



During the recent flooding in November 2009, the town of Mallow bucked the trend by hitting the headlines for all the right reasons, as the recently completed first phase of the Mallow Flood Defence Scheme was successfully put to the test. Ken Leahy, Chartered Engineer and project manager for Arup Consulting Engineers provides an overview of the project and the solutions it offers

# Fighting flooding

## Mallow defence scheme passes its first major test

In the wake of the devastation caused by the recent nationwide flooding, there is a renewed public awareness of the significant impact it can have, both at a human level, in terms of distress and suffering, and in commercial terms, with several hundred million euros worth of damage caused nationally, in the November 2009 floods alone.

The town of Mallow in north Cork has a long history of flooding from the River Blackwater, with the town bridge being destroyed by flooding as long ago as 1628. The lower end of the main street flooded to significant depths, twice in 2008 alone.

However, the November 2009 floods proved to be a significant milestone for Mallow, as the recently completed first phase of the Mallow Flood Defence Scheme received an early test and passed with flying colours.

The flood peaked at around midnight on November 19, at which stage approximately 1.5m high floodwaters were held back by the newly-installed flood barriers. A great sense of excitement and community was evident in Mallow that night as local Cork County Council staff worked through the evening and into the night, erecting the demountable barriers, monitoring pumping stations, and putting traffic diversions in place. The large crowd of local residents and businesses, witnessing the flood defences in operation for the first time, voiced their delight at how their homes and businesses had been saved from potential devastation.

### Feasibility study

In 2002, the Office of Public Works (OPW), under the provisions of the Arterial Drainage Act 1945, commissioned Arup Consulting Engineers (Arup) to carry out a feasibility study for a flood relief scheme for the town.

The brief for the flood relief scheme was to provide protection against a one-in-a-hundred year flood event to approximately 125 residential properties and almost 100 commercial properties and associated critical infrastructure. The first stage of this feasibility study consisted of a desk study of all available data, including existing hydrometric data, anecdotal evidence of flooding, details of the catchment etc. A topographical and hydrographic survey was then commissioned to provide information on the existing channel, and a geotechnical site investigation was carried out to establish the prevailing ground conditions with respect to bearing capacities and permeability. Hydraulic modelling of the Blackwater, and its various tributaries, was then undertaken.

### Hydrology and hydraulic modelling

The approach adopted to the analysis of design flows for the River Blackwater drew upon the Flood Studies Report (NERC, 1975), and the Flood Estimation Handbook ("FEH"; Institute of Hydrology, 1999). There were two key river flow gauging stations on the Blackwater, at the site of the Mallow sugar factory, approximately 5km upstream



Demountable partially erected in preparation for flood.



Demountable put to the test during the flood.



Watermark after the flood.

of Mallow and at Killavullen, approximately 12km downstream of Mallow. The flow for the one-in-a-hundred year flood was derived using a statistical approach, making use of the local gauge data to derive an easily measured index flood, relating to a low-return period, multiplied by a factor from the regional growth curve to scale the index flood up to the one-in-a-hundred year event. The selected design flow for the Blackwater was 751m<sup>3</sup>/sec, excluding climate change.

Design flows were also calculated for the various tributaries within the town to allow joint probability modelling to be carried out. A hydraulic model of the River Blackwater was built in HEC-RAS v3.1, to identify the predicted one-in-a-hundred year flood levels through the town. This model was recalibrated following a major flood event in 2004, which provided an improved understanding of the channel calibration. The model was validated against the actual 1980, 2000 and 2004 flood events, generally achieving a very good match. Freeboard was also added following the methods of the Fluvial Freeboard Guidance Note 2001, produced by the UK Environment Agency, to take account of hydrological and hydraulic uncertainty, as well as the consequences of overtopping, and physical effects such as settlement.

### Flood relief options considered

Some options initially considered to protect against Blackwater flooding, included flood proofing properties, river restoration, and floodplain storage upstream of Mallow.

The option of changing the cross-sectional area of the channel, straightening the river downstream of Mallow Bridge, or constructing a flood relief channel downstream of Mallow Bridge were also considered. The potential for Blackwater flooding travelling up its tributaries through the town causing further flooding also needed to be addressed.

Following a detailed assessment of all options, the chosen solution consisted of defending against a combination of high Blackwater levels and high tributary flows through the use of 'direct defences' supplemented by flood relief culverts in some areas and the realignment of the Town Bridge approaches. 'Direct' flood defences consist of constructing defences along the affected lengths of the channel to prevent floodwaters from reaching potentially affected proper-

ties. Such defences include: defence walls, embankments, pumping stations, and demountable defences. These defences would be designed and constructed to facilitate future raising to allow for potential future climate change.

A detailed cost-benefit analysis was undertaken to confirm the commercial viability of the chosen scheme. This indicated that the proposed scheme had a very strong positive benefit cost ratio.

### Phasing of the scheme

In 2004, at the request of OPW, Arup produced a phasing report outlining how the works might be phased to ensure a speedy and beneficial implementation, while complementing annual budgetary constraints. Following this review, the scheme was divided into three distinct and self-contained schemes, namely; Mallow North, Mallow South and Mallow West, and these schemes were publicly exhibited in June 2005.

### Detailed design of proposed schemes

The detailed design of the proposed schemes embraced a range of specialist disciplines across Arup's Cork, Dublin, Leeds and Manchester offices.

These included civil, structural, mechanical, electrical, geotechnical and environmental engineering, hydrology, hydraulic modelling, geomorphology and river engineering, project management and cost control, and contract administration. Arup also provided the service of project supervisor for the design phase (PSDP).

A fundamental part of the design process involved consultation with the many stakeholders involved. These included: the Southern Regional Fisheries Board (SRFB), the National Parks and Wildlife Service (NPWS), Iarnrod Eireann, DoEHLG (Built Heritage and Archaeology), and each individual business owner and resident.

Some interesting and challenging aspects of the design included:

- design of a large flood defence embankment on very soft clay/silts requiring detailed stability and seepage analysis at all critical sections, which resulted in the use of localised berms to add restoring moment;
- the use of geotextile reinforcing membranes; and,
- provision for controlled construction methods and material testing.

The design of the pumping stations had to consider both existing and future predicted flows, the potential for future upsizing of sewers and the varying hydrostatic head, which all added to the complexity of the design.

A number of existing rubble masonry walls had to be retained and incorporated into the flood defences, requiring detailed assessment of their condition and design of appropriate remedial measures including pointing, grouting, stitching and the addition of concrete backing walls.

As some of the proposed works were adjacent to the Blackwater, a candidate special area of conservation and an important salmonid river, all solutions had to be discussed and agreed with the SRFB and the NPWS. An example of a solution arising from these discussions was the diversion of an existing stream and construction of a new fish pass. The proposed flood relief culverts had to be designed to withstand an internal pressure equivalent to a 3m hydrostatic head.

### Construction works

In 2005, following a Section 8 planning process, an advance works contract was awarded by Cork County Council for the elements of the Mallow North Scheme which were located on public lands. This contract, with a capital value of circa €2.5m was funded by OPW and was completed in early 2006 by McGinty & O'Shea Ltd.

In 2007, the remainder of the Mallow North Scheme was tendered under EU procurement rules and, in spring 2008, the Minister for Finance confirmed the construction of this scheme. This contract, with a capital value of circa €10m was constructed by Bam Civil Ltd reaching substantial completion in November 2009. The construction of the remaining schemes is being procured as a single contract under EU procurement rules. At the time of going to print, tenders have been received and are being evaluated. It is anticipated that work on this contract will commence in spring of this year.

A sample of the main construction elements include:

- approx. 1250 linear metres of reinforced concrete flood defence walls up to 5m in height;
- approx. 900 linear metres of flood defence embankments up to 5m high and 40m wide;
- a total of 84 linear metres of demountable flood barriers up to 3.5m high;
- approx. 1400 linear metres of precast concrete culverts of varying dimensions up to 5.2m x 2.3m internally;
- approx. 1000 linear metres of new or diverted streams including a new fish pass structure;
- significant re-grading works at Mallow Bridge to improve conveyance;
- seven foul drainage pumping stations up to 7m deep, with pumped capacities of up to 700 l/sec and associated telemetry;
- extensive services and drainage diversions;
- installation of large penstocks to isolate and control flows to flood relief culverts;
- soil grouting to prevent seepage; and,
- strengthening of existing rubble masonry walls.

There are a number of locations where permanent defence walls cannot be constructed. The most critical of these is across Bridge Street, which is the main artery through the town. To ensure the continuity of the flood defence at these locations, temporary demountable barrier systems are being used.

These systems consist of extruded aluminium posts, which are bolted

to baseplates cast into the ground, and aluminium dam beams, which slot in between these vertical posts. Special rubber seals complete the system.

### Flood warning system

In conjunction with the construction of the flood defence scheme, the OPW have also developed and implemented a sophisticated flood warning system. This system uses data supplied by upstream gauges which is modelled to accurately predict the time and level of the peak of the flood. This data is relayed to a central server from automated telemetry stations at all gauge locations and is monitored by Cork County Council via a web-based user interface.

### Engineering and nature in harmony

The success of the Mallow Flood Defence Scheme is another example of the delivery of a sustainable engineering solution developed in harmony with nature for the benefit of society.

The OPW, the lead agency for flood risk management in Ireland, is implementing this scheme, together with other similar schemes around the county as part of their strategy for tackling flooding over the coming years. In addition to this 'direct' defence work, the OPW are also currently embarking on a series of catchment flood risk assessment and management (CFRAM) studies to comply with the EU Floods Directive 2007. This work will provide valuable information to help local authorities manage flood risk at a strategic planning level so as to minimise the need for 'direct' defences in the future. The Government, in the recent Budget 2010, reiterated its commitment to dealing with flooding in this country by increasing funding to the OPW flood relief section for the implementation of the above initiatives.

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**Ken Leahy is an associate with Arup Consulting Engineers, based in the company's Cork office. He is a Chartered Engineer and also holds a Postgraduate Diploma in Construction Law. He has been responsible for the design, management and contract administration of numerous civil engineering contracts. Ken is Arup project manager for the Mallow Flood Defence Scheme and was co-author of a technical paper on the design and implementation of the Mallow Flood Relief Scheme, which can be downloaded from the Arup website at [www.arup.ie](http://www.arup.ie)**