Future Flood Maps: Summary

Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

1. Introduction

The Flood Risk Management (Scotland) Act 2009 (FRM Act) introduced a co-ordinated and partnership approach to how we sustainably tackle flood risk in Scotland. To fulfil this we are considering all sources of flooding and whole river catchments when making flood risk management decisions.

A key milestone of the FRM Act is the production of flood hazard and flood risk maps for Scotland. These maps provide the most comprehensive national source of data on flood hazard and risk:

The Climate Change (Scotland) Act 2009 sets out responsibilities for climate change mitigation and adaptation and places duties on the public bodies relating to climate change. These include acting in the way best calculated to help deliver the Scottish Climate Change Adaptation Programme and to act in the way they consider the most sustainable.

SEPA's climate change commitment statement includes a commitment to using our flooding roles to greatest advantage to improve climate resilience for Scotland's communities. This includes preparing information that can be used by people to better understand the impacts of climate change on flood risk and to factor this into their decisions.

The flood map information available has now been extended to include future flood hazard maps for a single climate change scenario for the medium likelihood event for river and coastal sources of flooding.

The addition of a climate change scenario to the flood hazard maps for river and coastal flood sources helps to support an improved understanding of future flood hazard and flood risk which, in turn, enables more informed decisions to be made about long term flood risk management planning.

This summary provides information on the available future flood map scenarios including the climate change projections used. Its primary purpose is to support Scottish Government, local authorities, Scottish Water and other responsible authorities in their understanding of how the maps were developed and support internal/external briefings and enquiries. This in turn will help to increase public awareness and understanding of flood risk. Previous knowledge of the flood maps and their development is assumed.

2. Climate change scenarios

The river and coastal future flood hazard maps were developed following the same modelling and mapping approaches as for the present day flood hazard map scenarios but with peak flows and extreme sea levels revised to reflect projected changes under a climate change scenario.

The leading source of climate information for the UK is the UK Climate Projections.
The scenarios used within the future flood hazard map scenarios were based on UK Climate Projections 2009 (UKCP09) (Murphy, et al., 2009) which was the best information available when the national modelling was undertaken (2011-2013).

Since then, a new set of projections, UK Climate Projections 2018 (UKCP18) (Lowe, et al., 2018) has been published and is now the most up to date information on the future climate of the UK to 2100. These projections were not available in time to inform the development of the current future flood maps. The future flood map climate change allowances will be reviewed in light of the new UKCP18 information, which can be incorporated into future updates.

2.1 Interpreting projections

Projections are estimates of future climate outcomes. They are produced for a range of potential future climates, however they may not capture all possible outcomes and the real world may follow an alternative pathway.

Probabilistic projections assign probabilities to different possible climate change outcomes, which indicate how much evidence from climate models and observations supports a particular future outcome within that scenario (Murphy, et al., 2009).

For each scenario, a spread of modelled climate change outcomes are produced by running a large number of variants of a model with different input values[1]. These are used to generate a distribution. The 50th percentile, sometimes called a central estimate, could be considered a level for which as much evidence is produced for a lower outcome as for a higher one within that scenario.

2.2 Emissions scenario

The impact of climate change on flood risk will depend on how much global action there is to reduce greenhouse gas emissions and on characteristics of a local area.

Future greenhouse gas emissions depend on a range of social, economic and technological factors, including for example population and economic growth, as well as unknowns about how the climate system responds. To predict future climate certain assumptions about social, economic and physical changes to our environment that will influence climate change are needed. For this reason, climate projections are produced for different emissions scenarios which correspond to different socio-economic pathways.

SEPA's future flood hazard maps have been prepared using projected changes in river flow and sea levels under the UKCP09 **High emissions scenario**[1]**.** This scenario is based on the Special Report on Emissions Scenarios A1FI scenario used in the Intergovernmental Panel on Climate Change's 4th Assessment report (IPCC AR4).

[1] More information and explanation of UKCP09 probabilistic projections and emissions scenarios can be found in the UKCP09 Projections report.

The High emissions scenario is a scenario where greenhouse gas emissions continue to rise, with no action taken to mitigate climate change, leading to a greater global temperature increase.

The future flood hazard maps have been produced **for a single emissions scenario**. The actual level of change in flood hazard will depend on future emissions, climate response and actions we take to manage future flood risk. However, the maps allow people to see for the first time where climate change may increase flood risk in Scotland.

The use of a high emissions scenario is considered to be appropriate for strategic level flood hazard mapping as the maps can help inform significant and long-lasting flood risk management decisions.

The following sections detail the climate change scenarios used within the river and coastal future flood maps.

Please note however, there are differences between the scenarios used within the future flood maps and the allowances contained in SEPA's *"Climate change allowances for flood risk assessment in land use planning guidance".*

Planning authorities should refer to the information on SEPA's Land Use Planning Guidance web pages.

2.3 River

For the future river flood hazard maps river flood hazard climate change, estimates of future flood flows are generally based on an assessment of the vulnerability of Scotland's river catchments and coasts to the impacts of climate change from a 2011 study for SEPA by the Centre of Ecology and Hydrology.

The reference for this study is Kay, A., Crooks, S., Davies, H., & Reynard, N. (2011). *An assessment of the vulnerability of Scotland's river catchments and coasts to the impacts of climate change. Wallingford: Centre for Ecology and Hydrology*. The full report and a summary are available from our website.

The CEH 2011 study produced probabilistic estimates for changes in peak river flow for river basins across Scotland for High, Medium and Low emissions scenarios for 2020s, 2050s and 2080s time horizons. The study used the UKCP09 projections for precipitation and temperature.

Climate change uplifts from the **High emissions scenario 67th percentile**[2] for the **2080s (2070-2099 time period)** for the relevant river basin region were applied within each hydrometric area to uplift the input medium likelihood (1 in 200year) flows to the models.

Table 1 in the Appendix indicates the river basin regions and uplifts applied.

[2] The 67th percentile can be described as an uplift that 67% of the modelled scenarios fall below and 33% fall above within that emissions scenario i.e. unlikely to be exceeded in this emissions scenario.

There are a small number of locations where alternative uplifts have been used, including:

- Locations where the present day flood hazard maps have been updated but a climate change scenario consistent with that used in the national river flood mapping was not available. The mapping from other available scenarios was used as a proxy providing the uplifted flows were within 20% of the flow plus the appropriate CEH 2011 study uplift.
- Within a number of small, urbanised catchments where the river flood maps are based on outputs from surface water flood hazard modelling, 20% rainfall uplifts were used.

Detail of the locations in which an alternative uplift has been used is provided in Table 2 in the Appendix.

2.4 Coastal

Climate change may impact coastal flooding through changes in mean sea level or through changes in storminess which affect surge and waves.

For the future coastal flood maps, the **UKCP09 High emissions 95th percentile relative sea level rise projections for the year 2080** were used and applied to the medium likelihood (1 in 200year) sea levels. The uplift applied varied around the Scottish coastline.

The 95th percentile confidence level from UKCP09 was used to allow for an increase in global sea level rise projections since the publication of UKCP09. However, there is additional uncertainty associated with ice sheet dynamics that is not fully taken account of in the projections.

Sea level rise projections under a high emissions scenario have increased in the latest UKCP18 climate projections. Initial analysis has indicated that the 95th percentile of the UKCP09 High emissions scenario for 2080 could be considered a proxy for the 50th percentile from the UKCP18 high emissions scenario (RCP8.5) sea level projections for 2100[3]. This suggests that with limited global action to tackle climate change there is a 1 in 2 chance the level of sea level rise by 2100 will be higher than that mapped in the future coastal flood maps.

Sea levels are projected to continue to rise beyond 2100 for all emissions scenarios in the UKCP18 exploratory projections to 2300 (Met Office Hadley Centre, 2018b).Under the UKCP18 high emissions scenario (RCP8.5), the scenario mapped in the future flood hazard dataset is likely to be exceeded shortly after 2100.

Additional sea level rise beyond the current projected ranges cannot be ruled out as there is uncertainty regarding the Antarctic ice sheet contribution to sea level rise. (Fung, et al., 2018).

[3] Using the UKCP18 21st Century sea level projections (Met Office Hadley Centre, 2018a)

3. Caveats

3.1 Future flood map data not available areas

There are a small number of locations for which suitable future flood map data is not available. These locations are identified using the Future Flood Data Not Available layer. Data for the present day flood maps will still be available in these areas. The lack of future flood map data in these locations does not indicate that there is no future flood risk.

As part of our ongoing flood map improvement programme, we will look to address the lack of suitable future scenario flood data and work with our flood risk management partners to improve the flood maps in these areas.

3.2 Single scenario mapped

The future flood maps published currently are based on a single potential future scenario for the 2080s.

As outlined in section 2.2 this represents one possible future. There are uncertainties regarding emissions, climate response and actions we take, which mean changes in flood risk could be smaller or larger than those mapped.

3.3 Other potential future changes not represented

The future flood maps take account of:

- Projected changes in sea level for the coastal flood hazard map;
- Projected changes in peak river flows for the river flood hazard map.

The future flood maps do not reflect other potential future changes which are likely to influence flood risk, which are subject to additional uncertainties, such as:

- Changes in river channel or floodplain geomorphology;
- Changes in land use;
- Population changes;
- Condition of defences or other infrastructure;
- Construction of new Flood Protection Schemes, bridges or culverts;
- Coastal erosion;
- Changes in wave overtopping at the coast.

Within the river flood hazard mapping methodology, an assumption was made that channel capacity would remain equal to the pre-climate change median annual flow (QMED). Tidal boundaries within the river flood models used Mean High Water Springs (MHWS) levels for all scenarios and were not adjusted to account for climate change, so impacts in estuarine areas may be greater than those shown in either the river or the coastal flood hazard maps.

The coastal flood hazard maps are generally based on still water design sea levels only, showing the risk from high tides and storm surge, but not from wave overtopping or wave run up, with the exception of Dundee, Eyemouth and Grangemouth.

Wave heights at the coast are often limited by water depth, so sea level rise will increase wave height and overtopping rates at the coast so that the impact of climate change on coastal flood hazard will likely be greater than that shown in the future coastal flood map which only considers projected changes in sea level.
Coastal erosion may also increase with rising sea levels. For more information on coastal erosion in Scotland see Dynamic Coast: Scotland's Coastal Change Assessment. For information, the Dynamic Coast project team are investigating the likely impacts of climate change on future coastal erosion rates within a current phase of research and it is anticipated that research outputs will be published in due course.

3.4 Representation of Flood Protection Schemes (FPS)

We have developed our maps in some locations by incorporating detailed modelling from studies for flood protection or alleviation schemes.

In some locations with FPS, flood map updates have been made to scenarios up to the present day medium likelihood (1 in 200 year), with the future medium likelihood under a climate change scenario (1 in 200 year plus climate change uplift) retaining outputs from SEPA's national river modelling. The future flood maps do not show any residual benefit from Flood Protection Schemes above their Standard of Protection in these locations.

Detail of the FPS locations in which the source of the modelling information differs between the present and future scenarios can be found in Table 3 in the Appendix.

4. Future Developments

Over time, as SEPA makes ongoing developments to the flood maps, updates to the future flood map datasets will be made and additional datasets may be released.

4.1 Surface Water

Flood risk from surface water is expected to increase with climate change due to projected increases in rainfall intensity. Heavy rainfall events which can cause flooding in the UK are likely to become more frequent in the future (Bennet, et al., 2015) (Chan, et al., 2018).

A future surface water flood map has not been published at the current time.
We intend to publish a future surface water flood map in later releases of SEPA's flood maps. This will use new information that is currently in development to account for how climate change may affect short duration rainfall events typically responsible for surface water flooding.

The models used to develop the UKCP09 climate projections did not have sufficient resolution to analyse the type of rainfall events typically responsible for surface water flooding. SEPA's surface water hazard mapping project therefore included a scenario with a 20% rainfall intensity increase for the 2080s based on DEFRA guidance (DEFRA, 2006), which represented the best understanding at that time.

The present day low likelihood surface water flood hazard maps used the medium likelihood flood event rainfall intensity increased by 20% nationally based on the DEFRA (2006) guidance for the 2080s. This layer may provide a first indication of those areas potentially at risk in the future, however due to projected changes in rainfall intensity it may not show all locations that may be affected in the future.

Research undertaken by UK Water Industry Research (UKWIR) in 2017 provides the most recent analysis of predicted increases in rainfall intensity due to climate change for sub daily rainfall events. The central projections from the UKWIR 2017 study for the North West and North East of the UK for the 2080s are higher than the 20% increase recommended in the DEFRA 2006 guidance. The present day low likelihood hazard maps may therefore be an underestimate of future medium likelihood surface water flood hazard under a high emissions scenario for the 2080s.

Work to produce guidance on revised rainfall uplifts for short duration rainfall based on high resolution UKCP18 outputs is ongoing in the FUTURE-DRAINAGE research project led by Newcastle University. Project delivery is expected by the second half of 2021 due to revisions in core UKCP Local (2.2km) data from UKCP18.

Appendix

Table 1: Summary of the percentage uplifts used to estimate the potential effect of climate change on flood flows under a High emissions scenario for the 2080s 67th percentile from the Kay et al. 2011 study

River basin region	Hydrometric Area (HA)	% uplift to peak flow from the 2080s High emissions 67th percentile from the CEH 2011 study.	Note
North Highland	1, 2, 3, 4, 5, 6, 7, 8*	37	*For HA008 see Table 2
North East	9, 10, 11, 12, 13 (northern)	24	
Tay	13 (southern),14, 15, 16	35	
Forth	17, 18, 19, 20, 21 (coastal)	40	
Tweed	21	33	
Orkney and Shetland	107, 108	41	
West Highland	93, 94, 95, 105, 106	56	
Argyll	87, 88, 89, 90, 91, 92, 104 (Kintyre), 105	56	
Clyde	82, 83, 84, 85, 86,104 (Arran)	44	
Solway	77 ,78, 79, 80, 81	44	

Table 2: Future river flood hazard map for medium likelihood – locations where alternative uplifts have been used

Hydrometric Area	Location	Note
HA007	Forres	Available scenario from the local study was a 15% uplift. Percentage uplift for the high emissions scenario for the 2080s 67th percentile from CEH study (Kay et al. 2011) would have been 37% for this Hydrometric Area.
HA008	All of HA008	HA008 was incorrectly identified as being in the North Highland river basin region rather than the North East region for application of the climate change uplifts during the National Fluvial modelling contract. A 37% uplift has been applied within the river flood hazard map climate change scenarios but the uplift for North East Scotland from the CEH study (Kay et al. 2011) for the 2080s High Emissions 67th percentile is 24%. Analysis indicated that this made a limited difference in terms of the number of properties likely at risk.
HA019	South Gyle	A number of map updates using surface water or Integrated Catchment Management (ICM) study results were carried out in small, urbanised catchments. In these locations the medium likelihood plus climate change scenario has been updated using the available scenario from these projects which was a 20% uplift in rainfall.
HA084	Yoker, Rutherglen, Glasgow (Merrylee), Paisley (Candren Burn area)	
HA085	Alexandria, Dumbarton.	
HA086	Greenock	
HA012	Aberdeen culverted watercourses	Available scenario from the Integrated Catchment Management study used a 20% uplift in rainfall and a river flow uplift of 24% (consistent with the North East Scotland region average from the CEH study (Kay et al. 2011))

Table 3: FPS locations in which the source of the modelling information differs between the present day and future river medium likelihood scenarios

Flood Map	Hydrometric Area	Location
River Flood Hazard Map	HA007	Elgin Nairn (not a formal FPS)
	HA018	Bridge of Allan
	HA019	Murrayfield, Water of Leith Niddrie Burn south of A7
	HA083	Kilbirnie

References

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