Requirements for completing computer river modelling for Flood Risk Assessments

Guidance for Developers - version 7

We are the Environment Agency. We protect and improve the environment and make it **a better place** for people and wildlife.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

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Executive Summary

You have received this document because you have either requested flood risk model information from the Environment Agency for use in completing a Flood Risk Assessment (FRA), or you have been in consultation with the Environment Agency about your intentions to complete an FRA.

This document is intended to be used by developers as a guide to completing computer river modelling as part of an FRA which satisfies the requirements of your local Environment Agency office.

It has been developed from National Guidance and contains requirements of your local Environment Agency Office (West Thames Area, Environment Agency South East), and should be used to ensure there are no hold ups within the consultation process once the FRA has been submitted to us. It details requirements for hydrological and hydraulic modelling, model outputs such as flood outlines and levels and information that are to be submitted as part of the FRA. If the guide is used when completing river modelling for your FRA it will be less likely we will require the submitted FRA to undergo a lengthy process of further amendment and review post submission. If the model is intended to produce results to alter the Flood Map then the Flood Map Policy, which is available by request using the contact details below, must be considered before the modelling starts.

We have included a checklist in Appendix A which you can use to ensure you have included all the necessary items when submitting your Flood Risk Assessment.

This document applies to Flood Risk Assessments using river modelling. However, many of the principles apply equally to coastal modelling.

If there is any doubt about the modelling requirements for an FRA you should contact the Development & Flood Risk Team in your local Environment Agency office at the earliest opportunity to discuss what would be needed.

When contacting us you should ensure that you are speaking to the area office local to your site of interest. Further details of Environment Agency office locations can be found on our website www.environment-agency.gov.uk on our ‘contact us’ page. Details of the West Thames Area, Environment Agency South East office can be found in Section 7.1 of this guide.

Please read our Standard Notice supplied at the end of this document, which details our terms and conditions.

If you have any queries about the content of this document or suggestions for improvement please email kirsty.butler@environment-agency.gov.uk .

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1. Introduction

Purpose of this Document

The purpose of this document is to provide guidance for carrying out computer river modelling within a Flood Risk Assessment (FRA). FRAs may be carried out by individuals, developers, consultants or Local Planning Authorities for a variety of reasons (e.g. for development purposes).

Previous to this guidance, the FRA consultation process was frequently delayed or prolonged due to insufficient or inaccurate information being submitted where river modelling had been carried out.

This document provides a comprehensive guide to the information and approach expected of a complete FRA. It is intended to give our best practice guidance on the standards that should be used when carrying out computer modelling of watercourses when completing an FRA, and to comply with our local requirements.

Consultants, developers and Local Authorities that follow this guidance will reduce the likelihood of further revisions of the model, or further information being requested during consultation with the Environment Agency. This will minimise the delays in our response, and help us to be as efficient as we can be in the model review process.

Use the checklist in Appendix A of this document to ensure you have enclosed all the required documents and files for a review of your FRA.

Further details about undertaking Flood Risk / Consequence Assessments for the construction industry are given elsewhere, in particular in CIRIA Report C624. Further information may be required for land use development purposes as detailed in PPS25.

2. Modelling Requirements

It is not always necessary to produce a hydraulic model for all flood risk assessments. A decision on whether to construct a model should be made based on the scale and nature of the potential flood risk, as well as the scale of the development and existing information available on flood risk. In many less complex assessments, simple hydrological and hydraulic analysis may be all that is required. CIRIA Report C624 recommends a staged approach to Flood Risk Assessment to determine the need for and extent of such a model.

If there is any doubt whether a model is required, this should be discussed with local Environment Agency staff (Development and Flood Risk Teams for Land Use Planning, Flood Risk Mapping & Data Management Teams for other modelling requirements) at the earliest opportunity. Requirements at specific locations should always be discussed with local Environment Agency staff to ensure that any site-specific factors are identified, which may require special treatment when carrying out the modelling.

Even if a model is not constructed, an assessment of the impact of any proposed development on runoff should be carried out using Flood Estimation Handbook (FEH) techniques in almost all cases. The science report 'Improving the FEH statistical procedures for flood frequency estimation' published in June 2008, is available on our website through the Publications catalogue and should be referred to for updated FEH methods.

DEFRA/Environment Agency R&D Technical Report W5-074/A "Preliminary Rainfall Run-off Management for Developments" provides further information on runoff assessment for developments.

2.1 Objectives of the Model Study

The objectives and the required outputs of the modelling exercise should be defined at the outset. These should be reviewed at regular intervals and at completion.

At an early stage, the design condition should be clarified. This may, for example, include a freeboard and an allowance for climate change. Further information on freeboard is in R&D W187.

2.2 Data Collection

If you have not already requested information for your FRA, we recommend you submit a one-off request for information from your local Environment Agency External Relations Team (see Section 7). They will be able to provide you with any available existing data relevant to your site including channel survey, topographic survey (LiDAR), historic flood events, hydrometric data, existing models, flood levels, extents and flows. These data sets are detailed below.

If you will be collecting new survey data as part of your FRA, please refer to Appendix B 'Survey Requirements for Flood Risk Assessment'. This also contains the survey reporting format we expect with the FRA.

2.2.1 Hydrometric and Survey Data

The Environment Agency may hold existing hydrographic and floodplain survey data which may be of use in a flood risk assessment. External Relations will be able to assist with any requests for data.

River flow, river level and rainfall data relevant to the model should be collected where these exist. This should be requested as part of the one-off request to the Environment Agency for data at the start of the FRA. An understanding of the uncertainty and confidence within this data should be sought from its owners and further developed.

The Flood Estimation Handbook should be used as a source of hydrological data. Refer to the science report 'Improving the FEH statistical procedures for flood frequency estimation' for updates. The UK HiFLOWS Project also provides up to date information for gauging stations including AMAX and POT data www.environmentagency.gov.uk/hiflowsuk

2.2.2 Historic Information

Information on historic flooding (e.g. newspaper articles, photos, flood marks) should be collected and utilised to guide the survey extent and to aid the modelling process. Such data is particularly valuable as it can provide information on historic flooding prior to the periods covered by hydrometric data. A search of the Internet can often provide useful information, the Chronology of British Hydrological Events may contain useful information. However, the effect of any alterations and additions to the watercourse and associated structures since the date of the recorded event needs to be considered.

The West Thames Environment Agency office holds GIS shapefiles of historic fluvial flood event extents where we have records of events. We also have a limited number of records on locations which have suffered from surface water flooding, sewer flooding and groundwater flooding. There ma have been flooding in the catchment that we do not have a record for therefore you are advised to contact the relevant Local Authority for additional historic flooding information.

2.2.3 Previous Modelling

The West Thames Environment Agency office have carried out detailed river modelling for a number of catchments for flood risk mapping studies, the design of flood alleviation schemes and previous flood risk assessments. You may wish to use this information for your study, however we advise you to contact the External Relations team before requesting this data to determine if existing modelling is available for your area of interest.

Where existing models are available, consideration should be given to whether these could be used as part of the flood risk assessment. Data from the Environment Agency will be supplied with any relevant data warnings or disclaimers, which must be

considered in the FRA. There may be cost, licensing and intellectual property right (IPR) issues associated with the use of models, which External Relations can help once a data request has been received.

We recommended check surveys are undertaken if the FRA intends to use existing survey data provided by the Environment Agency or third parties at key locations to ensure that the data provided is compatible with current conditions.

The Environment Agency may not own the Intellectual Property Rights to hydraulic models completed by third parties that we hold. We may therefore not be able to release information you are aware we hold if we do not have the required permissions to use it in FRAs. However, in accordance with Operational Instruction 'Use of 3rd party IP from Flood Risk / Consequence Assessments' , ownership of the IPR or an approved IPR licence is not required for us to use the data in accordance with our statutory obligations.

Contact External Relations (Section 7.1) if you wish to request modelled data.

2.3 Choice of model software

The modelling software chosen should be capable of producing the required output. It will generally be appropriate to choose commercial hydraulic/river modelling software that is in widespread use.

In certain circumstances, for example where the applicability of a model to a specific situation has not been previously demonstrated, it may be necessary to carry out independent benchmarking tests to demonstrate model performance using standard data. Examples of how this may be achieved under a range of scenarios are provided in the Defra/Environment Agency R&D Report 'Benchmarking of hydraulic river modelling software packages' (W5-105) which is available via the Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme website.

2.4 Type of model

The choice of which model set up to use should be made between a fully hydrodynamic 1D or 2D model or a steady-state backwater model, flood routing model or combination of methods.

A full hydrodynamic model must be used if the study area contains either structures whose operation varies with time (e.g. pumps, sluices, and tidal outfalls) or a tidal estuary where tidal water levels increase going up the estuary. This should also be employed in complex tidal/fluvial situations and where the watercourse is subject to rapid increases and decreases in flow. If there is significant floodplain storage and complex flow routes on the floodplain then 2D modelling of the floodplain may be more representative. In other cases, either a steady-state or hydrodynamic model may be chosen. It should be noted that a steady-state model is unlikely to give a reasonable estimation of water levels where storage is present.

2.5 Hydrological Assessment

A hydrological assessment of the flood flows should be made using the methodology described in the Flood Estimation Handbook and the Environment Agency's Guidelines on use of the Flood Estimation Handbook. Contact the FRM&DM team if you require a copy of our guidelines.

FEH is the industry standard for flood frequency estimation. As a result of R&D funded by the Environment Agency and Defra and carried out by CEH (the publishers of FEH) a number of changes to the statistical procedures were recommended (see Kjeldsen. T. R., Jones. D. A., and Bayliss. A. C., 2008. Improving the FEH statistical procedures for flood frequency estimation. Science report SC050050/SR. Environment Agency, Bristol.)

These changes (where practicable) have been incorporated into recent work carried out by the Environment Agency and we advise they are incorporated into flood frequency estimation work carried out by 3rd parties.

The changes do not deviate from the overall framework of the FEH methodology. However, the most technical details of the method have been updated to improve the performance of the procedure.

The report details the updates to the statistical method including:

- A new equation for estimating QMED at ungauged catchments
- An improved procedure for using donor catchments for estimating QMED at ungauged
- catchments
- An improved procedure for formation of pooled growth curves.

These improvements should be adopted as standard practice by anyone involved with flood frequency estimation in the UK

The Revitalised Flood Hydrograph Method (ReFH) was released in 2006 and has superseded the FEH rainfall-runoff for most fluvial flood risk applications in England and Wales. The ReFH method should be used in place of FEH rainfall-runoff for most applications.

Wherever it is available, the hydrological assessment should use local data to improve the estimation of flood flows.

If a hydrodynamic model is used for the modelling, the hydrological assessment should include consideration of peak flows, flood volumes and shape of the flood hydrograph. If the problem includes storage (e.g. reservoir storage or a tide-locked watercourse) it is essential that the critical duration storm for storage (which often differs from the critical duration for peak flow) is identified. If a steady-state model is used, this may be limited to just consideration of peak flows.

Hydrological inputs should be estimated for a range of return periods up to and including the design flow (typically the flow with an annual probability of exceedence of 1%), and should include an appropriate allowance for climate change. This is a 20% increase in peak river flows, as advised in PPS25. We request design events of 1 in 5, 1 in 20, 1 in 100 and 1 in 100 year + 20%.

If using the FEH methodology, the proforma in Appendix C must be completed to justify decisions made, and provide a record of calculations.

2.6 Surface Water Flooding

An assessment should be made of the local topography and drainage routes to determine whether flooding might occur on the site if local drainage was overwhelmed by intense rainfall, or backing up due to high levels in the receiving watercourse. Given these findings, recommendations should be made on the design of any buildings on the site to eliminate the risk of significant flood damage.

Strategic Flood Risk Assessments (SFRAs), Surface Water Management Plans or any local sources may be useful when looking for evidence of surface water flooding.

2.7 Guidance for Tidal Breach Analysis on the Thames

Whilst we provide information and advice as set out below, the responsibility for the modelling being fit for purpose remains with those undertaking the modelling. Depending on the site, alterations may be necessary and should be considered in the initial request for information. If there is any doubt please contact the Tidal Thames team to discuss (details in section 7.1).

The general approach for the Tidal Thames (Teddington Weir to Purfleet) and the tidally dominated section of the tributaries is as follows:

The latest Thames Estuary Joint Probability (ISIS model) is used to give the variation in tide levels for a number of possible return periods and to select an extreme case to coincide with a breach in the defences.

The approach is to obtain (from our External Relations team) advice on the critical breach location, the 1 in 200 year level for the Tidal Thames and the tidal hydrograph relevant to the site location. We will also provide breach width (this depends on the type of defence).

Location of the breach is selected to give the most severe condition at the site. We achieve this by examining topographical data from LiDAR surveys and estimating the most likely flow route to the site. The breach should be taken down to the landward ground level, not necessarily that adjacent to the wall, which may be a bank forming part of the defence. The level of breach should be justified in the report including providing ground level plans and sections. Weir coefficients for the breach should also be explicitly stated and justified in the report.

The breach should be open for 18 hours for a hard defence and 36 hours for a soft or composite flood defence. The model should then be run for as long as it takes to reach the maximum flood extent.

For sites downstream of the Thames Barrier, generally, the breach should be taken to occur on the rise of the tide before the peak tide because the surge element will tend to span over three tide cycles. For single tide breach assessments between Teddington Lock and the Thames Barrier the breach should be taken to occur on the rise of the peak tide and should be considered breached when the tide level reaches the breach level. The exception to this is when the property is within approximately 100 metres of the defences. In this scenario the velocity may be an important factor in relation to the forces that new buildings and structures would have to withstand should a breach occur.

When necessary additional breach model runs should be carried out taking the breach to occur at the top of the peak tide to calculate the worst case water velocities. The decision on whether to carry out additional peak velocity modelling should be justified in the report based on the site ground levels relative to the 200-year river level and the proximity to the breach location.

The flow calculated through a breach is then routed through the urban area using a hydraulic model based on LiDAR ground survey. The LiDAR data can also be requested from our External Relations team. The LiDAR grid size recommended for urban areas is 5m or less. If it is above 5m it needs to be justified, but should never be greater than 10m. The use of 1D or 2D modelling depends on the location of the site in relation to the breach location and the topography of the ground in the proximity of both. The choice of a 1D or 2D model needs to be clearly reasoned in the report.

The LiDAR survey data often needs manual alteration to deal with errors such as the inability of LiDAR to detect flow routes through openings under viaducts and low ground "hidden" by vegetation. Velocity and depth of flows at the site are dependent on the passage of the flood through the urban area. Velocities need to be discussed/considered in relation to the integrity of any buildings or part of any buildings to be used as a safe flood refuge.

There will be a significant time lag between the breach occurring and water actually reaching the site if your site is a significant distance from the Thames. Only 2D modelling will illustrate this and will therefore be useful for emergency planning. Similarly only 2D modelling can assess the peak flood velocities where this is needed.

The output data must include flood levels clearly referenced to ordnance datum.

3. Model Building

3.1 General

The model should be built to represent the key flood flow routes, flood storage and structures in the study area. The defined study area should be sufficient to demonstrate the effects of any development on locations upstream and downstream from the site of the proposed development. Blockage scenarios should be considered if appropriate.

3.2 Upstream Boundary (Inflows)

The upstream boundary or boundaries should be developed under the hydrological assessment described in Section 2.2.6. For some models, one single upstream inflow per flood event may be sufficient, whilst for others, many upstream boundaries may be needed if a number of tributaries or other inflows are present. The choice of location of the upstream boundaries should be based on hydraulic considerations, not on the upstream limit of the development. The upstream boundary should be far enough upstream to allow the full impact of the development on upstream water levels to be identified.

3.3 Downstream Boundary (Levels)

The downstream boundary should be at a location where the relationship between level and flow is well defined, e.g. a weir. Where this is not possible, it should be sufficiently downstream of the area of interest so that any errors in the boundary will not significantly affect predicted water levels at the proposed development site. For a typical fluvial river, a rule of thumb is that a backwater effect extends a length L=0.7D/s, where D = bankfull depth and s = river slope. Hence if the downstream boundary is greater than L from the site it is likely that any errors in the rating curve at the boundary will not affect flood levels at the site. If the downstream boundary is tidal, it should be a location where a tidal curve can be accurately defined. Any tidal boundary should take into account both the astronomical tide (i.e. the tide caused by the gravitational effects of the Moon and the Sun and reported in published tide tables) and storm surges (i.e. the elevation of tidal levels caused by weather conditions). Careful consideration of combined probabilities10 may be required in such cases. The Environment Agency holds extensive extreme tide information from Flood Risk Mapping Studies.

3.4 Hydraulic Coefficients

The coefficients used in the model (e.g. channel roughness, weir coefficients) should be determined with guidance from standard textbooks. These texts should be referenced in the modelling report. Work is ongoing to produce guidance relevant to the UK, but in the meantime standard works such as Chow and Hicks & Mason can provide some guidance. Further information on roughness can also be obtained from the Defra / Environment Agency Conveyance Estimation System (CES) – http://www.river-conveyance.net/

4. Model Calibration, Verification and Sensitivity Testing

4.1 Calibration

Wherever practicable, the hydrological assessment and the hydraulic model should be calibrated against recorded flows and/or water levels from observed flood events. If calibration data is available, the model should be calibrated using at least three separate events. If no calibration data is available, a 'reality check' on the predicted levels and flows can often be carried out from photographs, historic information and anecdotal accounts of flooding.

The coefficients used in the calibration process should only be varied within the possible ranges suggested in the standard textbooks. The calibration of steady-state models should consider flow and flood levels. Calibration of hydrodynamic models should also consider the timing of the flood peak, flood volume and shape of the flood hydrograph.

4.2 Verification

If calibration is carried out, at least one separate observed event should be run through the model after the calibration to verify the adjustment of parameters.

4.3 Sensitivity Testing

The model should be tested by adjusting the key parameters within it to assess the effects on calculated flood levels. Unless otherwise agreed with the Environment Agency, the following parameters should be tested as a minimum:

- model inflows
- downstream boundary condition
- channel roughness and
- key structure coefficients

The range of parameters used in sensitivity tests should reflect uncertainties, possible changes due to climate change and variations in hydraulic coefficients (e.g. from seasonal changes or periodic maintenance). The parameters should be increased and decreased by a set percentage (usually 20%) and the results compared to the original run to assess whether the model gives expected results (i.e. the results are inside the set percentage increase and decrease). If the results vary significantly more than the set percentage then more investigation is required.

Sensitivity to blockage of critical structures should also be tested. The 2004 R&D study 'Scoping study into the hydraulic performance of bridges and other structures, including effects of blockage, at high flow' includes current understanding & some interim guidance.

Using the outputs of the sensitivity tests

The results of the sensitivity tests should be used to assess the possible circumstances that could cause flood levels to be significantly higher than the modelled best estimates. Examples are blockage of a downstream culvert, underestimation of design flows (if hydrometric data is poor) or increase in channel roughness in the event of decreased maintenance. Given the findings, recommendations should be made on the design of any buildings on site to eliminate risk of significant flood damage to the building.

5. Model Report Requirements

A report must accompany the submission to describe the modelling method and assumptions. The report is to enable a review of the model and results to be carried out. In some cases, only the report will be used to evaluate the appropriateness of the model, therefore it must be thorough. It should be a self-contained report that will provide sufficient information to allow future use of the model by the Environment Agency including if necessary replicating the work undertaken. The detail of the report should be appropriate to the complexity of the modelling.

5.1 Format of reporting

The report should be in a format that is easy to transmit electronically, and must include all plans and schematics. Adobe pdf files are therefore preferred. The language should be clear and non-technical where possible.

The following plans should be included with the report:

- A location plan at an appropriate scale, with national grid coordinates and OS basemapping, identifying geographical features, street names and all watercourses or bodies of water in the area of the site.
- A plan and description of any structures which may influence local hydraulics.

5.2 Report

For a comprehensive report, we suggest the following report structure, in line with the model requirements in Section 2.

Introduction

General site description:

- Larger scale plan showing location in the catchment
- What the site is used for currently
- Size of the site
- What is proposed
- Whether the Agency have been involved with the site previously (existing consents or
- references)
- Brief Flood History of the site
- The flood extents / flood zones that the site falls within
- Source of flooding on site / mechanisms of flooding
- Watercourses/drainage ditches in the area

Objectives of the Model Study

Provide a justification for why the modelling exercise has been undertaken and the planned objectives of the exercise. Indicate any deviations from the original objectives or planned project outputs, and outline the reasons why these occurred.

Method Statement and Justification

The report should include a clear method statement, detailing how the modelling has been carried out to fulfil the objectives.

Data sources

List all data used in the model and provide these when submitting the report.

Detail methods of data capture and/or sources of data, and the processes by which the raw data were converted.

Any reference to earlier work should be clearly referenced, and applications or development of existing models should be subject to the same rigorous inspection methods.

State the ownership of the data collected and the format of the data.

Uncertainty in data sources should be referenced especially where data have been discounted due to low confidence.

Provide the Environment Agency's data request reference here (usually prefixed with "WT"). Any licences and disclaimers accompanying data should be provided as an appendix.

Hydrological model

Explain why the chosen methodology is suitable for the catchment. Report details of decisions made and justifications for these. The FEH proforma provided in Appendix C must be supplied with the report. It is essential that this information is supplied for us to be able to undertake a full model review.

The report must include a table of the design inflows to be used in the hydraulic model.

A complete description of the catchment areas contributing to flooding at the proposed site must be supplied.

Hydraulic model

A hydraulic model will need to be produced for a Flood Risk Assessment where the effect of flood risk to the site can not otherwise be demonstrated (existing information, hand calculations etc). It will be necessary to produce a hydraulic model where the flood risk before and after development needs to be demonstrated, if the development involves changes to the river channel or structures, or if the development includes flood storage.

Provide a description of the hydraulic modelling approach including a description of the watercourse being modelled. The discussion must include justification of the selected modelling software including a technical description of the model and it's components. Only a brief technical description is required if the tool is well known to the Environment Agency / widely applied, such as ISIS, TuFLOW and HecRas. Include the name and version of the software used.

Justify the decision to use fully hydrodynamic 1D or 2D model or a steady-state backwater model, flood routing model or combination of methods. Indicate any perceived advantages or disadvantages of applying the chosen tool.

Supply details of existing defences and local structures and how they have been represented in the model. Also supply details of how inflow and downstream boundaries have been represented.

Provide the schematic showing how individual parts of the model are connected, as an appendix.

Parameters

State and justify the derivation of the parameters (e.g. channel/overbank roughness, weir coefficients) used within both the hydrological assessment and the hydraulic model.

Calibration/Verification

Where calibration has been undertaken, the method used must be clearly illustrated and the number of independent data sets used for verification must be displayed. The model results must be presented against observed values for key locations for each verification data set, and descriptive statistics applied to describe the error band in the model.

Sensitivity Analysis

Discuss what sensitivity tests were carried out and how, including which parameters were varied and to what extent. Describe the results of the sensitivity testing and discuss the potential effect these could have on the model output.

Results

Results of the hydraulic model should be indicated in a summary table showing roughness coefficients, peak flow, water surface elevation, flow velocity, Froude Number etc. at each cross section. If possible, calculated flood levels could be shown on cross section data.

Map(s) indicating the flood extents adjacent to and including the proposed site must be provided for the modelled design events.

Audit Trail

The audit trail developed should be described in unambiguous detail. This should detail the build stages, changes made and the file names of all modelling/model support files produced. Documentation should also be included within the model data files to clearly set out the conditions applied.

Limitations

Highlight and discuss any limitations of the model or modelling technique. The impact of such limitations on the present or future use should be clearly stated.

Data given to multiple decimal places gives the impression of high confidence in the accuracy. Avoid doing this unless you are able to state the accuracy and confidence in the data.

Conclusions

The report must include concluding remarks, which highlight key issues from other sections and draw attention to the critical locations and/or structures within the model.

The same key items in reporting will apply to both modelling and hydrology.

The conclusion should comment on the current flood risk to the development site and the proposed level of risk post development. It should also comment on the existing flood risk to locations upstream and downstream of the site and any changes to the level of risk to these areas following development.

5.3 Appendices

Additional items to include as appendices:

Environment Agency Data used in the FRA

- Copy of the data licence: Include a copy of the licence/copyright which accompanies the
- data provided by the Environment Agency.
- If an Environment Agency model has been used/adapted as part of the FRA, include the model disclaimer which was provided with the data. This is to ensure any data warnings have been regarded.

Appropriate Modelling Staff Involved

Include a description of experience/CV of modelling staff involved with the FRA. This is to demonstrate to the Agency that suitably qualified and experienced personnel have carried out the work described in this document. Table 1 below illustrates the expected levels of experience.

Complexity of flood estimation study	**Example of study**	**Value of flood defence works or damages**	**Indicative timescales for flood estimation**	**Competence criteria**	
				Analyst	**Supervision and approval**
Simple	Preliminary assessment; culvert capacity check	-	<1 day	Level 1	Level 2
Routine	Low-risk DC application	<£50,000	1-2 days	Level 1	Level 2
Moderate	Small FM study or medium-risk DC application	<£250,000	2-10 days	Level 2	Level 3
Difficult	Medium FM study or CFMP or pre-feasibility	<£1million	2-4 weeks	Level 2	Level 3

Very difficult	Major scheme design or large FM study / CFMP	>£1million	>1 month	Level 3	Level 3

1. The values in all columns are indicative.
2. DC: Development Control FM: Flood Mapping CFMP: Catchment Flood Management Plan.
3. The competence criteria should be interpreted as minimum levels
4. An analyst who has not carried out or supervised the study must give approval.
5. Level 1 – Hydrologist with minimum approved experience in flood estimation
6. Level 2 – Senior Hydrologist
7. Level 3 – Senior Hydrologist with extensive experience of flood estimation

Model Schematic

The schematic showing how individual parts of the model are connected should be provided, geo-referenced if possible.

5.4 Model Review during consultation

Once the model and report has been submitted to the Environment Agency for consultation it will be reviewed to determine whether the model is fit for the purpose of Flood Risk Assessment against the National Environment Agency guidance. We are not permitted to publish this guidance, however we have produced this guidance document to ensure the FRA model is fit for purpose. As an indication, our review of the model will focus on the items indicated in Appendix C.

We require at least 4 weeks to complete this. Please bear in mind that your model may require modification following the review, before the FRA can be accepted. You should allow for this within your timescales.

6. Updating the Flood Map

Flood Zones are used within the Environment Agency to delineate PPS25 flood zones and make planning decisions. The data is also used by a variety of external users, and can be viewed at www.environment-agency.gov.uk

If you would like the Flood Zones to be updated with FRA modelled extents, the model and outputs must be fit for purpose. Our requirements are as follows:

- Extents must represent the flood events with an annual probability of 1% (1 in 100), and 0.1% (1 in 1000).
- The model must be undefended, so not take account of any formal raised defences, in accordance with PPS25. You can check with the Flood Risk Mapping & Data Management team for a current list of formal raised defences. Other infrastructure (bridges, culverts, engineered channels, bypass channels) and embankments that are not flood defences, can be included in modelling and mapping flood zones.
- Flood Zones can only be updated with fluvial or tidal modelling.
- The modelling must be based on surveyed ground levels.
- Dry Islands within the floodplain may be mapped if they are larger than 200m2 and not less than 10m wide.
- Survey must show that the **land** (not the property) is at least 100mm above the flood level.
- The modelling outputs for the Flood Map purposes must make no allowance for blockages (although blockage modelling may still need to be considered as part of the FRA, as a sensitivity test).
- We will incorporate third party data that is suitable for flood zones where we have approved the model is to Environment Agency requirements, if we have the owner's permission to do so. For this, the owner will need to hand over all intellectual property rights on the data to the Environment Agency. See Section 6.3, future use of FRA model.

6.1 How to challenge

Please indicate within your FRA submission that you wish the model outputs to be considered for updating Flood Zones. We will then review the suitability of the model for this purpose as part of the FRA model review. If you are not carrying out modelling as part of your FRA, but you have evidence to challenge the Flood Map, please contact our Flood Risk Mapping & Data Management team at Wallingford, TH-WE-MAPPING-&-DATA@environment-agency.gov.uk

6.2 Timescales for updates

We make quarterly updates to the Flood Map in January, April, July and October. In order for us to be able to incorporate your new modelled extents into the Flood Map, we will require the final approved extents 10 weeks before an update.

6.3 Future use of FRA model

If the model is required to update the Environment Agency's Flood Map/risk assessment products to represent the as-built situation, ownership of the Intellectual Property Rights (IPR) or an approved IPR licence will be required by the Agency. A statement should accompany the report and model data to indicate the allowable future uses of the model and its associated documentation.

7. Other

7.1 Contact Details

Environment Agency South East, West Thames Area External Relations:

Email: WTenquiries@environment-agency.gov.uk

7.2 Quality Assurance and Audit Trail

Throughout the study, a well-defined audit trail should be defined and reported. This should include all relevant documentation and should link with the appropriate quality assurance procedures of the organisation carrying out the study. Provision should be made to make the relevant documentation available to others who may use the model in future.

Glossary of terms

Backwater Curve - The longitudinal profile of the water surface (in a non-uniform flow in an open channel) when the water surface is not parallel to the river bed. This is caused by a restriction such as a dam or weir, increasing the depth of the water above the normal water level that would result if the restriction were removed.

Backwater Effect - The effect where a dam or other restriction raises the surface of the water upstream from it above the normal water level.

Backwater Flooding - Flooding caused by downstream conditions such as a channel restriction and/or high flow in a stream at a confluence downstream of the flooding.

Backwater Model – A model built to represent the backwater effect.

Calibration – The process of adjusting parameter values in a model to try and match recorded data, so that the model can be taken as a good representation of reality.

Combined Probability – The chance of two or more independent events occurring concurrently.

Critical Duration Storm – The duration of storm necessary to produce the maximum instantaneous peak flow or volume at a specific location in a drainage system, for any given flood event probability.

Floodplain – Land adjacent to a watercourse over which water may flow in time of flood. This generally includes the defended floodplain, an area over which water would flow if flood defences were not present, or if flood defences fail.

Flood Routing Model – Process of determining progressively the timing, shape, and amplitude of the flow in a flood wave as it moves downstream at successive points along the river.

Hydrological Model – A mathematical model used to estimate the flow in a river that will result from rainfall. It will usually be based on such things as catchment size, geology and soil type, steepness, land use and storage within the catchment. The model will be calibrated and verified using recorded rainfall and flows, before using design rainfall to estimate the flows which might be expected in floods of different probabilities.

Hydraulic Model – A mathematical model used to predict possible future levels (and flows in a hydrodynamic model) taking into account the topography, shape and roughness of the river bed and floodplain, obstructions (e.g. weirs and bridges), and the inflows provided by the hydrological model etc. Models are calibrated using recorded historic flood data, where it is available.

Hydrograph – A graph showing the water level (stage), discharge, or other property of the flows in a river, with respect to time.

Hydrological Assessment – Carried out to understand the cycle of precipitation, consequent runoff, infiltration, and storage; eventual evaporation etc.

Intellectual Property Rights – The legal ownership of the content of the work in question.

Storage – Location where water is retained due to the lie of the land, man made influence or effect of tides / other river flows.

Steady-State Model – A hydraulic model in which the flow at any point in the model is constant with time (there can be many different flows but all are constant over time). This type of model cannot estimate the effects of storage on flood levels or downstream flows.

Hydrodynamic model – These estimate flows and levels throughout a flood event, and can therefore take into account the effects of storage on flows and flood levels.

Topographic Survey – Survey to measure and record the physical features of an area in horizontal and vertical dimensions.

Tributary – A river or stream that flows into a larger river.

Upstream / Downstream Boundary – The limits of the model or assessment upstream and downstream of the site of interest.

Verification – The process of checking the accuracy of the outputs of the calibrated model in comparison with recorded data. If sufficient data is available it is good practice to calibrate the model using some recorded data, and verify the model using data from other flood events.

List of abbreviations

PPS25 – Policy Planning Statement Note 25
TAN15 – Technical Advice Note 15
CIRIA – The Construction Industry Research and Information Association
DEFRA – Department for Environment, Farming and Rural Affairs
R&D – Research and Development
1D – One Dimensional
2D – Two Dimensional
FRA – Flood Risk Assessment

References

• Centre for Ecology and Hydrology, 1999. Flood Estimation Handbook. Wallingford, CEH. (Further details are available at http://www.nwl.ac.uk/feh/ or from CEH on 01491 838800.)

• Defra / EA R&D Programme. Joint probabilities - dependence mapping & best practice, FD 2308/TR1. HR Wallingford. 2003.

• Defra / EA, March 2004. Flood & Coastal Defence R&D Programme, Benchmarking Hydraulic River Modelling Software Packages, R&D Study: W5-105/TR1.

• Defra/EA R&D Programme. July 2004. Scoping study into the hydraulic performance of bridges and other structures, including effects of blockage, at high flow.

• D.M.Hicks & P.D.Mason. Roughness Characteristics of New Zealand Rivers. 1999.

• Environment Agency: Fluvial Freeboard Guidance Note. Technical Report W.187.2000.

• Environment Agency, 2000. Flood Estimation Handbook Guidelines (Parts 1 and 2) Bristol, Environment Agency.

• HR Wallingford (2004) Preliminary rainfall runoff management for developments: Users Guide. Defra / EA R&D Technical Report W5-074/A, HR Wallingford.

• Kjeldsen. T. R., Jones. D. A., and Bayliss. A. C., 2008. Improving the FEH statistical procedures for flood frequency estimation. Science report SC050050/SR. Defra / EA R&D Programme. (This is available on the Environment Agency website, through the Publications Catalogue. Search for product code SCHO0608BOFF-E-P.)

• Lancaster, J., Preene,M. and Marshall,C. 2004, CIRIA Report C624, Development and Flood Risk – Guidance for the Construction Industry, CIRIA, London.

• The Chronology of British Hydrological Events, http://www.dundee.ac.uk/geography/cbhe

• Ven Te Chow, Open Channel Hydraulics, McGraw-Hill 1959.

Appendix A

Checklist of items that must be submitted to the Environment Agency for consultation & review

- ✓ Model Report using format recommended in Section 5
- ✓ Survey Report (If appropriate)
- ✓ Data request reference from Environment Agency External Relations
- ✓ Location / site plans
- ✓ Maps of outputs – flood extents produced by the model
- ✓ Details of any challenges to the Flood Map (see Section 6)
- ✓ All model data files, including sufficient instructions allowing model to be run and viewed (time-step, runtime, initial conditions etc.) - see the model file checklist below.
- ✓ All documents and files provided electronically

Appendices:

- ✓ Data licence from the Environment Agency allowing use of our data and any associated model disclaimers
- ✓ Statement on future use of the model / IPR licence
- ✓ CV of modelling staff involved with the Flood Risk Assessment
- ✓ Model Schematic
- ✓ FEH proforma (if FEH has been used)

Model Files

HEC-RAS Models

Description	HEC-RAS file
project file	*.prj
geometric data file	*.g
steady flow data file	*.f
unsteady flow data file	*.u
plan data file	*.p
results file	*.o

ISIS Models

Description	ISIS file
river model data	*.dat
initial condition (if not in .dat file)	*.zzs
summary of output; maxima at all nodes	*.zzr
unsteady state output	*.zzn
run and error messages + bitmaps of convergence graphs	*.zzd
Binary results file	*.zzl
Run time parameters	*.ief
(Optional) Geographic schematic	*.gxy
(Optional) ISIS event files	*.ied
(Optional) calibration/verification points	*.cal
(Optional) maximum calibration/verification points	*.cus
(Optional) hydrologic boundary	*.zzb
(Optional) hydrographs	*.zzh
(Optional) FEH boundary	*.ied

TUFLOW Models

Description		TUFLOW file
File Path	Use relative path names for input files (e.g. "..\model\geometry.tgc") so that models are easily moved from one folder to another.	N/A
Control Files	TUFLOW Control File	*.tcf
	ESTRY Control File (if using 1D domain)	*.ecf
	Geometry Control File	*.tgc
	Boundary Conditions Control File	*.tbc
Data Input Files	Boundary Condition Database (bc_dbase)	*.csv
	Inflow and Outflow time series (e.g. hydrographs and hyetographs)	*.csv
	GIS files (2d_bc, 2d_mat, 2d_zln etc.)	*.mif / *.mid
	TUFLOW materials file	*tmf
Data Output File	SMS super file	*.sup
	SMS mesh file	*.2dm
	SMS data file	*.dat
	Text output of time series data	*.csv
	Files for viewing 2D and 1D domain results in GIS	*.mif / *.mid
	Flood duration outputs	
Check files	TUFLOW log file	*.tlf
	Estry log file	*.elf
	GIS formats for viewing graphically any errors, warnings and checks, the 1D network, 2D grid, 2D topography, 2D/1D boundaries and connections (e.g. 2d_grd_check)	*.mif/.mid

INFOWORKS RS (1D & 2D) Models

Description	INFOWORKS file
Transportable Database (Zipped up database containing all data: networks, events, results, ground models, calibration, etc.) NB: Data must be "checked in"	*.iwc

Appendix B

Survey Requirements for Flood Risk Assessments

Purpose of Document

This document is a statement of best practice from which is intended to improve the quality of surveys submitted to the Environment Agency South East, West Thames Area for flood risk assessments (FRA) by:

• Reducing the risk posed by using poor survey data.

• Ensuring survey is quality controlled and quality assured by the surveyor. It is their duty to ensure their work is carried out according to best practice, which includes a responsibility to carry out and document internal and independent checks of the survey.

• Making the process of validation of surveys more efficient and effective.

• Reliable and complete survey information will speed up the review of flood risk assessments.

Documentation

Every survey should be submitted with a survey report stating:

- ✓ Survey company name
- ✓ Date of survey
- ✓ Name of surveyor(s) with qualifications
- ✓ Purpose of survey and required survey accuracy with justification
- ✓ Method statement (techniques used)
- ✓ Details of source control and new control established on the site
- ✓ Manufacturer, model and serial number of survey equipment used for the survey together with calibration certificates
- ✓ Statement of results of self-checks (closures and cross-checks)
- ✓ Statement of results of independent checks
- ✓ Appendices of all survey field observations, computations and diagrams

✓ Submissions of data such as topographic survey, long sections and cross sections must be provided in a data formats agreed with modellers using the data. (i.e.) HECRAS, ISIS, XYZ

General

The model should be based on a topographic survey and/or channel survey of the watercourse. The upstream and downstream limits should be defined by the objectives of the flood risk assessment, rather than to the limits of the project / study area. The lateral extent of the survey should be sufficient to include the full extent of flooding. Guidance on this extent may come from flooding records and from the Flood Map. The extent of the survey work should be defined jointly by those undertaking the river modelling and those undertaking the survey in conjunction with advice from Environment Agency Flood Risk Mapping & Data Management staff.

The survey (and the model on which the survey is based) should continue far enough downstream so that uncertainty in the boundary condition does not significantly influence the estimated flood levels.

The cross sections surveyed should be representative of the channel and floodplain and the spacing between cross sections and orientation should be determined from the appropriate software documentation and textbooks. Consideration shall be given to the additional survey information that may be required between cross-sections in areas where detailed flood depths or extents are needed. This can be achieved by either adding further cross sections or surveying additional spot levels.

During the survey, information on structures, flood routes, potential blockages / obstructions to the channel and channel roughness should also be gathered.

All cross sections and other survey information shall be located in plan relative to the Ordnance Survey (OS) National Grid. It is considered best practice that the survey is undertaken by a land surveying company that is “Regulated by the Royal Institution of Chartered Surveyors”.

Errors

The primary objective is to control systematic and gross errors and blunders.

A systematic error is one that arises in all measurements made with particular equipment if the instrument is reading incorrectly due to constant or proportional instrument errors and / or environmental factors.

A gross error or blunder can arise through a method error, misidentification, and reading/writing errors.

Techniques

This section covers observations of the critical dimension for flood risk assessments - height / level above sea level (Ordnance Datum Newlyn (ODN)). It does not cover positioning although there may be instances where inaccurate plan affects height.

General

At least two permanent stations (e.g. PK nail in asphalt) should be established at the site of the FRA in places where they are unlikely to be disturbed. Simple descriptions (with photos) including level value are required to enable the EA to find them.

All spot levels shown on site plans / cross-sections shall be numbered and referenced to observations and field notes.

Line levelling should be carried out using a spirit level - not theodolite / total station. However, these instruments may be used to observe spot levels on a site or cross-section levels provided that a sample of points is checked by another method (e.g. spirit levelling).

Global Positioning System (GPS) or Global Navigation Satellite System (GNSS) observations

Observations must be made only with survey-grade dual frequency GPS or GNSS receivers at locations where the sky view is substantially clear above 15% elevation. New GPS control should be gross-error checked by levelling to (say) a spot level from a landline map or to an Ordnance Survey Bench Mark (OSBM). http://benchmarks.ordnancesurvey.co.uk and follow link to benchmark locator. Some minor and low risk developments do not justify the cost and time required to establish heights based upon GPS on the site. In these cases it **may** be acceptable to base the survey on OSBMs and this is at the discretion of the Agency's Development and Flood Risk Officer based on the appropriateness 'test' in PPS25.

Static GPS observations

Where static GPS observations are used to establish a benchmark, GPS baseline observations should be made to at least three source control stations (e.g. OS Net stations) for sufficient time to obtain a level of the required accuracy. Height of instrument should be checked by measuring more than once and using a different scale (e.g. feet), using two set-ups on the same point or by observing a second station with level connection between the two stations.

A text / html file of the report for at least one GPS baseline computation should be included in the survey report.

An unconstrained computation should be run holding one source control station fixed to published co-ordinates. The co-ordinates of the new GPS station are computed from this. Then the coordinates of other source control stations are computed from the new GPS station. The difference between observed and published level at unfixed source control stations should not exceed 20mm. The comparison table should be included in the survey report. A text /html file of the unconstrained computation report should be included in the appendix to the survey report.

A constrained computation should then be run. This holds all accepted source control stations fixed and computes an adjusted position for the new GPS station. A text / html file of the constrained computation report should be included in the appendix to the survey report.

Network RTK GPS

Network RTK GPS observations may be used if the accuracy of the technique is satisfactory for the purpose of the survey. Surveyor should follow The Survey Association guidance (http://www.tsa-uk.org.uk/guidance.php), published in November 2008. Self-checks and independent checks must be documented in the survey report.

Levelling

Source control for site levels and cross-section data should be GPS stations established as above. However, dependent upon the required accuracy of the survey, OSBMs may be used as source control.

The height above ODN for critical points on the site plan and for cross-section base point pegs should normally be spirit levelled. Critical points should be checked either by incorporating them as change points in a closed level loop or another form of independent check.

The survey report appendix should include a copy of the field notes for a two-peg test carried out on the level used for the survey within the previous two weeks. The test shall comprise observations before and after adjustment (if the level is adjusted).

All level runs must be closed to better than 12mm x $\sqrt{k}$, where k is the levelled distance in km. However closures should also reflect the accuracy of the levelling equipment being used.

The levelling should be connected and adjusted to two different benchmarks, to provide a self-check and an independent check. Note that the difference between levels based on OSBM source control and GPS source control may be up to 80mm within Environment Agency South East. The EA Survey Group has some data on this and can supply on request. Contact andrew.bevan@environment-agency.gov.uk stating the 1km grid ref of the site – e.g. SP 5923. Provided that these checks are made and incorporated in the levelling calculations, heights should be correct to within 0.05m.

If only one benchmark is used, a photo of the benchmark shall be included in the report with details of independent checks which were carried out (e.g. level comparison on spot heights from OS landline / mastermap mapping). Note that this is less reliable than use of two benchmarks and the EA would only expect heights surveyed using this method to be reliable to +/- 0.2m.

Please submit your Survey Report with your Flood Risk Assessment Report and modelling as part of your Planning Application submission.

Appendix C

Reviewing computer modelling for Flood Risk Assessments

As a guide, our review will consider the following aspects of the model and reporting:

General:

- Clearly defined objectives
- Flood Mechanisms identified
- Climate change considered
- Requirements discussed with Development and Flood Risk. Requirements at specific locations and design conditions (for example requirements of a freeboard and an allowance for climate change) should be discussed with local Agency staff to ensure that any site-specific factors are identified, which may require consideration when carrying out the modelling
- Site visits undertaken to ensure the model is realistic
- Appropriate approach to analysis for the site
- Checks carried out where existing models have been used, at key locations to ensure that the model / levels provided are compatible with current conditions. Changes summarised in report
- Location details and site plans provided
- Suitably qualified and experienced staff involved in building the model

Survey Data (see Appendix B regarding our survey requirements):

- Survey data used is current / appropriate
- Survey report submitted for checking
- Extent of the survey is sufficient to include the full extent of flooding. Extends far enough downstream so that uncertainty in the boundary condition does not significantly influence the estimated flood levels
- Representative spacing of the cross sections
- All hydraulically significant structures surveyed

Hydrometric Data:

- Relevant available flow, level and rainfall data used
- Hi-Flows database (v3.1.1) consulted to update records and check suitability of sites for use

Historic Data:

- Existing information on extent or depth of flood events provided

Hydrological assessment:

- Details of the hydrological analysis and justification for using the chosen method provided
- Justification if FEH methods have not been used
- Audit trail provided and all decisions justified
- Proforma provided for FEH calculations
- Justification provided if ReFH has been used in place of the statistical method
- Local data / knowledge used in the assessment / confidence in hydrometric assessment of gauge data considered
- Consideration of gauge station design & history
- Extent of gauge bypassing at high flows
- Effect of weed growth/blockages at the gauge
- Rating curves up to date for this assessment
- Calibrated and verified model using existing gauging station data, with regard to any limitations with this data
- If data is available, three events should be used for calibration, and 1 additional event for verification.
- URBEXT 2000 used plus update if there have been significant changes in the catchment
- Catchment boundary checks

Model Building:

- Initial conditions, choice of parameters, boundary locations and conditions
- Representation of key flow routes, storage and structures
- Methodology clearly stated

Model calibration, verification and sensitivity testing:

- Calibration attempted and appropriate
- Sensitivity tests carried out on parameters expected to have a major effect on predicted water levels, or if there is uncertainty in the parameters adopted
- Discussion of limitations of the model

Model accuracy and stability:

- Confidence limits stated for the model results (+/-mm)
- Discussion of model stability around the peak

Appendix D

a) Flood Estimation Calculation Record

b) Flood Estimation Calculation Record for single sites

(Separate attachments)

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Then call us on

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Calls to 03 numbers cost the same as calls to standard geographic numbers (i.e. numbers beginning with 01 or 02).

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