Appendix E: Modelling Methodology

Appendix E: Hydrodynamic Breach Modelling Methodology

This appendix presents the methodologies used to develop modelling outputs, including maximum flood depth, hazard rating and time to inundation maps, for the Strategic Flood Risk Assessment.

Rapid Inundation Modelling

The modelling methodology used for this SFRA uses a 'breach at the peak' approach or 'rapid inundation' approach. Rapid inundation modelling simulates breaches that occur suddenly just before the peak tidal level. As the maximum force and volume of water behind the defences will occur at the peak of the simulated water level it was agreed that this modelling scenario would provide the most rapid inundation of the system. A greater volume of water would surge through the breach with more rapid and higher floodwater velocities simulated, particularly in the vicinity of the breaches. This would correspondingly produce the most severe time to inundation results in the area local to the breach position and hazard with velocity playing a large part in the determination of the flood hazard category in certain areas. The results from these scenarios could then be used to determine the minimum time to inundation for vulnerable locations in the flood cell, particularly for the more vulnerable properties located closer to the flood defences.

The total volume of water entering the system will be slightly less compared with a modelled situation where the breach is open throughout the modelled simulation (i.e. open flood gate situation), and inundation will be slightly lower in the outlying areas of the flood cell. The rapid inundation methodology will however more appropriately test the potential flooding in more vulnerable lower lying areas close to the breach. This methodology was agreed with the Environment Agency (EA) prior to the commencement of the project.

The modelling carried out for this SFRA was based on the previous modelling undertaken as part of the Thames Gateway SFRA. It should be noted that although many of these breach locations were previously identified, all of the breach modelling conducted within this study is original and does not use or incorporate any previous modelling; each breach cell has been reconstructed exclusively for this study. In addition, every breach location has been assessed for suitability to this study.

Site Visit

Initially each breach was investigated to determine the location of the breach, the defence type and height, the width of the breach and the invert level of the breach. This was informed by the previous SFRA and validated using aerial photography and topographic data in the form of LiDAR. This information was then sent to the EA for confirmation and comment prior to visiting the site to ensure any points for discussion and further investigation were highlighted prior to the visit.

This database was then confirmed by a site visit where all breach locations, (with the exception of the inaccessible ones: CAS01, ROC01 & ROC02), were visited prior to commencement of the modelling process. This site visit was undertaken to ensure each breach location was positioned sensibly and properly represented within the model, and equally importantly that the wider flood cell was adequately represented with any important features noted.

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 8.5.2) and its daughter package Vertical Mapper (version 3.1).

The DTM is primarily based on filtered LiDAR data provided by the EA. 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). Filtered LiDAR data represents the "bare earth" elevation with buildings, structures (such as bridges) and vegetation removed. In this case, the LiDAR surveys return data at a horizontal resolution of 2 metres, 1 metre and 0.25metres (that is, a unique elevation level is given every two/one/0.25 metres in both the north-south and east-west directions). The LiDAR was provided by the EA for this study and the following information is provided for completeness:

- All of the data is referenced using the British National Grid OSGB36, the Z value is metres above Ordnance Datum Newlyn.
- Data from different, overlapping surveys, at different resolutions, have been merged together. The newest, and highest resolution data, has had precedence in the merging process. If the input data was at a resolution finer than 2 metres, it was re-sampled to 2 metres using the bilinear interpolation method in ESRI's Spatial Analyst software.

During the compilation of the DTM it was realised that there were gaps in the LiDAR coverage. In order to accurately represent each flood cell complete topographic data was needed. Synthetic Aperture Radar or SAR was used to infill the gaps. SAR is generally less accurate and has a lower resolution (approximately 5m compared to the 2m LiDAR) so is used only in areas where LiDAR is not available.

The LiDAR data combined with SAR data was used to create a DTM grid covering the complete study area. In addition to the 2m LiDAR some 25cm LiDAR data was obtained. This is generally available for areas of specific interest only, such as along defences, so is patchy. As 25cm LiDAR is very accurate the files are extremely large. To allow reasonable working times, the 2m LiDAR was used as a basis for the modelling and where 25cm LiDAR was available this was used to override the 2m data. This provided a more accurate representation of the topography within the flood cell.

Flood Cell Definition

Sixteen breach locations have been identified along the northern bank of the River Thames, and the Rivers Crouch and Roach within the Basildon Borough, Castle Point Borough and Rochford District Council administrative areas. Details are provided in Table E-1 and shown in Figure A-1.

Table E-1 Breach Characteristics

Code (TGSE update 2010)	Breach Name (TGSE update 2010)	Previous Code (TGSE SFRA 2006)	Previous Breach Name (TGSE SFRA 2006)	Easting	Northing
BAS01/CAS	Flood barrier, Fobbing Horse, Vange Creek	Cas09	Barrier Vange Creek	574044.7	184305.5
CAS01	Upper Horse	Cas01	Canvey Island 1	575200	183400
CAS02	Canvey Village, Lower Horse	Cas02	Canvey Island 2	577100	182600
CAS03	STW	Cas03	Canvey Island 3	578100	182000
CAS04	Canvey Island Golf Course	Cas04	Canvey Island 4	579437.5	182463
CAS05	Leigh Beck	Cas05	Canvey Island 5	581600	182700
CAS06	Sunken Marsh	Cas06	Canvey Island 6	580900	184300
CAS07	Castle Point Golf Course	Cas07	Canvey Island 7	579008.6	185005
CAS08	Benfleet Creek Flood Barrier	Cas08	Benfleet Marshes	578067.6	185605
ROC01	Morrin's Point	Roc05	Morrin’s Point	596298.3	186654.2
ROC02	Wakering Stairs	Roc04	Wakering Stairs	596900	187100
ROC03	Oxenham Farm	Roc06	Oxenham Farm	595745	188694.5
ROC04	Paglesham Eastend	Roc03	Paglesham East End	594767.5	192116.8
ROC05	Grapnells, Wallasea Island	Roc01	Wallasea Island	594700	195000
ROC06	Loftmans Farm, Paglesham Creek	Roc07	Paglesham Creek	592370.3	193694
ROC07	South Fambridge	Roc02	South Fambridge	585500	196200

Code (TGSE update 2010)	River	River Classification	Defence Type	Breach Width (m)*	Breach Invert Level (m)	Crest Height APPROX (m)
BAS01/CAS	Vange Creek, Thames Estuary - Estuary	Estuary	hard defence - barrier	width of barrier-45	1	6.5
CAS01	Holehaven Creek, Thames Estuary	Estuary	hard defence with earth embankment	20	2.4	6.4
CAS02	Holehaven Creek (mouth), Thames Estuary	Estuary	hard defence with earth embankment	20	2.3	6.5
CAS03	Thames Estuary	Estuary	hard defence with earth embankment	20	2	6.9
CAS04	Thames Estuary	Estuary	hard defence with earth embankment	20	1.7	6.8
CAS05	Thames Estuary	Estuary	hard defence with earth embankment (breach at flood gate)	20	1.5	6.3
CAS06	Benfleet Creek, Thames Estuary	Estuary	hard defence with earth embankment	20	2.7	6.5
CAS07	Benfleet Creek, Thames Estuary	Estuary	hard defence with earth embankment	20	3.2	6.3
CAS08	Benfleet Creek, Thames Estuary	Estuary	hard defence - barrier	width of barrier-50	2.5	7.5
ROC01	Thames Estuary - Open Sea	Open Coast	earth embankment	200	1.7	5.1-5.3
ROC02	Thames Estuary - Open Sea	Open Coast	earth embankment	200	1.7	4.9-5.4
ROC03	The Middleway	Tidal river	earth embankment	50	1.5	4.8
ROC04	River Roach	Tidal river	flood gate	50	2.3	4.5
ROC05	River Crouch	Tidal river	earth embankment	50	1.5	4.4-4.3
ROC06	Paglesham Creek, River Roach	Tidal river	earth embankment	50	1.8	4.6
ROC07	River Crouch - River	Tidal river	earth embankment	50	1.2	5.6

Code (TGSE update 2010)	Source of water level info	200 year	200 year with 100 years of Climate Change allowance	1000 year	100 year with 100 years of Climate Change allowance
BAS01/CAS	Thames Estuary Extreme Water Levels (2008)	5.15	6.25	5.68	6.77
CAS01	Thames Estuary Extreme Water Levels (2008)	5.15	6.25	5.68	6.77
CAS02	Thames Estuary Extreme Water Levels (2008)	5.12	6.22	5.63	6.75
CAS03	Thames Estuary Extreme Water Levels (2008)	5.12	6.22	5.63	6.75
CAS04	Thames Estuary Extreme Water Levels (2008)	5.05	6.14	5.54	6.65
CAS05	Thames Estuary Extreme Water Levels (2008)	5.02	6.12	5.51	6.62
CAS06	Thames Estuary Extreme Water Levels (2008)	4.95	6.05	5.43	6.55
CAS07	Thames Estuary Extreme Water Levels (2008)	4.95	6.05	5.43	6.55
CAS08	Thames Estuary Extreme Water Levels (2008)	4.95	6.05	5.43	6.55
ROC01	Anglian Region Extreme Tide Levels (2007)	4.49	5.54	4.83	5.88
ROC02	Anglian Region Extreme Tide Levels (2007)	4.48	5.53	4.82	5.87
ROC03	Anglian Region Extreme Tide Levels (2007)	4.46	5.51	4.81	5.86
ROC04	Anglian Region Extreme Tide Levels (2007)	4.43	5.48	4.58	5.63
ROC05	Anglian Region Extreme Tide Levels (2007)	4.36	5.41	4.64	5.69
ROC06	Anglian Region Extreme Tide Levels (2007)	4.43	5.48	4.58	5.63
ROC07	Anglian Region Extreme Tide Levels (2007)	4.40	5.45	4.64	5.69

Once the DTM grids and breach locations were obtained and confirmed, 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 and computationally efficient 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. 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 distant from 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. This is typically not an issue in models where the inflows are based on tidal levels rather than a specific volume, as in this case.

Within this study there were a number of flood cells that had to be artificially constrained (notably ROC05 and ROC07 flood cells). In these cases local features as well as topography were used to inform the decision as to where to terminate the flood cell. In the case of the Rochford flood cells, natural water courses were used as these were thought to provide a natural break in the topography.

Extreme Water Level Derivation

Water levels were taken from *Environment Agency: Thames Tidal Defences Joint Probability Extreme Water Levels 2008, Final Modelling Report, April 2008* preferentially where available and appropriate for particular breach locations. Where this study did not cover particular breach locations *Environment Agency, Anglian Region, Eastern and Central Areas Report on Extreme Tidal Levels, 2007* was used to obtain water level information. Where modelled nodes were present within close proximity to specific breach locations unmodified water levels were used. Where a significant distance was present between the modelled nodes and the breach locations, modelled water levels were factored based on chainage to provide more realistic water levels.

Climate Change

PPS25 recommended contingency allowances have been applied to the extreme water levels obtained from the above studies in order to simulate climate change scenarios (100 years of climate change simulated up to 2110). Where climate change modelled runs were undertaken as part of the above studies, PPS25 allowances were applied to the closest run scenario to obtain 2110 water levels (i.e. for the *Environment Agency: Thames Tidal Defences Joint Probability Extreme Water Levels 2008, Final Modelling Report, April 2008* a model run was undertaken for 2107, so only three years of the appropriate PPS25 climate change contingency need be added).

Breach Modelling

Sixteen breach locations have been identified; eleven along the northern bank of the River Thames, two on the River Crouch and three on the River Roach. These are all located within the TGSE area of Castle Point, Basildon and Rochford administrative areas as shown in Figure A-1 and Table E-1.

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 (Release 2009, Service Pack 4). This section discusses the modelling 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/overtop 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. Release 2009, Service Pack 3 was used for this study. 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 within each flood cell, using the MIKE21 program's mesh generator application which creates a mesh of triangular elements covering the defined 'flood cell' - the land that has an elevation below the peak tidal level with the potential to flood (see above).

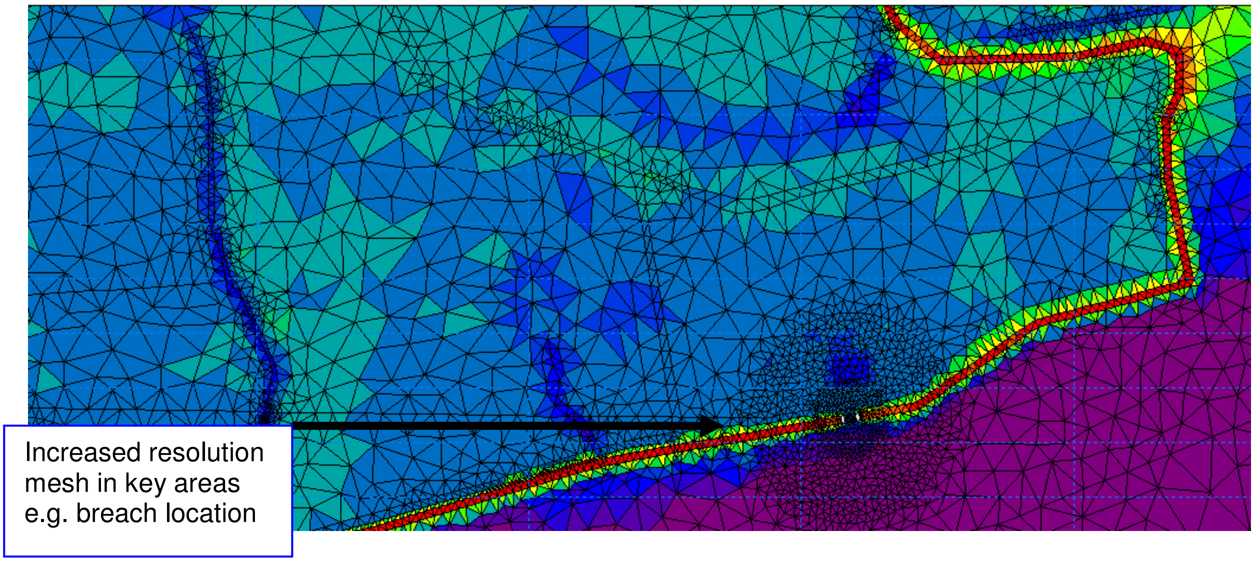
One of the advantages of the flexible mesh application is that the element size within the mesh can be varied depending upon the complexity of the floodplain, features of interest, and the location of topographic features which are thought to have a significant impact on flood propagation. By adding 'control lines' during the development of the mesh, the triangles or elements 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/ditch/topographic feature. In this way, the mesh is 'forced' to follow the features accurately and use level values at very specific points.

It was decided that considering these models are for strategic and not site specific purposes that small features such as culverts and small drainage ditches will not be included within the mesh. Taking into account the size of the study areas, the determination of all culverts and small features was outside the scope of the study.

In order to accurately represent the hydraulics around the breach locations 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.

Once the final mesh is developed and the triangles generated, elevation values are imported into the mesh at each triangle vertex from the previously created DTM, utilising the 2m LiDAR data and where available the 25cm LiDAR. This then provides the 3-dimensional 'playing field' for simulating the breach scenario.

Figure E-1 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[1]' or 'Earth Embankments'. According to EA guidance (Environment Agency SFRA Guidance[2]), the breach width adopted for the above categories is 20 metres and 50 metres respectively for tidal rivers/estuary and 50 metres and 200 metres respectively for open coast (see Table E-2).

[1] The EA consider revetted clay walls to be a hard defence. For many clay walls, either revetted or not, the main cause of failure is from overtopping and the back of the defence being compromised. Once failure has commenced, the structure will be rapidly washed out regardless of the face of the structure. The resulting gap will, by consequence of the construction, be much wider than a solid structure such as piles or concrete

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

Table E-2 Environment Agency Breach Guidelines

Location	Defence Type	Breach width (m)
Open Coast	Earth bank	200
	Dunes	100
	Hard	50
	Sluice	Sluice width
Estuary	Earth bank	50
	Hard	20
Tidal River	Earth bank	50
	Hard	20
Fluvial River	Earth bank	40
	Hard	20

The land water boundary along Canvey Island, Castle Point and Southend-on-Sea is classified as tidal river/estuary to Shoeburyness point and as open coast to the east of this point. The Rivers Crouch and Roach are considered as river/estuary (Table E-1).

Within this study there are breaches in hard defences, earth embankments and flood barriers/gates.

The repair time required to close a breach is assumed to be 20.5 hours, covering two tidal cycles. In the hydraulic modelling undertaken for this study, the breach in the flood defence wall occurs prior to the peak tidal level occurring on the second peak and remains open for the remainder of the simulation. This total simulation corresponds to approximately three tidal cycles, with two smaller peaks either side of the maximum peak. This allows any potential overtopping to occur on the first tidal cycle prior to the breach and a subsequent tidal cycle after the peak to allow water to enter through the open breach in the second cycle.

Defences

The defences along the coastline are variable in standard. There are lengths of defence that fall below the 1 in 200 year design standard. As such, models including the potential for overtopping as well as breaching have been constructed. These models allow a breach to be forced through a section of chosen defence but also allow overtopping of the defences to occur where the defences are lower than the simulated water level. In addition to this, an overtopping scenario was also run where no breach occurs. This gives a flood water extent from overtopping alone, or ‘actual’ flood risk.

Defence heights have been determine from the most appropriate and accurate supplied data. In the main this has been LiDAR data, 25cm taking precedence over 2m LiDAR data. On Canvey Island, and stretches of the coastline in Castle Point data was supplied by the EA as points with associated levels. This data was triangulated and used to determine the height of the defences in the areas where available. The EA were also contacted on a number of occasions regarding the height of the defences and for clarification on the supplied levels.

The Easthaven and Benfleet barriers were confirmed to have a crest height of 6.65m AOD with adjacent defence crest heights at 6.6mAOD. The East Haven Barrier tie in defence has a crest height of 6.7mAOD (concrete cap at 6.7mAOD and sheet pile to 6.6mAOD). This information has been used to update the supplied point data where relevant. Ideally, the defence crest heights would have been surveyed and this data used to set crest heights within the model. As this was not available the best supplied data has been used but it should be recognised that this introduces a limitation to the modelling process and results.

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.

A number of material roughness classifications have been identified within the study area, for example water - 0.03 (for the river), urbanised - 0.08, rural/non-urbanised land - 0.04, road - 0.02, and rail - 0.03. The distribution of these factors has been defined using aerial photography, OS maps and knowledge gained by the site visit in order to vary the conveyance rates throughout the flood cell domain.

Tidal Model Boundary Conditions

Within the MIKE21 model, tidal water level boundary files (in this case located in the Rivers Thames, Crouch and Roach) 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 *Environment Agency: Thames Tidal Defences Joint Probability Extreme Water Levels 2008, Final Modelling Report, April 2008* and *Environment Agency, Anglian Region, Eastern and Central Areas Report on Extreme Tidal Levels, 2007* for the present day and with climate change allowances.

Boundary conditions have been applied along the middle of the River Thames, and the opposite banks of the Crouch and Roach. This was simulated to ensure a true representation of the modelled water levels were applied at the breach locations. In locations where smaller watercourses propagate flood water from the main river to the specific breach location, water levels will naturally be modified by the funnelling process of water travelling up a smaller watercourse.

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 2010) breach and overtopping;
- A tidal flood event with a return period of 1 in 200 years (with climate change 2110) breach and overtopping;
- A tidal flood event with a return period of 1 in 200 years (with climate change 2110) overtopping only[3];
- A tidal flood event with a return period of 1 in 1000 years (present day 2010) breach and overtopping;
- A tidal flood event with a return period of 1 in 1000 years (with climate change 2110) breach and overtopping;
- A tidal flood event with a return period of 1 in 1000 years (with climate change 2110) overtopping only[4].

[3] In the case of Canvey Island, two overtopping simulations were run: one where the Easthaven and Benfleet Barriers were operational and one where these defences failed

[4] In the case of Canvey Island, two overtopping simulations were run: one where the Easthaven and Benfleet Barriers were operational and one where these defences failed

Breach Time

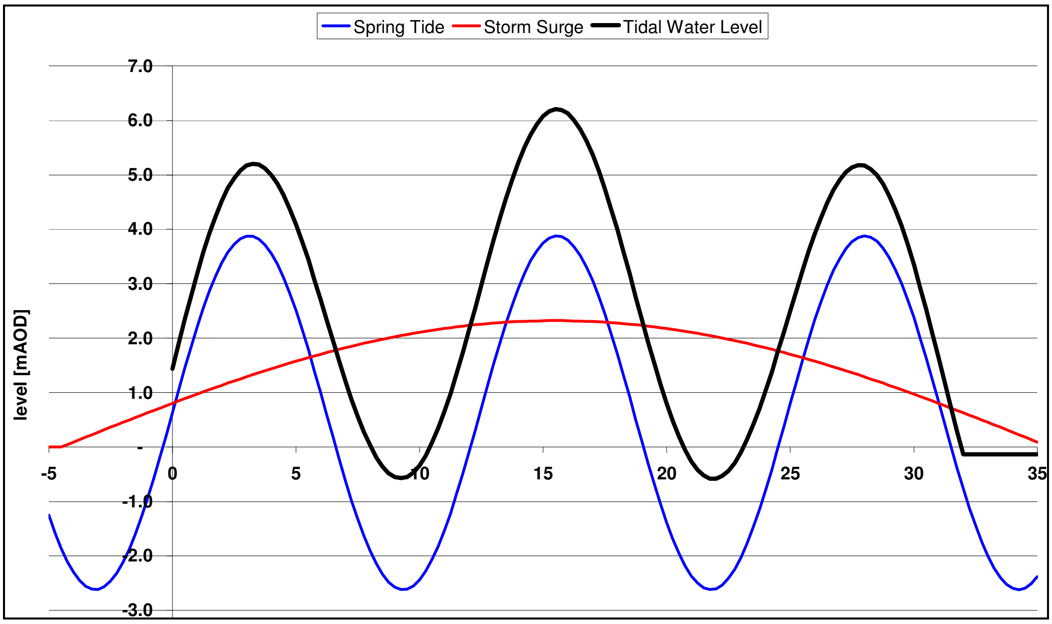
The water levels during a tidal flood event are generated by a summation of the astronomical tide levels and the storm surge residual, as shown in Figure E-2.

In terms of speed and force of floodwaters, the worst time for a breach to occur is when the maximum hydrostatic force has built up behind the flood defences. Therefore, the modelling undertaken for this study was run where the flood defences suddenly breach just before the tidal level acting on the flood defences is at a maximum.

A one hour 'lead-time' prior to the maximum flood level was included to ensure that, once the breach had occurred, the water level continued to rise and the maximum volume of water possible was able to travel through the breach at the maximum water level. This was seen as a compromise between the breach open method and the breach at peak method and the corresponding results.

The models were run for 36 hours. This allowed the potential for overtopping before the breach, during the first tidal cycle and ensured water could enter the model through the breach for the second and third tidal cycles.

Figure E-2 Example of Tidal Curve with Breach Time



Modelling Outputs

Modelling analysis presents data to identify the residual risk and actual risk of flooding from a failure or overtopping of local defences. The mapping of the model outputs as flood depth, flood hazard and time to inundation within the study area provides the three councils with flood risk information to enable more detailed consideration of the risk of flood water inundation, 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/overtopping, with the tidal events using the 2D hydrodynamic modelling programme Mike21), the results were processed to produce the above outputs. GIS processing and mapping tasks have been performed using MapInfo Professional (Version 8.5.2) with the Vertical Mapper spatial analysis add-on (Version 3.1).

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 all scenarios run. Composite depth maps were also created taking the maximum depth at each point where breaches coincided.

Hazard Rating

Flood hazard is a function of both flood depth and flow velocity. Due to this dependence on velocity, it is common during tidal flood events for the maximum flood hazard at a certain location to occur before the maximum floodwater level occurs, i.e. while floodwaters are flowing and the velocities are higher.

In order to assess the maximum flood hazard during a flood event, the hazard level at each element of the MIKE21 mesh is assessed at every time step of the model simulation.

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:

*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 E-3 Hazard categories based on FD2320, DEFRA & Environment Agency 2005

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

A flood hazard rating grid was created for each of the breach locations for all flooding scenarios. A composite grid was then created for appropriate overlapping areas by extracting the maximum flood hazard rating value (where applicable) for each point, considering all relevant model output grids.

Time to Inundation

As previously stated, a breach was simulated in the models one hour before the peak tidal level. Flows then tended to pass through the breach, inundating the flood cell, for approximately five to six hours, after which the tide level had again retreated well below the breach invert. After another six hours (11 to 12 hours after the breach) the next high tide would again push water through the breach causing further flooding for a further five to six hours.

From examining the results it was decided that the vast majority of land that was inundated by the model was inundated within six hours of the breach occurring. Some of the outlying areas (some distance from the breach) were affected by the second peak.

The MIKE21 application 'Data Extraction FM' was used to extract 'snapshots' of the model results 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, 12-16 hours and 16-20. Where overtopping occurred prior to the opening of the breach, this has been classified as such using a hatching.

For each model run, a mesh of polygons was derived in GIS (in this case, MapInfo format), each containing the approximate time of inundation for each triangular element composing the model mesh. All empty (zero) elements were then deleted and a 3-dimensional grid file (using the time of inundation as the vertical z-value) was created to define the time to inundation for each model simulation.

These grid files could be used as the final output of the time to inundation process. However, the results are 'patchy' and complicated in places, mainly due to a finite number of breach locations being used (sixteen in this case). Ideally, a very high number of breach locations would have been used in the modelling (for example every few hundred metres or more) but this is impractical considering the computing power and time that would be required. This should be noted by the reader for all output results, i.e. results are from a discrete number of breach locations and therefore may be subject to change if the breach location were to change.

As overtopping is possible at any point where the defences are below the water level (due to the variable defence standard), some overtopping will be classified within the time to inundation bands from the breach event. This is particularly noticeable in areas a significant distance from the breach that are shown as inundated within the first hour of the breach event (i.e. water would not have time to flow from the breach to these locations within the first hour). This should be considered by the user.

Appendix F: Data Register

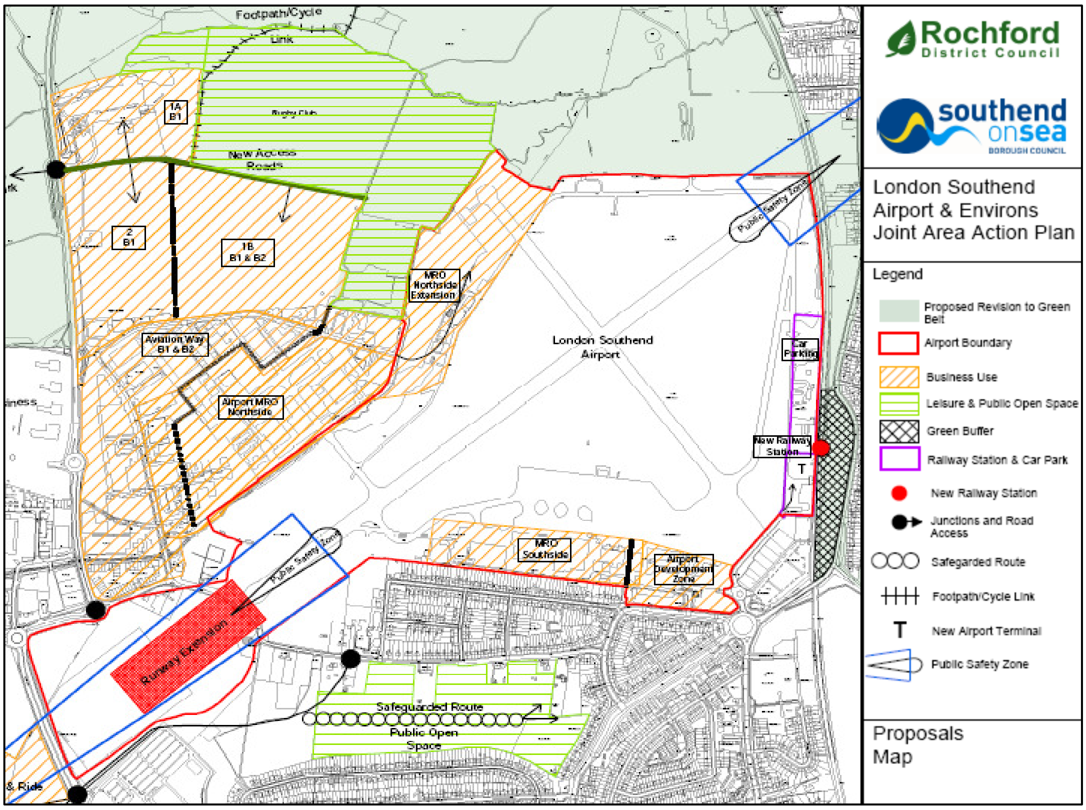
Appendix F - Data Register

Project Type	**Project**		**Supply Project**			
SFRA Review	Thames Gateway South Essex Strategic Flood Risk Assessment Review (Level 1 or 2)		Sheet Number	1		
Date updated	08/10/2010		Job Number	D130256		
Filename	Description	To - Name	From - Name	Medium	Confidence	Date of Issue
council_extent_rochford.tab	Rochford District Boundary	Emily Blanco (SW)	Sam Hollingworth (RDC)	CD		1-Jun-10
nat_floodzone2_v3_14.shp	GIS outline of Flood Zone 2	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
nat_floodzone3_v3_14.shp	GIS outline of Flood Zone 3	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Prittle_20yr.shp	GIS outline of 1 in 20yr return period for Prittle Brook	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Prittle_100yr.shp	GIS outline of 1 in 100yr return period for Prittle Brook	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Prittle_100yrCC.shp	GIS outline of 1 in 100yr return period including allowances for climate change for Prittle Brook	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Prittle_1000yr.shp	GIS outline of 1 in 1000 year return period for Prittle Brook	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Eastwood_20yr.shp	GIS outline of 1 in 20yr return period for Eastwood Brook	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Eastwood_75yr.shp	GIS outline of 1 in 75yr return period for Eastwood Brook	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Eastwood_100yr.shp	GIS outline of 1 in 100yr return period for Eastwood Brook	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Eastwood_100yrCC.shp	GIS outline of 1 in 20yr return period for Eastwood Brook	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Eastwood_1000yr.shp	GIS outline of 1 in 100yr return period for Eastwood Brook	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Eastwood_nodes.shp	GIS layer of nodes along Eastwood Brook model	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Defence_01_polyline.shp	Extract from the National Flood and Coastal Defence Database for the study area	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
20100406 Rochford DC multi-agency flood plan.doc	Flood plan for Rochford DC	Emily Blanco (SW)	Sam Hollingworth (RDC)	Project Space		1-Jun-10
625k_V5_BEDROCK_Geology_Polygons.shp	GIS layer of Bedrock geology across study area (1:625,000 Mapping)	Emily Blanco (SW)	British Geological Survey	Downloaded freely from BGS website		1-Jun-10
625k_V5_DYKES_Geology_Polygons.shp	GIS layer of dykes across study area (1:625,000 Mapping)	Emily Blanco (SW)	British Geological Survey	Downloaded freely from BGS website		1-Jun-10
625k_V5_FAULT_Geology_Lines.shp	GIS layer of geological faults across study area (1:625,000 Mapping)	Emily Blanco (SW)	British Geological Survey	Downloaded freely from BGS website		1-Jun-10
UK_625k_SUPERFICIAL_Geology_Polygons.shp	GIS layer of Superficial geology across study area (1:625,000 Mapping)	Emily Blanco (SW)	British Geological Survey	Downloaded freely from BGS website		1-Jun-10
OS_1_50_000_scale_colour_raster_108849_139928.tif	1:50,000 Ordnance Survey Mapping of study area	Sarah Littlewood (SW)	EmapSite	Downloaded freely from Emap website		1-Jun-10
TQ68.TIF and similar…	1:25,000 Ordnance Survey Mapping of study area	Emily Blanco (SW)	Sam Hollingworth (RDC)	CD		1-Jun-10
Less susceptible to surface flooding.shp	Areas Susceptible to Surface Water Flooding Dataset: GIS layer of areas LESS susceptible	Emily Blanco (SW)	Environment Agency	CD		1-Jun-10
Medium susceptibility to surface flooding.shp	Areas Susceptible to Surface Water Flooding Dataset: GIS layer of areas with MEDIUM susceptibility	Emily Blanco (SW)	Environment Agency	CD		1-Jun-10
More susceptible to surface flooding.shp	Areas Susceptible to Surface Water Flooding Dataset: GIS layer of areas MORE susceptible	Emily Blanco (SW)	Environment Agency	CD		1-Jun-10
connecting_cows.shp	GIS layer of connecting critical ordinary watercourses	Emily Blanco (SW)	Environment Agency	CD		1-Jun-10
cows.shp	GIS layer of critical ordinary watercourses	Emily Blanco (SW)	Environment Agency	CD		1-Jun-10
Main_Rivers.shp	GIS layer of Environment Agency Main Rivers	Emily Blanco (SW)	Environment Agency	CD		1-Jun-10
South_Benfleet_Location_Map.pdf	Map showing the extent of the South Benfleet Flood Storage Area (FSA)	Emily Blanco (SW)	Environment Agency	CD		1-Jun-10
South Essex CFMP.pdf	South Essex Catchment Flood Management Plan	Emily Blanco (SW)	Environment Agency	CD		1-Jun-10
Anglian RBMP.pdf	River Basin Management Plan for the Anglian River Basin District	Emily Blanco (SW)	Environment Agency	CD		1-Jun-10
DG5 Register postcodes Essex (Anglian Water).xls	Database of recorded incidents of sewer flooding across the study area	Sarah Littlewood (SW)	Anglian Water	Email		1-Jun-10
051FWCDV4D1.zip	GIS layer of Environment Agency Flood Warning Areas (FWAs)	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
051FWCDV4D2.zip	GIS layer of Environment Agency Flood Warning Areas (FWAs)	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
051FWCDV4D3.zip	GIS layer of Environment Agency Flood Warning Areas (FWAs)	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
051FWCDV4D5.zip	GIS layer of Environment Agency Flood Warning Areas (FWAs)	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
051FWCDV4D6.zip	GIS layer of Environment Agency Flood Warning Areas (FWAs)	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
051FWCDV5A1.zip	GIS layer of Environment Agency Flood Warning Areas (FWAs)	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
051FWCDV5B2.zip	GIS layer of Environment Agency Flood Warning Areas (FWAs)	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
051FWCDV5B3.zip	GIS layer of Environment Agency Flood Warning Areas (FWAs)	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
051FWFEF7B.zip	GIS layer of Environment Agency Flood Warning Areas (FWAs)	Sarah Littlewood (SW)	Environment Agency	CD		1-Jun-10
Crouch_20yr.shp	GIS outline of 1 in 20yr return period for fluvial part of the River Crouch.	Sarah Littlewood (SW)	Environment Agency	CD		1-Oct-10
Crouch_100yr.shp	GIS outline of 1 in 100yr return period for fluvial part of the River Crouch.	Sarah Littlewood (SW)	Environment Agency	CD		1-Oct-10
Crouch_100yr_CC.shp	GIS outline of 1 in 100yr return period including allowances for Climate Change for fluvial part of the River Crouch.	Sarah Littlewood (SW)	Environment Agency	CD		1-Oct-10
Crouch_1000yr.shp	GIS outline of 1 in 1000yr return period for fluvial part of the River Crouch.	Sarah Littlewood (SW)	Environment Agency	CD		1-Oct-10
Roach_20yr.shp	GIS outline of 1 in 20yr return period for fluvial part of the River Roach.	Sarah Littlewood (SW)	Environment Agency	CD		1-Oct-10
Roach_100yr.shp	GIS outline of 1 in 100yr return period for fluvial part of the River Roach.	Sarah Littlewood (SW)	Environment Agency	CD		1-Oct-10
Roach_100yr_CC.shp	GIS outline of 1 in 100yr return period including allowances for Climate Change for fluvial part of the River Roach	Sarah Littlewood (SW)	Environment Agency	CD		1-Oct-10
Roach_1000yr.shp	GIS outline of 1 in 1000yr return period for fluvial part of the River Roach.	Sarah Littlewood (SW)	Environment Agency	CD		1-Oct-10
RDC Core Strategy Submission FINAL.pdf	Core Strategy Document	Emily Blanco (SW)	Sam Hollingworth (RDC)	Project Space		1-Jun-10

Appendix G: London Southend Airport & Environ JAAP

Southend-on-Sea Borough Council and Rochford District Council are in the process of preparing a planning framework to guide development at the proposed London Southend Airport and the neighbouring employment areas. This planning framework is known as the Joint Area Action Plan (JAAP) and is illustrated in Figure G-1 below. The two Councils have published their 'Preferred Option' for development which has been used as a basis to make a strategic assessment of flood risk which is described below.

Figure G-1 London Southend Airport JAAP



Fluvial Flood Risk

Environment Agency Flood Zones

The Eastwood Brook is a Main River which flows in a south west to north east direction to the north west of the Southend Airport JAAP area as illustrated in Figure G-2 below.

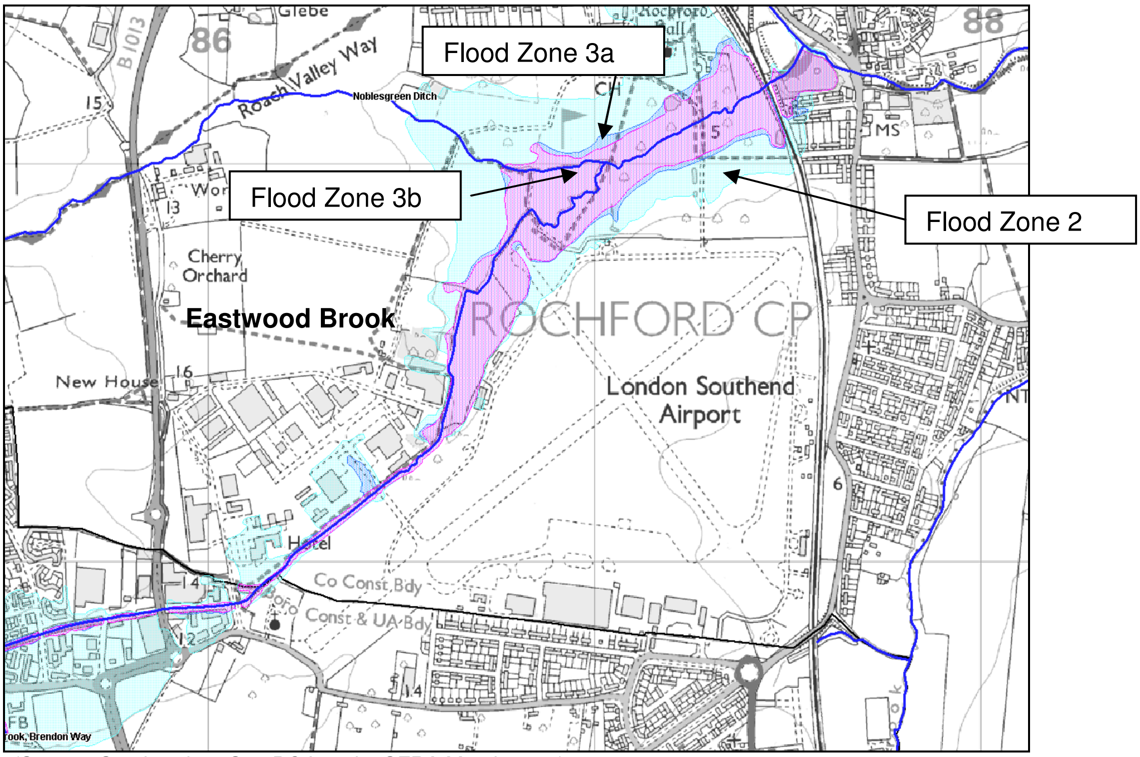
The JAAP outlines development for business uses to the north west of the airport adjacent to the Eastwood Brook (MRO Northside Extension). This area is currently shown to lie within Flood Zone 3b associated with the Eastwood Brook. Flood Zone 3b is defined as the functional floodplain and only water-compatible (mainly water-based) uses and essential infrastructure, as defined by Table D2 of PPS25, are considered appropriate in this location.

Airport MRO Northside is also proposed for business use. A small section of the potential development area adjacent to the Eastwood Brook is located in Flood Zone 3b, with small pockets of Flood Zone 3a and Flood Zone 2. A sequential approach to the development layout would have to be applied in this location to ensure that no development is located in Flood Zone 3b, and less vulnerable uses are located in Flood Zone 3a and Flood Zone 2.

The northern half of Aviation Way B1 and B2 is located within Flood Zone 1. However, the southern half of this plot, adjacent to the Eastwood Brook contains some small pockets of Flood Zone 2, 3a and 3b. A sequential approach to the development layout would have to be applied in order to steer development into the lower areas of flood risk.

A detailed FRA will be required for all development located in Flood Zone 2, 3a or 3b including Aviation Way, Airport MRO Northside and MRO Northside Extension.

Figure G-2 Environment Agency modelled Flood Outlines – Eastwood Brook.



(Source: Southend-on-Sea BC Level 1 SFRA March 2010)

Environment Agency Modelled Fluvial Flood Depths

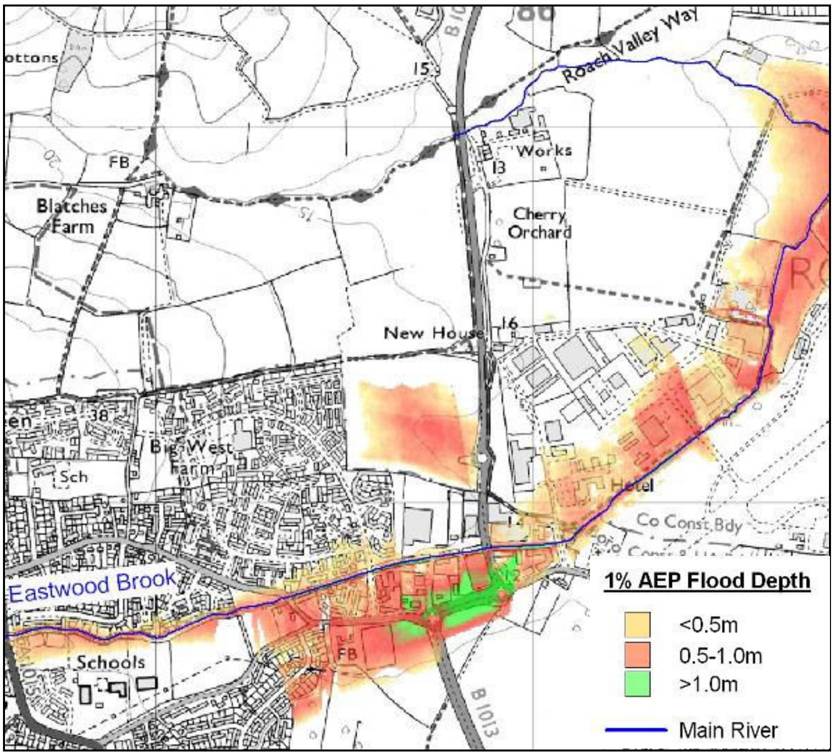
The Environment Agency has recently completed a flood risk study for the Eastwood Brook. The flooding mechanism for this watercourse is described as *'overtopping of river banks leading to low velocity flooding in most areas with flood depths ranging between 0.3m and 0.5m'* (Table 3.17 included in the Catchment Flood Management Plan).

The Environment Agency has assigned this watercourse a 'high priority' natural channel maintenance regime and they provide flood warning with a 2 hour lead time.

With reference to the fluvial flood depth map for Eastwood reproduced in Figure G-3 below and Figure G-1 Development Layout, it can be seen that flood depths may reach 1.0m within the proposed 'Airport MRO Northside' development area. Depth modelling is not included in the CFMP for the northern extent of the JAAP but Figure G-3 suggests that depths may also be greater than 1.0m in the area identified for the 'MRO Northside Extension'.

It should be noted that the airport has previously experienced flooding from the Eastwood Brook including in 1981 when the brook burst its banks leading to flooding of the airport hanger.

Figure G-3 Fluvial flood extent and depth for Eastwood (1% or 1 in 100 year probability)



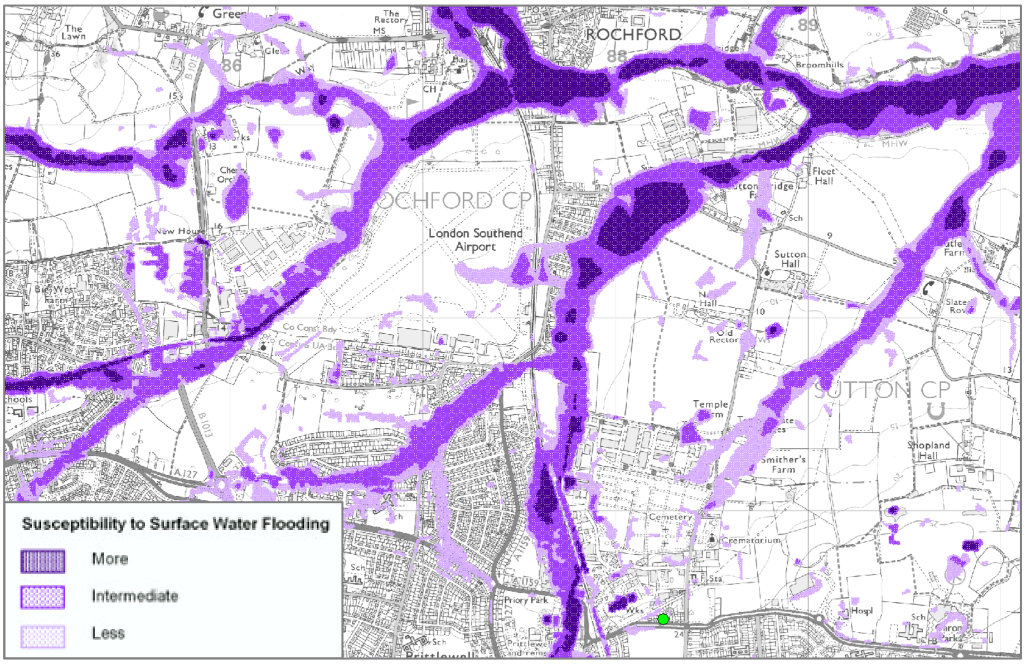
(Source South Essex CFMP – Final Plan August 2008, EA.)

Surface Water Flood Risk

The Environment Agency published maps to illustrate 'Areas Susceptible to Surface Water Flooding' in July 2009. This data has been created to provide an overview to where the potential for flooding from surface water needs particular assessment.

The Environment Agency Areas Susceptible to Flood Risk maps (extract included in Figure G-4) highlight that surface water flooding may be an issue to the north west of the JAAP including the proposed development at Aviation Way, Airport MRO Northside and MRO Northside Extension. The surface water flood maps use ground levels in the modelling, therefore, areas of potential surface water flooding often follow river corridors. This is the case at the airport JAAP where the Eastwood Brook and Prittle Brook corridor is highlighted as being at surface water flood risk. In addition, there are smaller pockets of potential risk illustrated to the east of the runway, local to the proposed new railway station building.

Figure G-4 Environment Agency Areas Susceptible to Surface Water Flooding



(Source Southend-on-Sea BC Level 1 SFRA, September 2010)

Tidal Flood Risk

Detailed breach and overtopping modelling has been considered for tidal sources at 9 locations along the Southend seafront and 7 locations along the Rochford frontage. These identify the flood risks associated with a failure in the flood defence, through a breach and by overtopping. Modelling at all locations has highlighted that the London Southend Airport site is not at risk of tidal flooding from the Thames Estuary or North Sea.

Groundwater Flood Risk

The South Essex Catchment Flood Management Plan states that groundwater flooding is not a major issue in this area. The presence of London clay reduces the risk of groundwater flooding as it creates an impermeable barrier between the ground surface and the underlying aquifer (where present).

The Southend Airport JAAP is underlain by river terrace deposits of silt and clay, with sand and gravel river terrace deposits following the Eastwood Brook corridor to the west of the JAAP. There have been no groundwater flooding incidents reported to the Environment Agency or the Council within the Southend Airport JAAP area.

There is little recorded information currently available on groundwater flooding. The proposed Phase 2, 3 and 4 Surface Water Management Plan (anticipated in Spring 2011) may provide a greater level of detail and should be referred to as part of a site-specific FRA.

Flood Risk Assessment Guidance – Southend Airport JAAP

A site-specific FRA should include details of the proposed surface water drainage system including storm water storage. As the Eastwood Brook is adjacent to the proposed development area in the north west, it seems logical that surface water drainage be discharged to this watercourse. It should be noted that there is potential that if a rainfall event co-insides with the Eastwood Brook being in flood, the outfall for the development drainage system may become surcharged. This could cause surface water to back up into the development site causing surface water flooding.

Any discharge to a main river watercourse will require consent from the Environment Agency and will require attenuation to discharge at a flow rate to be confirmed with the Environment Agency (potentially Greenfield runoff rate).

As part of a site-specific FRA, historic flood records where available should be referred to in order to verify the potential surface water flood risk. A site visit should also be used to assess and ground truth the data.