02 - THE DUBLIN FLOODRESILIENCITY PROJECT WITHIN A EUROPEAN SURFACE WATER MANAGEMENT CONTEXT

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Abstract
Dublin City Council (DCC) is one of eleven partner organisations, drawn from eight European cities, which form the Interreg IVB flood risk management good practice project known as the FloodResilienCity (FRC). The FRC project aims to promote an innovative approach to flood risk management and prevention based on the 4A's concept: **A**wareness; **A**voidance; **A**lleviation and **A**ssistance.

DCC's involvement and interest in the project is prompted by a need to develop sustainable flood risk management in the urban environment to deal specifically with **Pluvial Flood Risk**, pluvial flooding being the key component of surface water flooding. Coastal and fluvial risks have already been addressed for Dublin and this project aims to integrate pluvial flood risk identification, forecasting and management seamlessly with existing systems.

Jacobs were appointed in June 2010 by DCC as the External Expert to provide support with technical aspects of the Dublin FRC project over a 2 year period. The overall aim of the project is to develop a **Pluvial Flood Risk Management Strategy** for Dublin.

This paper reviews:

- Recent pluvial events and the nature of the pluvial flood risk in Dublin with specific reference to pluvial flooding in August 2008 and July 2009.
- The programme of specific work packages being progressed under the Dublin FRC project.
- The role of the Dublin FRC project in the development of good practice to address pluvial flood risk across Europe through the wider FRC project and through collaborative working with the European Water Association and EC Working Group F which advises on implementation issues associated with the European Floods Directive.
- Synergies with evolving Surface Water Management practice and planning in the UK and Europe.
- Current outcomes with a focus on pluvial flood forecasting, risk mapping and innovative approaches to managing pluvial flood risk.

Glossary

CoP	Code of Practice	DCC	Dublin City Council
FRC	FloodResilienCity	FRM	Flood Risk Management
EWA	European Water Association	MEM	Major Emergency Management
PRA	Principal Response Agency		
SAFER	Strategies and Actions for Flood Emergency Risk management		

1. Background to the Interreg Programme

The INTERREG North West Europe programme is a financial instrument of the European Union's Cohesion Policy which funds projects that support transnational cooperation & promote harmonisation of spatial planning between member states.

The aim is to find innovative ways to make the most of territorial assets and tackle shared problems of Member States, regions and other authorities. It is premised on some problems being too large for one member state to address on its own and that these are best addressed through transnational cooperation and knowledge sharing and creating transnational templates of good practice.

Dublin City Council Environment and Engineering Department has participated in a number of Interreg NWE projects both in Programme IIIB (which ran between 2003 and 2008) and the current Programme IVB (2007 to 2013).

Participation in IIIB included:

- Project SAFER (Strategies and Actions for Flood Emergency Risk management) which developed a strong flood risk management paradigm advocating (i) spatial planning and land use management, (ii) technical flood defences and (iii) flood damage protection and emergency planning.
- Project NOAH which promoted the Uncertainty Gap paradigm as a tool for activating nested emergency/flood response and recovery plans in the event of a flood.
- The current Interreg IVB **FloodResilienCity** project is a partnership of nine organisations active in flood risk management and two universities as indicated in Figure 1. It is drawn from eight European cities, and aims to promote flood resilience through application of the 4A's framework: **A**wareness; **A**voidance; **A**lleviation and **A**ssistance which is based on a concept for FRM originally proposed by the Scottish Government.

Figure 1: The FloodResilienCity Project Partners

FloodResilienCity (FRC) is addressing three principal themes which cover the main issues confronting the urban flood risk environment:

- Climate change.
- Room for the River.
- Pluvial (surface water) urban flood risk.

The DCC past Interreg experience has confirmed the need to modify the transnational project templates of good practice to allow for local conditions:

- Different geographic and climatic conditions.
- Different administrative arrangements.
- Different flood hazards.

Scale: the longest of Dublin's three main rivers is the Liffey but at a mere 72km in length this is several orders of magnitude smaller than major European river systems.

Administration implications: Major Emergency Management (MEM) planning is formulated under the 2006 DEHLG framework which required the various Primary Response Agencies (PRA) to develop protocols and procedures for combining their separate response plans. This includes the seminal feature that the local authority is the pre-nominated lead PRA in the event of a flood. The last provision reflects the importance in the flood emergency response cycle of many aspects of the local authority work: spatial and statutory planning; development of flood defences; operation and maintenance of drainage networks; housing; roads and traffic management; fire brigade and civil defence and liaison with local communities.

Flood hazards: Dublin had been aware for some time that at least four types of flood hazard constituted real dangers in the Dublin urban environment including:

1. Drainage infrastructure
2. Dams
3. Coastal flooding
4. River flooding

In the years immediately prior to the FRC project there were an increasing number of high intensity rainfall events which caused direct pluvial (surface water) flooding and raised the requirement to develop a strategy to address a fifth flood hazard:

5. Pluvial flooding

Pluvial flooding arises during high (almost tropical) intensity rainfall and is often associated with summer thunderstorm activity, though it can arise from high intensity rainfall pockets within longer duration storm events. It can therefore be very localised or much more widespread, possibly across a whole urban area – such as Dublin. It is typified by overland flow and ponding *before* the runoff reaches a watercourse or drainage system. The risk is exacerbated when the drainage system is overwhelmed (sub-surface flows from the drainage system can also contribute to pluvial surface water flooding). It can occur anywhere, even areas at a high elevation well above the river or coastal floodplain, and often in areas which were never expected to have a risk of flooding. The hazard associated with pluvial flooding can arise from rapid and sometimes deep ponding or high velocity flows along roads and streets especially where gradients are steep. The risk from pluvial flooding appears likely to increase with climate change in common with other types of flooding.

It became apparent that the Dublin Flooding Initiative, which aims to address all types of flooding, must, as well as developing constituent strategies to deal with each hazard type, ensure that these are integrated without contradiction or omission. The immediate concern of the FloodResilienCity project is to develop the "missing" pluvial strategy for the city which is to include:

- Assessment of the overall pluvial flood risk
- Identify the areas which are most at risk
- Develop Codes of Practice to mitigate risk for new development and existing areas

The Dublin FRC Pluvial Flood Risk Management Project Study (the Dublin FRC project) was awarded to Jacobs Engineering Ireland following an EU public procurement procedure to support DCC in the development of a Pluvial Flood Risk Management Strategy for Dublin. The key components of the Dublin FRC project and the inter-relationship with wider but relevant FRM initiatives in Ireland and Europe are illustrated in Figure 2.

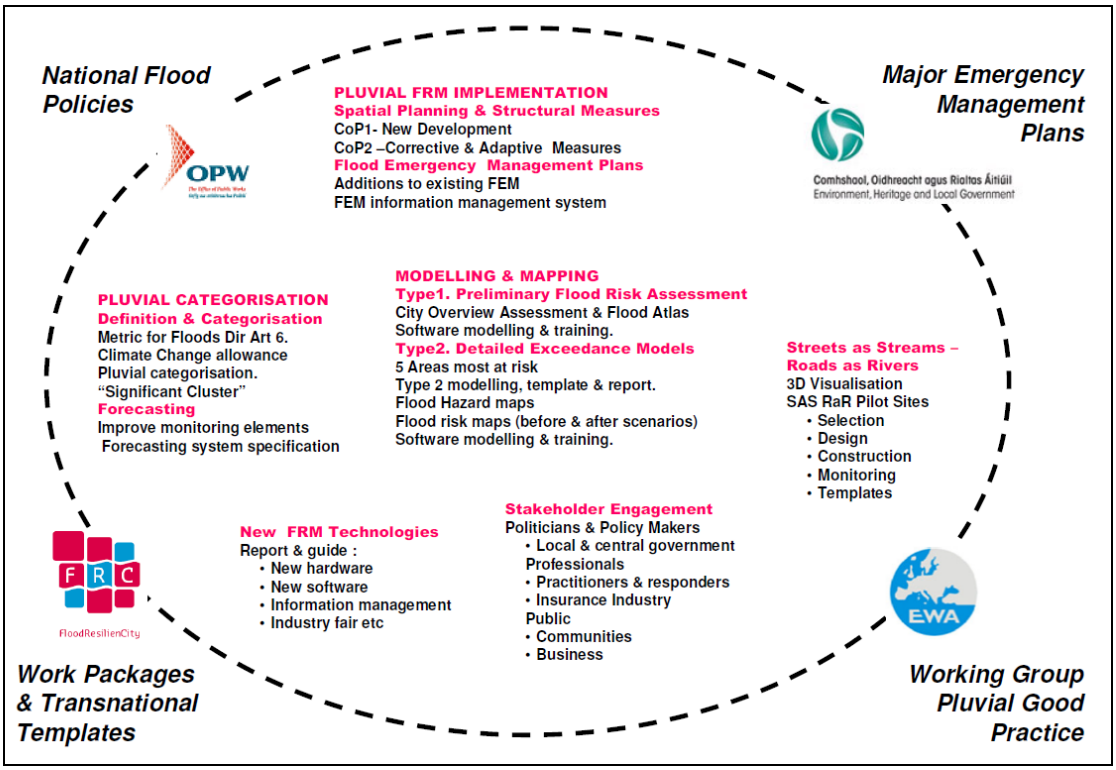
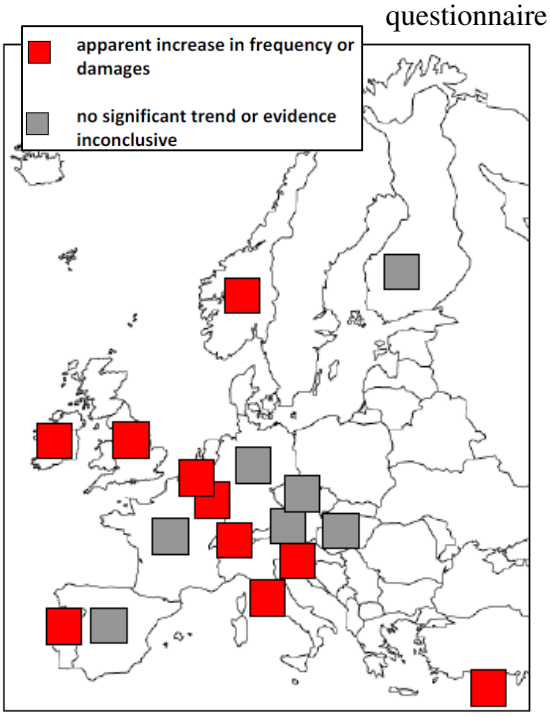


Figure 2: Key Elements of the Dublin FloodResilienCity Project Pluvial Study

2. European Context

In addition to the role of the Dublin FRC project as part of a major European FRM research and good practice programme, close links have also been formed with initiatives taken forward by the European Water Association (EWA) in relation to better understanding pluvial flood hazard across Europe. This in turn has linked with the work of the European Commission Working Group F which works with the Commission in addressing implementation issues associated with the Floods Directive. In particular, a paper was prepared following an expert workshop meeting facilitated by EWA on Pluvial Flooding in

Europe held in Brussels in October 2009 (European Water Association, 2010). DCC contributed to this meeting. A key outcome from the expert meeting was the need to prepare and circulate a questionnaire to obtain further information on the nature and extent of the problem across Europe. The EWA report helped to inform further discussion of key issues relating to pluvial flooding at the European Commission Working Group F special workshop on Flash Floods and Pluvial Flooding held in Cagliari, Sardinia in May 2010. A full report on the workshop has been prepared by Working Group F which includes analysis of the questionnaire responses. Some of the key outcomes are summarised in a paper and presentation by Falconer (2010) at the IFAT conference in Munich in September 2010.



Overall, there was a good response to the questionnaire with approximately two-thirds of EU Member States responding through their representative organisations – these were augmented by responses from FRC project partners. An apparent increase in frequency of both pluvial and flash flooding has been noted in several countries (Figure 3) and specific measures to manage pluvial flood risk are being applied by several EU member states. It was concluded that pluvial flooding appears to be recognised as a growing flooding threat across Europe, more in Western and Northern Europe but progressively in other parts of Europe.

Figure 3: Reporting by EU Member States on Trend in Frequency of Pluvial and Flash Flooding Across Europe

SICAdapt! Project

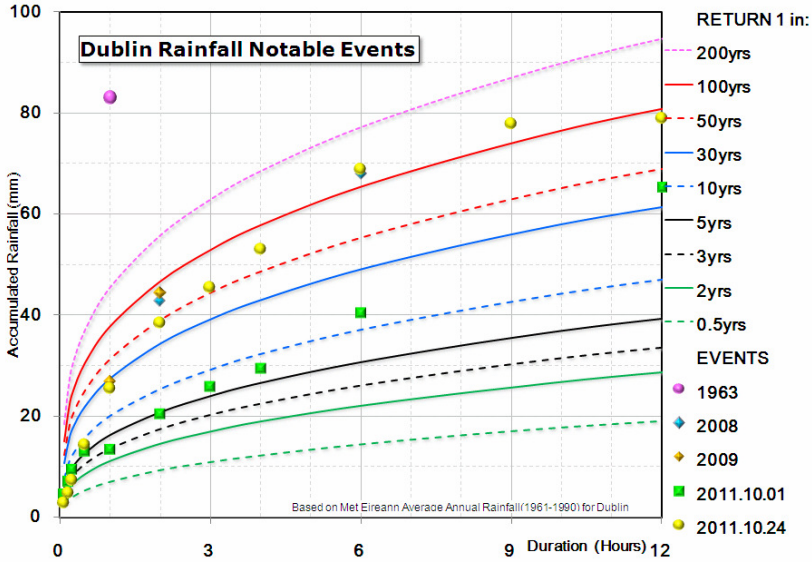
Eight projects (including FRC) in the Interreg IVB NWE programme have formed a Strategic Initiative Cluster (SIC) to develop adaptation to the spatial impacts of climate change. This initiative is addressing four environments, the Built, the Water, the Natural and the Social.

Recent Pluvial Flood Events in Dublin

There have been a number of significant pluvial/ surface water events in Dublin in the last few years including:

- November 2002
- August 2008
- July 2009
- October 2011 (2)

Each of these created widespread flooding in Dublin but the most recent was the



most severe. Data is currently being collated.

3. Overview of the Dublin FRC Project

The main elements of the Dublin FRC pluvial project are indicated in Figure 2. These elements comprise various tasks as indicated in the flowchart in Figure 4 which shows their inter-relationship under the broad headings of:

- Pluvial flood information, forecasting and monitoring
- City Exceedance modelling
- Pluvial flood risk management implementation
- New technologies in flood risk management

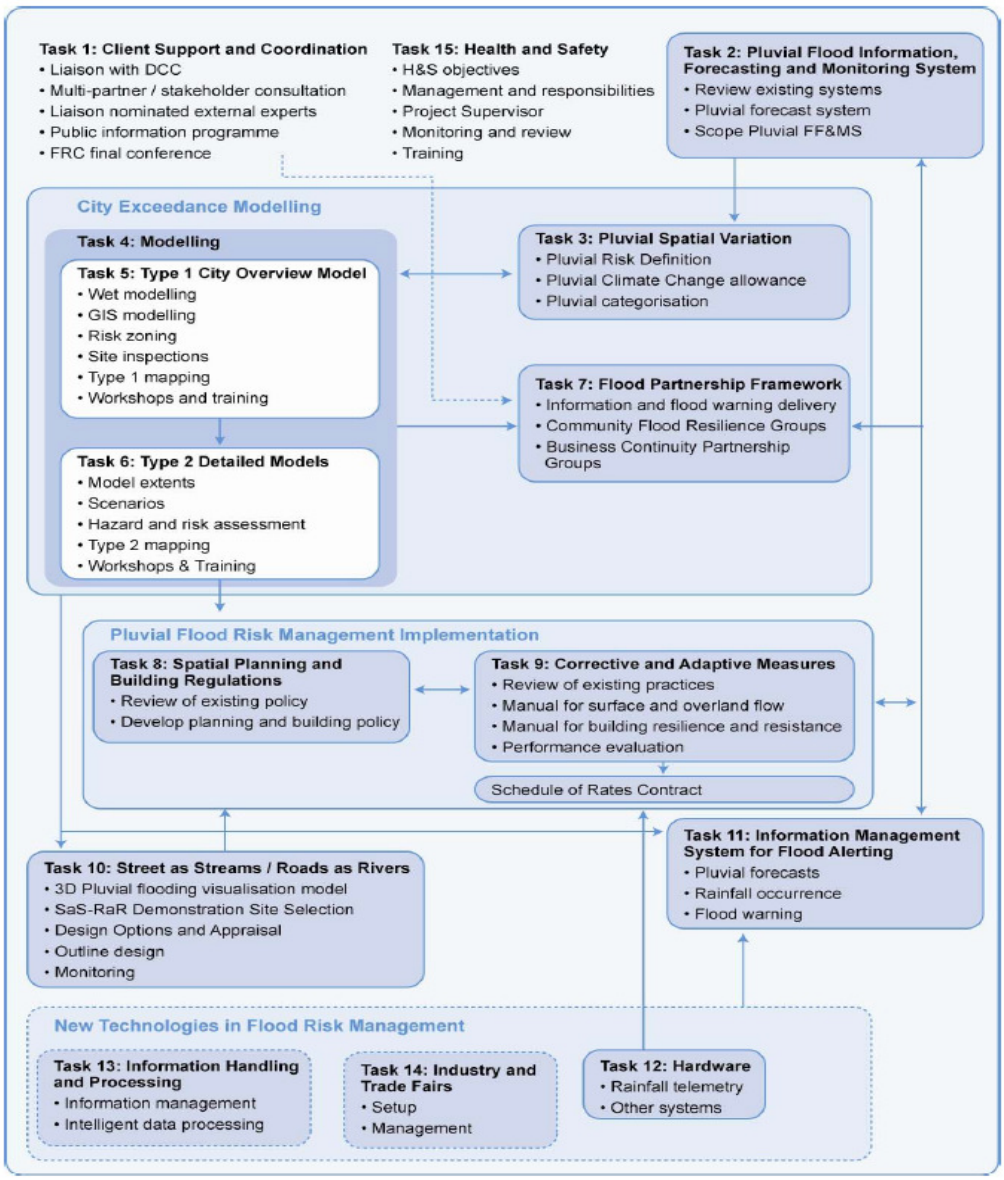


Figure 4: Summary Flowchart of Project Tasks

Outcomes from this project must integrate with measures and procedures to address other forms of flooding under the Dublin Flood Initiative – in particular the system and procedures for pluvial flood forecasting and the provision of warnings.

The majority of these core elements and their task components have now progressed to an advanced stage – pluvial flood forecasting and information management system requirements have been reviewed, city overview modelling and risk mapping has been completed, and detailed modelling and risk assessment is now being undertaken for selected high risk areas prior to trialling on site of various mitigation measures based on the guidance which is being incorporated in the Codes of Practice. These measures will include designated 'Streets-as-Streams/Roads-as-Rivers' surface water flowpaths. Wherever possible, opportunities for innovation in pluvial flood risk mitigation measures will be included in the trials.

Aspects of some of the main elements of the project are outlined below.

Pluvial Flood Forecasting

In reviewing requirements for a pluvial flood forecasting system a key aspect has been compatibility with the systems that already exist for other types of flooding with the overall aim of achieving an efficient and effective combined system for flood warning in Dublin. The various components of a pluvial forecasting system have been assessed and likely lead times and trigger levels considered together with instrumentation and communication requirements, which are reviewed in the 'information and management systems' element of the project. Review of the forecasts and warnings which were available for the November 2002, August 2008, July 2009 and July 2010 storm events, and the characteristics of these events, has informed this process. It is also anticipated that characterisation of events will enable relevant risk mapping to be readily accessed for the forecast event to support flood emergency response.

Proposals for a warning system are likely to be based on a 3 tier approach broadly as set out below:

BE AWARE
Early warning forecast of heavy rainfall (24-48hr lead time)
Based on available meteorological analysis and forecasting capabilities. Spatial distribution broadly for the Dublin area, the main purpose being to ensure readiness.

>>> BE ALERT
Heavy rainfall warning (12 to 24 hour lead-time)
Based on forecast models and available web-based specialist information on atmospheric conditions. The detail of the forecasts is likely to be related to known intensity triggers. Updates are likely to be available on a 6-hour basis, and with forecast periods extending over 1 to 2 days, this means that forecasts and warnings can be updated and refined within a lead-time of 12-24hrs. with reasonable definition of quantity and areas likely to be affected

>>> >>> TAKE ACTION
Event "flash" warning (2 to 3 hours lead-time)
The production of this final stage of warning depends more on information from monitoring rainfall activity, by radar and tele-metering rain gauges, than from forecasts. Having issued a heavy rainfall warning this stage would seek to confirm or modify the earlier forecast, and to add necessary detail on location and intensity. Tracking of radar echoes and monitoring near

real-time rainfall, especially in areas from which rainfall is approaching, are likely to be key elements in providing this level of warning**.**

Hazard and Risk Assessment and Mapping

As a precursor to modelling, GIS based 'Dry' mapping was initially undertaken to indicate likely surface water flowpaths (Figure 5) and significant ponding areas. This has allowed definition of surface water catchments and also informed early site inspection of likely high hazard areas, which, together with review of records of past pluvial inundation, enabled the project team to gain a better understanding of pluvial flood risk across Dublin and the mechanisms involved. Key issues include the very high proportion of basement properties in Dublin (estimated to exceed 16,000) and the variable nature of the topography, including extensive flat areas where low threshold and basement properties may be particularly vulnerable, but also some deep ponding areas and also some steep areas where high surface water velocities may be a hazard. This early mapping and site inspection also facilitated the identification of surface features which could significantly influence 2D surface flow 'Wet' modelling, such as underpasses and links through rail and road embankments.

For the city-wide Type 1 'Wet' modelling a 2D surface flow model has been constructed based on a 25m cell size and using TuFlow surface flow modelling software. A total of 6 separate models were constructed based on surface flow catchment boundaries and size, as indicated in Figure 6. Lidar data was available for the digital terrain model.

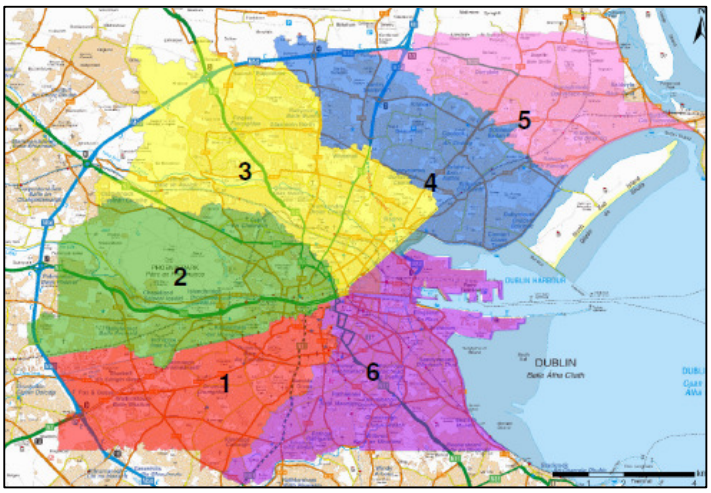


Figure 5: Extract from Surface Water Flowpath Mapping

Figure 6: Type 1 Model Boundaries

In the Type 1 model infiltration allowances were adjusted to take into account the sub-surface drainage system capacity by estimating a 'Drainage Capacity Equivalent Rainfall Value' for different sub-cell areas within each model. This value was determined based on drainage system modelling undertaken as part of the Greater Dublin Strategic Drainage Study.

Model runs covered 1, 3 and 5 hour duration events for 1:10, 1:50, 1:100, 1:200 annual probability design storms together with a 1:100 annual probability event with an allowance for climate change. Depth, velocity and hazard (combined depth and velocity hazard) maps have been prepared. An example or hazard mapping for central Dublin is shown in Figure 7.

Type 2 models for selected high risk areas using a finer 5m grid and linking with the drainage system are currently being constructed using TuFlow and Estry model software (Figure 8). Risks maps are also being prepared for key receptor groups based on 'Human Health and Critical Infrastructure', 'Economy' and 'Environment and Cultural Heritage' each with

appropriate thresholds for high, medium and low risk. Risk is assessed for each 25m square grid cell and areas of risk defined on the basis of connected cells.

Figure 7: Extract from Type 1 Hazard Mapping

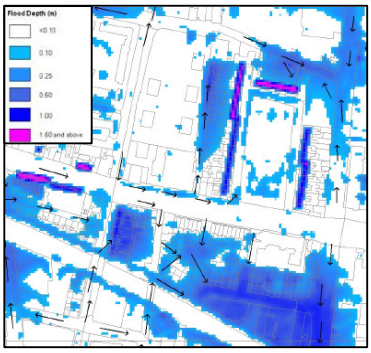


Figure 8: Extract from Type 2 Depth Mapping

4. Approaches to Managing Pluvial Flood Risk in Dublin

Development of a pluvial flood risk strategy for Dublin will largely be based on the hazard and risk assessment and mapping, development of the pluvial flood warning system and guidance provided in two Codes of Practice (CoP):

- CoP1 - Spatial Planning and Building Regulations – which reviews existing regulations and proposes amendments and additions to these in relation to pluvial flood risk.
- CoP2 – Corrective and Adaptive Measures – which provides guidance on appropriate mitigation measures to address pluvial flood risk.

In evaluating appropriate measures, it is proposed that identification of opportunities to achieve benefits across more than one sector be encouraged through application of a 'FAB-Plus' test where benefits are firstly sought for **F**lood risk mitigation, **A**menity enhancement and **B**iodiversity enhancement 'Plus' others such as, for example, carbon reduction/sequestration, waste re-use, regeneration uplift and recreational enhancement.

In CoP 2 it is proposed that guidance on the evaluation of measures is firstly provided and principles have been set out. Guidance on measures is broadly grouped under:

- **Generic and Quick Win Measures** – those which can be applied universally across the whole of the Dublin administrative area and aim to raise the overall level of resilience to pluvial flood risk. They apply to areas of high risk and lesser risk and therefore cover areas where the level of risk does not justify investment in Site Specific Resilience measures. Those measures which are low cost or easy to implement and yet achieve a significant benefit are categorised as Quick Wins.
- **Community Flood Resilience Measures** which require engagement and participation at community or householder level. Specific actions may be required to implement building resistance and resilience measures and it is considered that ownership of that responsibility will be an important element of effective resilience raising. A draft outline template to provide broad guidance to community groups and householders on the types of measure that may be appropriate for a particular type of property has also been prepared to support this section of CoP2.

- **Site Specific Resilience Measures** which are normally applicable only in areas of identified high risk. They are likely to involve capital investment and there may be an ongoing maintenance commitment.

The guidance and referenced case study examples is based on a review of relevant literature and developing good practice in Ireland, the UK, more widely in Europe and locally. A summary is provided at the end of each section under the three main headings above which summarise the scope of application of each measure, the likely key advantages ….and risks, relative cost, anticipated level of maintenance required and who is likely to have responsibility for implementation.

Innovative approaches are identified including the use of 'leaky-butts', 'aggregated micro-storage' and certain measures where there may be scope for realising a certain amount of carbon sequestration. It is intended that some of these approaches will be trialled by DCC during the 'Streets-as-Streams/Roads-as-Rivers' (SaS/RaR) element of the project. The trials are likely to focus on the selected Type 2 detailed model areas and will include the trialling of designated SaS/RaR surface water pathways.

Particular attention is being given to measures to deal with pluvial risk to basement properties where, for example, in addition to other measures some form of self actuated 'riser step' may be appropriate to seal gaps where the access threshold is at pavement level. Wherever possible, opportunities are encouraged to identify 'GreenWaterSpace' where storage (perhaps with carbon sequestration potential) may be provided in existing urban green space areas linked by bio-swales along green corridors, where possible, or designated SaS/RaR surface water flow-routes.

5. Synergies with evolving Surface Water Management Practice and Planning in the UK and Europe

As indicated in Figure 9, the Dublin FRC project mirrors many of the elements involved in the preparation of Surface Water Management Plans in the UK which are generally prepared in accordance with current UK SWMP guidance (Defra 2010).

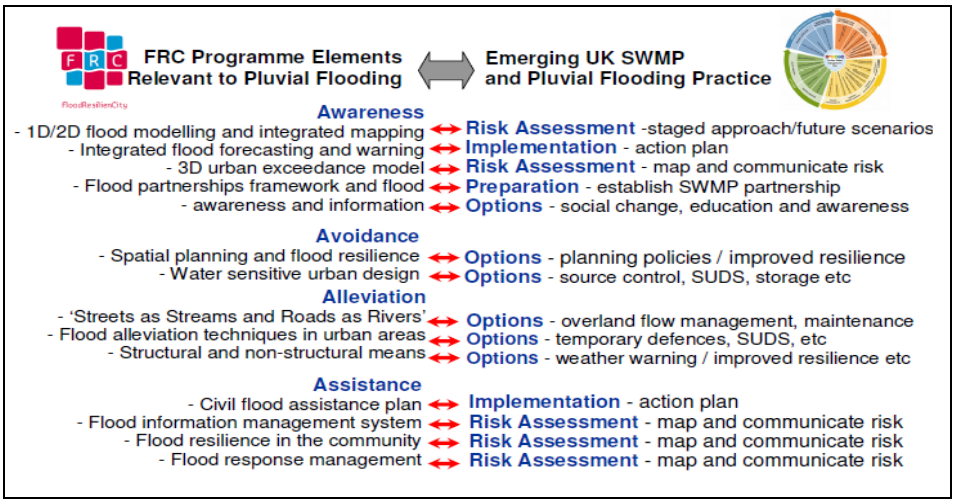


Figure 9: Synergies between the Dublin FRC Pluvial Project and UK Surface Water Management Practice

Dublin is perhaps unique in that the flood risk from many different sources, including pluvial flooding, is high and it is crucially important that the systems and measures to address each of these types of flooding are closely integrated. In addition, and with specific regard to pluvial flooding, Dublin has major challenges to address. These include the very high proportion of basement properties which are potentially at risk; the relatively flat topography in many areas which when coupled with low property threshold levels (and basements and below ground infrastructure) increases the risk during less extreme rainfall events; some deep ponding areas; areas with relatively steep gradients where high surface water velocities are a hazard; and the high density of development in the city centre areas.

All these flood risks must be addressed to allow Dublin to continue to grow and realise its full potential as a 'Flood Resilient City' of the future. In doing so, and as part of an integrated flood risk strategy for all flood risks under the Dublin Flood Initiative, Dublin can act as an exemplar in contributing to the ongoing development of good practice in pluvial flood risk management as well as wider and integrated flood management practice in Europe.

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