What is the Risk of Flooding from Surface Water map?

Report version 2.0

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

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

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

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

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Environment Agency
Horizon House, Deanery Road
Bristol BS1 5AH
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

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E: enquiries@environment-agency.gov.uk.

What is this document about?

It explains why and how the Risk of Flooding from Surface Water map was produced including:

- Historic and legislative context
- How it was produced
- What validation was carried out
- How locally produced information has been incorporated
- How we have ensured consistency while using both nationally produced mapping and locally produced information
- What outputs are available

Who does it apply to?

This document will be useful for:

- Risk Management Authorities and other partners (under the Civil Contingencies Act, for example), including:
  - Lead Local Flood Authorities (LLFAs)
  - Local Planning Authorities (LPAs)
  - Local Resilience Forums (LRFs)
- Commercial and non-commercial customers
- Environment Agency staff including the following teams:
  - Partnership and Strategic Overview
  - Customers and Engagement
  - Flood Resilience
  - Sustainable Places
  - Regional Incidents and Emergency Planning
  - LRF and Flooding sub-group representatives

Contents

1 Introduction

In 2013 the Environment Agency, working with Lead Local Flood Authorities (LLFAs), produced the Risk of Flooding from Surface Water (RoFSW) maps (known at the time of creation and validation as uFMfSW - updated Flood Map for Surface Water). The RoFSW map is the third national surface water map produced by the Environment Agency under our Strategic Overview role. We consider it to represent a significant improvement on the previous surface water flood maps, both in terms of method and representation of the risk of flooding. We have considerably improved the modelling techniques and data used, and also incorporated locally produced mapping where this is available to represent features best modelled at a local scale.

The Risk of Flooding from Surface Water information assesses flooding scenarios as a result of rainfall with the following chance of occurring in any given year

- 3.3 % (1 in 30)
- 1% (1 in 100)
- 0.1% (1 in 1000)

It provides the following data for each flooding scenario:

- Extent
- Depth
- Velocity (including flow direction at maximum velocity)
- Hazard (as a function of depth and velocity)

It also includes information about the source of the data (i.e. whether it was from the nationally produced modelling or locally produced modelling) and the confidence in the data outputs.

This document describes in detail:

- the background to the production of the maps
- the method used to produce the maps
- what is included in the resulting maps
- a summary of the strengths and limitations of the maps

2 Background

This section sets out the historical and legal context behind why the Environment Agency has produced the Risk of Flooding for Surface Water map.

2.1 Why has the Environment Agency produced surface water flood maps?

Although managing the risk of flooding from surface water is the responsibility of LLFAs, we've produced these maps under our strategic overview role in England and strategic oversight role in Wales. This is a role which was given to us by government following the recommendations of Sir Michael Pitt's review of the 2007 summer floods.

A key part of this role is to provide local authorities and partners with data, tools and guidance on flood risk management activities. The distribution of flood risk data supports local authorities and contributes towards the aim of our Strategic Overview role to ensure all floods are assessed and managed.

In April 2013, the strategic oversight role in Wales transferred from Environment Agency Wales to Natural Resources Wales. The Environment Agency produced the 2013 updated Flood Map for Surface Water on behalf of Natural Resources Wales.

2.2 Previous nationally produced surface water flood mapping

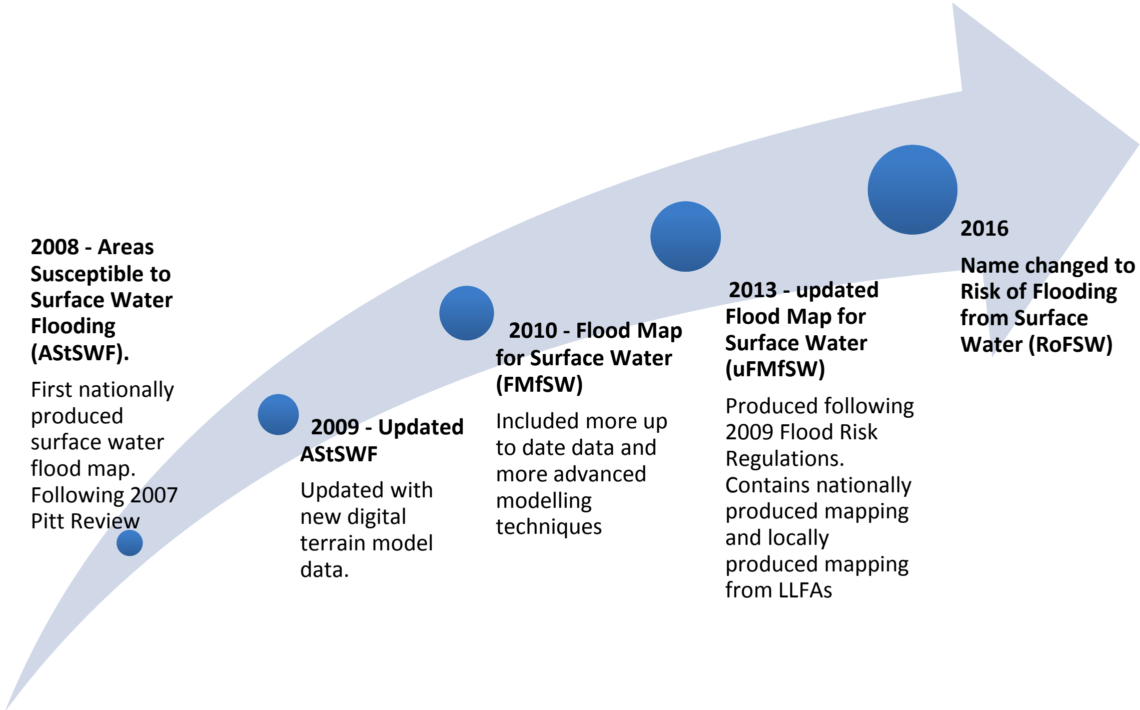
The Environment Agency shared two surface water flood maps to support local flood risk management in England and Wales.

- Areas Susceptible to Surface Water Flooding maps (2008)
- Flood Map for Surface Water (2010)

The first map was produced following a recommendation in the Pitt review that the Environment Agency, supported by local authorities and water companies should urgently identify the areas that are at highest risk from surface water flooding.

The differences between the previous nationally produced surface water flood mapping products are explained in more detail in section 4.6

Summary of nationally produced surface water flood maps.



2.2.1 Areas Susceptible to Surface Water Flooding maps

JBA Consulting developed the first nationally produced model of surface water flooding in 2007 and we procured a license to use the map, not the model itself, from JBA in 2008. We bought it so we could provide Local Resilience Forums (LRFs) with an initial indication of areas that may be susceptible to surface water flooding.

We first supplied it to LRFs in August 2008. We updated this in July 2009 (when new digital terrain model data became available) and sent the data to Local Planning Authorities (LPAs) in England. Following consultation with the Welsh Government, Welsh Local Government Association and the Planning Inspectorate, the data was made available to LPAs in Wales in November 2009. It was also provided to Regional Resilience Teams for use in their functions which relate to emergencies as defined and as required by the Civil Contingencies Act 2004.

2.2.2 Flood Map for Surface Water (2010)

In March 2009 the Environment Agency commissioned JBA Consulting (working in partnership with Halcrow) to work with us to develop the Flood Map for Surface Water (FMfSW).

FMfSW used more up to date data, and more advanced modelling techniques to better represent the mechanisms that cause surface water flooding. This included a number of improvements to the original model in areas where it was known to be weaker; for example considering:

- an additional rainfall probability
- the influence of buildings
- reduction of effective rainfall through taking account of drainage and infiltration
- a better digital terrain model that incorporated the Environment Agency's high quality LIDAR data

The FMfSW was made available in 2010 to the same organisations as the AStSWF map.

2.2.3 Locally agreed information

Although FMfSW (2010) used more up to date data and more advanced modelling techniques to represent surface water flooding, in some areas (particularly extensive, flat landscapes) AStSWF was felt to provide a better representation of flooding. Neither map was considered definitive, but provided information to support local flood risk management. We asked each LLFA to make a decision on their locally agreed flood risk information, i.e. which map (AStSWF, FMfSW or local information) best represented the flooding in their area. In some cases they selected different maps to represent different parts of their area. This process provided useful feedback from local experts.

2.3 Flood Risk Regulations

The Flood Risk Regulations 2009 which implement the requirements of the European Floods Directive aim to provide a consistent approach to managing flood risk from all sources across Europe.

Under these regulations, LLFAs are responsible for producing flood hazard maps for surface water within designated Flood Risk Areas (as defined in the Preliminary Flood Risk Assessments), and the Environment Agency is responsible for publishing these maps by December 2013. The updated nationally produced surface water flood mapping was created, in part, so that LLFAs could use these maps to meet the requirements of the Flood Risk Regulations.

More information about the requirements of the Flood Risk Regulations is shown in Annex A.

3 What is Risk of Flooding from Surface Water?

It has been created from:

- the Environment Agency's nationally produced surface water flood mapping, and;
- appropriate **locally produced mapping** from LLFAs

These were brought together into one map to form the Risk of Flooding for Surface Water (RoFSW) (see section 5.4). Our aim is to provide the best single source of information on surface water flooding for England that includes local information and knowledge. **LLFAs can update the Risk of Flooding from Surface Water with local information.**

3.1 What is the nationally produced surface water flood mapping?

The new nationally produced mapping improves on previous maps in many ways by using **local information** supplied from LLFAs and **better data and modelling techniques**. Some LLFAs supplied the following local information as **inputs to the modelling**:

- drainage rates
- percentage runoff rates
- critical storm durations

Where LLFAs were not able to supply this information we used values that were felt to give the best national representation.

We based the improvements on the findings of pilot studies which we carried out with LLFAs. These studies also highlighted that there was a demand for updated maps.

Section 4 and Annex B provide more information about the modelling techniques used.

3.2 Why produce the Risk of Flooding for Surface Water map?

There are a number of drivers and benefits for producing the Risk of Flooding for Surface Water map:

- To help LLFAs, customers, Environment Agency and government understand surface water flood risk consistently across all England and Wales.
- To help LLFAs focus on managing surface water flood risk.
- To help the Environment Agency to take a strategic overview and provide evidence for future funding decisions.
- To provide the public and other customers with easy access to consistent information on surface water flood risk enabling them to make better informed decisions.

- To meet ministerial commitments to make updated and improved surface water flood mapping available for England and Wales. Government have funded the update to the nationally produced mapping.
- To make it easier to share information with our customers. Until now, surface water flood mapping was not publicly available from a single organisation or place.
- To use new data and modelling techniques to produce a more representative picture of flood risk.
- To meet the requirements of the Flood Risk Regulations in the most efficient and cost effective way and reduce the burden on LLFAs.

The data also enables the government to meet their commitment to make updated and improved surface water flood mapping available to insurers, as set out in the Statement of Principles between members of the Association of British Insurers (ABI) and Government and now in Flood Re . It will also help inform the planning process in relation to surface water flood risk.

3.3 Why is it an improvement?

The RoFSW improves upon previous nationally produced surface water flood mapping as it:

- incorporates significant improvements in modelling techniques
- incorporates significant improvements in data:
    - We now have digital terrain information at 2m resolution or finer for over 90% of urban areas in England and Wales. Although there are still some areas with coarser resolution data (5m) where the flood maps will be less accurate, these are significantly reduced from previous national surface water flood maps.
    - The data used is more representative of flow routes than before. However, it still cannot represent every detail of the urban landscape and very local mechanisms of flooding.
- combines appropriate local mapping from LLFAs with national mapping to provide an improved and consistent picture of surface water flood risk
- provides velocity and depth information for a range of flood probabilities

Although it is an improvement, there are inevitably still assumptions in the model. Urban drainage capacity is the biggest uncertainty in the modelling. Whilst we have obtained local drainage rates where possible, we have made assumptions where no drainage data was available and in these areas the outputs of the model may be less representative.

Improvements in the modelling are detailed further in Annex B.

3.4 Accessing the data

The RoFSW information is Open Data. This means that anyone can download, use, and manipulate the dataset free of charge and without restrictions under the Open Government License (OGL), including for commercial use. The datasets can be found by searching for Risk of Flooding from Surface Water on http://data.gov.uk/.

4 Developing the nationally produced modelling

This section gives an overview of the approach used for the nationally produced modelling and how this compares to the previous national surface water products.

Further detail of the methodology used for the nationally produced modelling and mapping can be found in the **National modelling and mapping method statement - May 2013** available from local Environment Agency offices.

It should be noted that the approach will differ in the areas where locally produced flood mapping is being used to replace the nationally produced modelling. The approach for these areas is outlined in Section 5.

4.1 Scope of the nationally produced mapping

4.1.1 Flooding from local sources

In 2010 the Flood and Water Management Act (FWMA) defined 'surface runoff' in the following terms:

"The flooding that takes place from the 'surface runoff' generated by rainwater (including snow and other precipitation) which: (a) is on the surface of the ground (whether or not it is moving), and (b) has not yet entered a watercourse, drainage system or public sewer."

This is the main type of flooding shown by the RoFSW.

The nationally produced surface water flood mapping only indicates where surface water flooding could occur as a result of local rainfall. It does not fully represent flooding that occurs from:

- ordinary watercourses
- drainage systems or public sewers caused by catchment-wide rainfall events
- rivers
- groundwater.

Due to the modelling techniques used, the mapping picks out depressions in the ground surface and simulates some flow along natural drainage channels, rivers, low areas in floodplains, and flow paths between buildings. Although the maps appear to show flooding from ordinary watercourses, they should not be taken as definitive mapping of flood risk from these as the conveyance effect of ordinary watercourses or drainage channels is not explicitly modelled. Also, structures (such as bridges, culverts and weirs) and flood risk management infrastructure (such as defences) are not represented.

LLFAs in their Preliminary Flood Risk Assessments (2011) identified surface water flooding as the most significant source of flooding compared to groundwater or ordinary watercourses, although there is often interaction between these sources. Although the nationally produced surface water flood mapping is for surface water flood risk only, it can be valuable when combined with local experience and knowledge to inform the overall picture of flood risk in the area.

4.1.2 Other influences on water levels

The nationally produced surface water flood mapping does not take account of the effect of pumping stations in catchments with pumped drainage.

No allowance is made for tide locking, high tidal or fluvial levels where sewers cannot discharge in to rivers or the sea.

Further information on the limitations of the modelling is given in section 8.2.

4.1.3 Antecedent conditions

The modelling assumes an initial level of soil moisture (or antecedent condition) and then represents the way the infiltration rate slows as rainfall continues – so, as the soil becomes more saturated, runoff increases (see section 4.2.3). However, it cannot account for all possible antecedent conditions and therefore if rain falls on already fully saturated ground, flooding may be more extensive than is shown on the maps.

4.1.4 Scenarios

The nationally produced surface water flood mapping presents the surface water flood risk for a **'current day' scenario**. The mapping does not take into account possible 'future' scenarios such as climate change, urban creep, or various post-scheme implementation scenarios.

4.1.5 Flood defences and flood alleviation schemes

The method does not explicitly take into account flood barriers or defences (fluvial, tidal or surface water) or any flood alleviation schemes.

4.2 Hydrological (rainfall) modelling

4.2.1 Description

The RoFSW models the response of the ground surface to a rainfall event with the following properties and rationale:

Rainfall Event Properties	Rationale
1 in 30 1 in 100 1 in 1000 chance of occurring in any year	To meet the requirements of the Flood Risk Regulations 2009 and for consistency with national flood mapping for rivers and sea, the modelling and mapping work was undertaken for three rainfall probabilities. The 1 in 30 rainfall is the largest common design standard for urban drainage. Note that unlike previous nationally produced surface water flood mapping, the modelling did not include a rainfall probability of 1 in 200 chance of occurring in any year.

Rainfall Event Properties	Rationale
1 hour 3 hour 6 hour storm durations	Choosing a single representative critical storm duration is difficult, because any modelled area will include a number of sub-catchments of different size, steepness and shape. A short duration storm (around 1 hour) generally better represents the type of event that leads to surface water flooding, but there is also evidence that longer storms may be critical in flatter areas. Critical duration is also strongly linked to the topography. In low-lying areas, near to rivers, the critical duration is long because surface runoff drains into these areas from larger catchments. On hill slopes the critical duration is generally short because the greatest flood depth arises from high intensity rainfall. The modelling includes storm durations of 1, 3 and 6 hours for each rainfall probability. These are merged into a 'worst case' maximum output for each probability, to ensure a realistic approximation of critical storm duration is represented in all locations.
50% summer rainfall profile	Total rainfall depths for each rainfall probability / storm duration were scaled across a standardised storm profile to produce design hyetographs. Two standard profiles are typically recommended in the Flood Estimation Handbook: a 75% winter profile, for rural catchments, and a 50% summer profile, for urban catchments. The summer profile is more peaked than the winter profile, because of the prevalence of intense convective storms during the summer, so the intensity is greater in the middle of the storm. The summer profile is more likely to be critical for surface water flooding.

The probability relates to the chance of rainfall, and not of the resulting flood extent occurring. It provides a general indication of areas which may be more likely to suffer from surface water flooding in these rainfall probabilities. However, use of multiple storm durations should make the final mapping more representative of a 1 in x chance flood, rather than only representing a 1 in x chance rainfall event.

4.2.2 Depth-duration-frequency curves

England and Wales was divided into 5km x 5km "tiles" that provided the basis for rainfall estimation and subsequent hydraulic modelling. For each tile, a model of rainfall depth-duration-frequency (DDF) was constructed using parameters available from the FEH (Flood Estimation Handbook) CD-ROM at the tile centroid, and the techniques outlined in Volume 2 of the FEH. Each DDF curve was then used to calculate a tile-specific total rainfall depth for a storm of given duration and probability.

4.2.3 Adjustments to calculate effective rainfall

Adjustments are made to calculate effective rainfall. These differed depending on whether areas were urban or rural.

Urban areas were defined based on Ordnance Survey MasterMap information for grid squares 250m by 250m. Where more than 50% of the grid square consists of man-made land uses (including all buildings, roads, paths and other hard-standing) the square was determined as "urban" and urban runoff rules were applied. All other squares were defined as "rural" and ReFH rainfall-runoff methods were applied.

Adjustments in rural areas

The approach for calculating **runoff in rural areas** used the rainfall losses model from the Revitalised Flood Hydrograph (ReFH) rainfall-runoff method and parameters from the National Soil Resources Institute (NSRI) ‘SERIES Hydrology’ data.

The losses in the model are controlled by the maximum soil moisture storage capacity. The model calculates the volume of runoff at each time step as a function of the current soil moisture content, so that the percentage runoff increases as the rainfall continues. This increase is fairly minor for short duration storm events.

Adjustments in urban areas

In urban areas, rainfall is reduced to 70% to represent infiltration, then a rainfall reduction of 12mm/hr is applied to represent the effects of the drainage system.

The **runoff coefficient** of 70% was chosen for **urban areas** as this is a good average runoff coefficient for built-up areas including gardens and green verges and a mix of city centre and more suburban land uses. The FEH catchment descriptor assumes a 70% coefficient for urban areas.

The losses model from the ReFH rainfall-runoff method that was used for rural areas was also applied for calculation of runoff within the green portions of urban areas.

Urban drainage systems vary in nature between catchments, those built at different times and using different techniques. Their effectiveness in different storm events is linked to very local characteristics such as the arrangement and capacity of road gullies and whether drainage is via combined or separate sewerage systems. Previous national studies have carried out analysis of the sewer capacity to derive a nationally representative figure, from the following factors:

- service level (or standard of protection from flooding) for drainage systems (between 1 in 5 and 1 in 30 years, centred around 1 in 10 years)
- estimates of critical storm duration (0.5 to 2 hours)
- estimates of percentage impermeable area (30% to 80%)
- estimates of DDF rainfall parameters

The calculated range of sewer capacities was in the range between 5mm/hr and 54mm/hr; with a **typical drainage removal rate of 12mm/hr** across catchments in England and Wales. Independent validation carried out as part of these earlier studies confirms that 12mm/hr is a suitable ‘typical’ value to represent the effects of urban drainage, and there is no new information available that contradicts this assumption.

A **drainage removal rate of 12mm/hr** has therefore been adopted in the nationally produced mapping unless otherwise specified by LLFAs. In areas of known low or high drainage capacity, LLFAs could substitute alternative values of 6mm/hr or 20mm/hr.

4.3 Digital Terrain Model (DTM)

4.3.1 Description

The modelling and mapping use the Environment Agency's 2012 composite DTM product, known as FMfSW DTM 2012. This is a LIDAR / NEXTMap composite digital terrain model.

It provides a continuous model of "bare earth" topography across England and Wales at a horizontal grid resolution of 2m. It includes all the LIDAR data obtained by the Environment Agency up to April 2012 but does not include any LIDAR data held by LLFAs or Water & Sewerage Companies (WaSCs). The LIDAR has good coverage of urban areas as a programme to infill all areas greater than 3km^2 was completed in August 2011.

The composite dataset consists of:

- Environment Agency LIDAR (a composite of 0.25m, 0.5m, 1m and 2m data downgraded to 2m resolution)
- Infoterra LIDAR (1m and 2m data available under the Pan Government Agreement 2)
- Intermap Technologies NEXTMap Britain IfSAR data

A breakdown of the proportions contained in the final DTM is shown in the table below (in order of precedence, so items lower in the list were only used if those above were not available):

Environment Agency LIDAR	67.7%
Infoterra 1m LIDAR	0.8%
Infoterra 2m LIDAR	0.2%
NEXTMap SAR	31.3%

A map showing the location of the different data sources used across England and Wales is shown in Annex C.

4.3.2 Quoted accuracy

All LIDAR within the composite DTM has a quoted accuracy of ±15 cm or better in its original form, although it is thought that the accuracy of Environment Agency LIDAR data has been closer to ±5cm since 2005.

The NEXTMap data (derived from Interferometric Synthetic Aperture Radar) has a quoted vertical accuracy of ±1 m or better.

These data and accuracy statistics will only reflect a "snapshot" of the landscape at the time of data capture and where the landscape has subsequently changed (e.g. due to urban development, natural change, landfill, coastal realignment), then the potential for anomalies is much greater.

4.3.3 Model resolution

Flood modelling was carried out on a **2m resolution grid** for all England and Wales. The underlying DTM data varies in horizontal resolution from 0.25m to 5m; the DTM data was re-sampled to a 2m grid, so in some places some of the detail of the finer resolution LIDAR data has been lost.

A 2m regular grid is fine enough to allow the model to represent some small scale features of the urban landscape such as pathways between buildings that may significantly influence wider inundation patterns. However, although a 2m grid means that the overall patterns of flooding are more representative than they would otherwise be, this does not mean that the mapping is accurate to the nearest 2m, due to the other uncertainties in the modelling.

4.3.4 Representation of buildings

Surface water flooding, especially in urban areas is influenced by features of the urban landscape, particularly buildings and roads. In certain types of catchment, buildings are an important factor in determining pathways for surface water flooding. A lack of buildings in the model can contribute to inaccuracy in the modelling.

The value of modelling buildings has to be balanced against the considerable data processing overheads (for inputs and outputs) and potential implications for model stability.

Ordnance Survey MasterMap data was used to raise the ground level within building footprints (according to the bare earth DTM) by an average of 0.3m. Typically the building is raised by 0.3m above the average height of the building footprint to give an upstand with a horizontal 'floor level', which deflects flow. An algorithm was used to ensure that the building floor levels are always at or above ground level even on the steepest slopes.

This requirement was based on the conclusions of the FMfSW improvements pilot studies (Halcrow/JBA Consulting, 2012), which demonstrated the importance of modelling the "deflection effect" of buildings on surface water flows.

Buildings are also represented so water can flow through them once the depth exceeds the height of the upstand. This is consistent with reports of flooding in steeper catchments where water is observed to pass through, rather than around, buildings. This approach provides the best compromise currently available for building representation in nationally produced surface water flood modelling.

4.3.5 Representation of structures

Where the resolution of the DTM was downgraded to 2m from the higher resolution LIDAR data, this has removed some of the detail of local surface features. This means that some features, such as smaller hydraulic structures or flow paths may not be represented in the model.

Some flow paths under bridges and through embankments are not captured within the DTM because the top of the feature is represented rather than the opening through it.

These features include:

- road and railway embankments
- bridges
- subways
- tunnels

This can cause runoff to back up and flood a larger area "upstream" of the feature, and areas "downstream" of the obstruction may be unrealistically shown as being free from flood risk. If these locations were not edited, the resulting flood extent would show a different pattern of flooding than would be expected in reality.

The DTM was manually edited to represent flow paths through "flyover" features that present unrealistic obstructions to known flow routes. The model run is completed and the results from the model run were used to identify where water is retained. Edits are then made to the local DTM values and a further model run is undertaken until satisfactory results are achieved. Approximately 91,000 edits were made to the DTM as part of this project, which is an increase of over 50,000 from previous generations of national surface water modelling.

4.3.6 Representation of other features

The representation of the **road network**, which is known to preferentially collect and route storm water when it rains, was improved within the DTM.

Road surfaces, selected from OS MasterMap data, were **lowered by 0.125m** (the height of a British Standard kerb) to better delineate these important pathways in the hydraulic modelling and mapping. Using this method to represent roads ensures that the principal flood pathways along roads are better represented in the 2m model grid.

This approach may overestimate the routing effect of roads in rural areas where there are fewer raised kerbs or where the kerb height is substantially less because the road has been resurfaced.

Other features such as fences, walls, dropped kerbs and speed bumps may not be explicitly represented within the DTM. These subtle changes in local topography can significantly affect the direction of flow and extent of flooding particularly during higher probability events where depths may be low. These small scale hydraulic features cannot be represented in a national scale model, but could be incorporated in local scale modelling at a finer resolution.

4.4 Hydraulic modelling approach

4.4.1 Description

The flood modelling approach was based on the **direct rainfall** concept where net, or effective runoff volumes, applied to each grid cell in the hydraulic model are routed dynamically across the DTM surface, identifying flooding pathways and areas where ponding will occur. The approach simply allows rainfall to spread across the surface of the DTM and allows water to move and pond in topographical low points.

The direct rainfall approach was used for both previous nationally produced surface water flood mapping exercises and is widely accepted as an appropriate method for analysing higher magnitude, lower probability storms where subsurface drainage systems are likely to be overwhelmed and/or inlet capacities exceeded.

England and Wales was divided into approximately 7100 5km x 5km tiles. These modelling tiles included a 500m overlap with adjacent tiles to ensure that modelled areas overlap sufficiently and "edge effects" are not visible in the final map.

4.4.2 Modelling software and equations

The routing/model simulations were carried out using the **JFlow+ 2D hydraulic model** which solves the Shallow Water Equations.

JFlow+ is commercially available software which has been benchmarked using the test cases proposed by the Environment Agency in the Science Report SC120002,

Benchmarking the latest generation of 2D hydraulic modelling packages, and the results have been submitted to the Environment Agency. Results for Test 8A which considers rainfall and point source surface flow in an urban area have demonstrated the ability of JFlow+ to deliver robust modelling of direct rainfall applications.

4.4.3 Manning's n values

The Manning's n values are varied according to Ordnance Survey MasterMap Topography Layer Feature Code. The values are varied to take account of variability of hydraulic roughness of different land uses and their influence on wider inundation patterns. The variability in values allows some of the effects of vegetation and other hydraulic obstructions not represented explicitly in the model to be approximated.

Typical values used were 0.02 for tarmac roads or pavement, 0.03 for grassland areas and 0.1 for heavy woodland and vegetation.

4.5 Validation

Validation of the nationally produced mapping results was undertaken for three pilot areas using historical observations and local modelling data (see section 9 of this document for further details).

4.6 Comparison of nationally produced modelling approach with previous national mapping

The table below shows a summary of the differences in modelling approach between the nationally produced surface water flood mapping and the previous products. Note that where local mapping has been used in the RoFSW this is likely to use different approaches, parameters or data.

	Nationally produced surface water flood mapping (2013)	FMfSW (2010)	AStSWF (2008)
Hydraulic modelling	2D overland flow modelling	2D overland flow modelling	2D overland flow modelling
Model software and equations	JFlow+ (Shallow Water Equation-based)	JFlow-DW (diffusion wave-based) - does not solve full shallow water equations	JFlow-DW (diffusion wave-based) - does not solve full shallow water equations
Hydrological modelling	Direct Rainfall approach with allowances for the sewer network and infiltration (see below).	Direct Rainfall approach with allowances for the sewer network and infiltration (see below).	Direct Rainfall approach with no allowances made for the sewer network and infiltration.
Design rainfall	FEH depth-duration-frequency parameters defined on a regular 5km grid (with no areal reduction factor applied) for rainfall with a probability of occurring in any year: • 1 in 30 • 1 in 100 • 1 in 1,000	FEH depth-duration-frequency parameters defined on a regular 5km grid (with no areal reduction factor applied) for rainfall with a probability of occurring in any year: • 1 in 30 • 1 in 200	FEH depth-duration-frequency parameters defined on a regular 5km grid (with no areal reduction factor applied) for rainfall with a probability of occurring in any year: • 1 in 200
Storm duration(s)	**1, 3 and 6hrs** used for all scenarios (unless specified locally by LLFA) 50% summer storm profile	1.1hrs used for all scenarios 50% summer storm profile	6.25hrs used for all scenarios 50% summer storm profile

	Nationally produced surface water flood mapping (2013)	FMfSW (2010)	AStSWF (2008)
Reduction in rainfall to represent sewers	In urban areas, a default loss of 12mm/hour	12mm/hour	0mm/hour (No reduction due to sewer drainage represented)
Reduction to rainfall to represent infiltration	Urban 70% runoff coefficient is applied In rural areas, runoff variation based on nationally mapped local soil types uses the ReFH losses model, and NSRIs 'SERIES Hydrology' data. Runoff parameters adjusted by local drainage information (from LLFAs and Water and Sewerage Companies) where available.	Urban 70% Rural 39%	100%
Digital terrain model (DTM)	Bare earth LIDAR/NEXTMap composite DTM provided by Geomatics in 2012. LIDAR data 2m horizontal resolution or finer in 90% of urban areas, 5m NEXTMap SAR elsewhere.	Bare earth LIDAR/NEXTMap composite DTM at 5m horizontal resolution provided by Geomatics in 2010 containing Environment Agency LIDAR, PGA2 LIDAR and SAR.	Infoterra bare earth LIDAR and GeoPerspectives DTM provided in 2007.
Model grid size	2m regular grid	5m regular grid	5m regular grid
Representation of buildings	Use of a (typically) 0.3m high "up-stand" and depth-varying roughness coefficients within the OS MasterMap building footprint.	Represented explicitly as unfloodable objects in the DTM. Building footprints raised by 5m in DTM as defined in 2009 OS MasterMap data.	Not represented

	Nationally produced surface water flood mapping (2013)	FMfSW (2010)	AStSWF (2008)
Representation of structures	DTM was manually edited in over 91,000 locations to improve flow through ‘flyover’ features, such as rail/road embankment culverts, bridges etc.	DTM was manually edited in over 40,000 locations to improve flow through ‘flyover’ features, such as rail/road embankment culverts, bridges etc.	DTM was manually edited in over 5,000 locations to improve flow through ‘flyover’ features, such as rail/road embankment culverts, bridges etc.
Representation of other features	Road network defined in OS MasterMap Topography data lowered by 0.125m.	Not taken into account	Not taken into account
Manning's n values	Varied by OS MasterMap Topography Layer Feature Code	0.1 rural, 0.03 urban	0.1
Mass balance	0% (JFlow+ is mass conservative)	±1%	Not recorded
End of simulation criteria	Rainfall event duration + 3hrs	Dynamic stopping condition. Models stop running if the number of wet cells is unchanged over a 1 hour period.	Dynamic stopping condition. Models stop running if the number of wet cells is unchanged over a 1 hour period.
Downstream boundary conditions	Free outfall	Free outfall	Free outfall
Validation	3 pilot areas using historical observations and local modelling data	11 areas using historical observations and local modelling data.	Some qualitative comparison against historical observations and local modelling data.
Sensitivity testing	None	None	None

5 Incorporating local information

5.1 Overview

LLFAs are responsible for managing the risk of flooding from surface water and therefore have local knowledge about the surface water mechanisms in their area. Some LLFAs have also created their own surface water flood maps. This has been an important feature of surface water management plans and local flood risk management strategies, where detailed mapping work has been carried out. To ensure the RoFSW is the best single source of surface water flooding information for England and Wales, the LLFAs were given the opportunity to:

- review the nationally produced mapping
- submit their own local surface water mapping for inclusion where compatible

LLFAs were asked to complete the review process or submit their local mapping by 22 June 2013. As a result of this 32 local models were submitted for inclusion in uFMfSW v1. A map showing the areas where locally produced mapping has been included in uFMfSW v1 is shown in Annex D.

LLFA maps have been created using a range of methods and data. It is important that local and nationally produced mapping is sufficiently consistent and compatible so information can be brought together into a single map. This enables Risk Management Authorities and customers to **interpret surface water flood risk in a consistent way across England and Wales** and make better informed decisions.

5.2 Reviewing the nationally produced surface water flood mapping

LLFAs were asked to review the nationally produced mapping by:

- using local recorded flood data and local knowledge to identify areas that are known to flood, and to highlight unexpected patterns of flooding
- identifying how confident they are in the national mapping
- comparing locally produced information with the nationally produced mapping to determine which mapping is more representative for each area

5.3 Submitting locally produced mapping

5.3.1 Compatibility

We took the principles behind the RoFSW, and identified which **elements of the modelling or model input or output data have a significant influence on the resulting flood maps or on the way that they will be used.**

Minimum standards were set for locally produced information. There are also **recommended standards** which offer 'good practice' approaches to surface water modelling at this scale but do not need to be met for data to be included in the RoFSW. More information about compatibility criteria and where to find more detailed guides to technical modelling specifications can be found in related guidance **Submitting locally produced information for updates to the Risk of Flooding from Surface Water**.

5.3.2 Requirements for locally produced mapping

Locally produced information has been included where it:

- includes a flooding scenario as a result of rainfall with **1 in 30**, **1 in 100** and **1 in 1000** chance of occurring in any year (where the 1 in 1000 was not available, alternatives could be agreed, as shown below)
- includes flood **extent**, **depth, velocity, and flow direction data**
- takes into account the **deflection effect of buildings**
- takes into account **sub-surface drainage**
- uses a model grid size no larger than **5m**
- provides the best representation of flood risk within the LLFA area
- is compatible with the nationally produced mapping and the Regulations
- has an equal or higher confidence score than the nationally produced mapping

These requirements will also apply to any locally produced mapping that is to be included in future updates of the RoFSW.

Alternatives to 1 in 1000 chance scenario

Where outputs for a flooding scenario for rainfall with a 1 in 1000 chance of occurring (in any year) were not available this did not automatically exclude the locally produced mapping from being incorporated. In some cases, other available scenarios were used and merged with the nationally produced modelling for a flooding scenario for rainfall with a 1 in 1000 chance of occurring in any year to create a worst case scenario to use in place of locally modelled 1 in 1000 probability data.

These scenarios included:

- a flooding scenario for rainfall with a 1 in 200 chance of occurring in any year
- a flooding scenario for rainfall with a 1 in 100 chance of occurring in any year adjusted to take into account climate change predictions

5.3.3 Other influences on water levels in locally produced modelling

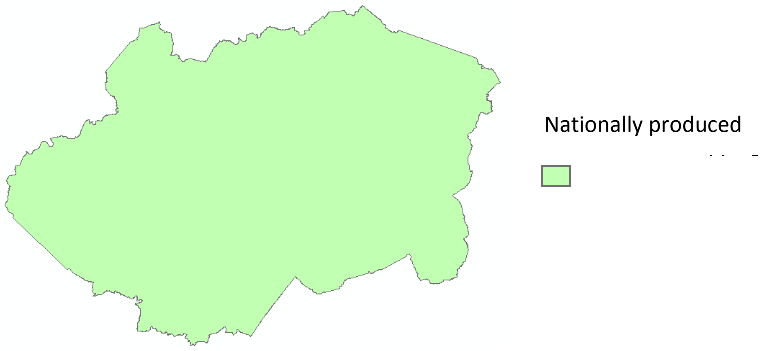
Some locally produced surface water flood models take into account main river, and possibly coastal/estuary components. It is quite common to run integrated catchment model scenarios with low and high water levels in main rivers and other receiving water bodies and interfaces (such as gates or outfalls). Factors such as phasing of tide cycles and gate operations can have a large influence on surface water flooding in coastal locations.

To ensure compatibility with the nationally produced mapping, LLFAs were asked to provide model output data for a modelling scenario where flooding is **predominantly the result of surface water conditions**, and where non-surface water influences (such as river, sea and groundwater conditions) do not unduly exacerbate, dominate, or equal the representation of surface water flooding conditions.

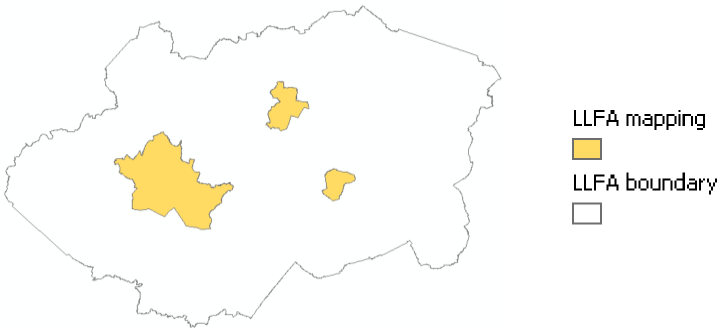
5.4 Creating the RoFSW

The RoFSW draws together nationally produced mapping and appropriate locally produced mapping from LLFAs in the following way.

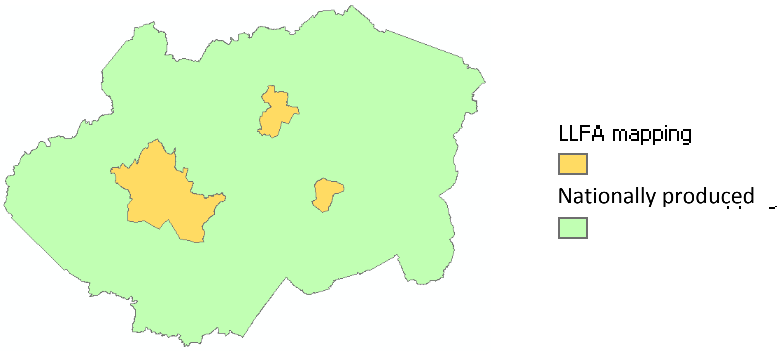
Nationally produced mapping is available for whole LLFA area.



LLFAs identify compatible and more representative mapping for areas within their boundary.



Nationally produced and local mapping are brought together to form a single map - the RoFSW - where LLFA mapping replaces nationally produced mapping for a defined spatial area.



6 Post-processing national and local model outputs

We held workshops across the country in November 2012 as part of the Defra / Welsh Government / Environment Agency capacity building programme to gather views from LLFAs on creating a consistent map. Based on feedback from LLFAs and common modelling post-processing practice we have processed the national and local model outputs.

See Annex E for examples using model outputs, of the **effect of the processing** at two different levels of detail: a detailed view so that the effects can be clearly seen, and a wider area view, which is similar to the finest scale at which the published maps will be viewed.

6.1 Re-sampling to produce a consistent regular grid

The nationally produced mapping has been produced at a **2m model grid resolution**.

All locally produced model outputs have been **re-sampled to a 2m grid**. When data is re-sampled, we have applied a number of processes and assumptions to create a new dataset from the original data.

Some locally produced model outputs exist in Triangulated Irregular Network (TIN) format, rather than a regular square grid. TINs are another way of representing topography in models. All TINs were re-sampled into a regular grid at 2m resolution to create a consistent format. Examples are shown in Annex E.

6.2 Filtering model output data

Based on feedback from LLFAs, we have:

- **removed flooded areas with a very low hazard rating below 0.575** (for more information on how hazard is calculated see section 7.5).

  There is **no filtering on depth information alone**.

- **removed areas of flooding with a total area of less than 100 square metres** (to ensure the maps are clear and avoid presenting data at too fine a scale)
- **filled in isolated dry areas (within a larger flooded area) of less than 50 square metres**

Where cells are joined diagonally, they are deemed to be part of the same flooded area.

See Annex E for further information.

7 Outputs

7.1 Overview

For each rainfall probability (3.3% (1 in 30), 1% (1 in 100) and 0.1% (1 in 1000) chance of occurring in any year) the following datasets have been created:

- extent of flooding
- depth
- velocity (including magnitude and flow direction at maximum velocity)
- hazard

In addition there are datasets that contain information about the source of the data (i.e. whether it was from the nationally produced modelling or locally produced modelling) and the confidence in the data outputs:

- model details
- suitability

The RoFSW outputs are banded to make the data easier to interpret for map users and to provide a consistent final map. Note that for the published version which will be available to view on our website as part of the **Risk of Flooding from Surface Water** map, we have merged some of the depth and velocity bands together, to provide a simpler, clearer picture for the public, with just three depth bands and two velocity bands.

Validation work focussed on the mapped flood extents. There is likely to be greater uncertainty in depth, velocity and hazard datasets.

7.2 Extent of flooding

The extent of flooding is available as a separate layer for each rainfall probability and each shows the area modelled as flooding at that probability or greater.

The published map available to view on our website as part of the **Risk of Flooding from Surface Water** map appears as one layer with the following categories:

High	Flooding occurring as a result of rainfall with a greater than 1 in 30 chance in any given year (annual probability of flooding 3.3%)
Medium	Flooding occurring as a result of rainfall of between 1 in 100 (1%) and 1 in 30 (3.3%) chance in any given year
Low	Flooding occurring as a result of rainfall of between 1 in 1000 (0.1%) and 1 in 100 (1%) chance in any given year
Very Low	Flooding occurring as a result of rainfall with less than 1 in 1000 (0.1%) chance in any given year

7.3 Depth

Based on feedback from LLFAs, the following categories have been selected for banding flood water depth (above ground level).

Depth (m)	Threshold
< 0.15	
0.15 – 0.30	At 0.15m, flooding would: • typically exceed kerb height (standard kerb height is 125mm) • likely exceed the level of a damp-proof course • cause property flooding in some areas
0.30 – 0.60	At 0.30m flooding is likely to cause property flooding. This is based on average property threshold levels.
0.60 – 0.90	Property-level flood resilience measures are typically effective up to a water depth of 0.60m above floor level. Above depths of 0.60m these measures are likely to be much less effective and structural damage is more likely to occur. However, as floor levels vary, the maximum flood depth where resilience measures are still effective may be in a range between 0.60m and 0.90m above ground level.
0.90 – 1.20	Very likely to exceed the maximum flood depth where property-level flood resilience measures are still effective.
> 1.20	

The published map available to view on our website as part of the **Risk of Flooding from Surface Water** map groups these into categories of ‘below 300mm’, ‘300 – 900mm’ and ‘above 900mm’.

7.4 Velocity

7.4.1 Speed

There were no strong views from LLFAs on appropriate categories for water velocity. We have selected categories which show a simple spread of data and are consistent with previous studies.

The following categories are used for flood water velocity in metres/second (for context, typical walking speed is approximately 1.5m/s):

- < 0.25
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00

The published map available to view on our website as part of the **Risk of Flooding from Surface Water** map groups these into categories of ‘less than 0.25 m/s’ and ‘over 0.25m/s’. We know the majority of the public’s preference is for depth and direction and most people are not interested in the speed of water. So to keep things simple we are only using the two categories to show whether water is moving, or is effectively still.

7.4.2 Direction (at maximum speed)

The flow direction at maximum speed has been created for the standard 2m grid cell resolution; it has also been produced at a reduced resolution of 25m for easier display. It is split into eight directional bands: N, NE, E, SE, S, SW, W, NW.

Flow direction data was not a compulsory requirement when locally produced modelling was supplied, so in some locations where local data has been used there is no information available. We hope LLFAs will provide flow direction data for future updates.

7.5 Hazard rating

We have gone a step further than the requirements of the Flood Risk Regulations and also produced maps showing hazard rating based on a function of simultaneous depth and velocity for England and Wales. This uses the following equation taken from Defra R&D on risks to people, where:

Hazard rating = depth x (velocity + 0.5) + debris factor

Debris factors are also defined in Defra R&D on risks to people. The nationally produced surface water flood mapping uses a debris factor of:

- 0.5 for depths less than or equal to 0.25m
- 1.0 for depths greater than 0.25m (irrespective of the type of land use).

As mentioned above in section 6.2, we have removed areas from the mapping that have a very low hazard rating below 0.575 using these debris factors. This is where flood water depth and velocity are low.

The following hazard categories are used:

- low hazard (hazard rating 0.5 - 0.75)
- moderate hazard (hazard rating 0.75 - 1.25)
- significant hazard (hazard rating 1.25 - 2.0)
- extreme hazard (hazard rating 2.0 and above)

For more information about calculating hazard ratings and for further definitions of the hazard categories above, please refer to Defra R&D on risks to people.

7.6 Model details

This layer gives information about the source of the modelling information and the parameters used.

When LLFAs provided locally produced information for inclusion in the RoFSW, we asked them to provide some background information (metadata). **This information is provided with the maps so that map users can identify the source of the information.**

A description of the information available is shown in the table below. The model details layer contains both information about the nationally produced surface water flood mapping and the locally produced information.

Attribute	Description	Database name	Example
ID (auto-generated)	This is a number auto-generated by GIS software	ID	15467
LLFA name	Full LLFA name	Name	Puddleton County Council
Data owner	LLFA name, or 3rd party name (if applicable)	Data_own	Puddleton County Council
Model domain reference	A unique reference for your model	Dom_ref	Example: RiverTow_2010_03 (for a model carried out in River Town completed (or updated) in March 2010)
Model name	Name of model including reference to location	Mod_name	River Town SWMP modelling 2010
Description	Describe reason for modelling	Descrip	River Town SWMP covering town centre (completed March 2010)
Model completion date	Date model complete (or the last update to the model)	Mod_date	03/2010
Model type	Type of model	Mod_type	Hydraulic model with basic drainage/surface interactions
Model software	Name of software used	Mod_soft	TUFLOW
Hydrology type	Name/type of hydrology used	Hyd_type	Direct rainfall - FEH Depth Duration Frequency
Source digital terrain model	Source of digital terrain model used	DTM	LIDAR EA
Source DTM resolution	Grid resolution of the digital terrain model	DTM_res	1m / 2m
Model grid resolution	Resolution of the model grid	Mod_grid	2m
Storm duration	Rainfall storm durations	Stor_Dur	1hr, 3hr, 6hr

Representation of sub-surface drainage	Representation of sub-surface drainage	Sewer	Reduction in rainfall amount of 12mm/hr
Surface roughness values	Source of information on surface roughness defined according to land use	Manning	OS MasterMap
Representation of buildings	Representation of buildings in urban areas	Build	Raised building footprints by 300mm
Debris factor (this is only mandatory where hazard information is provided)	Debris factor(s) used in calculating hazard rating as defined in [Defra R&D on risks to people](#) Hazard rating = depth x (velocity + 0.5) + debris factor	Debris	Debris factor of 0.5 for depths <=0.25m, and 1.0 for depths >0.25m (irrespective of land use type)* **N.B. these figures are used as standard in Infoworks software, but can be varied in TUFLOW*
Confidence score	Confidence score assigned to locally produced modelling - see Annex B for more information on assessing confidence.	Confid	3
Comments	Other details about model	Comments	None

7.7 Suitability

The suitability data gives an indication of the scale that the data is applicable at, based on the confidence in the modelling at that location, and can inform better decision making by helping users understand the reliability of the data for assessing flood risk at different scales.

As part of the modelling process all areas were assigned a default confidence rating, which relates to the suitability shown above, based on the modelling methodology, data availability and parameters used in that location. Unless there was clear evidence to change this during the review process these are unchanged from the default value.

Much of the data from the RoFSW has a suitability category of ‘county to town’ or ‘town to street’ unless local modelling was used or there was clear evidence available to validate the results. Where model results correlated well with historic flood records the confidence rating was raised. Where correlation was poor the confidence rating was lowered. In some cases the data may be more or less reliable than shown, but this has not been changed if there is no clear evidence to amend the rating. As more local evidence becomes available to LLFAs, they will be able to submit this for future updates to improve the suitability rating, in addition to any new local modelling, and therefore this should improve further for future updates.

The descriptions of the suitability are as follows:

Suitability: 'it's good enough for...'		Reliability: 'how good is it for...'		Examples of this kind of flood risk information
Indicative suitable scale	**Indicative suitable use**	**How reliable is this for a local area?**	**How reliable is this for an individual property?**	
National to county - suitable for identifying which parts of countries or counties are at risk, or which countries or counties have the most risk.	Suitable for identifying areas with a natural vulnerability to flood first, deepest or most frequently.	Very unlikely to be reliable for a local area.	Extremely unlikely to be reliable for identifying individual properties at risk.	The first "National Flood Risk Assessment" (NaFRA, 2004, 2005, and 2006). The first national surface water map "Areas Susceptible to Surface Water Flooding" (AStSWF, 2009).
County to town - suitable for identifying which parts of counties or towns are at risk, or which counties or towns have the most risk.	Suitable for identifying approximate extents, shallower and deeper areas.	Unlikely to be reliable for a local area.	Very unlikely to be reliable for identifying individual properties at risk.	The majority of the current NaFRA which dates from 2008. The second national surface water map "Flood Map for Surface Water" (FMfSW, 2010).
Town to street - suitable for identifying which parts of towns or streets are at risk, or which towns or streets have the most risk.	Suitable for identifying flood extents, approximate depth of flooding, and identifying streets at risk of flooding.	Likely to be reliable for a local area (and so the information is suitable for areas of land, not individual properties).	Unlikely to be reliable for identifying individual properties at risk (and so the information is suitable for areas of land, not individual properties).	Some parts of the current NaFRA which benefit from good local data and have been validated (checked). The Flood Map for Planning (Rivers and Sea) (previously known as the Flood Map, containing Flood Zones).
Street to parcels of land - suitable for identifying which parts of streets or parcels* of land are at risk, or which streets or parcels of land have the most risk.	Suitable for identifying flood extents, depths and approximate velocities.	Very likely to be reliable for a local area (and so the information is suitable for areas of land, not individual properties).	Likely to be reliable for identifying individual properties at risk (though not whether they flood internally, so the information is suitable for areas of land, not individual properties).	Flood models and maps from detailed local studies, which have been successfully calibrated (tuned) and validated (checked) against observed local flood data.
Property (including internal) - suitable for identifying which parts of a property are at risk (including internal / external distinction), or which properties have the most risk.	Suitable for identifying flood extents, depths, velocities, and distinguishing between street and property flooding.	Extremely likely to be reliable for a local area.	Likely to be very reliable at identifying individual properties at risk, including depths of flooding internally (this provides a genuine property level assessment).	Flood models and maps of the whole water system. These are exceptionally detailed local studies which benefit from excellent input data such as long records. This kind of information is only available in a limited number of areas.

8 Strengths and limitations of the RoFSW

8.1 Strengths

We learned from past studies and pilots to develop the RoFSW with the aim of producing the best national surface water flood map for England and Wales. The strengths of the maps include:

- 2 metre model grid used, so many small ground features are taken into account
- high quality ground level information, which was enhanced to better represent buildings and roads, with manual editing to "flyover features"
- a wide range of storm scenarios were modelled using three flood probabilities (1:30, 1:100 and 1:1000)
- the influence of land use and soil type were taken into account
- more accurate local mapping provided by LLFAs was incorporated where it was compatible
- complex processing which reflects LLFA preferences to make the maps as clear as possible, for example in filtering out particularly small areas of flooding whilst retaining potentially significant flooded areas
- depth, velocity, flow direction and hazard maps have been produced

Local validation by LLFAs improved the ‘suitability’ information where flood records were available. This ‘suitability’ information allows users to understand the variation in the reliability of the data for a range of uses. We therefore have a map which contains broadly nationally consistent data, and which is suitable for comparing risk from surface water flooding in different places. In some locations, we know that the maps are also a good reflection of recorded flooding. There is also the opportunity to further refine the data in future by incorporating local information.

We regard the map as the best available source of national information on surface water flooding. It is an excellent starting point for understanding patterns and probability of surface water flooding.

8.2 Limitations

Although the RoFSW is a significant improvement on past nationally produced surface water flood mapping, it is important not to lose sight of the limitations which remain. These include the following:

- We assumed a single drainage rate for all urban areas within the nationally produced modelling unless LLFAs were able to give us better local data. Modelled flood extents are particularly sensitive to the way drainage is taken into account. Omitting large subsurface drainage elements such as flood relief culverts and flood storage can also significantly affect the modelled pattern of flooding.

- The nationally produced modelling assumes a free outfall and so does not take into account tide locking or high river levels which may prevent surface water from draining away freely.
- Limited recorded surface water flood data exists for LLFAs, so in many places LLFAs have not yet been able to validate the nationally produced modelling.
- As with many other flood models:
    - The input information, model performance and modelling that we used to create the nationally produced modelling vary for different areas. For example, in many areas, the ground level data is based on detailed LIDAR information, but where this is not available ground levels are much less accurate. Similarly, models of this type tend to perform better in steeper rural areas than in flat urban areas. These variations affect the reliability of the mapped flood extents and, in turn, the suitability for different applications.
    - RoFSW does not take individual property threshold heights into account so the map shows areas that may potentially flood but cannot accurately predict the impacts on individual properties.
    - The flood extents show predicted patterns of flooding based on modelled rainfall. The patterns of flooding from two similar storm events can vary due to many local circumstances.

Consequently these maps cannot definitively show that an area of land or property is, or is not, at risk of flooding, and the maps are not suitable for use at an individual property level.

9 Validation studies

9.1 Overview

When we developed the nationally produced surface water flood mapping, we benefitted from the experience gained in developing the 2008 and 2010 national surface water flood maps, and also from the feedback received from local authorities as users of these maps. We were also able to take note of the findings of the 2012 surface water mapping pilot studies. Validation was an important part of all of these studies, and consequently has influenced the development of the RoFSW.

Further validation was carried out to assess how well it reproduces observed flooding and how well the discrepancies between the nationally produced map and observed flooding are reflected by the confidence rating.

The validation work carried out as part of the pilot studies demonstrated the sensitivity of the modelling to the rainfall-runoff coefficients, and therefore helped us to decide which values to use. The validation process carried out on the RoFSW modelling results allowed us to ensure that the confidence scores reflect how well the model was performing.

The review process described in section 5.2 allowed validation to be carried out at a local level. Early validation was also undertaken for the three pilot locations of Greater Manchester, Gloucestershire and Rhondda Cynon Taff. This used both qualitative methods and quantitative analysis of flooded properties identified by the nationally produced map. For Greater Manchester, only a visual comparison between model outputs and validation data was possible due to the quality of the data. For Gloucestershire and Rhondda Cynon Taff, where point data sets of recorded flood incidents are available, two methods for validation were used

9.2 Greater Manchester

Validation data from Greater Manchester consisted of polygons of flooding recorded in Bolton, with source noted as surface water, and polygons of other wet spots recorded in Bolton. However, the lack of further suitable evidence makes it difficult to draw conclusions about model performance. The nationally produced map correctly identifies some known flooding locations, but not all. There are some areas of significant flooding shown on the map that have no known flooding history. There is little evidence of an improvement in results compared to previous national surface water flood mapping.

The validation data was of insufficient quality to assess whether the assigned confidence ratings were appropriate

9.3 Gloucestershire

Validation data for Gloucestershire consisted of a point dataset of recorded possible surface water flood incidents from summer 2007 and an output from an InfoWorks ICM model for 1 in 100 probability event roughly consistent with the 2007 event. The local model represents sub-surface drainage through a linked sewer model and therefore provides a good test of quality of the nationally produced model.

The validation showed a close correspondence between the two models, with both picking out properties reported as flooding in 2007. The nationally produced mapping predicts significantly deeper water than the InfoWorks model, but the two models predict approximately the same areas of lower and higher velocity.

The dataset of properties flooded in summer 2007 allows a quantitative comparison of properties predicted as flooding to be made for floods recorded in Cheltenham. However, property counts are sensitive to buffering and the thresholds that area applied. The result is consistent with previous studies with the majority of properties observed to flood being correctly identified by the nationally produced map. The nationally produced map and the local InfoWorks ICM give similar results in identifying the location of the properties that flooded in 2007.

9.4 Rhondda Cynon Taff

For Rhondda Cynon Taff a point dataset was available showing surface water incidents that have been recorded over a period of approximately ten years. We would expect this to correspond most closely with the 1 in 30 probability event. However, there is little correlation between the national flood map and the locations of flood incidents, which are scattered throughout the urban areas with no obvious clustering.

9.5 Further information

All three generations of national surface water flood mapping show a similar performance in terms of validation of properties shown in areas at risk of flooding, correctly identifying approximately a third of the 1,000 buildings known to have flooded. This stresses the importance of using the maps as an indication of patterns and probability of flooding, as feedback suggests that these have improved considerably over the three generations of national surface water flood mapping, and confirms that the data is not suitable for identifying individual properties at risk.

Further information on the validation work that was carried out can be found in the **National modelling and mapping method statement - May 2013** and the **Updated Flood Map for Surface Water – National Scale Surface Water Flood Mapping Confidence and Validation – March 2013** reports, available from your local Environment Agency office.

Future validation exercises would benefit from more locations and data to test against. Our recommendation is that good quality records are kept – including flood extents and depths, and the date of flooding, as well as the properties affected.

10 Where to go for more information

10.1 Further supporting documents

This document is the first of a suite of supporting documents that will help you understand what the RoFSW is, how it can be used and how it will be maintained in the future. The other documents that will be produced include the following:

- **Risk of Flooding from Surface Water – Understanding the map** – document describing what the maps are suitable for and their limitations. Available online - https://www.gov.uk/government/publications/flood-risk-maps-for-surface-water-how-to-use-the-map
- **Submitting locally produced information for updates to the Risk of Flooding from Surface Water** – document describing how the RoFSW map is updated. Available from your local Environment Agency office.
- Further detail of the methodology used for the nationally produced modelling and mapping can be found in the **National modelling and mapping method statement - May 2013** available from your local Environment Agency office.

10.2 Who to contact for more information

For further information please contact:

- the Environment Agency National Customer Contact Centre on 03708 506506 for general queries
- the Environment Agency DataInfo team on data.info@environment-agency.gov.uk for any questions about the data download or licensing
- your LLFA for queries about **local** surface water flood risk mapping and management

Annex A – Flood Risk Regulations

A.1 What do the Flood Risk Regulations say?

The Flood Risk Regulations (2009) (the Regulations) implement the requirements of the European Floods Directive which aims to provide a consistent approach to managing flood risk from all sources across Europe. The approach is based on a six year cycle of planning which includes the publication of:

- Preliminary Flood Risk Assessments (PFRAs) by 22 December 2011
- Flood hazard and risk maps by 22 December 2013
- Flood risk management plans by 22 December 2015

As part of the Preliminary Flood Risk Assessment, LLFAs identified Flood Risk Areas, which are designated areas where flood risk from local sources is considered to be significant as identified in accordance with government guidance. Under the Regulations, there is only a requirement for LLFAs to produce flood hazard and risk maps, and for the Environment Agency to publish them, in Flood Risk Areas. However surface water flood risk is widespread and needs to be managed both in and outside Flood Risk Areas through Local Flood Risk Management Strategies which are required under the Flood and Water Management Act, and so Defra and Welsh Government asked us to produce them for all England and Wales.

A.2 What are flood hazard maps?

The term 'hazard' has been described in previous research as a combination of the effects of water depth, velocity and debris. The term 'hazard' is described in the Regulations, and defines flood hazard maps as showing:

- the likely **extent** of flooding
- **depth** of flooding
- the **direction** and **speed** of flow
- the **probability** of the floods occurring

The nationally produced surface water flood mapping, and therefore also the RoFSW, enables LLFAs to meet the requirements of the Regulations for flood hazard maps for surface water within designated Flood Risk Areas (as defined in the PFRAs).

A.3 Rainfall probabilities

To meet the requirements of the Regulations, the RoFSW assesses a flooding scenario as a result of rainfall with the following chance of occurring in any given year (annual probability of flooding is shown in brackets):

- 1 in 30 (3.3%)
- 1 in 100 (1%)
- 1 in 1000 (0.1%)

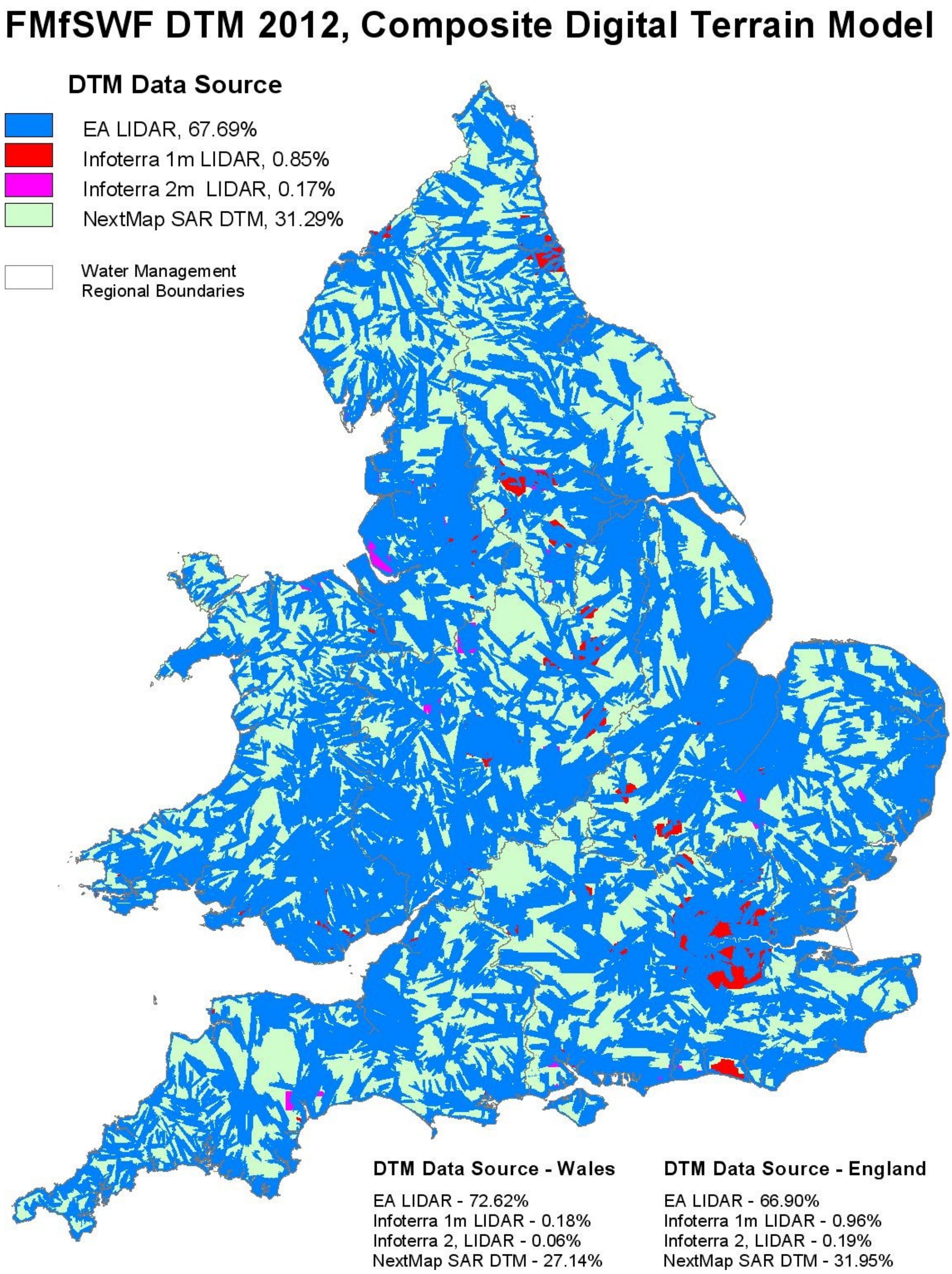
Previous nationally produced surface water flood mapping and most locally produced mapping does not provide all of this information.

Annex B – Model improvements

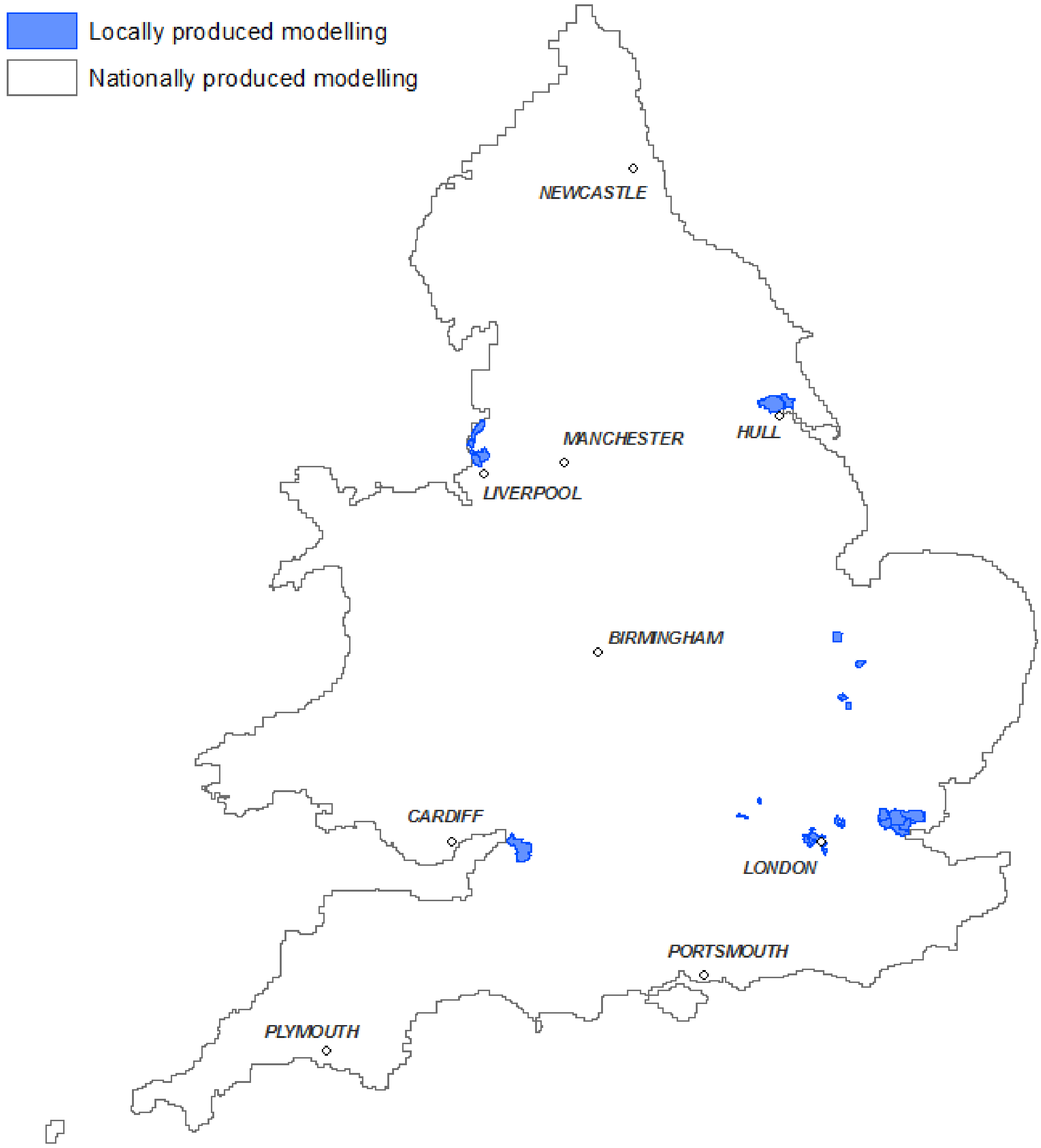
The table below outlines the improvements in modelling techniques and data that make the updated nationally produced surface water flood mapping a more representative map of surface water flood risk than previous nationally produced mapping.

Area of improvement	Improvements
Digital terrain model	Environment Agency's LIDAR/NEXTMap composite DTM which includes high resolution (2m or finer) LIDAR for **all urban areas greater than 3km²** in England and Wales. Small topographic features and flow paths can be represented in the model.
Model grid size	The flood modelling will be undertaken on a **2m resolution** grid for all England and Wales. Our confidence in this data will also depend on other inputs to the model such as the Digital Terrain Model.
Representation of buildings and other topographic controls on flow	OS MasterMap data has been used to **represent buildings in the digital terrain model**. The method allows flood water to flow into the building footprint once the water depth exceeds 300mm. The road network is known to preferentially collect and route water. Road surfaces as defined in OS MasterMap will be lowered by 125mm (height of a standard kerb) to better delineate these flow routes.
Reduction to rainfall to represent sewers	Drainage capacity is the source of greatest uncertainty in the modelling. Information from LLFAs on drainage capacity, infiltration/runoff rates has been incorporated into the model where it is available. Where local information is not available, the modelling has used a **default drainage rate of 12mm/hr** to reflect the 'national average' capacity of urban drainage systems.
Reduction to rainfall to represent infiltration	Land use has a strong influence on the way water on the surface behaves. OS MasterMap data on land cover, and data on soil type and land permeability is used to represent the **spatial variation in runoff and infiltration rates**.
Storm duration(s)	The duration and intensity of a rainfall storm that causes the most flooding varies widely between areas as it is strongly linked to the topography. Information from LLFAs about rainfall storms that have the greatest effect in an area has been incorporated into the model where available. Where local information is not available, storm durations of **1 hour, 3 hours, and 6 hours** using the 50% summer rainfall profile.
Surface roughness (Manning's 'n')	OS MasterMap data has been used to define spatially vary surface roughness according to land cover type.
Flooding as a result of rainfall probability	The model produced outputs for flooding outcomes as a result of three rainfall probabilities - **1 in 30, 1 in 100 and 1 in 1000** chance of occurring in any year.
Model software and equations	The modelling software uses more detailed mathematical equations (full shallow water equations) permitting production of more accurate velocity information.

Annex C – DTM Data Sources



Annex D – Source of modelling in uFMfSW v1



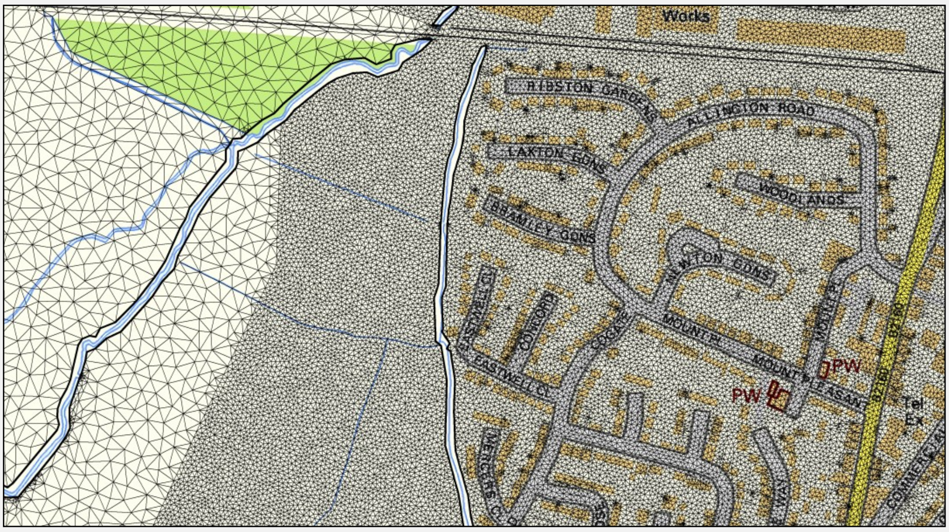
Annex E – Post processing examples

E.1 Re-sampling to produce a regular grid

E.1.1 Detailed view

Model outputs re-sampled from Infoworks 2D mesh export (TIN) to a 2m resolution regular grid.

Infoworks mesh export



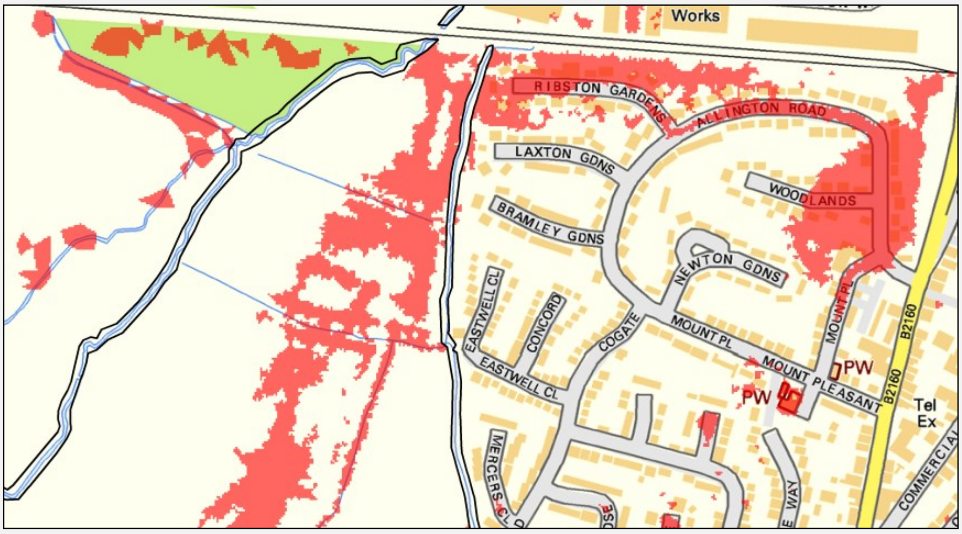
Re-sampled to 2m regular grid

E.2 Filtering - removing very low hazard below 0.575

E.2.1 Detailed view

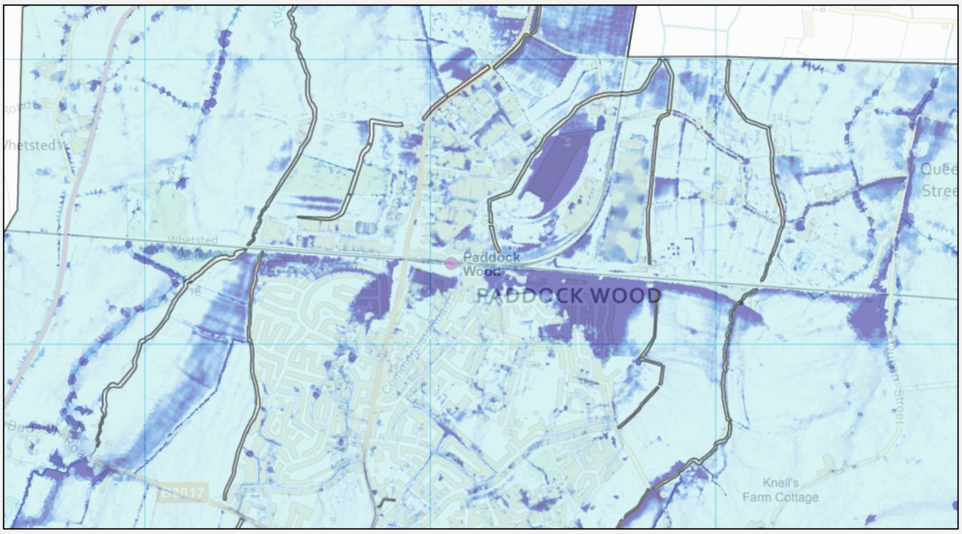
Model output data before filtering

Filtered model output data - removing very low hazard below 0.575

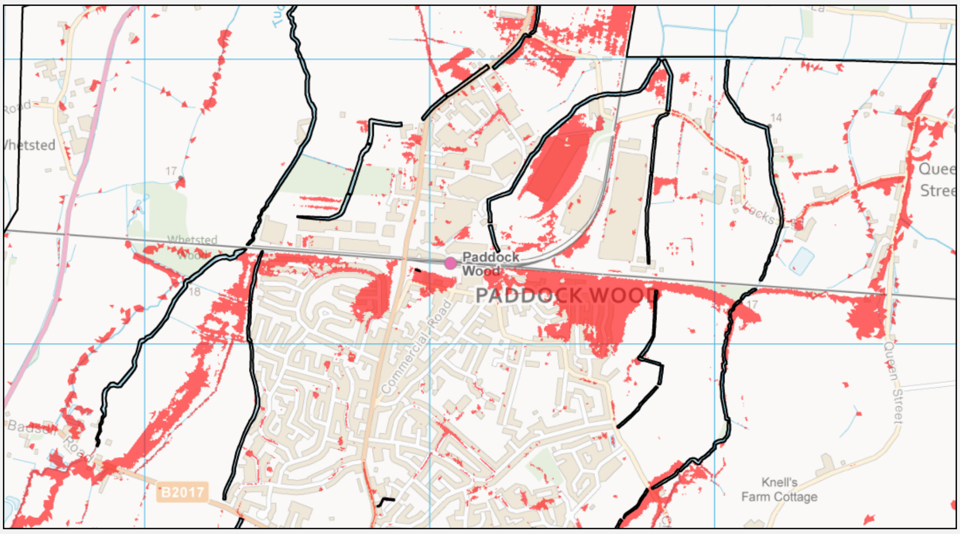


E.2.2 Wider area view

Model output data before filtering



Filtered model output data - removing very low hazard below 0.575

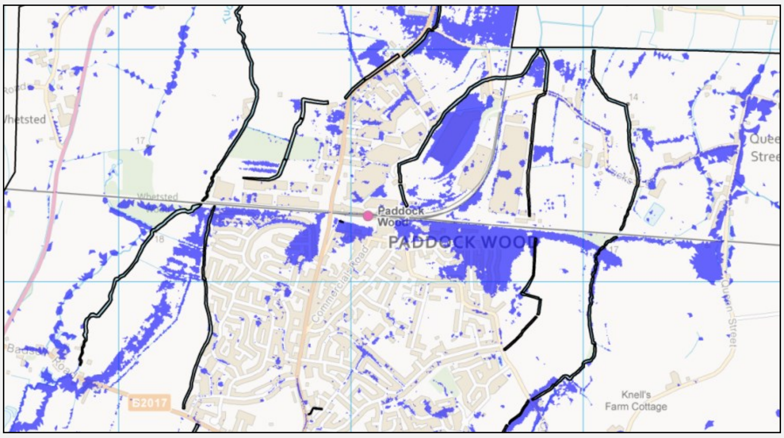


E.2.3 Wider area view - removing flooding below 0.1m, 0.3m, and 0.5m thresholds

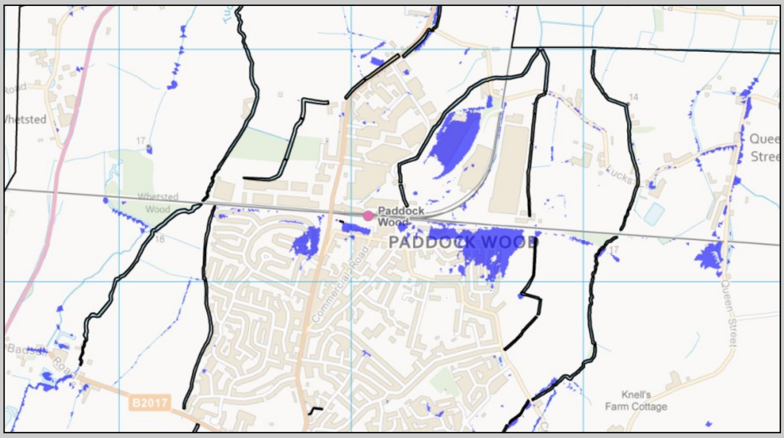
The RoFSW is filtered by hazard rating, rather than a depth threshold. However, this information is provided for context as many locally produced studies use a depth threshold, rather than a hazard rating, to filter model output data.

Filtered model output data - removing depths below a threshold

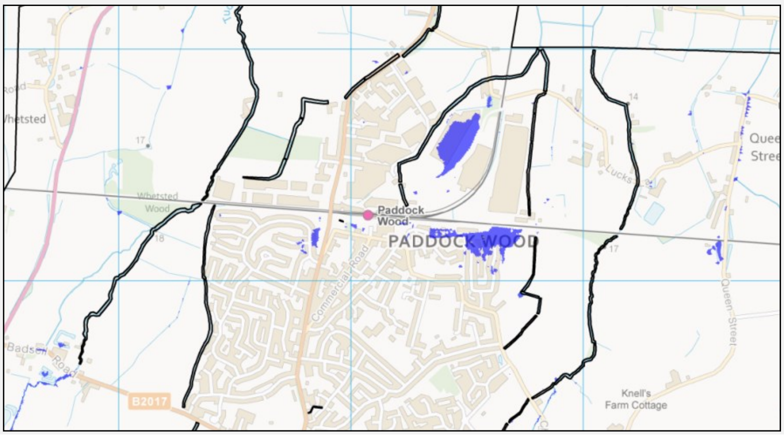
0.1m



0.3m



0.5m

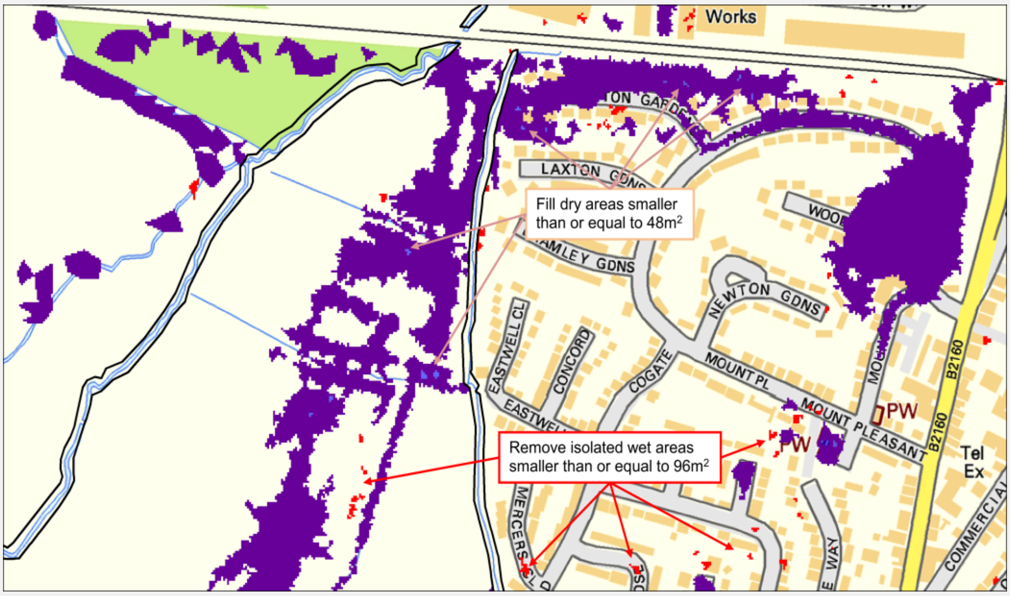


E.3 Filtering - removing small areas of flooding / filling isolated dry areas

Removing small areas of flooding less than 100 square metres (due to the grid size this equates to areas smaller than or equal to 96 square metres), and filling dry areas less than 100 square metres (due to the grid size this equates to areas smaller than or equal to 48 square metres).

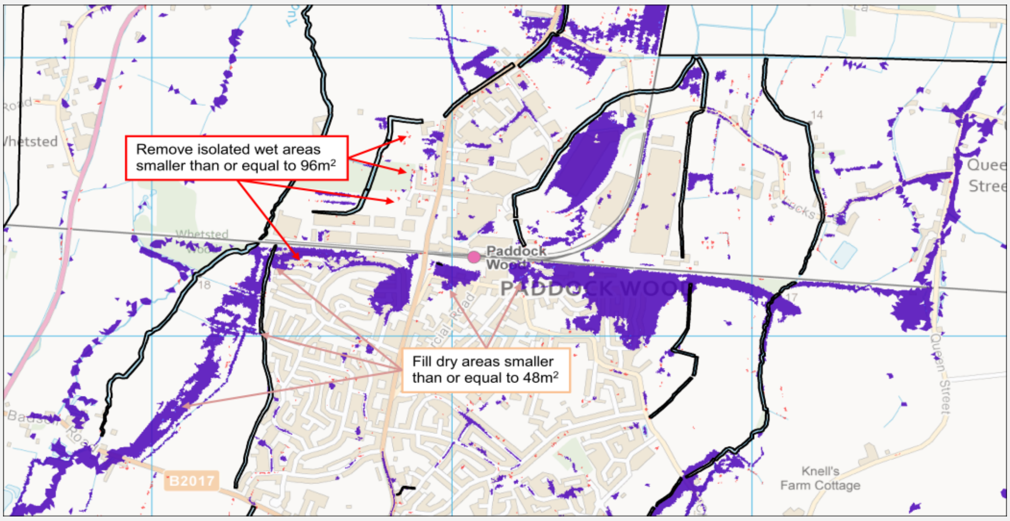
E.3.1 Detailed view

Filtered model output data



E.3.2 Wider area view

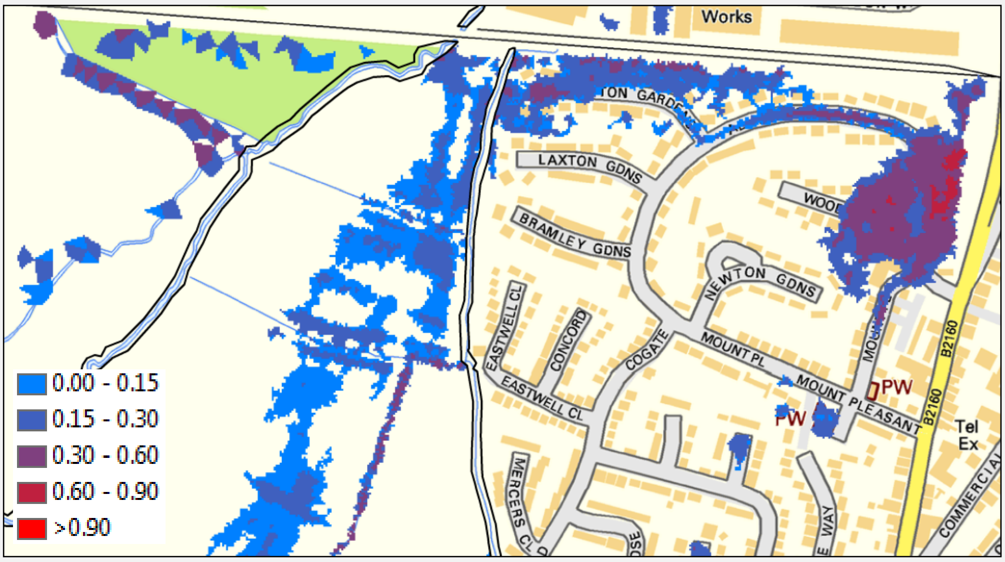
Filtered model output data



E.4 Banding - depth

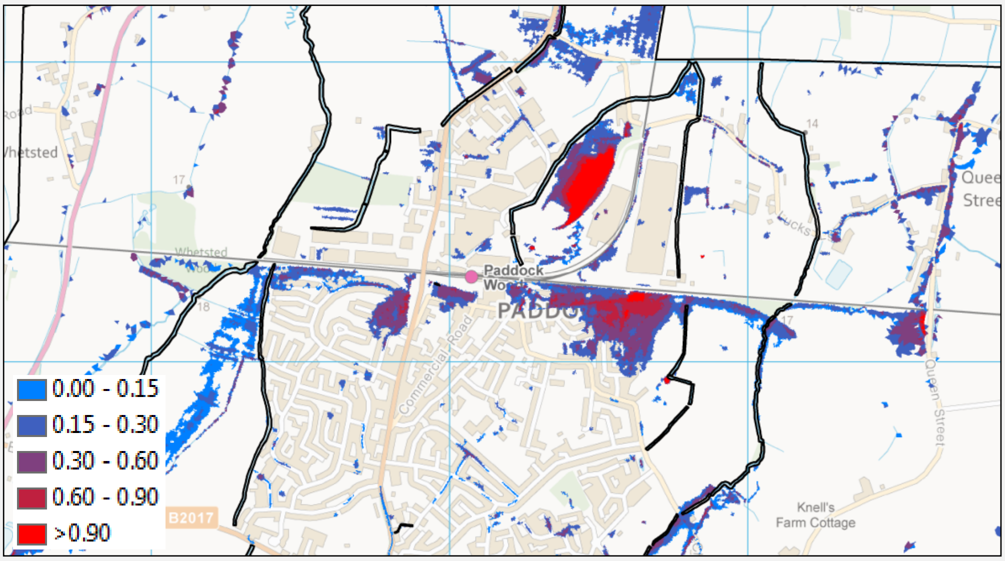
E.4.1 Detailed view

Banded model output data



E.4.2 Wider area view

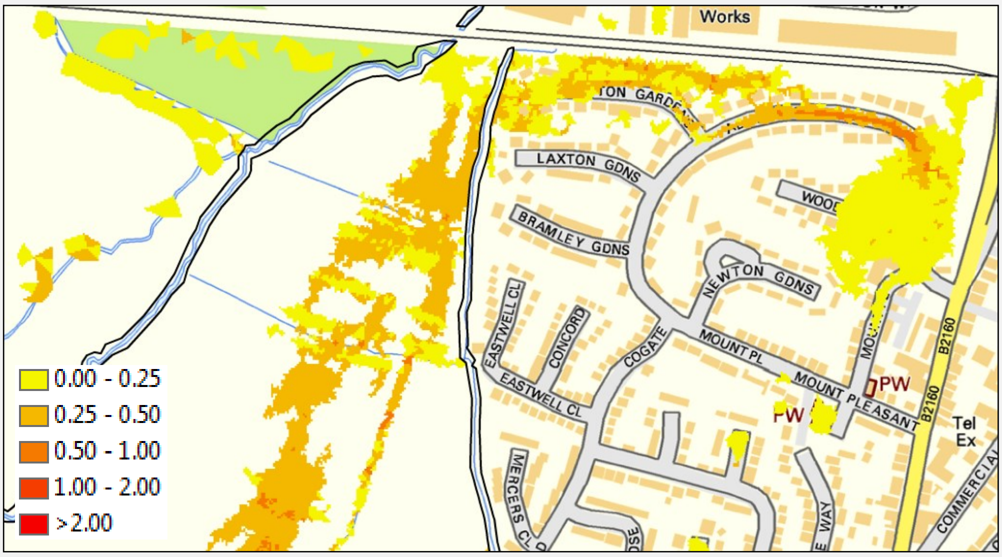
Banded model output data



E.5 Banding - velocity

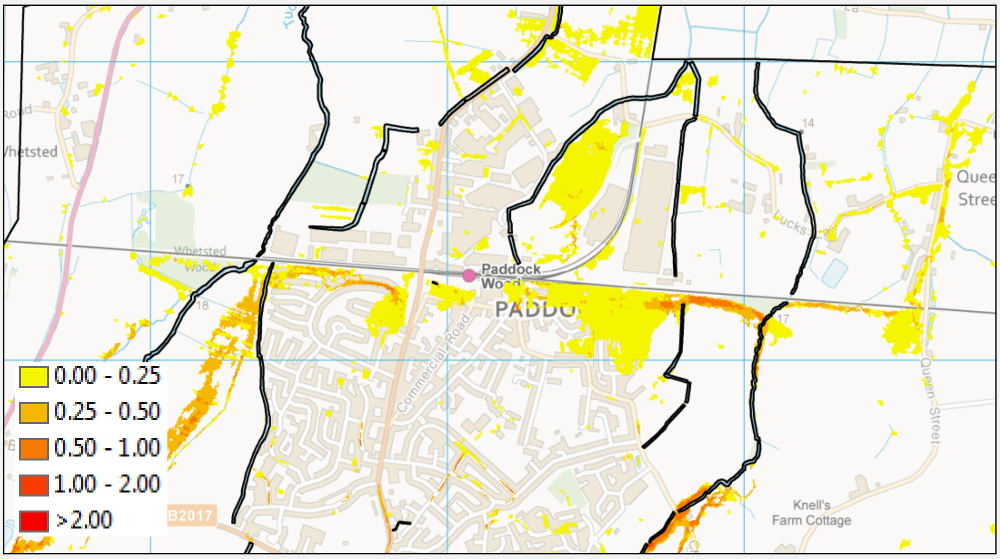
E.5.1 Detailed view

Banded model output data



E.5.2 Wider area view

Banded model output data

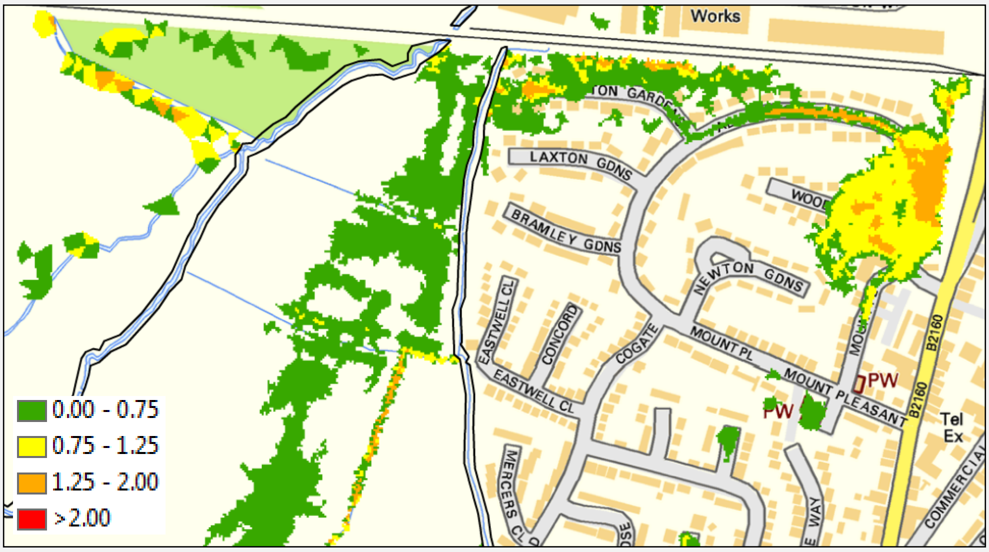


E.6 Banding - hazard rating

These examples are provided for information only; maps showing hazard ratings are not necessary to meet the requirements of the Flood Risk Regulations.

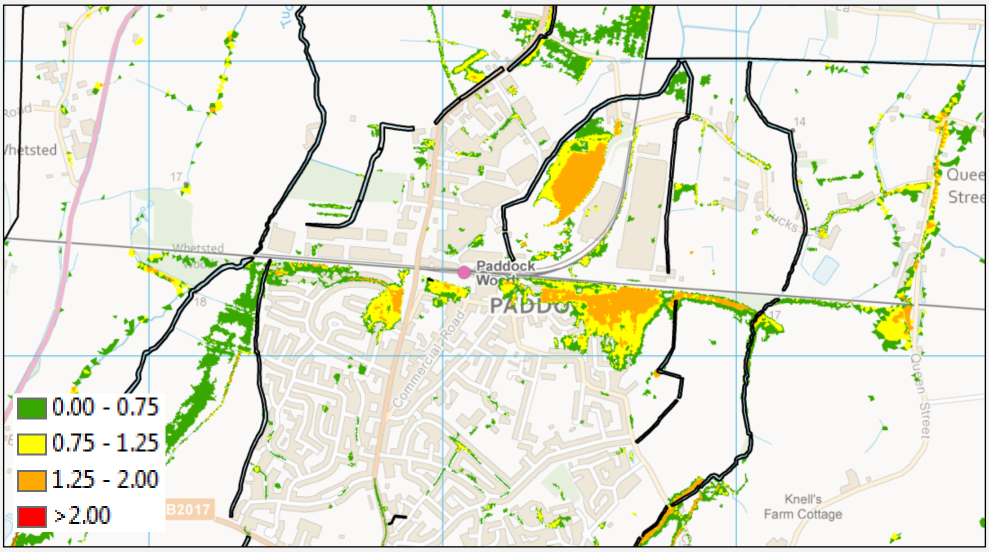
E.6.1 Detailed view

Banded model output data



E.6.2 Wider area view

Banded model output data



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