Annexes to Surface Water Management Plan Technical Guidance

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www.ukwir.org

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This document is also available on the Defra website.

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Annex A – Roles and responsibilities of the partnership

a.1 The table below outlines the roles and responsibilities of partner and stakeholders involved in the SWMP process. It is recognised that the list of stakeholders provided here is not definitive and as the SWMP develops it may become evident that other stakeholders need to be engaged. For example, once flood risk has been assessed and mapped it may become clear that owners of other critical infrastructure (e.g. electricity sub-stations) are at risk of flooding, and at this point the relevant organisations should be engaged.

Partner or Stakeholder	Role in SWMP	Responsibility for sharing information about:	Potential constraints	SWMP will inform how they:
Local authority	**Lead partner** for the SWMP responsible for ensuring that objectives are set and met and that a partnership approach is adopted.	• Land-use planning and urban development, • Highways drainage (Highways Agency for major routes) • Urban green space • Sustainable drainage systems in their control • Ordinary watercourses in their control • Strategic Flood Risk Assessment (PPS25) • Reported flooding incidents • Costs and practicalities of re-engineering streets and green space as flow routes or storage • Operations and maintenance regimes • Property values and damage due to flooding	• Resources and expertise to lead development of SWMP	• Prepare for emergencies (together with others in Local Resilience Forums[1]) • Allocate land-use and adopt surface water management policies • Control drainage for new development through planning controls • Use opportunities arising from development and redevelopment to work in partnership with developers to implement the SWMP • Communicate with residents about surface water flooding • Refurbish and improve the urban environment • Plan operations and maintenance regimes

[1] http://www.ukresilience.gov.uk/preparedness/ukgovernment/lrfs.aspx

Partner or Stakeholder	Role in SWMP	Responsibility for sharing information about:	Potential constraints	SWMP will inform how they:
				• Invest in local flood risk management, in particular highways drainage and ordinary watercourses
Environment Agency	**Essential partner** for the SWMP responsible for main river and coastal flooding. They may also develop a national coordination role ensuring consistency and high standards in SWMP.	• River flows, levels and flooding • River flow models • CFMP • Reported flooding incidents • DEM data (e.g. LiDAR) • Interactions between rivers or the sea and drainage systems • Operation and maintenance regimes • Long term investment plans • National Property Dataset (subject to licensing restrictions)		• Prepare for emergencies • Communicate with residents about all sources of flooding • Invest in flood risk management (especially for smaller urban 'main' watercourses) • Plan operations and maintenance regimes
Water Company (sewerage provider)	**Essential partner** for the SWMP responsible for public sewer systems and the reduction of sewer flooding. Responsible for 'effectually draining'[2] their area.	• Sewer network capacity and performance • Reported flooding incidents • Sewer network models • Costs and practicalities of sewer rehabilitation • Drainage Area Plans and Sewerage Management Plans • Long term investment plans • Sustainable drainage systems in their control	• As private companies there are concerns over data sharing and confidentiality issues	• Prepare for emergencies • Communicate with residents about sewer flooding • Undertake Drainage Area and Sewerage Management Plans • Plan their investment in sewerage systems • Respond to climate and population change • Work with developers to adopt some drainage infrastructure for new developments

[2] Water Industry Act (1991), more information at http://www.opsi.gov.uk/acts/acts1991/Ukpga_19910056_en_1

Partner or Stakeholder	Role in SWMP	Responsibility for sharing information about:	Potential constraints	SWMP will inform how they:
Internal Drainage Board	**Potential Partner** for the SWMP if responsible for land drainage and surface water management in or near to urban areas.	• Sustainable drainage systems in their control • River/channel flows, levels and flooding • River/channel flow models		• Plan their investments in drainage facilities • Plan operations and maintenance regimes • Respond to climate and population change • Plan operation and maintenance regimes
Riparian Owners	**Potential Partner** or **stakeholder** for the SWMP if responsible for improvement to open channel or culverted watercourses essential to surface water drainage.	• Flooding incidents • Operation and maintenance of channels in their control	• Lack of willingness to engage and share information	• Deliver channel improvements and maintenance to reduce flood risk
Householders, businesses and landowners (the community)	**Potential partner** or **stakeholder** for the SWMP.A valuable source of information about historical flood occurrences and preferences for flow exceedance routes and/or storage. They can also be involved in the development of solutions.		• Reluctance to share information about historical flooding, due to risks of 'blighting' property	• Understand and respond to local flood risks • Take steps to manage runoff from their business premises or land • Take steps to protect their property from surface water flooding
Developers	**Key stakeholder** or **potential partner** for	• Development proposals as early as possible, thus ensuring any		• Provide strategic surface water drainage infrastructure such as

Partner or Stakeholder	Role in SWMP	Responsibility for sharing information about:	Potential constraints	SWMP will inform how they:
	the SWMP especially where large areas of new development are planned and there are opportunities for a strategic approach to surface water drainage.	surface water issues are fully integrated into the SWMP		SUDS. • Provide drainage from and around buildings • Respond to climate and population change
Highways Agency	**Potential partner** for the SWMP where main or trunk roads form a key part of the drainage or flood risk	• Historical flooding of main or trunk roads • Drainage records of main or trunk roads		• Design road drainage to minimise surface water runoff • Plan exceedance routes
Navigation authorities	**Potential Partner** for the SWMP where navigation channels (e.g. canals) present an urban flood risk and/or conveyance or storage for excess surface water.	• Information on navigation channels		• Plan for conveyance of navigation channels

Annex B – Data requirements for a SWMP study

b.1 The table below outlines data and information which is considered to be required to undertake a SWMP study. The table outlines the nature of the data, which organisation may hold the data, typical formats which the data may be available, and the reason the data is necessary. In addition, the data types have been categorised to assist data collation, into the following categories:

- 1 – asset data and information;
- 2 – background information;
- 3 – historical information;
- 4 – future development information;
- 5 – document and plans, and;
- 6 – water quality information

b.2 The need for different data and information will vary from location to location, depending on what is currently available, and the nature of the SWMP study. The list is not intended to be comprehensive, but indicates typical data which should be considered.

Category	Data type	Source	Common format	Why is it required
1	Highway drainage records	Upper tier highway authority	Reports	Whilst the extent and quality of records is highly variable, these data are useful if inadequate highway drainage exacerbates surface water flood risk
1	'Ordinary' watercourses	Lower tier drainage departments, Internal Drainage Boards		Capacity and condition of 'ordinary' watercourses essential to operation of the urban drainage system. Culverted watercourses are especially vulnerable to future flood risk. Flow models should be obtained if they exist, although frequently existing models do not include these

Category	Data type	Source	Common format	Why is it required
1	Maintenance regimes and records	All partners	Reports	Poor maintenance of drainage assets can commonly exacerbate surface water flood risk. This information can be used to target improved maintenance regimes in the locations considered at highest risk of surface water flooding.
1	River or coastal models and asset data	Environment Agency	Model files or databases (e.g. NFCDD)	Important where the influence of river or tidal levels influence flood risk directly or through interactions with the urban drainage system
1	Foul / combined / surface water models	Water and sewerage companies	Model files or GIS	Most water companies hold models of their foul and combined system. There are fewer existing surface water models. Existing models should be used with caution if they were originally built for purposes other than flood risk assessments.
1	Drainage asset data	Water and sewerage companies	Commonly database or GIS	In the absence of existing information asset data can be used to construct models or examine capacity. Public sewer records are available to local authorities and are periodically updated. This could also include historic survey information (e.g. flow surveys, impermeable area surveys)
1	Information on local watercourses	Internal Drainage Boards	Model files or reports	Some IDBs maintain hydraulic models. Otherwise, information on levels, capacity and condition should be available to understand their contribution to flood risk
1	Location of critical infrastructure	Local Resilience Forums	Report or GIS information	Location of critical infrastructure: hospitals, schools, power (generation & distribution), water, transport etc. Much of this information can be obtained from mapping and will be general knowledge locally. It is used to assess critical infrastructure exposure to surface water flooding.
2	OS Mapping data	Local authorities have licence for this data	GIS	Useful for background mapping
2	Ground data	Any of the partners may hold this	LiDAR / SAR	This information is required to undertake any analysis of overland flow routes
3	Historic flood incident data	All partners should hold this		Critical information to understand where historical flood incidents have occurred. It is particularly useful to try and understand the source of flooding if possible.

Category	Data type	Source	Common format	Why is it required
3	Rainfall data	All partners may hold this, data can be purchased from the Met Office	.RED or .XLS files	Historical rainfall data is critical for running computer simulations of historical flood incidents.
3	Anecdotal evidence	Local press, Fire and Rescue, members of the public	Newspapers, archives, reports, photos, videos	This evidence can be critical in improving understanding of flooding, and verifying records. Sources such as the local press, local ‘flood action’ groups, CCTV data or fire & rescue can be especially useful when verifying predictions of historical flood incidents and enhancing the understanding of historical flooding locations
4	Strategic Flood Risk Assessment	Local Planning Authority	Report and mapping	Essential source of information if completed although it is widely recognised that many do not include adequate assessment of surface water flooding
4	Catchment Flood Management Plan	Environment Agency	Report and mapping	Useful document to guide the over-arching catchment flood management principles, although it is primarily concerned with fluvial and coastal flooding.
4	Existing incident management plans	Local Resilience Forums	Reports	Local Resilience Forums will have incident management plans which include planning for flood incidents. Many do not currently include an allowance for surface water flood risk
5	Development proposals	Local Planning Authority	GIS	These are required to understand how development could be influenced by, or influence flood risk

b.3 The table below illustrates some additional data or information which is not considered to be as critical, but nevertheless may be helpful as part of the SWMP study

Category	Data type	Source	Common format	Why it may be required
1	Borehole records	Environment Agency		Only needed if groundwater contributes to surface water flooding
2	Geological data	Environment Agency	GIS	Needed if an infiltration assessment is required to assess suitability for SUDS
2	Aerial photography	Any of the partners may hold this	Photos, GIS	Good for understanding land-use, potential locations for above ground storage, and visualising flood extents (historical and predicted)
3	DG5 register	Water and sewerage companies		The DG5 register indicates properties that have experienced ‘internal’ sewer flooding due to hydraulic incapacity. ‘External’ flooding locations are also recorded. Further investigation often reveals complex surface water interactions but extreme weather related sewer flooding is not included. Companies also maintain more general records of flooding incidents, often indicating assumed flood mechanisms
5	Drainage Area Plans	Water and sewerage companies	Reports and GIS	This information could be useful to assess performance of the foul and surface water drainage systems. New Sewerage Management Plans developed following updated SRM methods will provide information that is more consistent with the needs of a SWMP.
6	Water quality information	Environment Agency	Spreadsheet and GIS	Only required where water quality is being considered as part of a SWMP. The Environment Agency hold data on current river water quality and river classifications.
6	Continuous and intermittent discharges	Water and sewerage companies	GIS	To assess the impact of surface water runoff on receiving water quality information on discharges from urban drainage systems (combined or surface water) may be required. Only required where water quality is being considered as part of the SWMP

Annex C – Technical Note: Selecting a modelling approach

Introduction

c.1 This guidance note provides a technical review of available methods and tools to undertake surface water flood modelling. It highlights the different approaches available and provides the pros and cons of different modelling tools, and it outlines some of the key technical issues associated with surface water flood modelling[3]. In this Guidance we do not reference specific software but describe the main features of a range of generic approaches and then compare advantages and disadvantages of each. A simple decision making aid is described to help choose an approach with knowledge of strengths and weaknesses. It is recognised that technology in this area is improving rapidly and that we do not present an exhaustive list of currently available methods.

c.2 Further technical information and guidance on modelling approaches for integrated urban drainage and surface water management can be found at:

- Making Space for Water, Risk Mapping: flooding from other sources, available at: www.defra.gov.uk/environ/fcd/policy/strategy/ha4a.htm
- Evaluation of modelling approaches for urban flood risk assessment. Evidence submitted to the Pitt Review, available at http://archive.cabinetoffice.gov.uk/pittreview/thepittreview/evidence.html
- WaPUG integrated urban drainage modelling guide, available at: http://www.ciwem.org/groups/wapug/WaPUG_IUD_Modelling_Guide_Draft_Rev1_v28_(June_09)_v01-001.pdf%20
- WaPUG User Note No. 40, Coupled 1D-2D modelling in Urban Areas, (soon to be) available at http://www.ciwem.org/groups/wapug/full_list_usernotes.asp
- Allitt, RA, *et al.,* (2008). 2D Modelling – The First Steps, available at: http://www.ciwem.org/groups/wapug/Spr08_Paper4_Allitt.pdf

c.3 Due to the multiple flood mechanisms and relative short durations of surface water flood events, good historical flood incident data is often sparse. Modelling of surface water flood risk is therefore useful to:

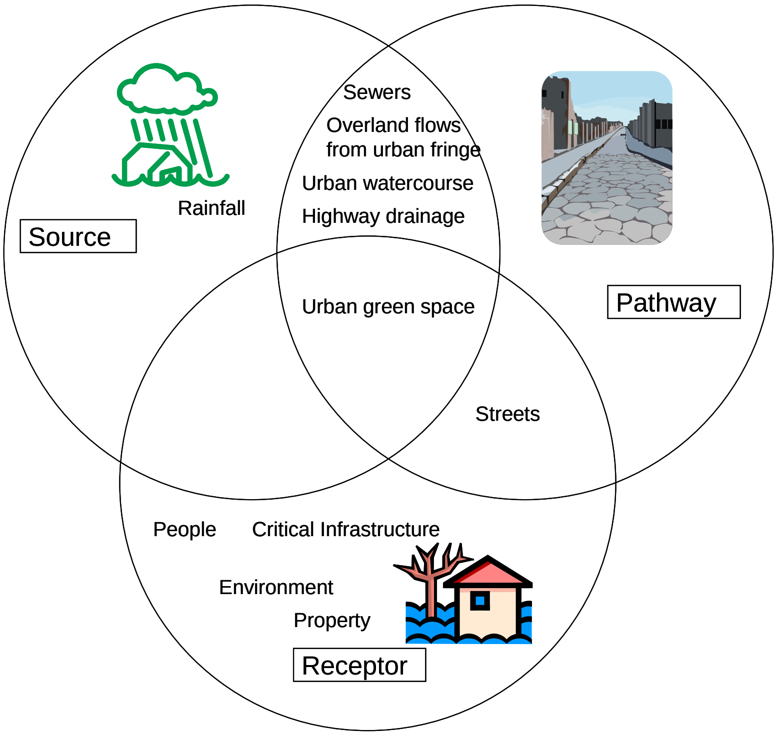
- understand the causes and probability of surface water flooding, both now and in the future;
- estimate the consequences of surface water flooding;
- test mitigation measures to reduce surface water flood risk;

[3] This includes representation of runoff, the use of terrain data, uncertainty analysis and representation of features of the urban environments. A detailed model calibration and verification note is also available.

- inform flood warning and incident management;
- inform spatial planning by identifying the locations at greatest risk of surface water flooding, and;
- prepare flood risk and flood hazard maps in areas of significant risk (to fulfil regulation 20 and 21 of the Flood Risk Regulations (2009)).

c.4 There are a variety of tools and approaches available to model surface water flooding, which are applicable at different spatial scales and can represent different flood mechanisms.

c.5 When considering the most applicable approach to model surface water flooding, it is useful to consider the source-pathway-receptor (SPR) model. In surface water management the SPR model is complex to apply since sources of flooding may also be pathways depending on the level of the detail considered. Sewers can be a source of flooding (e.g. through flooding from manholes) but also pathways (e.g. by transferring surface water to the receptor). Green space can be the source of runoff, a pathway and a receptor. Hence, when selecting a modelling approach it is important to have some understanding of the key surface water flooding mechanisms at work and the likely role different infrastructure might have in flood alleviation. The intermediate assessment should provide sufficient information to identify key flooding mechanisms.



Review of modelling tools

c.6 The technical note outlines four principal approaches to modelling surface water flood risk. Within each approach there are sub-approaches which are discussed in greater detail in the following sections.

1. **Rolling Ball** – surface water flow routes are identified by topographical analysis, most commonly in a GIS package.
2. **Direct rainfall –** rainfall is applied directly to a surface and is routed overland to predict surface water flooding.
3. **Drainage systems –** based around models of the underground drainage systems.
4. **Integrated approach** – representing both direct rainfall and drainage systems in an integrated manner, or linking different models together dynamically.

	1- Rolling Ball	2- Direct Rainfall	3- Drainage systems					4 - Integrated approach	
			3a	3b	3c	3d	3e	4a	4b
Spatial scale									
Coarse scale assessment	✓✓✓	✓✓✓	✓	✓	✓	✓	✓	x	x
Detailed appraisal	x	✓	✓	✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓
Representation of flood mechanisms									
Pluvial	✓	✓✓✓	x	x	x	x	x	✓	✓✓✓
Sewer (foul/surface/combined)	x	x	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Watercourse/Culverts	x	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓
Interaction between drainage systems	x	x	✓	✓	✓✓	✓	✓✓✓	✓✓✓	✓✓✓
Assessment of surface water flood risk									
Identify areas at risk from SW flooding	✓	✓✓	✓	✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓
Assessment of damages from SW flooding	✓	✓✓✓	✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Assessment of mitigation measures									
Above-ground mitigation	x	✓✓✓	x	x	✓✓	✓	✓✓	✓✓	✓✓✓
Below-ground mitigation	x	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓
Miscellaneous									
Costs to apply	£	££	£	£££	££	££	£££	£££	£££
Timescales	✓✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓	✓
Ease of application	✓✓✓	✓✓	✓✓	✓	✓	✓✓	✓✓	✓	✓✓
Data requirements*	✓✓✓	✓✓	✓✓	✓	✓	✓	✓✓	✓	✓

* Lower data requirements score higher (i.e. less data is needed to undertake this approach)
£ - £££ = Less expensive – More expensive
✓ – ✓✓✓= Poor - Good

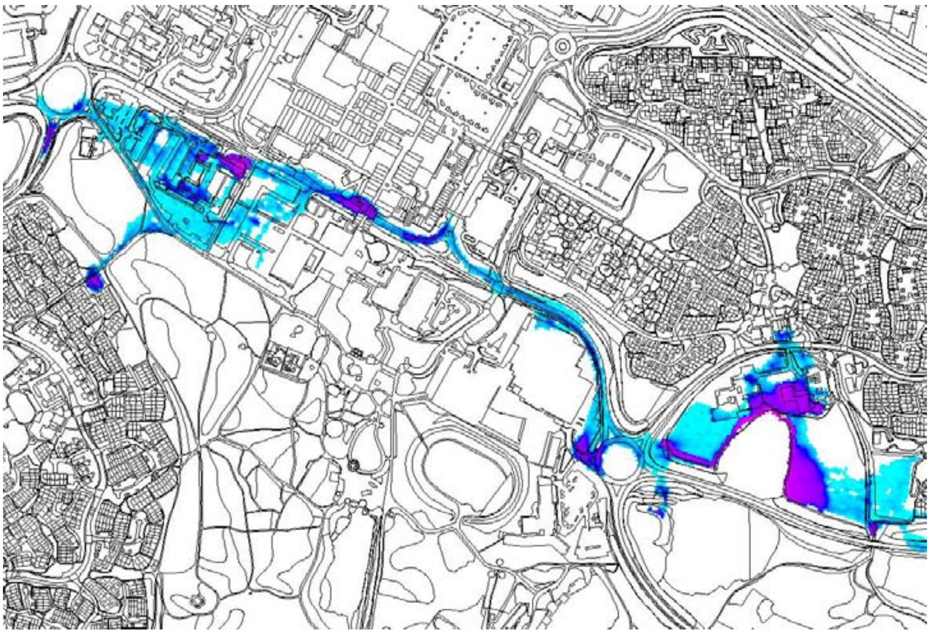
Method 1 - Rolling Ball

c.7 'Rolling-ball' methods (method 1) identify natural flow pathways determined by topography only. The analysis is completed within GIS software and uses terrain data from digital terrain models (DTM). The rolling ball method can be used in conjunction with tools predicting point sources of flooding (e.g. from sewers) to identify likely pathways and receptors. This information can be used to conceptually model 1D channels on the surfaces representing the flow pathway.

Method 2 – Direct Rainfall

c.8 'Direct rainfall' methods (method 2) apply rainfall events (of known probability) directly to models built using DEM/DTM data. Runoff volumes are computed and routed across the surface identifying pathways and areas where ponding and flooding would occur in low points. This routing can be done using a range of methods from full hydrodynamic modelling, to Manning's equation cellular approaches, to simplified methods.

c.9 In its simplest form no allowance is made for hydrological losses or the presence of underground drainage capacity. More sophisticated approaches vary hydrological losses by land-use type and 'remove' rainfall depth (in the range from 12-16 mm/hr) to account for flow removed by drainage systems. An alternative approach is to assume a uniform design standard for drainage (10-30 year standard of protection depending on understanding of performance of drainage system) and subtract the equivalent rainfall profile prior to simulating larger events. If information is known about spatially varying capacities of drainage in the study areas this information can be included as well. Outputs of the direct rainfall method provide estimates of the area and depth of surface water flooding.



Method 3 – Drainage systems

c.10 ‘Drainage system’ methods (method 3) are based around models of the underground drainage network. Rainfall inputs are applied to surface sub-catchments (with varying losses) and surface runoff is usually routed directly underground. When local hydraulic capacity is exceeded, pipes surcharge and flooding is generated at the surface. Flood waters can be allowed to return to the sewer system once capacity is available or else ‘lost’ from the system. Boundary conditions which affect drainage capacity (e.g. water level at outfalls) can be included as constant or time varying values.

Box 1 Use of existing drainage models for SWMP

Evidence from the IUD pilot studies has highlighted the difficulties of using existing drainage models for assessing surface water flooding. In the Brent North study the existing drainage model had a limited representation of the surface water sewers, which was required in the modelling to allow an integrated approach to assessing surface water flood risk.

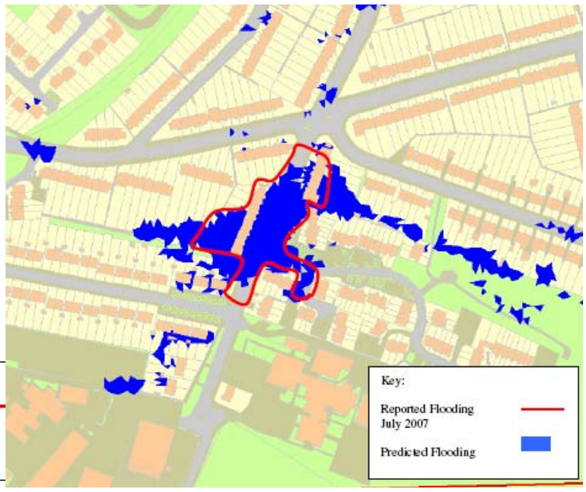
For more information the Brent North final report can be viewed at:
http://www.defra.gov.uk/environ/fcd/policy/strategy/ha2brent.htm

The River Aire ‘IUD pilot’ identified that drainage models built for assessing Unsatisfactory Intermittent Discharges (UID) will require “additional detail or completely rebuilding for use in detailed flood risk assessments, including the modelling of surface water sewers and other surface water drainage systems.”

The level to which existing models need to be updated to be appropriate for an integrated flood risk assessment will form part of the decision-making criteria.

c.11 Drainage system methods vary in complexity and hybrid approaches can be used where necessary:

- 3a - Users can choose to ‘store’ flood water in a virtual above-ground structure which can be dimensioned to provide an approximation of flood depth as well as volume.
- 3b - Internal flooding of properties (through direct connections to the drainage system) can be modelled by adding the detail of individual lateral sewer connections to each property.
- 3c - Where surface flood waters are known to flow away from the flooded manhole, 1d flow channels can be modelled on the surface diverting flows to remote storage areas and/or to other inlets to the underground system.
- 3d - Alternatively, flood hydrographs can be added, post simulation, to DTM or DEM flow models (as method 2) that route drainage exceedance flows through streets or in and around buildings. This is also known as an ‘uncoupled’ approach.
- 3e - An advancement on method 3d is to use a fully ‘coupled’ 1d (underground) and 2d (above ground) model which permits surface water flow across the modelled urban surface and re-enter the sewer network where this is an inlet and underground capacity.



Method 4 – Fully integrated

c.12 'Fully integrated' methods (method 4) are less well established but are the focus of current software development efforts and will become more available and commonplace in the near future. Two different techniques can be useful for surface water management assessments:

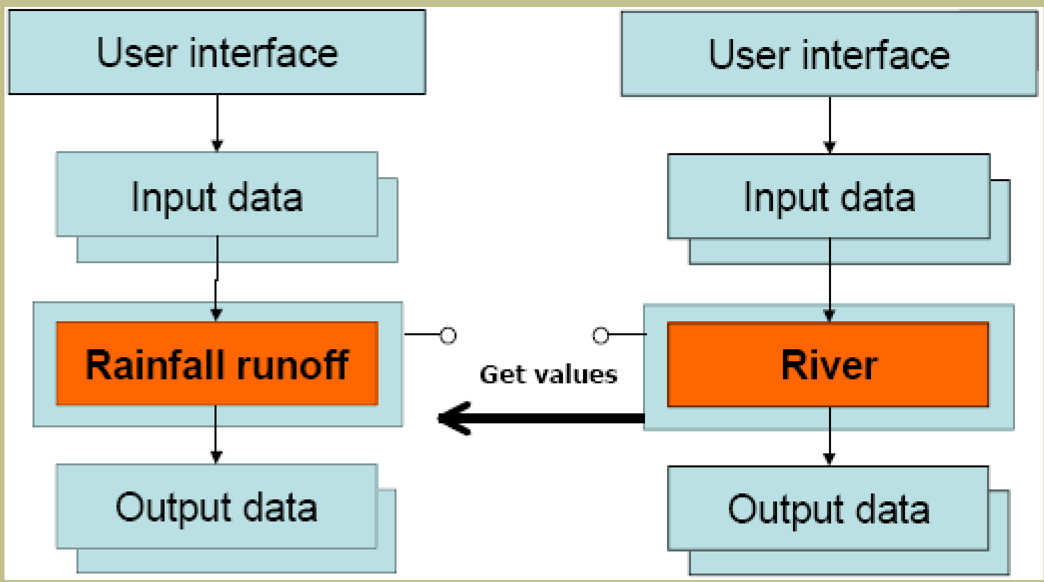
- 4a - Where surface and sewer systems interact with open or culverted watercourses an integrated urban drainage/river model method can be used. It can be used to more accurately predict flood risk from the fluvial system and/or the drainage system should its operation be influenced by flows in the river. Components of both systems can be represented in a single software tool or native systems can be retained but dynamically linked using simulation 'shells' such as OpenMI[4].

- 4b - Traditional drainage approaches (method 3) normally route urban runoff directly to a manhole. Enhancements in recent software capability mean that it is possible to directly apply rainfall onto a 2D surface. This generates runoff from the urban surface which is then intercepted by the gullies and manholes, thereby allowing a certain proportion of runoff to enter the drainage network. Likewise, when the drainage system is at capacity exceedance flows can be modelled over the 2D surface. In this modelling approach, both pluvial and exceedance flooding can be modelled. This is an enhancement on method 3, which can only represent exceedance flooding because in method 3 all runoff is assumed to directly enter the drainage network.

[4] For more information go to http://www.openmi.org/

Box 2 OpenMI

OpenMI is a tool used to dynamically link different software during simulations to allow the exchange of data between different software. Thus different components of the drainage system (e.g. sewer and river) can be represented in their native software systems and linked during a simulation to provide a combined system but in different software packages. An example of the OpenMI concept is illustrated in the figure below More information on OpenMI is available at http://www.openmi.org/reloaded/



c.13 Ultimately, methods which combine 4a and 4b will be technically feasible and able to represent in detail each part of the surface water systems and its interactions. However, such approaches will remain expensive to apply over large areas and require high certainty input data.

Selecting an approach to surface water modelling

c.14 Choosing a method (or range of methods) is a difficult process and somewhat iterative. Choice will depend on the presence of existing tools, available funds, and an understanding of existing flood risks and likely plausible mitigation measures. There is no substitute for good judgement, pragmatism and experience when choosing an approach. It is also worth noting that increasing the level of model detail does not necessarily correlate to improved surface water management mitigation measures. In some cases robust mitigation measures can be adequately assessed using simple models that are cheaper and relatively quick to apply. For example, to assess exceedance flow pathways to inform incident management plans, it may be possible to use a 'rolling ball' approach.

c.15 A flexible attitude to approach selection is required. If uncertainties in risk assessment or options appraisal are high, a more detailed approach could be adopted to improve the robustness of decisions at a later stage. It is important to record the provenance of data and models that use them as this will inform how to interpret model results (refer to chapter 2 for guidance on recording the provenance of data). Good use can be made of existing models but users must be aware of their limitations.

c.16 The level of complexity chosen for the modelling assessment will impact the outputs from the risk assessment and the likely mitigation measures to be tested. For example, if a direct rainfall method is selected it will be difficult to represent potential upgrades to the drainage network in the model, and this should form part of the decision-making criteria.

c.17 When choosing an approach, the following questions could be considered by experienced modellers and analysts:

- Is there currently sufficient data or tools to carry out the approach? Can these data or tools be acquired and at what cost?
- Does the approach represent the perceived flooding mechanisms?
- Does the approach allow damages to be calculated in the required detail?
- Does the approach allow likely mitigation measures to be tested?
- Can the approach be applied at the spatial scale required?
- Does the approach favour analysis of low or high probability events? Which is most important for the modelling assessment?
- Does the approach support the consideration of future risk (climate change, creep, and population growth)?
- Does the approach support representations of key interactions within urban drainage systems?
- Is the approach compatible with cost and programme constraints for the modelling assessment?

Method	Advantages	Disadvantages
1 ‘Rolling ball’	• Low cost and quick to apply over large areas (e.g. whole city). Useful as a screening tool prior to more detailed analysis • Process can be used to automate identification and creation of 1d flow paths for drainage model method • No rainfall input required. • Pathways will be common for all sources of flooding. • Useful if source (e.g. sewer flooding) is known • Best in areas with well defined terrain • Indicates possible ‘at risk’ areas if flood source can be pinpointed.	• Only indicates areas that might flood. • Does not represent interactions within surface water system • Not rainfall driven and does not support risk-based analysis • Poor in flat terrain areas • Cannot be used to test mitigation measures • Cannot distinguish between current and future risk
2. Direct rainfall	• Low cost and quick to apply over large areas (e.g. whole city). Excellent as a screening tool prior to more detailed analysis • Good for high magnitude, low probability storms where role of underground drainage system is minor. • Best in areas with well defined terrain • Rainfall driven and hence supports risk-based approach • Space varying hydrological losses can be applied • Underground drainage capacity influence can be crudely represented. • Flood extents and data can be used to map flood risk and hazard and calculate damages • Can be used to test above ground mitigation measures (e.g. flow exceedance pathways) but detailed DTMs or DEMs are required.	• Poor for low magnitude, high probability storms where role of underground drainage system is important. • Depends on quality of DTM. DTM requires ground-truthing for false obstacles. • Cannot be used to test below-ground mitigation measures with any certainty • Poor in flat terrain areas where method over-predicts flooding.
3. Drainage system methods	In general: • Makes use of existing investment in water company drainage models • The effect of sewer improvement and source control mitigation measures can be quantified.	In general: • Relies on availability of models of public sewer and other drainage networks • Existing models may need upgrading • Ignores pluvial flooding processes

Method	**Advantages**	**Disadvantages**
3a	• Very rapid, large area assessments possible.	• Difficult to associate flood volume with property damage • Difficult to verify models against sewer flooding records.
3b	• Rapid, large area assessments possible. Improves prediction of internal property flooding	• Can be costly and time-consuming to construct models but process can be successfully automated.
3c	• Rapid, large area assessments still possible. Approach can be applied selectively. • Dissociates source and receptor by modelling pathway. • Improves prediction of surface flooding location	• Linking flows and flood depth to damages requires many simplifying assumptions • Flow pathways must be pre-determined (though this can be automated).
3d	• Rapid, large area assessments still possible. Approach can be applied selectively. • Further improves prediction of surface water flooding. Flood extents and data can be used to map flood risk and hazard and calculate damages	• Links back to underground system are not included which introduces error, especially for high frequency events. • Depends on quality of DTM. DTM requires ground-truthing for false obstacles and important flow-directing features (e.g. walls, buildings etc.)
3e	• Further improves prediction of surface water flooding. Flood extents and data can be used to map flood risk and hazard and calculate damages	• Large area assessments are slow. Approach must be applied selectively in areas of high risk and consequence. • Depends on quality of DTM. DTM requires ground-truthing for false obstacles and important flow-directing features (e.g. walls, buildings etc.) • Representation of road gullies must be simplified or else becomes over-demanding.
4. Fully integrated methods	• Promise of the most accurate representation of the interaction between different components of the surface water / urban drainage system • Enables key interactions to be represented dynamically • Enables testing of full suite of possible mitigation measures – source control, drainage capacity and exceedance flow routing.	• Demanding in cost and time to apply. Application must be highly selective • Representing components of the system in non-native tools (e.g. rivers in a sewer model) forces compromises. • Dynamic linking of native tools (e.g. OpenMI) still in infancy, requiring further development

Key issues in surface water modelling

c.18 Surface water flooding is complex due to multiple sources, pathways and receptors of flooding. This section seeks to identify some of the key issues which are common when modelling surface water flood risk. Key issues discussed in the subsequent sections are:

- representation of features of the urban environment (e.g. buildings);
- representation of runoff from the urban environment;
- terrain data, including LiDAR, SAR and ground surveys, and;
- uncertainty analysis.

Representation of features of the urban environment

c.19 Standard damage calculators tend to use the centre-point of properties to identify and calculate damage to properties (i.e. National Property Dataset). Historically, fluvial and coastal flood risk modelling has often used a filtered Digital Terrain Model ('bare earth' ground model) to route flood water over the surface. In urban environments, buildings, kerbs and other features (e.g. walls, speed bumps) are critical to determining overland flow pathways and need to be considered as part of the modelling approach. This requires GIS layers of the roads, kerbs and buildings. Knowledge should also be supplemented by site visits. Buildings can be represented as:

- voids (solids blocks) – a void in the 2D domain and water will flow around it;
- porous walls – a proportion of water will seep through the building, and;
- high roughness zones – water will enter and travel through buildings very slowly.

c.20 The representation of buildings is critical to damage calculations. Many damage calculations use the predicted depth at the property centre-point to calculate damage. If buildings are represented the centre of the building will not be 'wet' during the simulation; therefore no damage will occur. However, post-processing of the results can be undertaken in GIS to interpolate a water depth at the property centre-point. If buildings are represented as porous walls of high roughness zones then sensitivity testing should be undertaken to assess the sensitivity of assumptions made with regards to water entering the property.

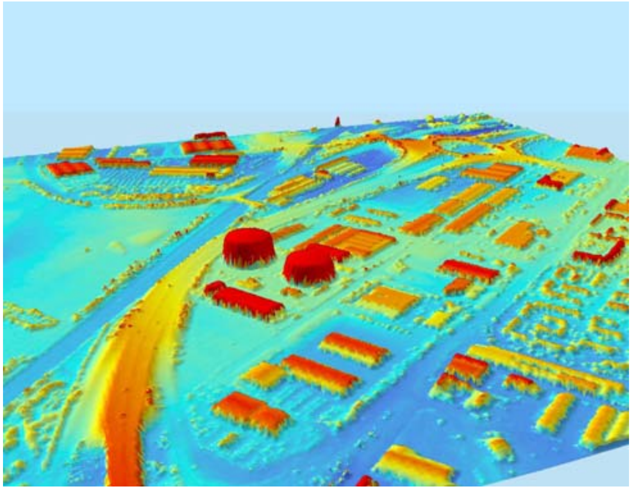
Representation of runoff

c.21 Runoff in the urban environment occurs from a number of sources including pluvial runoff within the urban area, direct connections to surface water or combined sewers (e.g. from roofs), or overland flows from the urban/rural fringe. The majority of modelling approaches are unable to appropriately represent all sources of runoff, which causes uncertainty in the representation of flood risk. Traditional drainage modelling (approach 3a-3e) assumes all runoff is routed directly to the underground system via manholes, whilst direct runoff approaches (approach 2) assume all runoff is from pluvial runoff or overland flow.

c.22 Modelling approaches which appropriately represent all sources of runoff (approach 4b) are still under development, and are generally expensive and time consuming to apply. Therefore, in the short-term it is likely that some trade off will be required, and modelling judgement will be necessary to understand the significance of assumptions made with regard to runoff in the urban environment.

Terrain data

c.23 The majority of approaches to assessing surface water flood risk require the use of a ground model, in the form of a DTM or DEM. These are data models of the ground surface showing the topography that determines flow pathways. The best models are derived from LiDAR (Light detection and ranging) remote sensing data and can be purchased from a range of commercial suppliers who apply filtering algorithms to exclude fixed or temporary objects. Data acquired on a 2m grid which is typical to rural areas is not sufficiently accurate for urban areas, and a spatial resolution of at least 1m is recommended.



c.24 This is because in order to replicate overland flow pathways in urban areas a vertical accuracy of ±50mm to ±150mm is required, which can only be achieved by LiDAR with 1m or sub-metre spatial resolution LiDAR require ground truthing to test for false obstacles (e.g. elevated structures like bridges) and shiny surfaces (e.g. water) where the DEM can be unreliable. For surface water flood risk modelling three principal ground models are applicable:

1. Digital elevation model (DEM) - unfiltered. This includes all permanent objects on the ground including buildings but can be processed to exclude cars and vegetation. High resolution data of at least 2m are required to delineate flow routes between buildings and along roads. The data can be ‘noisy’ and buildings are poorly defined making it difficult to assess flood risk.

2. Digital terrain model (DTM) - filtered. This is filtered to only represent the natural topography of the ground and excludes buildings. A high resolution is not necessary but it lacks precision for detailed investigations within urban areas.

3. DTM with buildings/roads added. This is filtered data processed to include buildings and roads the outline of which as been extracted from detailed mapping information. Roads can be ‘depressed’ into the surface and buildings can be either included as very high objects (essentially removed from the DTM) or as zones with high roughness. The effect is to purposefully route water along roads and around buildings.

c.25 The computational speed of 2D overland flow models is greatly influenced by the size of the elements within the 2D simulation mesh, and other software features to represent obstacles, voids and breaks in topography. Mesh size will depend upon the specific project requirements and will vary depending upon the topography with steeper slopes typically requiring smaller mesh sizes. It is recommended that a model contain a series of different mesh sizes with the smallest being in high risk flood areas, which may require an iterative approach.

Terrain model type	Advantages	Disadvantages	Best for
1 Digital Elevation model (unfiltered)	Includes buildings, roads and key flow pathways	Interpolation between low and high points creates 'slopes' not vertical structures. It's uncertain whether a property is flooded to a certain depth High likelihood of false obstacles High resolution makes computation of flows in 2d models very slow for large areas. Difficult to apply runoff models across whole surface – can generate instabilities.	Local examination of where drainage flooding exceedance flows travel. Flow data can be applied at a point or as part of a coupled underground – overground model.
2 Digital Terrain Model (filtered)	Lower resolution (~ 4m) speeds simulation when used in 2d models. In 2d flow models results are compatible with automated damage calculation tools (e.g. MDSF)	When used in 2d models, flow is not influenced by roads, buildings etc.	Direct rainfall methods to Identify high risk areas at a broad scale. Direct rainfall methods to identify flow pathways across potential development land

Terrain model type	Advantages	Disadvantages	Best for
3 Digital Terrain Model (building/roads added)	Lower resolution DTM can be used Runoff from buildings and roads can be included with suitable hydrology in direct rainfall methods. In 2d flow models flooded properties can be counted and flood damages calculated. If buildings are modelled as high roughness areas or with porous walls, results are compatible with automated damage calculation tools (e.g. MDSF)	Computational grid still needs to be small to delineate buildings and roads – hence simulation speeds in 2d models are still slow. If buildings are modelled removed from the computational grid results are incompatible with automated damage calculation tools (e.g. MDSF)	Direct rainfall methods at the urban scale. In drainage system methods where flow data can be applied at a point or as part of a coupled underground – overground model.

Uncertainty analysis

c.26 Surface water flood modelling is currently an uncertain science; this is due to the complex nature of surface water flooding (i.e. multiple sources and pathways), often incomplete records of surface water drainage (i.e. culverted watercourses, or surface water sewers), and a lack of historical flood incident records. In order to make identify and appraise mitigation measures it is vital that an allowance is made for the inherent uncertainty which will allow robust decisions to be taken.

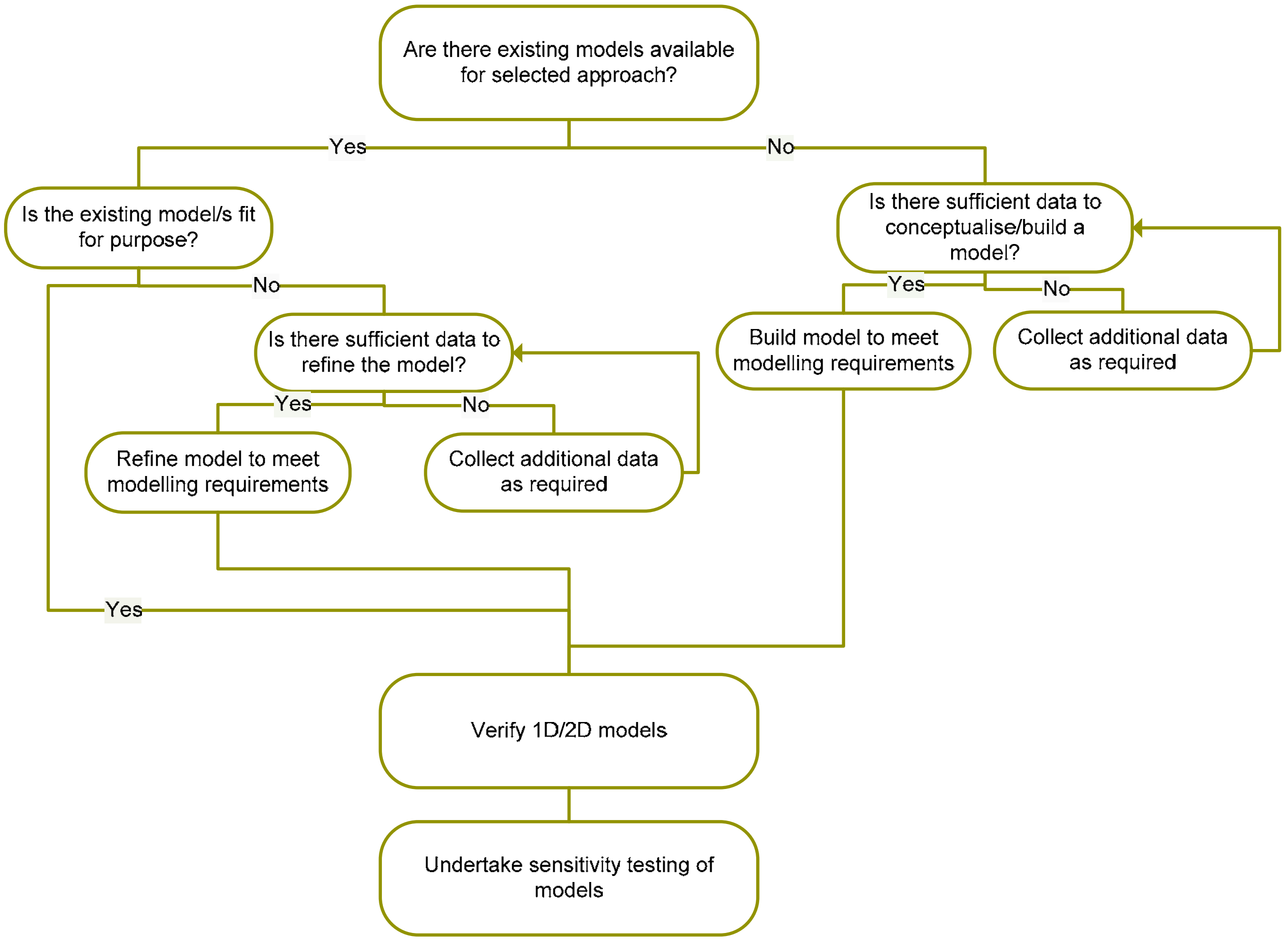
c.27 It is recommended that the provenance of input data is recorded at an early stage of any project so that any uncertainty or perceived weakness is understood and available for consideration during a risk assessment and identification and appraisal of mitigation measures. A data quality score, as outlined below, is a method for recording the provenance of data.

c.28 The quality of decision-making for mitigation measures will be affected by uncertainty in data, models and the approach chosen. Where a decision is dependant on uncertain information further data improvement can be justified and sensitivity analysis of the modelling should be undertaken (especially for “calibration” parameters). If further uncertainty analysis is required probabilistic approaches (e.g. Monte Carlo methods) are available to understand the effects of uncertainty on decision making.

Data Quality Score	Description	Explanations	Example
1	Best of breed	No better available; not possible to improve in the near future	High resolution LiDAR River/sewer flow data Raingauge data
2	Data with known deficiencies	Best replaced as soon as new data are available	Typical sewer or river model that is a few years old
3	Gross assumptions	Not invented but based on experience and judgement	Location, extent and depth of much surface water flooding Operation of un-modelled highway drainage ‘future risk’ inputs e.g. rainfall, population
4	Heroic assumptions	An educated guess	Ground roughness for 2d models

Annex D – Technical Note: Developing a modelling approach

Develop modelling approach



d.1 The framework outlined above indicates the process which should be followed to develop the modelling approach. The first step is to identify what existing models are available within the study area. For example:

- sewer models – typically existing sewer models developed by water and sewerage companies were not built to assess surface water flood risk, and may only include representation of foul or combined sewers;
- fluvial / tidal models – the Environment Agency have invested heavily in modelling of main rivers and tidal conditions to assess fluvial or tidal risk, and these models can be integrated with drainage models if required;
- ordinary watercourse models – existing models of ordinary watercourses are less common although some existing models may exist within local authorities or the Environment Agency, and;

- ground elevation models – all partners may have access to ground models, which are critical to assess overland flow routes.

d.2 Where possible, best use of existing models should be made, and a thorough review of what is currently available is recommended as the starting point of analysis.

d.3 If existing models do exist the key question to be addressed is whether the model/s is/are considered to be 'fit for purpose'; that is whether the model can be used to help make robust (i.e. reliable and accurate) decisions. Existing models generally only represent one component of the drainage system (e.g. sewers *or* rivers) and there may be a requirement to integrate these models as part of the SWMP study. In such cases, the existing models and possibly input data will need to be refined, integrated and re-verified to ensure the outputs are representative of reality.

d.4 If the existing model or models are considered to be fit for purpose then it is possible to move directly to verifying and calibrating the model against historical flood incident data. However, for early SWMP studies many existing models will need to be refined in order to be 'fit for purpose'. Examples of where existing models need to be refined in order to be 'fit for purpose' for assessing surface water flood risk includes:

- integrating sewer, fluvial/tidal and ordinary watercourse models;
- representing ordinary watercourses or culverts in the model;
- improving representation of surface water sewers, which are infrequently modelled in the majority of existing sewer models;
- including an overland flow component as part of the model;
- representing additional flows to the urban area from the rural/urban fringe (e.g. rural runoff), and;
- updating models to reflect recent schemes which have been put in place.

d.5 Where there are not sufficient data available to refine the model, additional data collection may be necessary through further site visits or CCTV surveys, for example. The data collection process should be highly targeted to ensure that any additional data collected will add value and information to the modelling process; for example by targeting data collection in the areas of perceived greatest risk or greatest uncertainty.

Box 3 Targeted data improvement programme to support modelling

In the Gloucestershire FESWMP, the second stage of the modelling assessment was to undertake pluvial and sewer modelling, for Cheltenham, Gloucester, Stroud, and Tewkesbury, which could be used to inform spatial and emergency planning. During the first modelling stage it was recognised the presence of culverts had a significant impact on flood risk. Therefore, a targeted data collection programme was instigated to survey all culverts for which data did not exist. These data were subsequently included in the models.

d.6 In some SWMP studies, no existing models may be available to develop the selected modelling approach. In such circumstances new models will need to be developed, and the first step is to identify whether sufficient data exists to conceptualise the required model. If sufficient data is not available, a targeted data collection programme should be carried out to gather the required data to conceptualise the model.

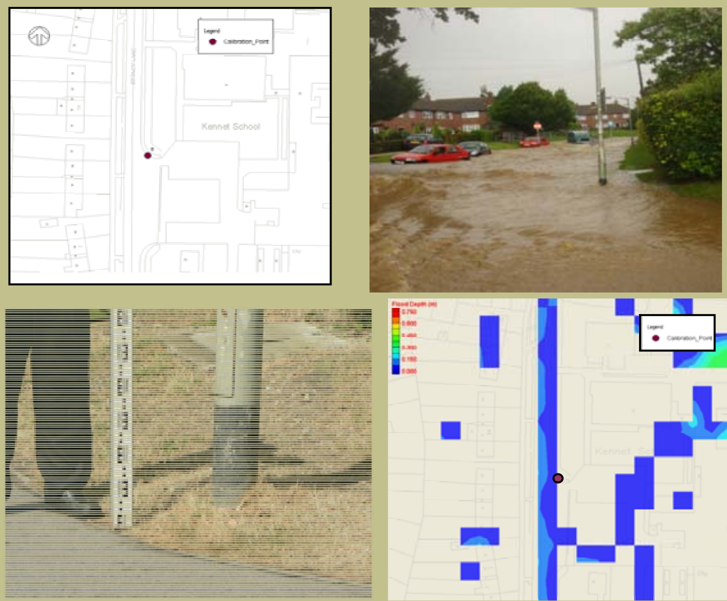
d.7 When the model has been conceptualised and built, it needs to be verified to give confidence in model predictions. Verifying and validating a model is a difficult and somewhat iterative process, often due to the lack of anecdotal information to compare model predictions against. Observations of flooding data will frequently be anecdotal, incomplete and inaccurate. In models which represent the 1D system (i.e. sewers or rivers) verification is frequently carried out by installing flow or level monitors at various locations in the system and capturing flows, levels and velocities for three of more rainfall events. This approach will give confidence that flows in the drainage system are appropriate, but it is likely that only high probability rainfall events will be captured by the monitoring.

d.8 Importantly, for the modelling to be credible, it must be able to represent known flooding locations. This is typically done by running the model for one or more historical rainfall events for which there is anecdotal evidence[5], and comparing the predictions flood locations and depths with historic records. The performance of the model predictions against historic flood incident data should be formally recorded.

[5] Anecdotal evidence on flooding will be available from a range of sources, and broad sweep should be instigated to capture as much information as possible. Information from the local press, photos and videos from local residents, data from emergency services, should be sourced where possible, in addition to evidence from partners on flood incidents.

Box 4 Model verification

In July 2007 Thatcham suffered widespread flooding, and over 1,100 properties were affected. As part of the first edition SWMP study, a detailed modelling approach was adopted which represented flows in the underground drainage system, and subsequent overland flows. The model was run for the flood event in July 2007, using observed rainfall data to verify the flood locations and depths. The verification was based on calibration point locations, which are specific locations where the modellers could compare model outputs with historic records of the flooding. To further corroborate the historic records a series of topographical site surveys were undertaken to approximate flood depths at specific locations, which were directly used to compare predicted flood depths from the model.



This was carried out to provide confidence that the model could replicate historic flooding, and thus gave greater confidence in model results.

d.9 Where satisfactory verification is not possible with the modelling approach selected it is possible that key interactions or processes have not been included. A more detailed modelling approach should be considered to include, for example, dynamic sewer – river interactions or coupled surface – sewer interactions that allow flood water to return to sewers. Evidence provided to the Pitt Review[6] contrasted the verification level made possible by a range of different modelling approaches.

d.10 The final step in developing the modelling approach is to undertake sensitivity testing of model parameters. Model parameters with high uncertainty should be subject to sensitivity testing. Where model results are particularly sensitive to parameter uncertainty a targeted data improvement programme could be instigated.

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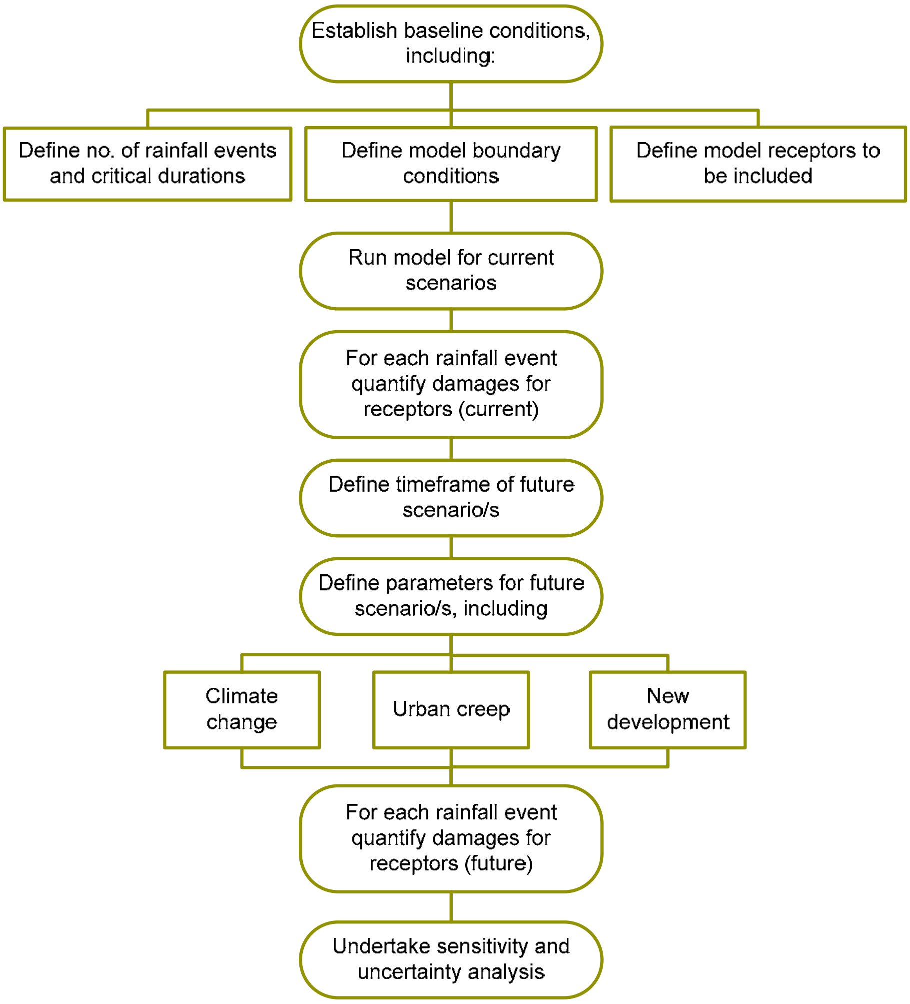
[6] Pitt Review (2008). Evaluation of Modelling Approaches for Urban Flood Risk Assessment, Report, Version 1, prepared for the Pitt Review. More information at http://archive.cabinetoffice.gov.uk/pittreview/thepittreview/evidence.html

Annex E – Technical Note: Quantifying current and future flood risk



Establish baseline conditions

e.1 Initially, the model boundary conditions and the receptors to be included in damage calculations should be defined.

e.2 A minimum of five rainfall events ranging from low to high probability should be simulated to provide a sound basis for calculating annualised damages. Methods which simply extrapolate annual damage from a single probability event should be avoided because this does not reflect the annual probability of a flood (and hence damage occurring).

e.3 The critical event duration should be identified for each flood probability; that is the event duration which gives the greatest total volume of flooding (i.e. worst case). Critical duration will vary depending on the physical properties of the whole surface water drainage system.

Box 5 Use of rainfall probability in SWMP

The guidance suggests that a consistent terminology is used to communicate the likelihood of flooding and the protection provided by drainage or flood defence infrastructure. For clarity, the probability of flooding should be expressed as a chance of flooding together with the probability, e.g. '*there is a 1 in 75 (1.3%) chance of flooding in any given year*' or '*the investment in new sewerage and other measures reduces the chance of flooding from 1 in 10 (10%) chance to 1 in 30 (3.3%) chance of flooding in any given year*'. Use of the term 'return period' should be avoided, as this can cause confusion with respect to when a flood incident is likely to occur again. The table provides some conversions across different methods for describing risk of flooding or the protection provided by infrastructure.

Chance of (flood) event occurring in any year	Annual probability of (flood) event occurring (%)	Return Period (years)
1 in 2	50	2
1 in 5	20	5
1 in 10	10	10
1 in 20	5	20
1 in 25	4	25
1 in 30	3.33	30
1 in 50	2	50
1 in 75	1.33	75
1 in 100	1	100
1 in 200	0.5	200

e.4 Depending on the modelling approach adopted consideration should be given to boundary conditions for the model simulations. These could include, for example:

- representation of upstream flow inputs;
- representation of downstream flow and levels, and;
- antecedent conditions.

e.5 The combined impact of different boundary conditions that may be totally independent or correlated in some way can influence flood predictions and should be considered as part of the modelling framework. Evidence of these interactions from knowledge of previous flood mechanisms will indicate this as an issue. Joint probability methods allow the calculation of the true probability of combined conditions that can result in flooding. An example in surface water management might be the joint probability of a 1 in 20 (5%) chance rainfall event occurring simultaneously with a 1 in 50 (2%) chance river level which disables free discharge of the drainage system to the river. In this case, the drainage system does not operate as intended and flooding occurs at a probability which is neither that of the rain event or the river level.

e.6 If joint probability analysis is required a Defra/Environment Agency R&D report[7] describing joint probability methods is an essential reference. The need for joint probability should only be considered after considering sensitivity within the models to different boundary conditions and only where it would assist robust decision making.

e.7 The receptors to be included in the damage assessment should be identified and agreed prior to undertaking any model simulations. Receptors include:

- property – including domestic and commercial property
- people – including health impacts of flooding and the risk to loss of life;
- environment – including damages to the environment due to flooding (e.g. pollution incidents and damage to environmental assets);
- critical infrastructure;
- disruption to services due to surface water flooding (e.g. traffic and businesses), and;
- emergency services costs.

e.8 Determining the receptors to include will vary from location to location depending on the nature of the flooding, but the damage assessment should include any receptors which could influence the risk assessment and subsequent cost-benefit analysis of mitigation measures.

Quantify current risk

e.9 The purpose of quantifying flood risk is to identify the annualised damages due to surface water flooding that are incurred by property (including critical infrastructure), people and the environment. The guidance provides a framework and outlines key principles for assessing such damages in a SWMP study.

Calculating damages to property

e.10 Outputs from model simulations can be used to assess damages to property. To calculate damages to properties model outputs should provide flood depths or volumes on the surface, which can be used to calculate damages on an annual basis

e.11 There are two principal methods discussed in this guidance which can be used to calculate flood damage to properties:

- infer a relationship between flood volumes and/or number of properties flooded and damage incurred, and;
- estimate depths of flooding at or within properties and apply a depth-damage relationship.

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[7] Defra and Environment Agency Flood and Coastal R&D Programme (2005. Use of Joint Probability Methods in Flood Management, A Guide to Best Practice, R&D Technical Report FD2308/TR2. More information at http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD2308_3429_TRP.pdf

e.12 The first approach applies an estimated relationship between volume of water on the surface or number of properties flooded and estimated damage to properties. As an example, if the estimated damage per property is £30,000 then total damages can be calculated by multiplying this by number of properties flooded for a range of event probabilities. Typically, this relationship can be calculated using data inferred from previous flooding incidents. The Hogsmill 'IUD pilot'[8] study estimated damages by relating the volume of flooding to the number of properties that might be impacted.

e.13 The second approach uses depth-damage curves. Depths are calculated at the property boundary or at the property centre-point and applied to give a depth-damage estimate based on property type, age and social class. This approach relies on representing depths of flooding, preferably spatially, and is considered to provide a better representation of damage to properties. Depth-damage curves are published by Defra in the 'Multi-Coloured Manual'[9]. The table summarises the two approaches.

Method	Requirements	Advantages	Disadvantages
Infer relationships between volumes / count of properties and damage	Flood volumes from a drainage system model OR Count of number of properties flooded Historical information relating extent of flooding at a location to property damage	Rapid and low cost Can use simpler drainage system methods	Inaccurate Relies on good data capture from previous flooding Data unlikely to differentiate damages by flood depth More difficult to differentiate between property type, age, and social groups Relies on source being close to receptor Cannot use with direct rainfall methods
Depth-damage calculations	Depths of flood estimated at property boundary or centre-point of property Depth-damage data	With fully integrated models can show impact of all sources of flooding on remote receptors Suitable for use with direct rainfall and drainage system methods Simpler to assess flood damage to different property types, ages, and social groups	Slower and more cost Modelling methods need to generate spatially distributed flood depths

[8] More information at http://www.defra.gov.uk/environ/fcd/policy/strategy/ha2hogs.htm
[9] Flood Hazard Research Centre (2005). The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques

e.14 Standard depth-damage curves, such as those used in the Multi-Coloured Manual take into account property age, type and social class of occupants in order to assess damages, but do not take into account Treasury Green Book[10] guidance on distributional impacts. Recent Defra guidance on adjusting economic appraisal to reflect socio-economic equity provides advice on how to factor in distributional impacts[11]. Where distributional impacts are to be included damages to property are weighted by a factor, which is highlighted in the table below. The guidance specifies that distributional impacts should be taken into account where:

- there is evidence of a bias in social class group at risk of flooding, and;
- the data and scale of the impact make it possible to consider social equity.

Social class	Description	Damage Weightings
AB	Upper middle and middle class: higher and intermediate managerial, administrative or professions.	0.74
C1	Lower middle class: supervisory or clerical and junior managerial, administrative or professional	1.21
C2	Skilled working class: skilled manual workers	1.22
DE	Working class and those at the lowest level of subsistence: semi-skilled and unskilled manual workers. Unemployed and those with no other earnings (e.g. state pensioners)	1.64

Calculating damages to people

e.15 Damages to property can be considered to be the tangible impacts of flooding. However, there are also intangible effects of flooding, which can form part of the overall damage assessment.

e.16 The impacts of flooding on householders include stress, health effects and the loss of possessions. There are two components to consider when discussing damages to health:

- stress-related impacts due to flooding, and;
- loss of life and injury.

[10] The Green Book, Appraisal and Evaluation in Central Government. More information at http://greenbook.treasury.gov.uk/

[11] Defra (2004). Flood and Coastal Defence Appraisal Guidance, FCDPAG3 Economic Appraisal, Supplementary Note to Operating Authorities, July 2004, available at http://www.defra.gov.uk/environment/flooding/documents/policy/guidance/fcdpag/fcd3update0704.pdf

e.17 Defra have produced guidance[12] on the incorporation of stress-related impacts for fluvial and coastal flood risk, and the principles can be applied to surface water management. This estimates a value of approximately £200 for flooding per year per household. The worked example in Annex E includes an assessment of health impacts of flooding.

e.18 If there is a perceived risk of loss of life or injury then it will be important to consider this as part of the damage calculation. Defra and Environment Agency research [13] shows how the risk of death or injury can be calculated through the analysis of data on the spatial extent, depth, speed of onset and velocity of flood water. Data is required about the types of building and the age and physical condition of people exposed to the flood. Velocity data can be extracted from 2d flow routing models. A worked example is provided by Defra in an update to the PAG, and is available at http://www.defra.gov.uk/environ/fcd/pubs/pagn/risktopeople.pdf.

Calculating damages to the environment

e.19 In some circumstances damages to environmental assets (e.g. heritage sites) will need to be monetised as part of the damage calculation. This should only be considered where environmental issues are likely to be significant in calculating damages and hence influence the cost-benefit analysis of options.

e.20 Surface water runoff from the urban environment can have a significant impact on receiving water quality. This can occur through: direct runoff entering rivers; surface water sewer outfalls; or through surface water entering combined sewer systems and leading to Combined Sewer Overflow (CSO) spills. Pollution in surface water runoff from the urban environment can represent an important barrier to meeting 'good' ecological status under the Water Framework Directive (WFD). Therefore, an assessment of the impact of surface water runoff on receiving water quality should be included as part of the risk assessment. It is not recommended that detailed water quality modelling be carried out as part of a SWMP study; rather the potential impact of surface water runoff should be considered as part of the risk assessment.

e.21 When taking an integrated view of flood management in urban drainage systems it is necessary to consider whether water quality improvements can be achieved at the same time. Engineering or non-structural interventions which provide dual benefits (with respect to flooding and water quality) provide greater value for money. Strategies to improve urban water quality can be included within River Basin Management Plans (RBMP) and developed using established approaches such as the Urban Pollution Management (UPM) procedure.

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[12] Defra (2004). Flood and Coastal Defence Appraisal Guidance, FCDPAG3 Economic Appraisal, Supplementary Note to Operating Authorities, July 2004, available at http://www.defra.gov.uk/environment/flooding/documents/policy/guidance/fcdpag/fcd3update0704.pdf

[13] Defra and Environment Agency Flood and Coastal R&D Programme (2006). Flood Risks to People, Phase 2, FD2321/TR2, Guidance Document, available at http://www.rpaltd.co.uk/documents/J429-RiskstoPeoplePh2-Guidance.pdf

Calculating damages to critical infrastructure, disruption to services and emergency services costs

e.22 Where critical infrastructure (e.g. hospitals, water treatment works, electricity sub-stations) is at risk from flooding this needs to be included in the risk assessment. The direct costs from the flood itself should be assessed, in combination with the indirect costs associated with the disruption causes by the flooding (e.g. cost of water treatment works being flooded and therefore being unable to supply water to homes). The cost of critical infrastructure being flooded is likely to be significant, and should therefore be included where the infrastructure is considered vulnerable to surface water flooding.

e.23 An indirect impact of flooding is the cost of disruption to services, in particular businesses and traffic. These can be included as part of the damage calculation, where they are likely to significantly affect the overall understanding of surface water flood risk (where risk is probability x consequence). The Multi-Coloured Manual provides guidance on when these costs should be included as part of damage calculations, and outlines the process to be followed.

e.24 The costs of emergency services responding to flooding incidents can also be incorporated to the damage calculations. The Multi-Coloured Manual outlines research undertaken following the autumn 2000 floods, which indicated that emergency costs were 10.7% of total economic property losses. This provides a justifiable multiplier in addition to property damages to account for emergency costs[14]. If more local information is available to support the inclusion of emergency costs this should be used in preference.

Quantify future risk

e.25 Examining future risk is important to understand how risk changes over time. The first step is to define the time horizon of the future scenario. How far into the future the risk assessment examines will depend on the planning horizon considered appropriate for the study. In any case the planning horizon should be far enough into the future to allow some analysis of creep, population growth and climate change. A planning horizon of 25 – 35 years is recommended. Where the SWMP study is planning new infrastructure to serve new development a design horizon of 100 years is recommended, in accordance with PPS25 Practice Guide. One timeframe (i.e. 30 years into the future) will probably be sufficient unless there is evidence of non-linear changes in the catchment over the time horizon.

e.26 Subsequently, the parameters to be included in the future scenario should be agreed, and could include urbanisation, urban creep and climate change. An allowance should be made for climate change as a minimum, and urbanisation and urban creep should only be included where it is considered to be an important driver for assessing future risks.

New development (including regeneration)

e.27 As part of the future scenario, proposed new development should be included, where relevant, to maximise the opportunities to reduce surface water flood risk through

[14] Flood Hazard Research Centre (2005). The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques

development or regeneration. The requirements to include new development as part of the detailed assessment should have been identified during the intermediate assessment. Principally, the detailed assessment can identify runoff requirements from the proposed development sites, to help reduce surface water flood risk within existing urban areas.

Box 6 Reducing existing surface water flood risk through development

A key component of the Leeds first edition SWMP was to assess how regeneration within East Leeds could be used as an opportunity to address existing surface water flooding through the development process. An extract from the Leeds report illustrates that surface water flood volumes could be reduced by up to 25% for the 10% probability (1 in 10 chance in any given year) rainfall event due to strategically planned drainage provision as part of major regeneration.

Sensitivity scenario	Flood volume (1 in 10 (10%) event), m^3	Percentage change from base	Comments
Base case	1,306	N/A	
Urban creep (10% of permeable areas paved)	1,973	51%	
EASEL growth (average densities)	982	-25%	Some areas experience increased flooding but overall reduction.
10% climate change uplift on rainfall	1,561	20%	
Free outfall to Wyke Beck	830	-36%	

e.28 There are significant opportunities to reduce existing surface water flooding in urban areas through development, and redevelopment/regeneration. In greenfield locations, the general principle is to limit runoff from the new development equivalent to existing runoff rates and volumes, taking into account the impact of climate change. In brownfield development, opportunities to reduce surface water runoff (and hence flooding), and redesign the urban landscape to make sufficient space for surface water should be maximised.

e.29 Currently key guidance on how to calculate gross storage requirements to achieve runoff and volume control from new development sites can be found in the Environment Agency/Defra publication 'Preliminary rainfall runoff management for developments' [15]. Local variations on this guidance are commonplace and a flexible approach is appropriate. SWMP partnerships should agree on local standards from the outset. The early engagement and agreement of Environment Agency development control staff is especially important.

[15] Defra and Environment Agency Flood and Coastal R&D Programme (2005). Preliminary rainfall runoff management for developments, R&D Technical Report, W5-074/A/TR/1, Revision D

e.30 SWMP can identify gross storage requirements (volume and type) over numerous development areas. This ensures a standardised approach has been applied and provides opportunities to under or over provide in certain areas so long as the net effect is as intended. It also removes uncertainty for developers when purchasing land without prior knowledge of the surface water storage needs.

e.31 The CPR 'IUD Pilot'[16] proposed a system where some strategic storage was provided as part of the area infrastructure by the regeneration agency. The remaining storage requirement was distributed over individual development sites but with less onerous requirements for attenuation of existing runoff (up to twice current runoff rates). The net effect of the whole scheme was to limit runoff to receiving waters to the satisfaction of the Environment Agency.

Urban creep

e.32 As defined in the River Aire 'IUD pilot' windfall developments are 'small, unallocated sites and additional houses built within the curtilages of large properties'. Urban creep 'includes extensions and the paving of gardens, some of which may fall outside the development control process.' The pilot study illustrated that in isolation windfall development and creep could be as important as climate change in terms of increasing surface water flood volumes because an increase in impermeable area increases both the volume and rate of surface water runoff which can cause overloading of drainage system or impact on river levels during a rainfall event. Urban creep can occur in several ways:

- windfall development;
- paving over of front or back gardens;
- development of green space, and;
- other impermeable areas such as car parks.

e.33 New planning changes from 1st October 2008[17] have removed permitted development rights for paving over front gardens with impermeable surfaces for areas >5m^2. The Government is also considering whether similar action can be applied to back gardens and commercial premises[18]. UKWIR have undertaken research in 2008/9 to develop a standard methodology for the prediction of urban creep; water and sewerage companies within the partnership can provide further information about this study.

Climate change

e.34 In any future scenario climate change should be factored into the analysis to allow for increases in rainfall intensity and depth and river flows. Existing Defra guidance (see Box 7) on indicative sensitivity ranges for peak rainfall and peak river flows should be used in climate change analysis. Standard practice in surface water and drainage modelling is

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[16] http://www.defra.gov.uk/environment/flooding/manage/surfacewater/urpilotkerr.htm
[17] For more information go to, http://www.planningportal.gov.uk/england/genpub/en/1115316438436.html
[18] Defra (2008). The Government's response to Sir Michael Pitt's Review of the Summer 2007 floods, more information at http://www.defra.gov.uk/environment/flooding/documents/risk/govtresptopitt.pdf

to increase the magnitude of each value in the design rainfall hyetograph by the Defra factors.

e.35 More localised and probabilistic climate change predictions are available from UK Climate Projections (UKCP09). UKWIR have undertaken research in 2008/9 to develop protocols for accommodating these predictions in drainage design; water and sewerage companies within the partnership can provide further information about this study

Box 7 Climate change rainfall indicative sensitivity ranges

Current Defra guidance provides rainfall indicative sensitivity ranges to be applied to the peak rainfall intensity to allow for climate change. In addition allowances can be made for peak river flows, if required. In the absence of any local information these should be applied to assess the impact of climate change.

<table>
<tr><th>Parameter</th><th>1990-2025</th><th>2025-2055</th><th>2055-2085</th><th>2085-2115</th></tr>
<tr><td>Peak rainfall intensity (preferably for small catchments)</td><td>+5%</td><td>+10%</td><td>+20%</td><td>+30%</td></tr>
<tr><td>Peak river flow (preferably for larger catchments)</td><td>+10%</td><td colspan="3">+20%</td></tr>
<tr><td>Offshore wind speed</td><td colspan="2">+5%</td><td>+10%</td><td>+10%</td></tr>
<tr><td>Extreme wave height</td><td colspan="2">+5%</td><td>+10%</td><td>+10%</td></tr>
</table>

For more information on this guidance click on the link:
http://www.defra.gov.uk/environment/flooding/documents/policy/guidance/fcdpag/fcd3climate.pdf

e.36 There are a number of factors which influence the number of model simulations required to quantify future risk, including:

- the number of rainfall events to be modelled – this should be the same as for the current scenario;
- the number of timeframes being considered – 1 future timeframe will be sufficient unless there is evidence of non-linear changes over time, and;
- iterations and combinations of future parameters – the future parameters can be run independently (i.e. climate change only), in combination (i.e. climate change plus creep), or both.

e.37 Determining the exact number of future model simulations should be influenced by the needs of the study, and sufficient simulations should be carried out to provide a robust assessment of how risks might change in the future.

e.38 Future risks are determined using the same models used to assess current risks but with parameters altered to accommodate new development, urban creep and climate change. Damages should be computed in the same fashion as for the current scenario.

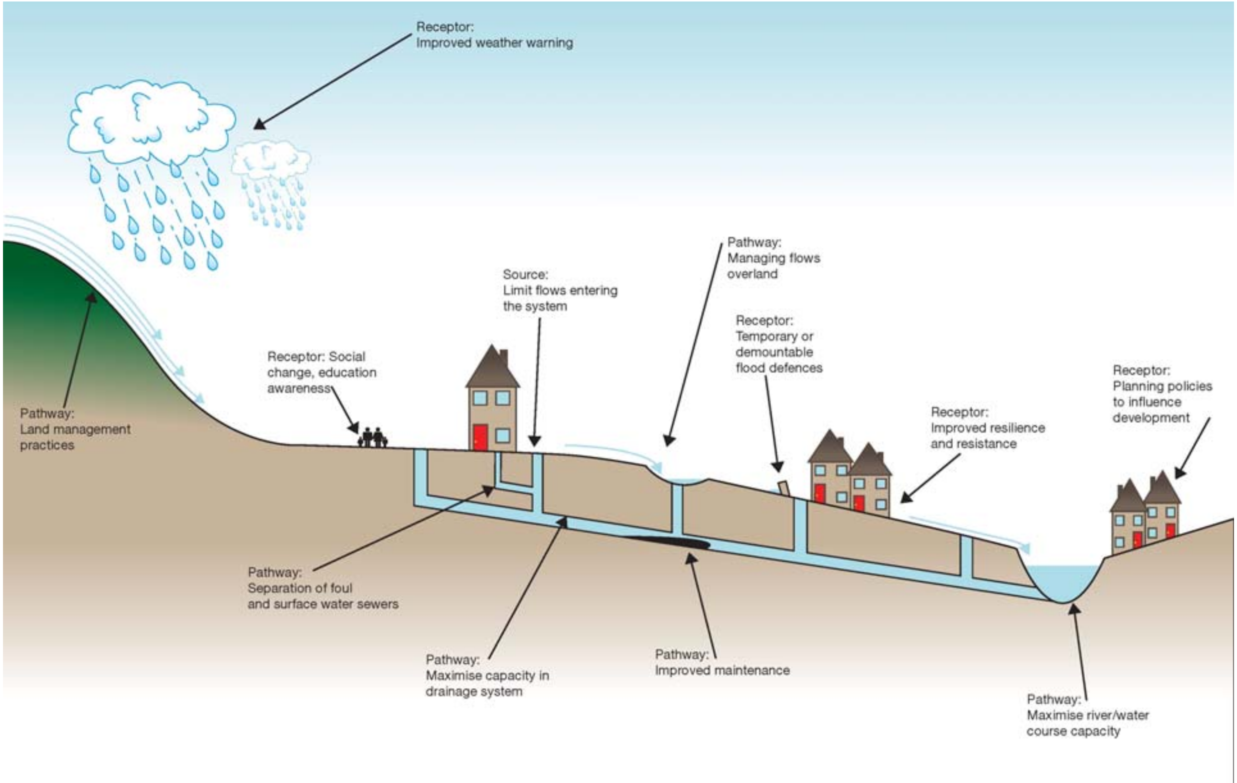
e.39 An assessment of the sensitivity of assumptions and uncertainty of model parameters should be undertaken as part of this step. This should be done to ensure that model results are robust and that an allowance is made for the uncertainty.

e.40 A calculation of annualised damages ought to be completed for two time horizons unless there is evidence of non-linear changes over time. Interpolation will be required between the current and future model runs to provide a year on year calculation of risk. Linear interpolation will be sufficient unless there is local evidence of non-linear changes over time.

Annex F – Measures to mitigate surface water flood risk

Introduction

f.1 This technical note outlines potential measures which can be considered to mitigate surface water flood risk. To identify potential measures it is useful to consider the source-pathway-receptor approach, and the technical note discusses measures based on this approach.



f.2 In the technical note both structural and non-structural measures are considered and discussed. Structural measures are considered to be measures which require fixed or permanent assets to mitigate flood risk. Non-structural responses are responses to urban flood risk that may not involve fixed or permanent facilities, and their positive contribution to the reduction of flood risk is most likely through a process of influencing behaviour. Behaviour can influence the probability of flooding and its consequences.

Mitigation measures - Source

f.3 Source control measures aim to reduce the rate and volume to surface water runoff through infiltration or storage, and hence reduce the impact on receiving drainage systems. Source control of surface water runoff can be achieved through the use of the Sustainable Drainage Systems (SUDS) approach to drainage. Runoff from the urban/rural fringe can be controlled at source to reduce downstream surface water flood risk, through SUDS or land management strategies. The use of SUDS can reduce surface water runoff pollution, and hence contribute to meeting the requirements of the WFD. Examples of SUDS include:

- green roof;
- soakaways;
- swales;
- permeable paving;
- rainwater harvesting;
- detention basins, and;
- ponds and wetlands.

f.4 Retro-fitting of sustainable drainage systems (SUDS) is challenging but possible with many examples of good practice from both the UK and abroad[19]. Measures can be considered at the household or neighbourhood level. SUDS can achieve multiple benefits including improvements in surface water runoff quality and potential for grey water reuse. CIRIA is currently authoring guidance on retrofitting SUDS in urban areas, which will be available in 2011.

Box 8 Stormwater management in Skokie, Chicago

Properties in the village of Skokie, Chicago, experienced regular basement flooding due to excess stormwater entering the combined system. Traditional solutions to resolve the problem such as sewer separation and installation of larger sewers to carry away the stormwater were too expensive to implement. To alleviate the flooding flow regulators were installed onto inlet controls along highways and streets. This prevented excess surface water runoff entering the sewer during peak rainfall, which alleviated basement flooding, and instead surface water was designed to 'pond' in the streets, and drain into the combined sewer when there was available capacity in the system. A key factor identified in ensuring the success of this program was public engagement and interaction to outline the benefits of this scheme, and it has achieved widespread public acceptance.

For more information on this project click on the links: http://www.skokie.org/public/flood.html

[19] http://retrofit-suds.group.shef.ac.uk/index.html

f.5 Green roof systems are another alternative and are best suited to buildings with flat roofs, such as schools and industrial units. Permeable pavements (e.g. in driveways and car parks) limit runoff and maximise potential infiltration opportunities.

f.6 Large surface water attenuation ponds are more difficult to retrofit within existing urban areas unless they utilise green space or are on the urban periphery, controlling runoff entering the urban area. The Hartlepool 'IUD Pilot' proposed such a solution (Box 9). Detailed guidance and case studies on a variety of sustainable drainage system is available through CIRIA[20]. Support to local authorities on SUDS and drainage in general is available through the LANDFORM network[21].

Box 9 Surface water storage to alleviate flooding

Hartlepool IUD pilot study examined the possibility of creating surface water storage (dark blue) on the urban periphery to alleviate downstream urban flooding. The study proposed to divert flows from the watercourse into a surface water storage pond (shown in picture in dark blue) to alleviate flooding in the downstream urban area (shown in picture in light blue)

For more detail on the Hartlepool pilot study the report can be found at http://www.defra.gov.uk/environ/fcd/policy/strategy/ha2/Hartlepool/finalreport.pdf

f.7 Where SUDS are proposed it is critical that the ownership, maintenance and adoption are determined early on. This will ensure that SUDS are properly maintained and operated. The proposed Floods and Water Management Bill will transfer responsibility for adoption and maintenance of new build SUDS to unitary and upper tier local authorities as SUDS approval bodies. Forthcoming national SUDS standards will provide the framework for adopting and maintaining new build SUDS. In the case of retrofit SUDS the partners involved in the SWMP study should agree who is best placed to adopt and maintain the system.

f.8 The suitability of different ground conditions for SUDS that rely on infiltration or just storage can be mapped to aid selection, as was done in the Lower Irwell 'IUD pilot' study (Box 10). This can provide a very useful tool, but these maps should only be used as a

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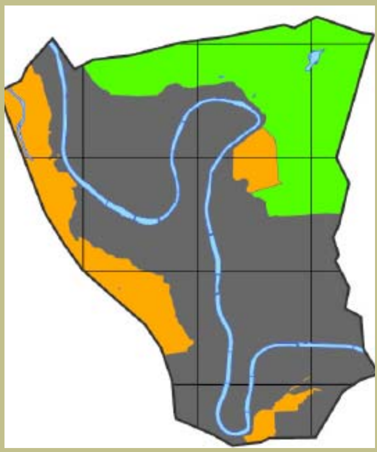
[20] http://www.ciria.org.uk/SUDS/publications.htm
[21] http://www.ciria.org/landform/

guideline, and will need to be supported by site investigations as part of SUDS applications.

Box 10 SUDS map

The Lower Irwell 'IUD pilot' developed a SUDS map based on the geology of the catchment, to identify which type of SUDS would be suitable in the catchment. The SUDS map indicated whether an area was suitable for storage-based (grey areas on map) or infiltration-based (orange areas on map) SUDS solutions, or both (green areas on map). This can be a useful tool for planners and others in determining the type of SUDS which are appropriate.



For more information on the Lower Irwell IUD pilot final report:
http://www.defra.gov.uk/environment/flooding/documents/manage/surfacewater/lowirwellreport.pdf

Mitigation measures - Pathway

f.9 These measures seek to manage the overland and underground flow pathways of water in the urban environment, and include:

- increasing capacity in drainage systems;
- separation of foul and surface water sewers;
- improved maintenance regimes;
- managing overland flows, and;
- land management practices.

Increasing capacity

f.10 A traditional way to limit flooding from drainage networks is to add storage to, or increase the capacity of, underground sewers and drains, as examined in the Torbay 'IUD pilot' study. Multiple benefits can be achieved if sewage pollution from combined sewer overflows is reduced at the same time. Surface ponding can be reduced by improving the efficiency or number of road gullies. The overall effectiveness of the existing system can be improved by pro-active maintenance to minimise blockages.

f.11 Flooding from urban watercourses can be reduced by adding channel capacity and/or providing storage in the floodplain (e.g. providing upstream storage in restricted urban areas). Flood risk from culverted watercourses can be reduced by opening up culverted channels (‘daylighting’) which also improves local amenity and habitat value.

f.12 Capacity in drainage and river systems can be out of balance, with drainage system flooding at a time when there is capacity in the river system. Mitigation measures should consider balancing the system but without increasing flood risk downstream for the full range of flood event probabilities. This will need careful consideration alongside the flood characteristics of the river itself. The Upper Rea ‘IUD Pilot’ explored the relationship between increasing sewer capacity and fluvial flood risk.

Separation of foul and surface water sewers

f.13 Many drainage networks in England and Wales are combined sewer systems, where the surface and foul water are all drained by a single system. During periods of heavy rainfall this can lead to backing up in the system causing foul flooding and pollution incidents. Separation of surface water from the combined system reduces flooding (and pollution risk) provided surface water is managed effectively. In growth areas separation also creates capacity in sewer networks for new connections.

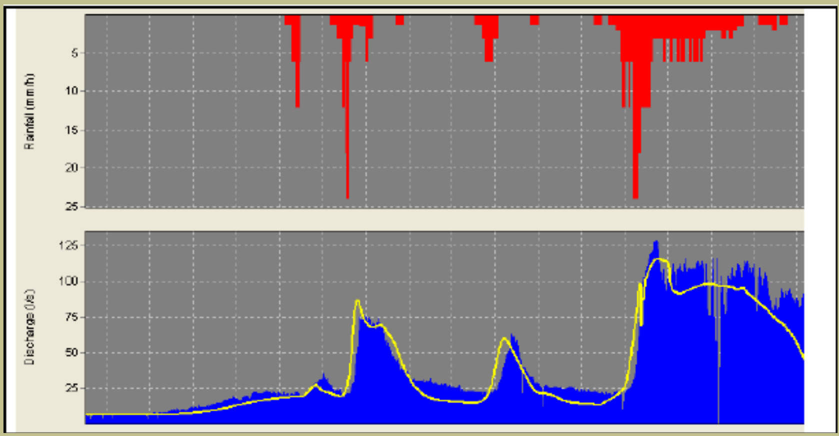
Box 11 **Sewer separation creating additional capacity in combined sewer systems**

In the Camborne, Pool and Redruth ‘IUD pilot’ study there was a lack of available capacity in the combined sewer system, which was a potential constraint on development. Through the development of existing brownfield sites surface water contributions to the combined system will be reduced which will generate additional headroom in the existing system and creates sufficient capacity to accommodate the full drainage from all new development. This has an additional benefit of reducing the rate, volume and frequency of spills from the combined sewer overflows (CSOs). This case study highlights the opportunity that new development provides to improve existing surface water flood risk and pollution incidents.

f.14 In the North Brent ‘IUD pilot’ the foul sewerage system was predicted to flood during a 1 in 2 (50%) chance rainfall event, due to significant amounts of surface water entering the foul system (see Box 12). Tracking misconnections, reducing infiltration and enforcing building regulations to prevent further misconnections are all possible mitigation measures.

Box 12 Surface water runoff into foul sewerage systems

The Brent North IUD pilot study identified that the foul system receives large volumes of runoff during storm events. Runoff enters the foul system through misconnections or cross-connections. Due to the high rainfall response the modelling predicted foul flooding for 1 in 2 year rainfall events. Removing the runoff into the foul system could virtually eliminate foul flooding up to the 1 in 30 year rainfall event.



Response in foul sewerage system due to rainfall

For more information on the Brent North IUD pilot study click on the link below:
http://www.defra.gov.uk/environ/fcd/policy/strategy/ha2brent.htm

Improved maintenance

f.15 Improved maintenance regimes can play a role in reducing surface water flood risk. The risk assessment phase will identify the locations which are at greatest risk of flooding, and this information can be used to target improved maintenance at the critical points of the system. In many urban environments there may be 'quick win' solutions or measures which can alleviate existing flood risk. In cases where drainage ditches are blocked, or there is evidence that inadequate maintenance of parts of the system then 'quick win' measures can be an effective way to reduce existing risk. For example, the Poringland 'IUD pilot'[22] identified blocked drainage ditches as a significant source of local flood risk, which were cleaned out as part of the study. Additionally, West Garforth[23] reduced flood risk in the area through a range of 'quick win' measures including desilting culverted watercourses and removal of flow obstacles.

Managing overland flows

f.16 A successful approach is to keep some surface water on the surface and control its passage through the urban environment to watercourses or storage locations. By creating flood routes, or using the highway network, flood water can be kept away from properties

[22] For more information on the Poringland IUD pilot study click on the link: http://www.defra.gov.uk/environ/fcd/policy/strategy/ha2porin.htm
[23] For more information on West Garforth final report click on the link: http://www.defra.gov.uk/environ/fcd/policy/strategy/ha2/WestGarforth/finalreport.pdf

in all but the most extreme events. Changes to profiling of roads, the height of kerbs and the position of speed controls can all be used, as well as using car parks, recreations areas or parkland as compensatory flood storage areas. Consultation with emergency planners is required to appropriately plan and design compensatory flood storage areas.

f.17 Detailed guidance on the approaches available and how to design them are included in CIRIA publication (C635) – Designing for Exceedence in Urban Drainage[24] The table (taken from C635) summarises different types of above ground storage and conveyance structures that can be used or provided (reproduced with permission from CIRIA).

Storage area (primary use)	**Description**	**Maximum water depth**	**Acceptable flooding hierarchy**
SUDS detention/retention ponds, infiltration basins etc	Additional storage used to attenuate peak flows for all storms up to normal design events. Volume of such structures could be increased to retain exceedance event volumes depending upon available area.	Varies depending upon storage area design	> 1 in 30 y SW > 1 in 100 y CS
Car parks	Used to temporarily store exceedance flows. Depth restricted due to potential hazard to vehicles, pedestrians and adjacent property. Could be residential, commercial or industrial.	0.2m	> 1 in 30 y SW > 1 in 30 y CS
Recreational areas	Hard surfaces used such as basketball pitches, five-a-side football pitches, hockey pitches, tennis courts.	0.5m unless area can be secured, then 1.0m	> 1 in 30 y SW only
Minor roads	Minor roads typically where maximum speed limits are 30 mph. Depth of water can be controlled by design.	0.1m	> 1 in 30 y SW > 1 in 30 y CS
Playing fields	Used for sport such as football and rugby. Set below the ground level in the surrounding area and may cover a wide area and hence offer large storage volume.	0.5m unless area can be secured, then 1.0m	> 1 in 20 y SW only

[24] CIRIA (2006). Designing for Exceedance in urban drainage – good practice, more information at http://www.ciria.org/acatalog/C635.html

Parkland	Has a wide amenity use. Often may contain a watercourse. Care needed to keep water separate and released in a controlled fashion to prevent sudden downstream flooding.	0.5m unless area can be secured, then 1.0m	> 1 in 30 y SW > 1 in 100 y CS
School playgrounds	Hard standing area of schools could provide significant storage. Extra care should be taken when designing such areas due to high number of children.	0.3m	> 1 in 30 y SW only
Industrial areas	Low value storage areas. Care should be taken in the selection as some areas used could create significant surface water pollution.	0.5m	> 1 in 50 y SW > 1 in 100 y CS
Major roads/motorways	Due to their primary function and importance only used for severe events.	0.1m	> 1 in 100 y SW > 1 in 100 y CS
Key: SW = surface water flooding CS = combined sewage system flooding y = year			

Land management practices

f.18 Land management measures which reduce surface water runoff rates and volumes can play a vital role in managing surface water flood risk[25]. Runoff from rural areas can contribute significant flows to watercourses which may flood further downstream in an urban area. Land management can achieve multiple environmental and flood risk benefits. The CFMP should be consulted where land management measures are proposed in the SWMP.

Mitigation measures - Receptor

f.19 Receptors are considered to be people, property and environment; those affected by flooding. Mitigation measures to reduce the impact of flood risk on receptors include:

- improved weather warning;
- planning policies to influence development;
- temporary or demountable flood defences;
- social change, education and awareness, and;
- improved resilience and resistance measures;

[25] For more information on Defra' s current research into land management practices is available at http://www.defra.gov.uk/environ/fcd/adaptationandresilience/landmanagement.htm

Improved weather warnings

f.20 Weather warnings are a vital means to prepare stakeholders for heavy rainfall which may cause surface water flooding. In 2008 the Met Office and the Environment Agency set up the Flood Forecasting Centre to provide services to service to emergency and professional partners. The Flood Forecasting Centre provides an Extreme Rainfall Alert (ERA) service to Category 1 and Category 2 responders. The ERA is issued at county level and is used to forecast and warn for extreme rainfall that could lead to surface water flooding, particularly in urban areas. It is designed to help local response organisations manage the impact of flooding. The ERA has two products:

- guidance – issued when there is a 10% or greater chance or extreme rainfall, and;
- alert – issued when there is a greater than 20% chance of extreme rainfall.

f.21 The ERA cannot provide site-specific real-time surface water flood forecast, but does offer a county level alert of impending rainfall. The alert is based on the probability of rainfall occurring, rather than being a definitive forecast.

f.22 Surface water flooding has very short lead times and is hard to predict because local topography and drainage infrastructure affects the direction or runoff and location of flooding. However, the assessment carried out as part of the SWMP study can identify the likely flow pathways and locations of ponding of surface water, which can be used in parallel with the ERA to improve emergency planning and response for surface water flooding.

Planning policies to influence development

f.23 Planning policies can be used to influence the location and requirements of new developments, regeneration, windfall development, or creep. For example, policies could be written to specify the surface water drainage requirements for specific development sites, which developers should adhere to, or to specify the requirements for windfall development sites. Planning policies can be formally adopted as Supplementary Planning Documents (SPDs). More information on SPDs can be found at http://www.planningportal.gov.uk/uploads/ldf/ldfguide.html.

f.24 New planning rules[26] have been established to control the permitted development of impermeable driveways in front gardens for areas >5m^2. This will slow urban creep in high risk areas.

f.25 Developers currently have a 'right to connect' to water company drainage systems enshrined in Section 106 of the Water Industry Act (1991). The proposed Floods and Water Management Bill is intended to amend this legislation, which will give sewerage undertakers greater ability to control additional connections to their drainage systems .

[26] CLG guidance on the permeable surfacing of front gardens. More information at http://www.communities.gov.uk/publications/planningandbuilding/pavingfrontgardens

Box 13 Working with the planning system

Telford & Wrekin 'IUD pilot' study was led by the planning authority, Telford & Wrekin Borough Council. It specified detailed developer guidelines and embedded these principles within a 'surface water management' Supplementary Planning Document (SPD) associated with the Local Development Framework.

The LDF (and associated SPDs) will be subject to consultation locally, and once completed it will be easier for the Council to enforce their surface water management objectives.

For more information see
http://www.defra.gov.uk/environment/flooding/manage/surfacewater/urpilottelf.htm

f.26 In addition the SWMP study can provide developer guidance to developers specifying the locally agreed requirements for surface water management. If guidance is developed through a partnership approach its adherence should ensure smooth passage of developer plans through to construction. The outputs from the SWMP should be used to help inform developers conducting level 1 and 2 site-specific flood risk assessments, in accordance with PPS25.

Box 14 Developer Guidance

The CPR IUD pilot study proposed to provide developer guidance to inform developers of the requirements outlined in their prototype SWMP. The developer guidance contains site-specific runoff details and attenuation requirements for each development site and will:

- Allow developers to understand the background to the SWMP and the underlying drainage principles and the reasons and limitations of the proposed higher discharge rates associated with the strategic surface water systems.
- Provide developers with a high degree of confidence in promoting development by removing the uncertainties associated with surface water requirements within developments.
- Allow developers to design drainage within developments knowing the constraints and criteria which they are required to meet, knowing the principles have been agreed by stakeholders and will be permitted through the planning process.

For more information on the CPR IUD pilot study click on the link:
http://www.defra.gov.uk/environment/flooding/manage/surfacewater/urpilotkerr.htm

Temporary or demountable flood defences

f.27 Temporary or demountable flood defences can be erected in areas more vulnerable to surface water flooding to reduce the consequences of flooding, and to route flood water to a safe location. These flood defences can be installed at the property level (e.g. flood guards on front gates/doors), or street level (e.g. through defences on roads which route water to a safe location, such as open green space). Temporary or demountable flood defences should be used in conjunction with improved flood warning, so that the flood defences can be installed in a timely manner, prior to flood incidents occurring.

Social change, education and awareness

f.28 Public education and awareness is considered to represent a critical component to the success of surface water management action plans. Social education programmes can help communities understand more about surface water flooding, as well as property-level measures which can be taken to reduce their exposure to surface water flooding. Social education and awareness programmes can also increase the take-up of flood warning services, which can help communities be more prepared to respond to heavy rainfall which could result in surface water flooding. The Environment Agency has undertaken a lot of research into public engagement, education and awareness, and appropriate personnel from the Environment Agency should be engaged when considering these options.

Improved resilience and resistance

f.29 Whatever other measures are adopted there will always remain a residual flood risk. Existing and new buildings can be adapted to reduce damages from this flooding. Resistance measures prevent water entering the property (e.g. demountable barriers). Resilience measures reduce the damage caused by water within the property (e.g. waterproof flooring). The Government is currently (December 2009) receiving applications to fund property-level flood protection, as part of a £5.5million grant scheme.[27] Research by Defra and the Environment Agency has indicated the benefits and costs of different types of flood resistance, resilience and repair, as well as examining the social component which is a key aspect for these measures[28]. Echoing the Pitt Review, the use of sandbags as a resistance measure is not recommended. A good engagement strategy throughout the SWMP will assist the acceptance of flood resilience and resistance measures, as well as an understanding of residual risk.

f.30 In accordance with PPS25, mitigation through building design (resilience or resistance) for new developments is considered to be the least preferred option to managing flood risk. Where mitigation is required, reference should be made to the guidance from Communities and Local Government on improving flood performance of new buildings (see Box 15). PPS25 states that “flood resistance and resilience measures should not be used to justify new development in inappropriate locations[29]”.

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[27] Defra (2008). Property-level flood protection and resilience – launch of £5 million property-level protection grant scheme, more information at http://www.defra.gov.uk/environment/flooding/manage/propertylevelgrant.htm

[28] Defra and Environment Agency Flood and Coastal R&D Programme (2008). Developing the evidence base for flood resistance and resilience: Summary report, FD2607/TR1, available at http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD2607_7322_TRP.pdf

[29] Communities for Local Government (2006). Planning Policy Statement 25: Development and Flood Risk, more information at http://www.communities.gov.uk/documents/planningandbuilding/pdf/planningpolicystatement25.pdf

Box 15 Improving flood performance of new buildings

Communities and Local Government have produced a report which provides guidance on improving flood performance of new buildings. This guidance examines the circumstances under which flood avoidance, resistance and resilience should be built into new buildings. In addition the guidance outlines how to design new buildings to improve flood performance. The table below, taken from the document, gives guidance on which approach and mitigation measures are considered suitable for different flood depths. Where considering incorporating flood resistance or resilience into new development, this guidance should be consulted.

	Design water depth*	Approach	Mitigation measures
Resistance/Resilience**	Design water depth above 0.6m	Allow water through property to avoid risk of structural damage. Attempt to keep water out for low depths of flooding *'Water Entry Strategy'******	• Materials with low permeability up to 0.3m • Accept water passage through building at higher water depths • Design to drain water away after flooding • Access to all spaces to permit drying and cleaning
Resistance/Resilience**	Design water depth from 0.3m to 0.6m	Attempt to keep water out, in full or in part, depending on structural assessment. If structural concerns exist follow approach above***	• Materials with low permeability to at least 0.3m • Flood resilient materials and designs • Access to all spaces to permit drying and cleaning
Resistance/Resilience**	Design water depth up to 0.3m	Attempt to keep water out *'Water Exclusion Strategy'*	• Materials and constructions with low permeability
Avoidance		Remove building/development from flood hazard	• Land raising, landscaping, raised thresholds

Notes:
* Design water depth should be based on assessment of all flood types that can impact on the building
** Resistance/resilience measures can be used in conjunction with Avoidance measures to minimise overall flood risk
*** In all cases the 'water exclusion strategy' can be followed for flood water depths up to 0.3m

The full guidance document is available at:
http://www.planningportal.gov.uk/uploads/br/flood_performance.pdf

Annex G – Example of short-listing methodology

Example of short-listing methodology

g.1 The worked example outlines an approach to short-listing options based on technical, economic, social and environmental criteria.

g.2 The results from the short-listing indicates that the do nothing, do minimum, strategic surface water storage and retrofitting measures should be taken forward for further analysis. In line with PAG the 'do nothing' option (no intervention and no maintenance) and 'do minimum' (continuation of current practice) should be taken forward to the detailed options assessment. Furthermore any measures eliminated at this point must be justified and document for auditing purposes.

Option No.	Option	Technical	Economic	Social	Environmental	Objectives	Overall	Take to detailed analysis?	Comments
1	Do Nothing	2	-1	-2	0	-2	-3	Yes	Do nothing should be carried forward to option appraisal stage
2	Do minimum	1	-1	-1	0	-1	-2	Yes	Do minimum should be carried forward to option appraisal stage
3	Sewer upgrades	1	-1	1	1	1	3	No	Technically this measure can be implemented and it is likely to be beneficial to society and the environment through reduced flooding and pollutions. However economically this is not feasible and is likely to have a cost-benefit ratio of <0.5
4	Strategic surface water storage	2	1	-1	2	2	6	Yes	This is technically feasible and will bring wider environmental benefits. The major problem is social acceptance of using green space as surface water flood storage
5	Separation	2	U	1	1	0	4	No	This will be technically possible, but the cost of carrying out sewer separation over a large geographic area is not viable. The cost-benefit ratio is likely to be negative
6	Retrofitting to reduce runoff	2	-1	1	1	2	5	Yes	Retrofitting is technically feasible, but it likely to be have a cost-benefit ratio of <1. There may be social disruption during the retrofitting process but long-term there will be social benefits, and this measure will have a positive impact on the environment