# DEVELOPMENT OF THE PLUVIAL FLOOD MAP FOR NORTHERN IRELAND

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## Abstract

This paper will outline the development of the pluvial or surface water flood map for Northern Ireland and will focus on the technical approach taken, the assumptions involved and the quality of the outputs. The refinement of the assumptions between the first and second generation maps will be examined and in particular the characteristics of the model and impact of the rain event profile. The assumptions used to build the base model must be understood, as they will directly influence the outputs. The testing of the emerging maps against known historical flooded areas will be detailed as this is absolutely necessary in order to gain an acceptable level of confidence in the model and therefore the map. The paper will also consider the need for a common or industry standard approach to risk from this source if the long-term aim of reducing the citizen's exposure to and impact from surface water flooding is to be realised while complying with the requirements of the EC Floods Directive.

## 1 Introduction

The Floods Directive (2007/60/EC) requires each member state to "*undertake a preliminary flood risk assessment*"[2] (PFRA) using "*available*

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*or readily derivable information"*[3]. As delegated competent authority the Department of Agriculture and Rural Development (DARD) through its Executive Agency, Rivers Agency, undertook the assessment for Northern Ireland. The first step of the process was to determine the scope of the exercise and this involved detailing the available information in the form of maps, reports and historical data. The identification of information gaps was then possible which, enabled a forward programme of work to be generated. One such gap that was immediately obvious was that of surface or pluvial flood mapping. The Agency had already created and published a strategic flood map[4] indicating areas which are predicted to be at risk in a 100 year fluvial or river flood event or a 200 year coastal event, but there was no publicly available pluvial or surface water layer to this map. To close this gap Rivers Agency commissioned WDR & RT Taggart, a Belfast based engineering consultant from the existing framework contract, who partnered with JBA Consulting on the production of the strategic surface water flood map.

## 2 First Generation Map

The original surface water map was intended to be a high level screening exercise of the areas at risk and so was based on some coarse assumptions and a high intensity rain event which, without doubt, would overwhelm the entire engineered storm water drainage infrastructure.

The rain event and assumptions applied were as follows:

(a) 0.5% AEP (Annual Exceedance Probability) or 200 year rainfall

(b) 6.25 hour rainfall duration

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[2] *2007/60/EC Chapter II Article 4(1)*

[3] *2007/60/EC Chapter II Article 4(2)*

[4] *http://www.riversagencyni.gov.uk/index/stategic-flood-maps.htm*

(c) 100% ground run off

(d) all engineered storm water drainage systems would be overwhelmed

(e) bare earth DTM (Digital Terrain Model) edited to remove structures such as bridges that cause an obstruction to flow pathways.

After production of the map and in addition to the above criteria, a 0.3 m depth threshold tolerance was applied to the output. In essence this removed any flooding less than 0.3 m deep from the map in an attempt to regulate some of the coarse assumptions and to ignore flooding which would be unlikely to enter buildings. This allowed the production of the first generation map which started the process and enabled quality assurance of the model and output to be carried out. Figure 1 shows a sample output from the first generation surface water map.

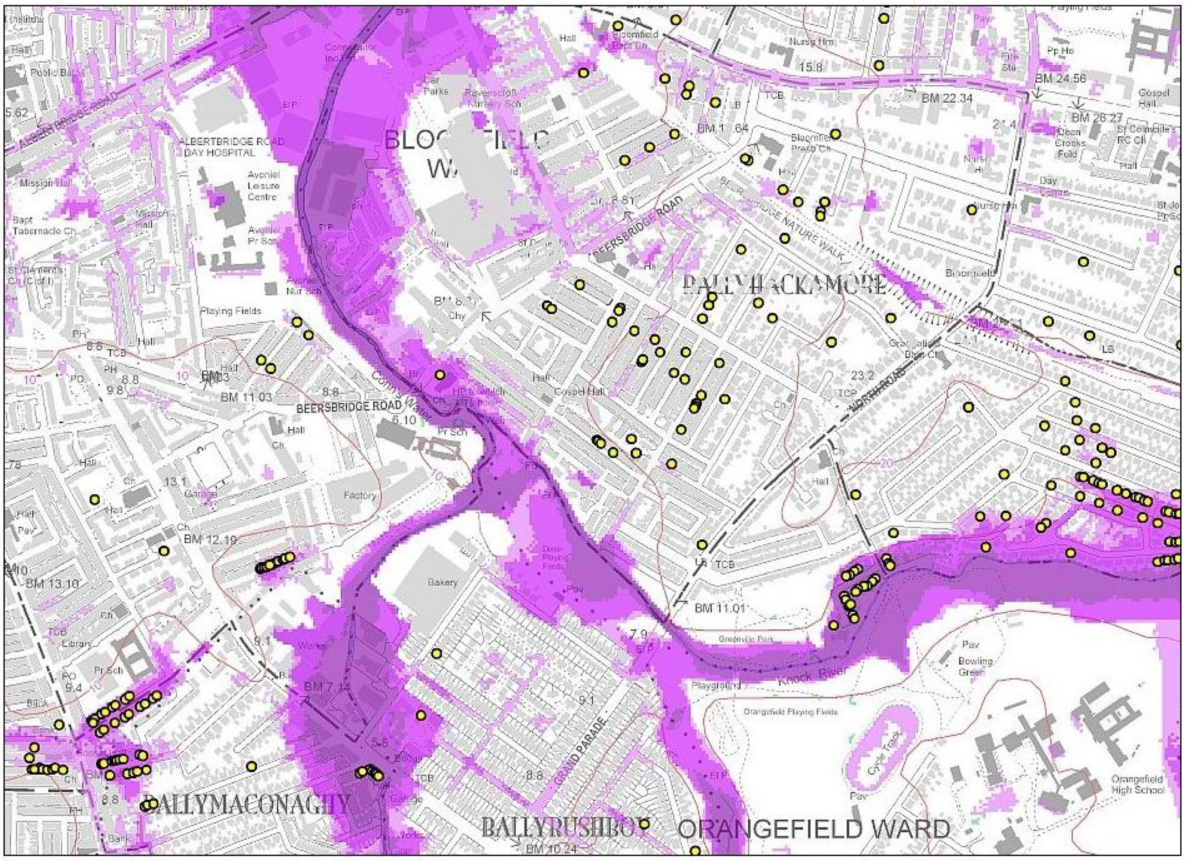


**Figure 1:** Version 1 of the surface water map. The yellow dots indicate 2007 hardship payments.

## 3 Real Life Event

On 12 June 2007 there was a significant flood event in Northern Ireland which predominately impacted upon the East of the capital city, Belfast. This event resulted in relatively widespread flooding of an urban area impacting upon 961 residential properties and numerous commercial properties. Rainfall records were available from a number of sites nearby which showed that there was a prolonged wet period with detailed analysis indicated that approximately 48 mm of rain fell in a one hour period giving an estimated return period of 0.3 to 0.2% AEP or between a 1 in 300 to 500 year rainfall event[5].

The widespread flooding of East Belfast in June 2007 prompted a political reaction from the Northern Ireland Executive who announced a £1,000 hardship payment to all householders affected by event. This resulted in over 900 payments in the area and as an unforeseen consequence provided flood impact data which was subject to third party validation. This, hardship payment data set, has proven to be invaluable when developing and validating the surface water map.

After this flood event extensive evaluation of the causes and impacts were carried out, with particular focus on the Knock and Loop Rivers in order to identify possible measures which would reduce the reoccurrence likelihood of the impact of a flood event of this type. This analysis showed that of the 427 properties affected with these catchments, 229 or 54% where as a result of fluvial flooding and 198 or 46% from pluvial sources. In addition this area is subject to coastal inundation and in order to determine if this was an influencing factor in the extent of this event, the rising river levels were plotted against the tidal level. The results are shown in Figure 2.

5 *Smyth et al, 2008, 'Fluvial and Pluvial Flood Risk East Belfast Flooding – June 2007' DEFRA Conference, Manchester 1-3 July 2008*

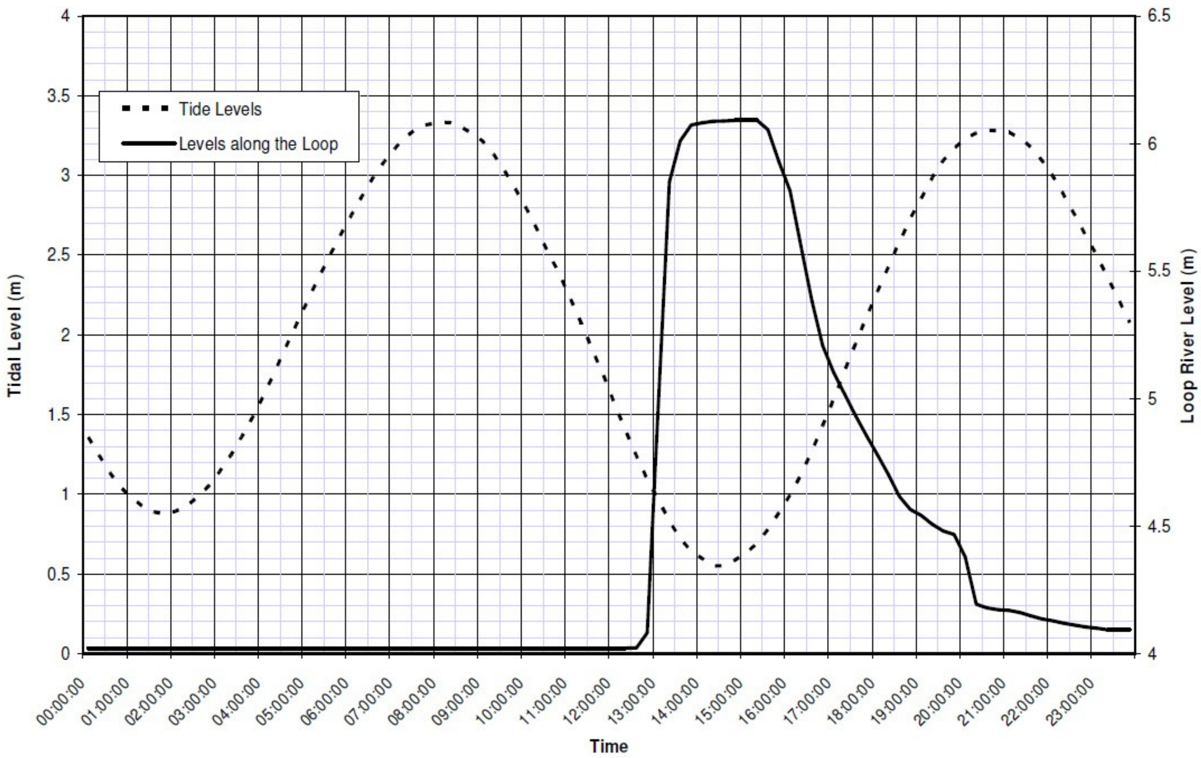


**Figure 2**: Comparison between the Loop River and tide levels on 12th June 2007[6]

It can be clearly seen that the event of 12 June 2007 was not a coastal event neither did the sea level influence the extent or severity of the flooding as the peak river water level occurred during the low tide. The hydrograph in Figure 2 also illustrates the speed of reaction of the river to this rain event. The rainfall recorders indicate that the peak rain event occurred between 12:30 and 13:30 and by 14:00 the Loop and Knock Rivers had risen by over 2m. Whilst the speed of pluvial events is not the subject of this paper, it is worth noting this data and considering it in the context of emergency response and effectiveness of pluvial flood warning in an urban situation.

[6] *12th June 2007 – East Belfast Flooding- Flood evaluation report' report by Jacobs for Rivers Agency*

## 4 Quality Assurance of Surface Water Map

The first generation surface water map was tested against the flood outline and hardship payment data generated from the June 2007 flood event. This analysis indicated that it captured many properties whose owners had received hardship payment but it had also developed a much larger flood extent and therefore included many properties that had not experienced flooding during the 2007 event, indeed up to 3,000 in the Belfast test area of 36km$^2$. It was therefore concluded that the map "*was conservative, and appropriate for use in the Preliminary Flood Risk Assessment as a screening device*"[7]. This map provided information that was incorporated into analysis that determined the flood risk indicators across Northern Ireland which will be subsequently used to inform the PFRA. It will also be useful when identifying the areas of "*potential significant flood risk*"[8] as required by Article 5 of the Floods Directive.

In addition to the Belfast test area the surface water map was examined against a number of other known pluvial flood hotspots across Northern Ireland. This testing added to our understanding and level of confidence in the outputs but was not as robust as the Belfast quality assurance given there was no externally checked data sources to validate the flooded area. In these cases we relied upon local knowledge and/or visual inspection to confirm the outputs of the maps.

In all modelling exercises the outputs are a direct consequence of the inputs, therefore the decisions taken at the early stages of development must be recorded and refreshed during the evolution of the model to

[7] *Version 2 of the Surface water Map Northern', Hankin et al, JBA, FEB 2010*

[8] *2007/60/EC Chapter II Article 5 (1)*

ensure that the outputs and their inherent inaccuracies are understood. For example, if the base DTM is a bare earth this means that buildings and trees have been removed from the data as part of the survey post-processing. Surface water flood progression is influenced by such features and so any map produced with a bare earth DTM will only ever deliver a high level screening output and will never be able to provide very accurate site specific data. The accuracy of the DTM is also determined by the vertical accuracy and grid spacing of the topographical survey inputs. Typically, this is generated using IfSAR (Interferometric Synthetic Aperture Radar), which can have a tolerance of ± 1.0m RMSE (Root Mean Square Error), or LiDAR (Light Detection And Ranging) surveys which can have a tolerance of approximately ± 0.15m RMSE, or a combination of both. For large models, covering a significant land area there may also be variances in the survey dates, quality and vertical accuracy so some areas of the map may show a closer representation of the real life flood event.

The output from the 1st generation surface water map indicated that 3.8% of properties within Northern Ireland are at risk from this source of flooding, which equates to approximately 31,500 properties. A predicted "climate change" version of the 1st generation surface water map was also produced and this indicated an increase in properties at risk to 38,000 or 4.6% of the building stock.

## 5 2ND Generation Map

Whilst it was concluded that the first version of the surface water map was suitable for inclusion in the PFRA the assumptions and inherent tolerances resulted in an overly conservative risk envelope which would have impacted upon future land use decisions. It was therefore decided to refine the map to better represent the real life experience of flood events.

The second generation map included the following changes and improvements.

1) Rainfall – 0.1% AEP (1000 year), 0.5% AEP (200 year) and 1.33% AEP (75 year) events all with a 1 hr duration
2) Infiltration and sewer capacity determined by catchment characteristic
    a) Infiltration – run off set at 80% for urban and 38-39% for rural
    b) Effective sewer capacity set at 12 mm/hr where present
3) DTM – buildings and roads layers incorporated and modified to reflect conveyance and obstructions to flow
    a) Buildings raised by 5 m
    b) Roads lowered by 0.15 m
4) Variable Manning coefficient dependant on ground type
5) GIS Post-Processing
    a) Flood depths below 0.1 m removed as the infiltration and sewer capacity detailed above, ensured that standing water less than this depth and over a few hundred square metres was not considered to be significant
    b) Isolated water polygons removed
    c) Dry islands removed

In addition to these improvements the new version of the model was run for three flood scenarios; low, medium and high probability. This enabled annualised damages to be calculated, similar to those available for flooding from rivers and the sea, ensuring full representation of all sources within the PFRA analysis. Looking to the future, the ability to generate these different scenarios will assist when developing the flood hazard and risk maps as required by Article 6 of the Flood Directive[9].

When the 2nd generation surface water map was tested against the hardship payment data from the study area in East Belfast, it encompassed a similar number of effected properties compared to the previous version but now there was a smaller number of properties that had not been flooded in the June 2007 event. Previously there were approximately 3,000 properties that where outside the hardship payment dataset, now about 2,000 in a 36 $km^2$ test area, a reduction of a third. This was achieved after testing a wide range of options and confirmed to the project team that the optimum configuration had been achieved. In addition the map outputs were examined against other areas across Northern Ireland that are known to be susceptible to surface water flooding which confirmed the results from the Belfast study area. A sample output from the second generation map can be seen in Figure 3, below.

[9] *2007/60/EC Chapter III Article 6(3)*

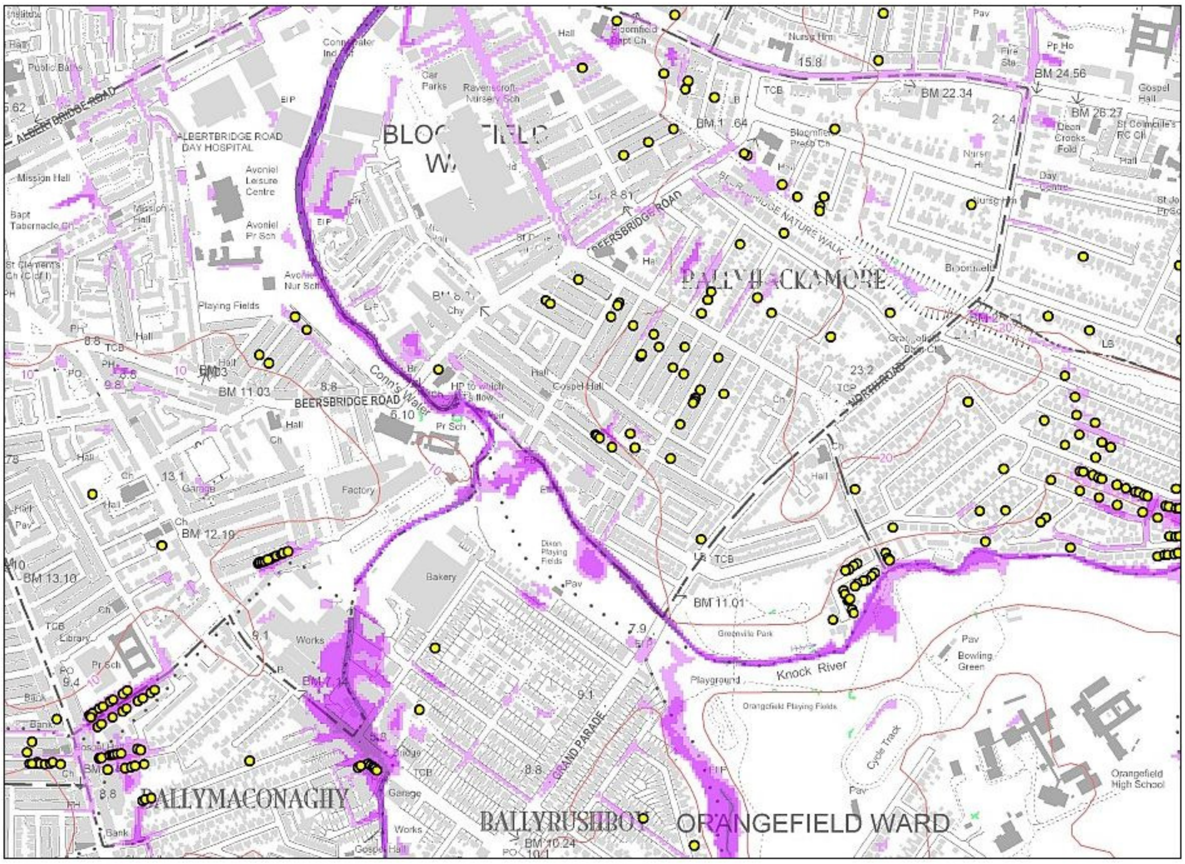


**Figure 3:** Version 2 of the surface water map. The yellow dots indicate 2007 hardship payments.

## 6 Input Sensitivity

In essence there were two significant changes to the inputs which generated the surface water maps for Northern Ireland; namely the model parameters and the rain event profile.

The changes to the base model parameters where implemented to ensure that the model was a better representation of real life flood events. These enhanced the usefulness, accuracy and application of the map outputs. The initial flood outlines, based on the bare earth DTM with no allowance for the existence of storm water drainage systems, resulted in exaggerated or overly conservative results which would rarely, if ever, be observed during a flood event caused by the magnitude of rain event used in the model. The improvements described in this paper were therefore fundamental to the operation of the model as they ensured delivery of a product which, whilst still strategic in nature, is now refined and capable of informing the public about the residual surface water flood risk. Given its accuracy it is also useful to drainage infrastructure owners as they can now identify areas that require closer attention and it provides land use policy makers with detailed information which will ensure that Flood Risk Management informs their decision making process.

The changes to the rain event profile present a slightly different challenge in that an assessment is required to determine how close the chosen rain event is to the real life weather patterns experienced in any particular region. This will obviously change by country and most importantly will be influenced in the future by the predicted impacts of climate change. An increase in surface water flooding is a very likely direct consequence of climate change as the design standards for storm water drainage systems is based on a commonly occurring rain event, typically 1 in 30 year return period. Systems built to this standard will not be able to cope with the more extreme, high intensity, short duration storms. This pattern of storm event will overwhelm the systems ability to perform. With an increase in storminess predicted we can therefore expect more surface water flooding and this leads to a dilemma for flood risk mapping and policy makers. If we use a longer duration high intensity rain event to generate our surface water maps this will result in a large "at risk" area which will then impact on land use decisions in those areas. If however we use an unrealistically short duration event this may grossly under estimate the risk which in the short term would bring a false comfort to those who live and work in these areas, and then undermine and discredit the map when a significant flood event occurs which was not predicted. In this regard there is a decision required by government as to the level of risk that is acceptable. There is a well established understanding of fluvial and coastal risk modelling. There is also established communication terms which reflect the 'industry standards', such as the 100 year flood events. There is, however, no such standard for pluvial flooding, given the emerging nature of this technology and the inherent difficult in predicting such events, thought needs to be given to this so that design standards are reasonable, affordable and defendable while at the same time offering an appropriate level of protection to those at risk.

## 7 Public Perception

Flood risk is a complex subject involving detailed topographical surveying, computer models and the communication of risk of a future weather event which is outside the control of mankind. The public when flooded are not generally interested in the source neither can they understand the differences between a map which is generated to show the impact of rising flood waters from rivers and the sea or one generated to show the consequence of intense rainfall, as in pluvial flood mapping. The person whose property has been subject to flooding wants to know what can be done to ensure that it does not reoccur and who is going to offer them assistance. We must always keep this and the use of our maps in mind during their development.

## Conclusion

The needs for a surface water flood map for Northern Ireland was established by a gap in the information available to develop the PFRA. The first generation map was too conservative given the bare-earth nature of the base model and the extreme nature of the rain event. The availability of good data from the June 2007 flood event ensured excellent quality assurance of the map outputs and enabled the inputs to be refined in order to produce a more accurate prediction of a flood event from this source. The risk appetite of the public still needs to be established in order that unnecessary blight or risk exposure is not a consequence in the long term. In conclusion the new surface water map will improve the information available to the public on the risk of any particular area and therefore will ensure that they and their government are in a position to make informed decisions particularly related to land use issues.

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