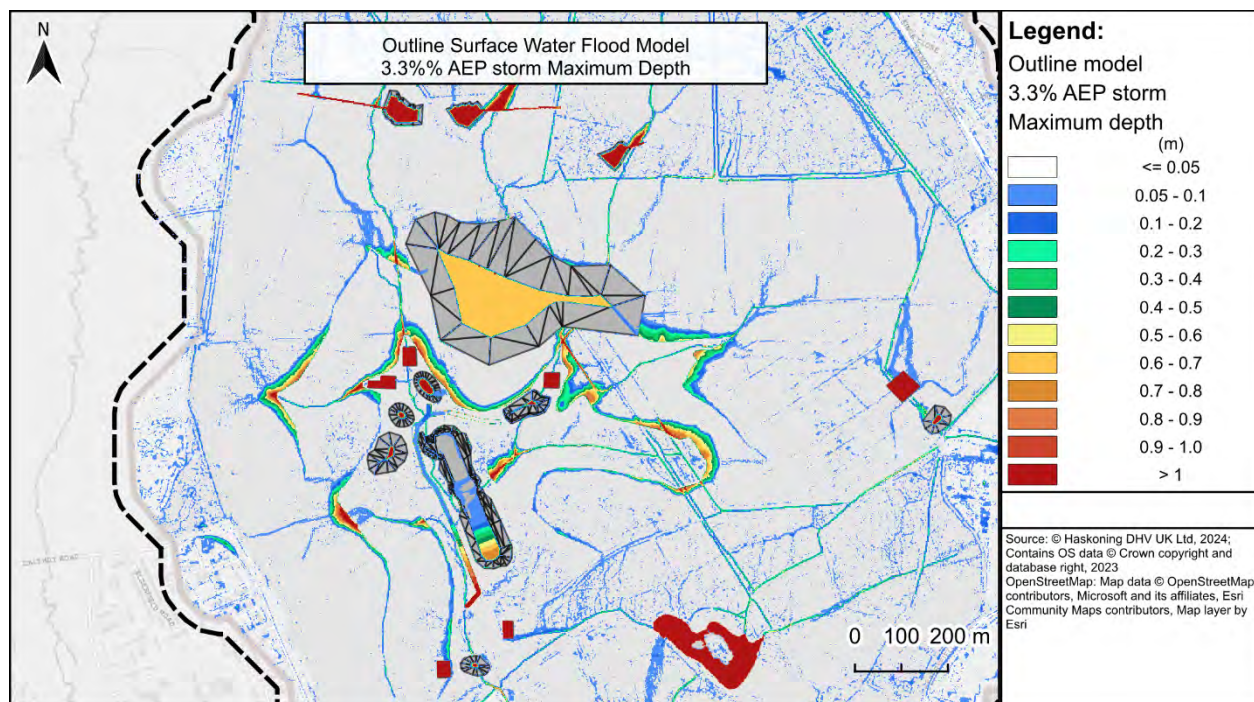


Figure 6-1: Outline 3.3% AEP Maximum Flood Depth Map

Table 6-2 below outlines the maximum water level within each basin during the 3.3% AEP storm.

Table 6-2: Maximum water level within the basins (3.3% AEP event)

Basin	Outline Scenario Maximum Water level (mAOD)	Water level at 25 hours (mAOD) (Approx. 24 Hours After Storm Event)
BasinC	38.03	37.61
BasinD	38.32	38.13
BasinE	38.24	37.53
SedBasin1	8.10	8.01
SedBasin2	5.18	5.17
BasinA2	21.95	21.95
BasinA1	21.79	21.79
CentralBasin	18.64	18.64
SedBasin3	15.73	12.05
Basin3	21.38	21.38
Basin5	8.53	8.53
Basin2	15.78	15.78
Basin6	4.95	4.95
SedBasin4	4.52	4.50
Basin4	26.56	26.56
BorrowPit	11.65	11.57
CulvertBasin	17.93	17.47

The results demonstrate that the model can contain the runoff from a 3.3% AEP event on site. The uppermost basins (excluding Basins C/D/E) are in the model but are not intended to be representative in shape to the final designed basins. Instead they are rectangular with sheer sides, allowing for easy quantification of volume within their outline by taking the area of the basin and the depth present. **Table 6-3** below outlines the area and volume within each of those basins during the 3.3% AEP storm.

Table 6-3: Maximum water volume within the 'Upper' basins (3.3% AEP event)

Basin	Area of Basin in the model (m ²)	Maximum Volume within the Basin (m ³)	Volume within the Basin at 25 hours (m ³) (Approx. 1 Day After Storm Event began)
SedBasin1	1241.5	8814.7	8702.9
SedBasin2	1155.5	4830.0	4818.4
SedBasin3	1066.4	15708.1	11783.7
SedBasin4	2425.0	8487.5	8487.5
Basin5	1003.6	7557.1	7557.1
Basin6	799.1	3156.4	3156.4

The rainfall stops within the simulation at approximately 5.5 hours. There is significant overland flow for the next 3 or 4 hours however after that point the amount of water moving slows significantly. Twelve hours after the rainfall has stopped (at 17.5 hours into the simulation) there is very little change in most basin volumes, although SedBasins 1, 2, and 3 still increase. By 25 hours into the simulation the only basin that is still filling is SedBasin 3 and that is due to pumping out of the Culvert Basin and the Borrow Pit. There is still a significant amount of water held behind bunds on site at the end of the simulation although the depths are relatively low. **Figure 6-2** shows the situation at the end of the simulation.

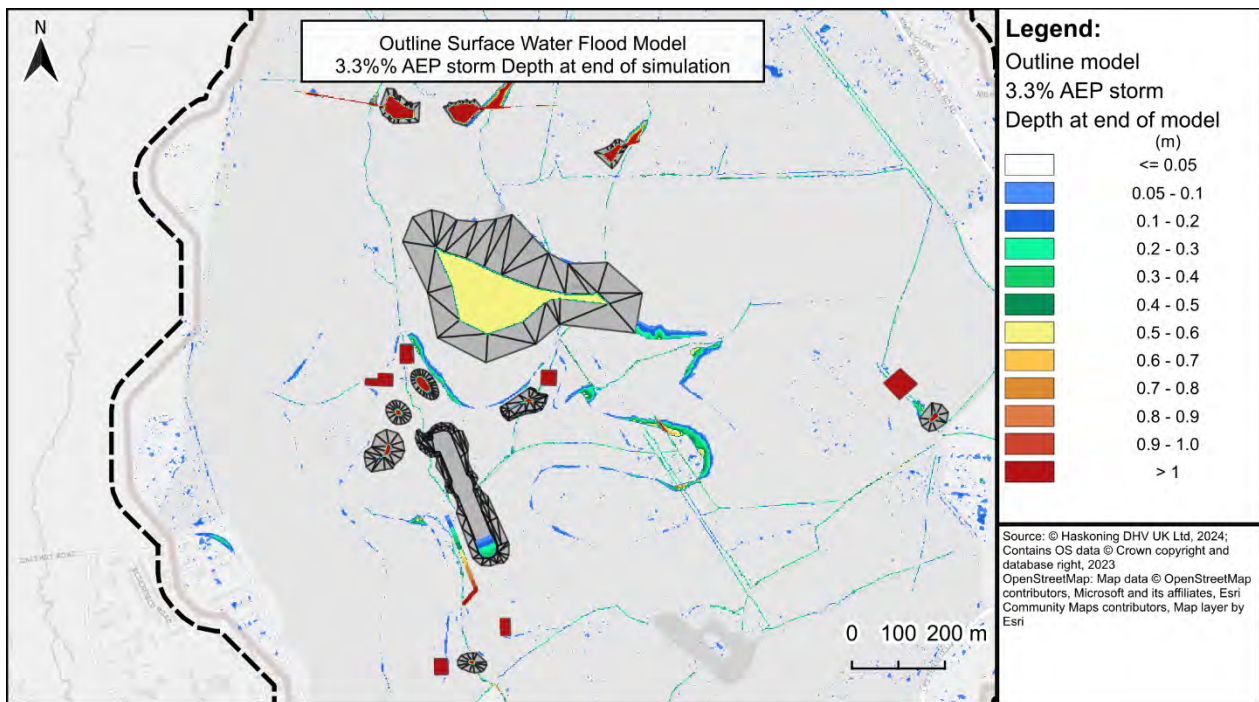


Figure 6-2: Outline 3.3% AEP Flood Depth Map at the end of the simulation

7 Model Condition

7.1 Overview

To provide an assessment of the condition of the model, a range of indicators have been reviewed, including undertaking sensitivity testing on a range of input variables of the model.

7.2 Running The Model

The hydraulic model was run utilising the ESTRY-TUFLOW 1D-2D modelling software. The following model engines were utilised:

- TUFLOW Solver Build: 2023-03-AC-iSP-w64
- HPC Solver Build: 3.30.0

The model was run using a default 1D ESTRY timestep of 0.5 second and a 2D TUFLOW timestep of 1 second, however, it should be noted that the model utilised the HPC and GPU Modules, which enable adaptive time stepping.

7.3 Run Performance

Analysis of the mass balance for all modelled events indicates that the TUFLOW mass balance is within the typical $\pm 1\%$ limits (**Figure 7-1**). Additionally, TUFLOW indicates that there were no negative depths within this simulation with the model running reliably for all simulated events and scenarios. The final cumulative Mass Error was $+0.02\%$.

Graph of Mass Error for 2D Domain

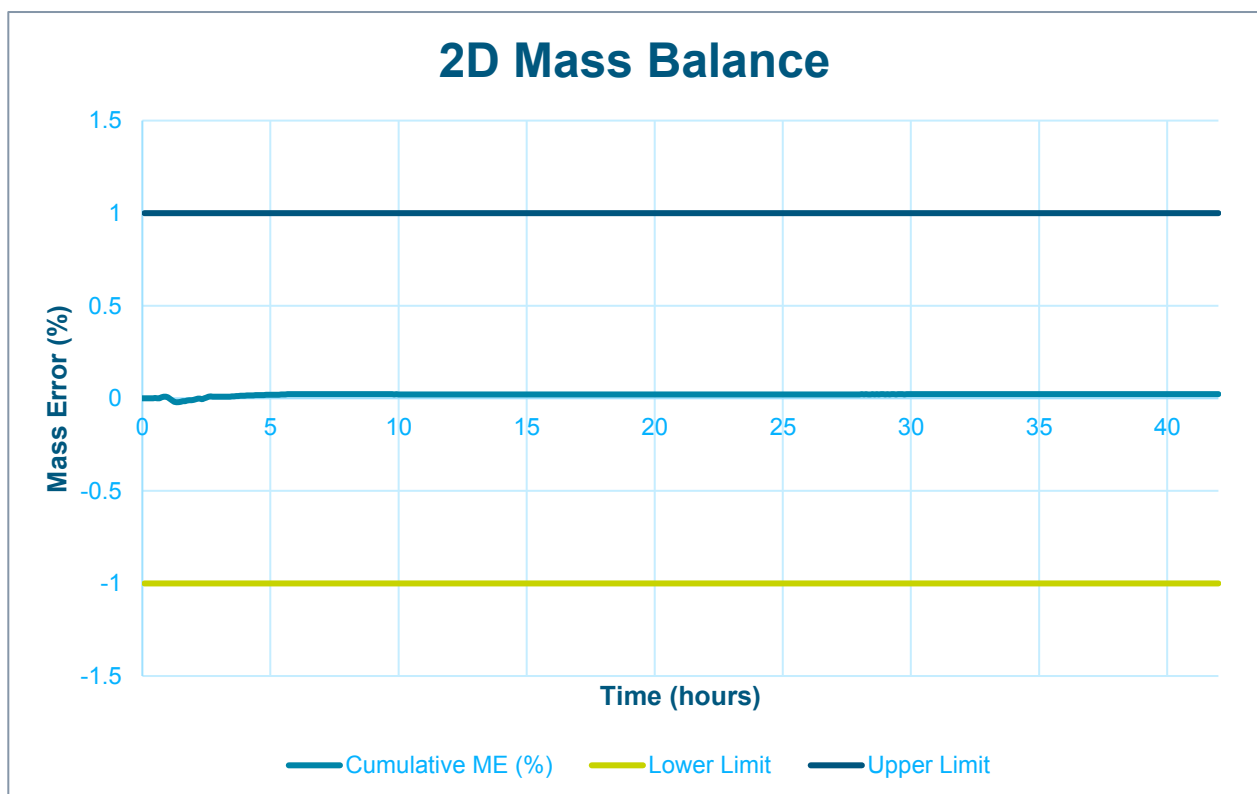


Figure 7-1: 2D Mass Error Graph

dVol for 2D Domain

The dVol output assesses the change in total volume of water within the model in m^3 . It should be noted that the final volume error was $52m^3$ which given the scale of the model and of the inflows, is very low (Figure 7-2).

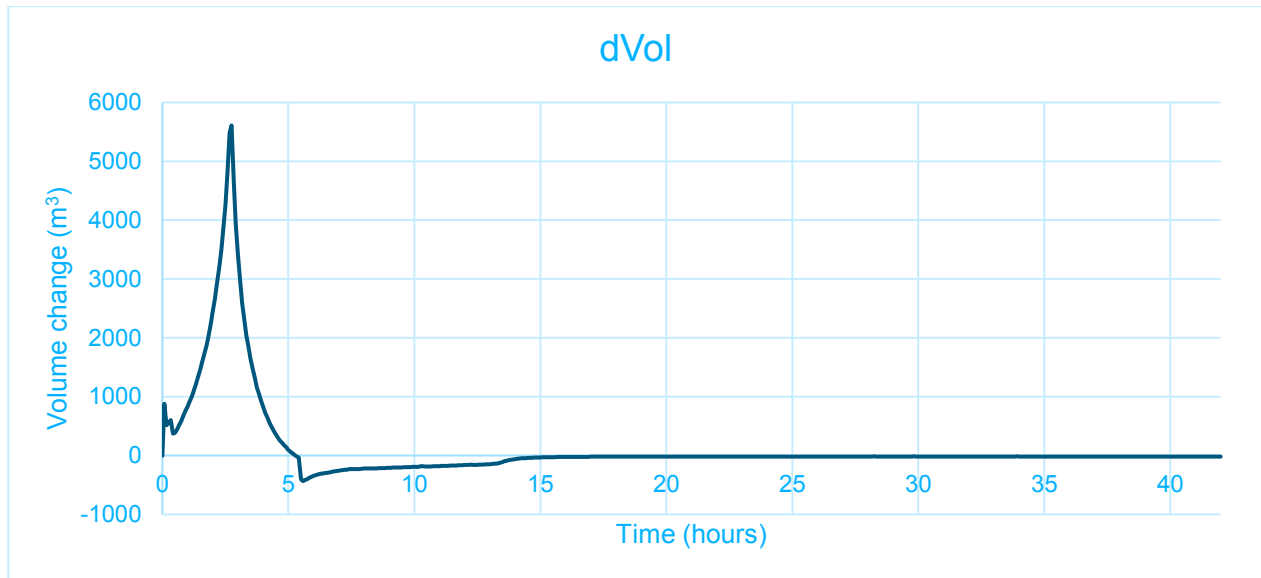


Figure 7-2: Havant Thicket dVol graph

HPC Timestepping Health

Below is a summary of the timestepping health for the 3.3% AEP Outline simulation. The key parameters are as follows:

dtTarget = The target timestep for the simulation.

iStep = This is the number of computational steps (i.e iStep 100 will be the 100th timestep calculated).

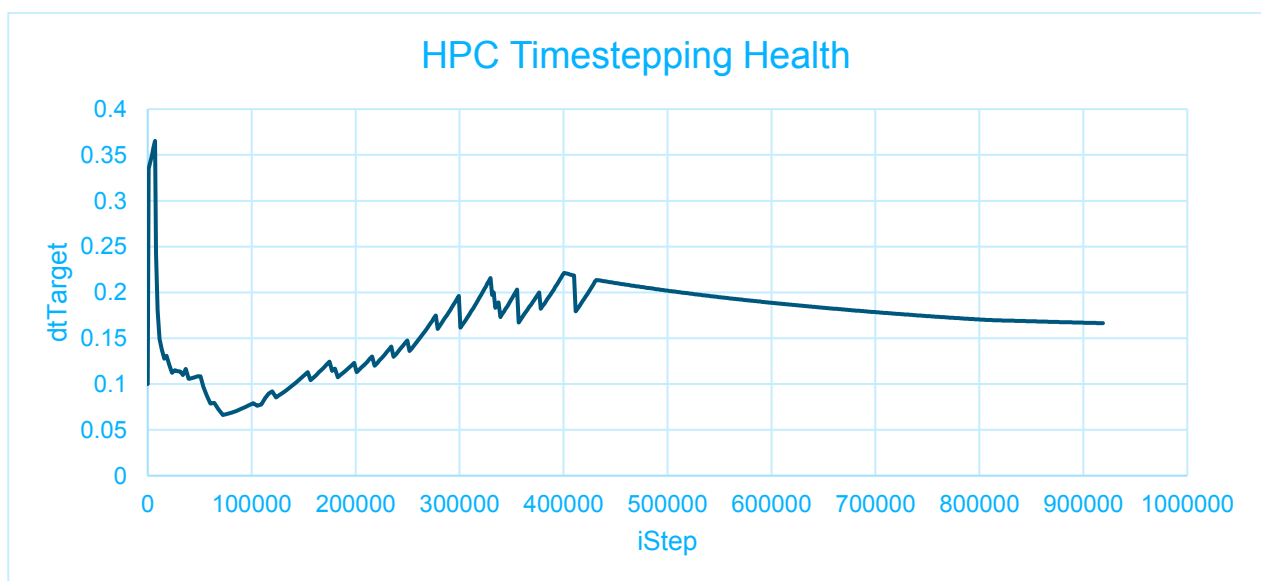


Figure 7-3: HPC Timestep Graph

The model has relatively good health as viewable by the fact that after the initial stabilisation the model has a fairly stable adaptive timestep.

7.4 Significant Issues

In the development of this numerical flood model, no significant issues have been determined (however, it should be noted that several timestep corrections associated with TUFLOW HPC did occur). The model runs within normal operating parameters.

7.5 Model Condition Conclusion

As the model behaved as expected, throughout the scenarios and events tested, as well as the observation that parameters used within the model are within normal operating limits and in line with best practice, the model is deemed fit for purpose.

8 Assumptions and Limitations

Hydrological and hydraulic models are constructed from empirical and numerical components that, by definition, have assumptions built into their underlying parameters and calculations. Other assumptions also arise in their development due to uncertainty in, or absence of suitable input data (e.g. percentage run-off). These assumptions and limitations are discussed below.

8.1 Data Limitations

Multiple sources of information have been used in the development of the hydrologic and hydraulic models. Table 8-1 provides a list of the data used in the development of the hydrological assessment and hydraulic model.

The data quality has been assessed in accordance with the Multi-Coloured Manual [5] and scored accordingly where;

- 1 = Best possible;
- 2 = Data with known deficiencies;
- 3 = Gross assumptions; and
- 4 = Heroic assumptions.

The Multi-Coloured Manual was written by the Flood Hazard Research Centre and was written in partnership with the Environment Agency. Accordingly, this rating system was deemed appropriate for use in this study.

Table 8-1: Data type and sources

Data Type	Sub Type	Source	Score	Comment
Hydrology	Hydrological Calculations	Flood Estimation Handbook	2	Site specific collection of hydrological data would be more accurate but is not proportionate to the scope at this stage.
1D Geometry	Pipe and Pump network	Various	3	The pipes have been sized according to standard dimensions and the pumps have been based off the provided FROG throughput rate. However the precise layout may change which would have corresponding impacts on basin sizing.
2D Geometry	Satellite Photography	Various	2	Recent satellite photography across various sources, however, with moderate resolution.
	Ordnance Survey Data	OS Website	2	OS Zoomstack Data. This data was utilised to estimate Manning's roughness values throughout the 2D TUFLOW Domain.
	LiDAR Data	Environment Agency	2	Open source EA LiDAR data was used to define topographic levels throughout the 2D TUFLOW Domain where more detailed topographic survey data was not available. The EA LiDAR Data available for this area had resolutions varying between 2m and 1m.

Should there be significant assumptions or deficiencies in any of the data utilised as part of this model, this could impact model results and therefore, the outcomes / conclusions reached as part of this study. This further emphasises the importance of sensitivity testing to determine the impact of changing key model parameters.

8.1.1 Assumptions

The 1D/2D hydraulic model has assumed:

- The Digital Elevation Model has been derived from OS Terrain50 data, filtered Environment Agency LiDAR data and topographic survey data is accurate and representative of the topography of the study area;
- 2D surface roughness values based on Ordnance Survey ZoomStack data. Verification of roughness areas has been undertaken, using online aerial photography;
- Initial water levels based on the outline of the pond;
- All structures in the model are free and clear of debris in the Outline scenario model runs.

8.1.2 Limitations

The following limitations of the hydraulic model should be noted:

- The numerical flood model has been produced to determine the flood risk profile for the study area and to understand the volume requirements for the uppermost sedimentation basins. It should not be used by third parties to assess flood risk elsewhere in the model domain.
- The model has been tested on normal design storms only, due to the complexity and variability of real storm events, the flood risk profile determined by this model is a prediction only.

It should be noted these assumptions and limitations are unlikely to have significant effects on the hydraulic modelling conducted as part of this study.

9 Recommendations & Conclusions

This study was commissioned to improve the understanding of flood risk at Havant Thicket. Additional focus was placed on understanding the amount of water which may be required, in a worst case scenario, to be stored in upstream basins.

The flood model has been undertaken, using an Environment Agency bench marked TUFLOW flood modelling software. The inflows have been derived using the FEH and ReFH2 approaches as appropriate, and these have been applied as direct rainfall across the model extent.

The representation of the 2D elements of the model have been derived from available Ordnance Survey Mapping (to inform the surface roughness values), Environment Agency LiDAR, and relevant site topographic survey where possible.

9.1 Recommendations

The following recommendations are made for future work within the study area:

- It is recommended that the design of the basins and, in particular, the pumped connections between the basins, be advanced. Whilst this hydraulic modelling study shows that it is possible to contain the required storm water on site, the current need to store this in the most upstream basins could cause them to become excessively sized. Understanding how much water can be passed to downstream basins would alleviate some of this issue.

9.2 Conclusions

The following conclusions have been made based on this study:

- The hydraulic modelling conducted as part of this study demonstrates that the site can contain the 3.3% AEP storm entirely within the site boundary, where the runoff can then be treated with flocculant until it is suitable for release.
- Through assessment of the outputs the hydraulic model has been determined to be fit for purpose.

9.3 Impact on flood risk

- The hydraulic modelling undertaken as part of this study has confirmed that the site, provided it creates suitably sized basins, can contain 3.3% AEP storm entirely within the site boundary.
- As such, it is concluded that the adaptations identified for the sedimentation basins would not result in an increase in flood risk and that water can continue to be stored in the upstream basins with no off-site impact.
- Furthermore, the conclusions related to the potential flood risk impact remain the same compared with the flood risk assessment previously undertaken and presented in the 2020 ES.

10 Bibliography

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