Appendix D: Hydrodynamic Breach Modelling Methodology

This appendix presents the methodologies used to develop flood outline, maximum flood depth, hazard rating and time to inundation maps for the Thurrock SFRA.

Topographic Data

A key component in the modelling process is the representation of topography throughout flood prone regions of the study area. For this purpose, a Digital Terrain Model (DTM) was derived for each of the modelled areas. A DTM is a three-dimensional 'playing field' on which the model simulations are run.

The platform used for the generation of the DTM was the GIS software package MapInfo Professional (version 8.5) and its daughter package Vertical Mapper (version 3.1).

The DTM is primarily based on filtered LiDAR data provided by the Environment Agency. LiDAR (Light Detection And Ranging) is a method of optical remote sensing, similar to the more primitive RADAR (which uses radio waves instead of light). In this case, the LiDAR surveys return data at a horizontal resolution of approximately 1 metre. Filtered LiDAR data represents the "bare earth" elevation with buildings, structures and vegetation removed.

The LiDAR data was used to create a DTM grid covering the study area.

Flood Cell Definition

Twenty-one breach locations have been identified along the northern bank of the River Thames within the Thurrock Borough Council administrative area. Details are provided in Table 1-1.

Once the DTM grids and breach locations have been obtained, the flood cell for each model must be defined. The flood cell is the geographical extent of the model, the area of the overall DTM that will be used in the model. While it would be possible to run each of the breach models using all of the derived DTM topographical data, it is far more sensible to define a smaller area on which to run each scenario.

Flood cells are typically defined by considering the topography of the area inland of the breach and the peak levels of the tidal events to be tested. MapInfo can be used to show areas of potential flooding by only displaying areas of the DTM that are below the predicted peak inundation levels in the vicinity of the breach, plus a freeboard of several hundred millimetres. Areas of the DTM that are not shown (that is, areas that are well above the tidal levels of interest) do not need to be considered in the model.

Where the local topography does not clearly define an enclosed flood cell it may be necessary to artificially enclose certain parts of the flood cell. This should only be done for areas that are not near the breach or any important areas of the model, and will typically be outlying or empty areas of the flood cell. For example, estuaries or flat, open fields at the far end of the flood cell. Since the model treats the boundaries of flood cells as 'glass walls' it is vital that any artificial boundaries do not affect levels in the important areas of the flood cell. However, this is typically not an issue in models where the inflows are based on tidal levels rather than a specific volume.

Extreme Water Level Derivation

Extreme tidal water levels in the River Thames are derived from the report 'Thames Tidal Defences, Joint Probability Extreme Water Levels 2008, Final Modelling Report, Halcrow (for the Environment Agency), as provided by the Environment Agency.

Climate Change

PPS25 recommended contingency allowances have been applied to the extreme water levels in order to simulate climate change scenarios.

Breach Modelling

Twenty-one breach locations have been identified along the northern bank of the River Thames within the Thurrock Borough Council administrative area as shown in Figure A1.

To assess flood propagation in events where the flood defences are breached, a hydraulic modelling analysis has been undertaken using the two-dimensional hydraulic modelling software MIKE21-HDFM (version 2007). This section discusses the methodology that has been applied for the hydraulic modelling analysis of the breach events. The choice of model is discussed, the model schematisation is described and the boundary conditions used are presented.

Model and Software Selection

To achieve the study objectives, the model used to estimate the maximum flood conditions was required to:

- Accommodate the effects of a flood flow (propagation of a flood wave and continuous change of water level);
- Simulate the hydraulics of the flow that breach the flood defences; and
- Generate detailed information on the localised hydraulic conditions over the flooded area in order to evaluate flood hazard.

MIKE21-HDFM was developed by the Danish Hydraulic Institute (DHI) Water and Environment and simulates water level variations and flows for depth-averaged unsteady two-dimensional free-surface flows. It is specifically oriented towards establishing flow patterns in complex water systems, such as coastal waters, estuaries and floodplains using a flexible mesh (FM) approach. The flexible mesh model has the advantage that the resolution of the model can be varied across the model area. The model utilises the numerical solution of two-dimensional shallow water equations.

Model Extent and Resolution

Flexible meshes were developed to define the topography of the land behind the breach, using the MIKE21 program's mesh generator application which creates a mesh of triangular elements covering the entire area prone to flooding. These areas are known as 'flood cells' and generally cover all land that has an elevation below the peak tidal level.

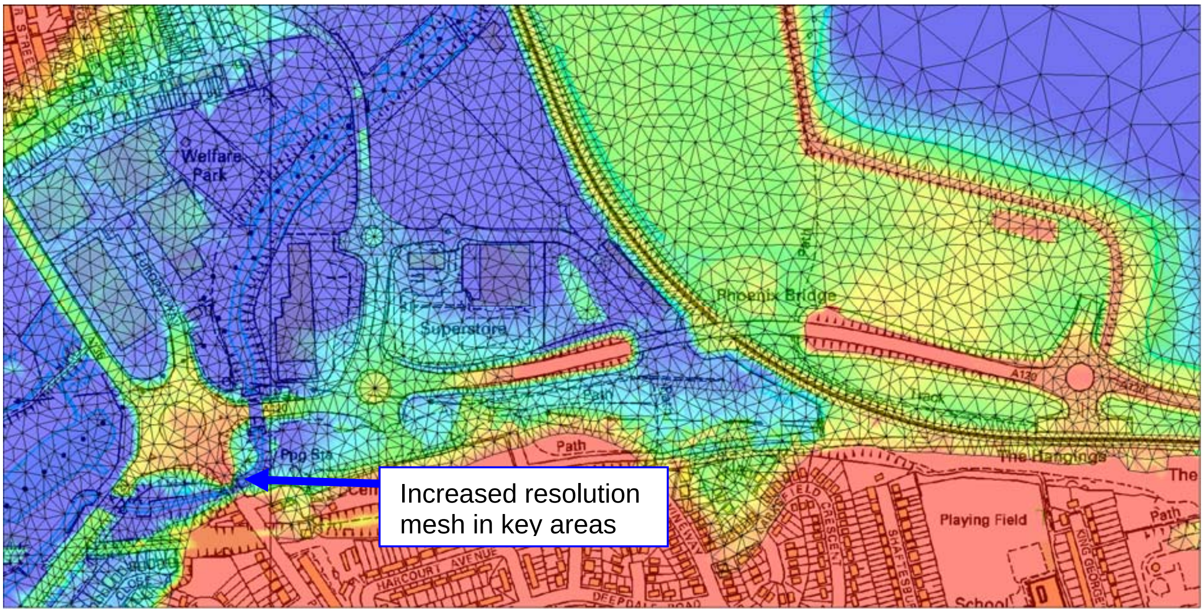
The element size in the mesh is varied throughout the model domain depending upon the complexity of the floodplain and the location of topographic features which have a significant impact on flood propagation. For example, more triangles would be present near a road, wall or bridge and less in areas of open floodplain.

In order to accurately represent the hydraulics around the breaches a comparatively small element size has been specified in the vicinity of the breaches. The breach itself is represented with a minimum of four elements across its width.

By adding ‘control lines’ during the development of the mesh, the triangles are forced to follow the alignment of the features ensuring the elevations of important features are picked up during the mesh generation. For example, control lines would be placed along each side of a road. In this way, the mesh is ‘forced’ to follow the road accurately and use level values at very specific points.

Once the final mesh is developed and the triangles generated, elevation values are imported into the mesh at each triangle vertex from the LiDAR data. This then provides the 3-dimensional ‘playing field’ for simulating the breach scenario.

Figure 2D Example of MIKE 21 HD Flexible Mesh



Breach Specifications

The breach width and exposure duration are determined by the type of defences and the nature of the adjacent water body. Flood defences are categorised as either ‘Hard Defences’ or ‘Earth Embankments’. According to Environment Agency guidance (Environment Agency SFRA Guidance[1]) for tidal rivers, the breach width adopted for the above categories is 20 metres and 50 metres respectively.

Almost all of the breaches simulated in this study involve ‘Hard Defences’ (20 metre breach). However, there are two breaches where the local defences are ‘Earth Embankments’ (50 metre breach). There are also a further two breaches where a sluice is breached. In these cases, the breach is assumed to be across the entire width of the sluice.

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[1] Agency Management System Document: Uncontrolled When Printed [10/01/07]

The repair time required to close a breach is assumed to be 36 hours, covering three tidal cycles. In the hydraulic modelling undertaken for this study, the breach in the flood defence wall occurred at the start of the model simulation (that is, the breach is always open to simulate a worst case scenario[2]) and remained open for 36 hours. This corresponds to approximately three tidal cycles, with the peak level occurring on the second peak, with two slightly smaller peaks either side.

According to the Environment Agency, the 'defence height varies slightly, depending on exposure, between 6.9m AODN to 7.2m AODN' within the study area. As this corresponds very closely to the range of 1 in 1000 year peak tides for the year 2109 (that is, with 100 years of climate change), it was assumed that the present day flood defences protected the study area from the 1 in 1000 year peak tide event in 2109. Therefore no overtopping is assumed to occur in this study and only the consequences of breaching have been simulated.

Hydraulic Roughness used in Modelling

Hydraulic roughness represents the conveyance capacity of the land or riverbed where flows are occurring. Within the MIKE21 model, hydraulic roughness is defined by the dimensionless Manning's 'n' roughness coefficient.

Three material roughness classifications have been identified within the study area – water; 0.03 (for the river), urbanised; 0.04 and rural/non-urbanised land; 0.07. The distribution of these factors has been defined using aerial photography and OS maps in order to vary the conveyance rates throughout the domain.

Tidal Model Boundary Conditions

Within the MIKE21 model, tidal water level boundary files (in this case located in the River Thames before the breach) are used to provide the important input of water volumes to the mesh. The tidal water level is defined in the river and determines the flow entering the flood cell through the breach.

The water level boundary file consists of real-time tide curves, using the tidal peak levels derived from the report 'Thames Tidal Defences, Joint Probability Extreme Water Levels 2008, Final Modelling Report, Halcrow (for the Environment Agency).

Model Simulations Undertaken

The following flood events were simulated for each breach location;

- A tidal flood event with a return period of 1 in 200 years (present day 2009);
- A tidal flood event with a return period of 1 in 200 years (with climate change 2109);
- A tidal flood event with a return period of 1 in 1000 years (present day 2009).
- A tidal flood event with a return period of 1 in 1000 years (with climate change 2109).

Modelling Outputs

Breach analysis presents data to identify the residual risk of flooding from a failure of local defences. The mapping of flood depth, flood hazard and time to inundation within the study area represents an

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[2] Worst case scenario in this strategic study is to simulate an open breach for the full three tidal cycles.

appreciation of the residual risk and provides Thurrock BC with additional information to enable more detailed consideration of the Sequential Test and PPS25 vulnerability classifications within Flood Zone 3a.

Once the meshes were defined and the models run (by flooding the meshes, through the breaches, with the tidal events), three layers were derived for each breach scenario and tidal event, to provide the following deliverables. GIS tasks have been performed using MapInfo Professional (Version 8.5) with the Vertical Mapper spatial analysis add-on (Version 3.0).

Maximum Flood Depth

The maximum flood depth is obtained from the water level achieved at each point in the model, minus the LiDAR topographic level at that point. This has been processed for the climate change scenarios (2109) only.

Hazard Rating

Flood hazard is a function of the flood depth and flow velocity at a particular point in the floodplain. Each element within the model is assigned one of four hazard categories ‘Extreme Hazard’, ‘Significant Hazard’, ‘Moderate Hazard’, and ‘Low Hazard’.

The derivation of these categories is based on Flood Risks to People FD2320 (DEFRA & EA, 2005), using the following equation:

$$\textit{Flood Hazard Rating} = ((v+0.5)*D) + DF$$

Where v = *velocity (m/s)*
D = *depth (m)*
DF = *debris factor*

The depth and velocity outputs from the 2D hydrodynamic modelling are used in this equation, along with a suitable debris factor. For this SFRA, a precautionary approach has been adopted inline with FD2320; a debris factor of 0.5 has been used for depths less than and equal to 0.25m, and a debris factor of 1.0 has been used for depths greater than 0.25m.

Table 1-2 Hazard categories based on FD2320, DEFRA & Environment Agency 2005

Flood Hazard			Description
🟩	HR < 0.75	**Low**	**Caution** – Flood zone with shallow flowing water or deep standing water
🟨	0.75 ≥ HR ≤ 1.25	**Moderate**	**Dangerous for some** (i.e. children) – Danger: flood zone with deep or fast flowing water
🟧	1.25 > HR ≤ 2.0	**Significant**	**Dangerous for most people** – Danger: flood zone with deep fast flowing water
🟥	HR > 2.0	**Extreme**	**Dangerous for all** – Extreme danger: flood zone with deep fast flowing water

Hazard outputs have been processed for the 1 in 200 year event (2009) and have been included in the Level 1 SFRA Report. Hazard outputs for the 1 in 200 year event with climate change (2109) and the 1 in 1000 year with climate change (2109) have also been processed and are presented within this Level 2 SFRA Report.

Time to Inundation

The time taken for floodwaters to spread across the flood cell has been mapped using the following methodology.

Time 0 is set to the time when tidal water enters the breach. This means that the <1 hour band encompasses all areas that are inundated (wet) within the first hour of water travelling through the breach and into the flood cell. Further bands have been produced to show wet cells at: 1-4 hours, 4-8 hours, 8-12 hours, and for each 4 hour interval up to 28-32 hours.

This has been processed for the climate change scenarios only.