Department for Environment Food & Rural Affairs

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Environment Agency

delivering benefits through evidence

Cost estimation for flood warning and forecasting – summary of evidence

Report –SC080039/R13

Flood and Coastal Erosion Risk Management Research and Development Programme

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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.

This report is the result of research commissioned by the Environment Agency's Evidence Directorate and funded by the joint Flood and Coastal Erosion Risk Management Research and Development Programme.

Published by:
Environment Agency, Horizon House, Deanery Road, Bristol, BS1 5AH

www.environment-agency.gov.uk

Email: fcerm.evidence@environment-agency.gov.uk.

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Dissemination Status:
Publicly available

Keywords:
Whole life costing, cost estimation, flood warning, flood forecasting

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Project Number:
SC080039/R13

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Miranda Kavanagh

Director of Evidence

Executive summary

This summary of evidence on cost estimation provides examples of costs associated with flood warning and forecasting where available. Insufficient cost information is currently available to provide unit costs for specific cost components to build up a whole life cost for establishing or improving a flood forecasting and warning system for a community at risk. This section has therefore provided available costs and case studies to assist guide appraisers when undertaking cost estimates for this aspect.

<table>
<tr><th colspan="3">Flood warning and forecasting</th></tr>
<tr><td>Key cost components</td><td colspan="2">Costs are typically low compared with flood extent reduction measures but include:
setting up any new organisational structures
installing, operating and maintaining hydrometric equipment
developing, configuring and running forecasting models
developing and running systems for generating and disseminating flood warnings
buying computer software and hardware to support the above operations
staff training and running flood exercises
raising public awareness of flooding and how to respond to flood warnings</td></tr>
<tr><td>Key asset types</td><td colspan="2">N/A</td></tr>
<tr><td>Data reviewed in specific guidance</td><td colspan="2">Limited data are readily available for flood warning and forecasting, but several case studies and examples are provided. Guidance is given in the absence of cost data to provide appraisers with information to assist with cost estimation.</td></tr>
<tr><td>Other relevant data</td><td colspan="2">Local or proxy records such as Environment Agency data and local authority information
Quotes direct from suppliers for smaller scale, low cost options</td></tr>
<tr><td rowspan="3">Relative cost importance</td><td>Enabling costs</td><td>Variable costs associated with setting up warning infrastructure and administration costs where these are not currently available.</td></tr>
<tr><td>Capital costs</td><td>Variable costs associated with hydrometric installation, development of forecasting and warning models, software and hardware costs and dissemination systems.</td></tr>
<tr><td>Maintenance costs</td><td>Variable costs associated with operational running costs and national, regional and local training and exercises. Costs remain low compared with measures to reduce the extent of flooding.</td></tr>
</table>

	Other cost considerations	May include management, publicity and public awareness campaigns
Cost estimation methodology	Initial concept/national appraisal	Some case studies and example projects provided to demonstrate cost elements required. Insufficient information currently available to derive unit costs or cost curves for the purposes of cost estimation.
	Strategic, regional, or conceptual design	No specific cost information provided. Guidance on data availability and procedures provided.
	Preliminary feasibility/design	No specific cost information provided. Guidance on data availability and procedures provided.
Design life information	Not really applicable, although components of a system will require periodic review/renewal.	
Quality of data	Little readily available information is available. A range of examples, reference case studies and reference projects is provided and guidance is offered to support appraisers for cost estimation.	
Additional guidance	Checklist of factors likely to influence capital and maintenance costs, and key factors to consider for detailed costs estimation List of R&D and general design guidance Case studies of recent schemes	

Acknowledgements

The authors wish to thank the Project Board (Ian Meadowcroft, Linsay Hensman and Adam Baylis) and the Environment Agency, Local Authority and Internal Drainage Board representatives and operational staff who were consulted. We would also like to thank Ken Higgins (HydroLogic Ltd), Richard Aldrich (Controlstar Ltd) and Jim Casey (OPW) for the provision of cost data and relevant case studies.

Contents

1 Flood mitigation measure – flood warning and forecasting

An operation flood warning and forecasting system typically uses some form of hydrological and hydraulic modelling to provide sufficient lead time to avoid loss of life and to allow flood defence measures to be operated. Forecast models are at the heart of reliable operational flood warning systems.

The benefits of flood warning (reduced loss of life through the evacuation and mobilisation of emergency works crews and the deployment of mitigation works to reduce flood damages) are covered in the Multi-coloured Manual (MCM) (Penning-Rowsell et al. 2013).

Establishing or improving a flood forecasting and warning scheme for a community at risk requires a number of components to ensure a reliable system that can operate during extreme conditions. It is essential that all components of a system are functional and that the transfer of information between components is reliable. This requires investment in a number of areas including data, software, hardware, forecast models and human assets (trained staff).

Not all components will be required in some circumstances, particularly where only low cost community warning options are required or where existing forecasting and dissemination systems are already provided by the Environment Agency such as the National Flood Forecasting System (NFFS).

1.1 Cost elements required for flood warning and forecasting

A number of cost elements are required to derive estimates for flood warning and forecasting. The following components may need to be considered as part of a whole life cost appraisal:

- setting up any new organisational structures
- installing, operating and maintaining hydrometric equipment and a radar network if not available
- developing, configuring and running forecasting models
- developing and running systems for generating and disseminating flood warnings
- buying computer software and hardware to support the above operations
- buying in meteorological forecasts, for example, from the Met Office
- staff training and running flood exercises
- raising public awareness of flooding and how to respond to flood warnings

In reality many of these aspects will be set up already and many cases will only require the development of new forecast models, the addition of new hydrometric equipment and additional training.

The costs associated with flood warning and forecasting may be shared with other aspects. For example, a flood warning scheme may include the costs associated with gauging station inspection and maintenance, telemetry costs and project management costs. However, these costs may be for staff members not associated with flood warning teams (for example, hydrometric teams) and the project management costs may be split between different projects or organisational functions.

Care should therefore be taken when determining the requirements for cost elements as part of an appraisal as many of the elements above may not be required.

1.2 Approach to cost estimation

Very little information is currently available on flood warning and forecasting scheme costs. A review of flood warning costs in England and Wales by the Environment Agency (Environment Agency 2007a) provided an indicative cost of £1,000 per property for the provision of flood warning.

Available indicative cost information has been collated and presented where available, to assist those performing cost appraisals for flood forecasting studies at a high level. This information covers a range of aspects required for the provision of flood warning and is provided here as a summary of evidence on cost estimation.

These costs may be more appropriate for initial conception design or national appraisals rather than for detailed feasibility or design. More specific information on local or similar previous studies may also be available from the Environment Agency or local authorities/Internal Drainage Boards (IDBs).

More detailed analysis of costs will require specialist support from organisations, staff or consultants experienced in providing the necessary elements required for a functioning flood forecasting scheme. Specific construction costs for some aspects would need to be determined from price estimating books, previous experience or tender returns at the design stage of an analysis.

1.3 Hydrometric equipment

Most warning or forecasting models require a basic network of meteorological and hydrometric stations, in particular river and rain gauges (unless models run directly from radar inputs). The UK has an extensive network of these, although particular gauges may not have been designed to acquire data during extreme conditions or to provide data in real time.

Flood forecasting is data hungry and has a high demand for rain gauges, river level and flow gauges, and associated telemetry connections. Most forecasting models will utilise existing gauges, but in some circumstances where the required spatial distribution or density of gauges is insufficient, additional gauges or new telemetry will be required – unless this can be substituted by rainfall radar data.

In some cases the gauge network may be insufficient or costly structural alterations to gauging stations may be required. An assessment of the requirement for new or altered gauging needs should be based on a review or scoping study of the existing adequacy of the network and the forecasting requirements.

An additional aspect to consider is the adequacy of the communications between gauging stations and the forecast system. The most common form of data communication is by telephone, but other options include satellite and GSM (Global System for Mobile Communications).

The maintenance of existing and new hydrometric networks is a major requirement for operational forecasting to ensure the network is in a constant state of readiness. The maintenance costs associated with this may be a large annual cost, but in many cases may be undertaken by other organisations or provided by other internal teams/funding provisions.

1.3.1 River gauging

Costs associated with new river gauging stations are provided in the Environment Agency's Flood Risk Management Unit Cost Database – 2007 version) (Environment Agency 2007b) and are summarised in Table 1.1. These costs are for flow gauging stations; level gauges are considerably cheaper.

Table 1.1 Environment Agency Unit Cost Database river flow gauging station costs

Average cost	Median cost	20th percentile	80th percentile
£112,000	£82,500	£34,000	£171,300

Notes: Costs are based on approximately 68 projects with a channel width of between 2 and 20 metres.

These costs may include the construction of a control structure, level measuring equipment (for example, transducers) control building construction, telemetry links, and access road and associated structures.

Significantly cheaper options for level or flow gauging may be available through the use of simple horizontally and vertically oriented acoustic doppler current profiler (ADCP) and ultrasonic flowmeters. An example from Ireland suggests that river gauging using simple gauge loggers could be provided for approximately £3,500 each (OPW 2011). Annual maintenance costs are likely to the similar at £3,500 per year.

1.3.2 Rain gauge

The cost for a tipping bucket rain gauge, telemetry and installation is in the region of £1,000–3,500 per gauge[1] (assuming either a low-cost tipping bucket or high-cost OTT weighting principal gauge). This represents the cost for a single gauge rather than a full automatic weather monitoring station which measures other variables and is likely to be significantly more expensive.

Maintenance costs are likely to be in the region of £1,000 per gauge for inspection and annual maintenance, replacement costs and £300 per year for telemetry costs.

1.4 Forecast models

Forecasting models vary in complexity from simple level-to-level correlations to highly automated integrated catchment flood forecasting models. The degree of automation and sophistication should be considered based on the needs for a particular location. While the type of forecast system will be typically based on existing hydrometric

[1] Personal communication from Ken Higgins, Hydro-Logic Ltd

networks or the enhancement or development of new networks, the system will need to be achievable and affordable. Model selection will therefore depend on:

- available data
- basin characteristics/complexity
- accuracy and reliability required
- lead time requirements
- needs of the flood risk communities

A scoping study to identify the catchment issues and to provide initial schematisation of a forecast model is sometimes carried out before developing a full model to help identify the most appropriate methodologies.

The costs for setting up, configuring and running forecasting models can be split into the following items:

- costs for the development of the system, reviewing the data, schematisation, model calibration, testing and configuration
- software licence costs
- hardware costs if not already available and in use
- operational running costs and staff training

The costs associated with the development of the system will vary depending on:

- type of models being developed
- catchment size and density of the gauging stations
- availability of existing models
- type of catchment

Catchment aspects that will affect the development and calibration are wide and varied. This might include aspects such as:

- degree of catchment urbanisation
- presence of reservoirs and flood storage/attenuation
- quality of the ratings at gauging stations
- seasonality
- upland areas and snowmelt considerations
- influence of groundwater
- impact of tributary and ungauged catchments
- impact of backwater effects, confluences and tidal locations

Each of these aspects and the distribution of risk locations will influence the type of model required and the extent of model development and calibration/validation. Many models have, in the past, been converted from existing models used for other purposes (for example, flood mapping), though this may not always be recommended or the lowest cost method.

In most cases, the costs of developing flood forecast systems are likely to be the largest element of the capital outlay where an existing warning and forecasting platform is available. Costs are likely to vary between £20,000 and £80,000 per scheme for project management and development of hydrological models.

Once developed, forecast models will require configuration on the forecasting platform. This is one area that has been underestimated in the past terms of staff resources to implement and maintain forecast models. Configuration is usually undertaken in-house by the Environment Agency but experience has shown that the cost for consultants to carry this out can be in the region of £3,000–5,000 per catchment forecast model.

An area of additional work associated with ongoing model improvement is the periodic review and re-calibration of existing models. This might include a number of aspects such as:

- dataset preparation
- extending the calibration period
- gauge rating updates
- parameter adjustment and re-calibration
- altered rain gauge weights
- lateral inflow adjustments
- performance testing and reporting

Work undertaken for the Environment Agency in 2009 suggested that the cost for Probability Distributed Model (PDM) re-calibration would vary between £400 and £1,200 per catchment[2] depending on the current performance of models and the work entailed in improving the calibration. Costs for kinematic wave routing model recalibration varied between £300 to £1,800 depending on the level of complexity and the factors affecting current performance. These costs did not include the costs associated with initial review of each catchment PDM model.

1.4.1 Examples from Ireland

The Strategic Review of Options for Flood Forecasting and Flood Warning in Ireland by the Office of Public Works (OPW) in 2011 examined a number of ongoing and recently setup forecasting and warning schemes. Table 1.2 provides a summary of these schemes and the costs involved in setting up and developing the forecast models, along with costs associated with the annual maintenance of gauges and telemetry systems. These costs are conservative in that flood forecasting model development at that time was fairly new to the OPW and includes an element of the learning required to implement these forecasting systems. The costs are based on an Ireland cost base and therefore may not be directly compatible with other countries. The costs also include all aspects relevant to setting up a forecasting system, some of which may not be directly relevant for particular appraisal applications.

[2] Personal communication from Paul Wass, JBA Consulting

Table 1.2 OPW review of the costs of ongoing and recently set up forecasting and warning schemes in Ireland

System	Source of flood risk	Models and software used	Cost (capital and maintenance)
Munster Blackwater Mallow Initial Flood Forecasting System (IFFS)	Fluvial	In-house development of an IFFS for the catchment. Originally spreadsheet based level correlation model	Standalone IFFS only: Capital: €39,000 Annual maintenance: €26,400
	Fluvial	Unified River Basin Simulator (URBS) rainfall run-off model; MWH Soft FloodWorks forecasting system	Capital: €335,000 Annual maintenance: €230,000
Suir Clonmel Initial Flood Forecasting System	Fluvial	Routing model in Microsoft® Excel spreadsheet	Capital: €57,000 Annual maintenance: €28,800
	Fluvial	URBS rainfall run-off model; FEWS software by Deltares	Capital: €335,550 Annual maintenance: €195,900
Bandon Flood Early Warning System (FEWS)	Fluvial	Level to level correlation model; HYDRAS 3	Capital: €60,000 Annual maintenance: €10,000 (preliminary estimate)
Tidewatch and Triton	Coastal	Tidewatch: Excel spreadsheet using O'Connell-Coe formula Triton: still water and wave overtopping model based on UKMO system	Capital: €300,000 Annual running costs: €50,000 Major updates: €20,000 (every four years)
ICPSS	Coastal	Hydrodynamic surge and tidal model; MIKE 21 software	Costs based on trial period only: Capital: €87,000 Annual running costs: €68,100
Marine Institute	Coastal	Ocean forecast model: ROMS Wave model: SWAN	Capital (hardware only): €400,000 Annual running costs: €280,000

1.4.2 Software licence costs

Software licence costs can vary significantly, but may be negligible in the case of spreadsheet or correlation models. It is anticipated that a forecasting organisation will have all of the required software required for flood warning or forecasting. No additional costs are likely unless specific or bespoke software applications are required for a particular location or scheme.

Where required, licence costs can be obtained from flood forecasting model software suppliers where the required software is not currently available.

1.5 Forecasting platforms

A forecasting system is required to collate hydrometric and meteorological data, run forecast models and provide the necessary decision support tools to assist in the provision of flood warnings. Key features of a forecasting system include:

- a centrally located and nationally consistent system
- a flexible design that permits different model software types to be linked together and to provide the ability to extend the service to increase coverage
- adoption of common data communications format
- a performance monitoring/reporting capability
- web-based report dissemination

Forecasting platforms will require initial financing in the short term to include the capital intensive funding of network improvements, hardware acquisition, specialist forecast platform software, backup facilities and other aspects. These are likely to be funded via special regional or national appropriations. Longer term financing will also be required to operate and maintain the system, for staff costs, to provide ongoing training and to upgrade hardware, software and forecast methodologies.

Systems that provide the above requirements for a forecasting platform are available from software suppliers such as the Deltares Delft-FEWS or the MWH Soft FloodWorks.

In 2002 the Environment Agency launched the National Flood Forecasting System (NFFS) with the objective of implementing a real-time forecasting platform capable of supporting all existing modelling approaches (therefore safeguarding previous model investment) and providing an open environment to link different model types from different model suppliers. The development costs for this system from 2002 to 2007 were £15 million (Pollard 2007).

1.6 Flood warning

Setting of flood warning thresholds and generating warnings can be achieved at a low cost where local knowledge and existing models and hazard mapping are available. Where existing models are not available and no information on flood extents or previous flooding is available, the provision of accurate flood warning triggers may require potentially expensive modelling.

1.6.1 Flood warning dissemination

Timely and accurate flood warnings require reliable and strong flood warning dissemination systems. Dissemination systems can be categorised as follows:

- **Indirect** – warnings issued by broadcast methods (local or national media) and internet warnings
- **Direct** – warnings issued directly to recipients via telephone, SMS text message, email, door knocking, loudhailer, siren and so on.

Costs for the dissemination of warnings will depend on the availability of existing systems and the approach chosen for dissemination. Costs are significantly larger for direct dissemination to individual recipients via suitable communication media. As flood warning services develop and coverage grows, additional people and organisations benefit from the service, and the resources required to manage information and communications also grow.

1.6.2 Low-cost community based telemetry and warning

The Environment Agency and other organisations recently trialled low-cost community based telemetry and warning signs to inform communities and critical infrastructure of flood risks. Some examples of these measures and costs are provided below. Costs are provided as examples but are specific to the problems identified and depend on the approach taken to provide warning.

Typical telemetry and warning triggers

HydroLogic Ltd (www.hydro-logic.co.uk) has extensive experience in the provision of lower cost telemetry and warning trigger solutions typically used for open watercourse level monitoring and culvert screen applications (Figure 1.1), or for use in control structures that require installation monitoring.

Figure 1.1 Example telemetry and level sensor set up at a trash screen

Table 1.3 gives estimated costs provided by HydroLogic for a range of applications. These provide indicative cost estimates for standard telemetry and warning trigger applications where installation is straightforward and good access.

Table 1.3 Indicative costs for telemetry and warning trigger solutions

Product/system	Assumptions	Total cost
Relatively simple telemetry system	Provision and installation of hydrostatic level sensor, staff gauge and telemetry	£1,500 – equipment £950 – installation and running costs
More advance telemetry system with CCTV	Provision and installation of hydrostatic level sensor, staff gauge, telemetry and camera	£2,800 – equipment £1,400 – installation and running costs
Signage and warnings system	Provision and installation of above with additional warning signs	An additional £1,000–5,000 depending on size and whether signage is indoors or outdoors

Notes: Costs reflect 2011 prices excluding VAT.
Prices reflect fully installed system and first year's operating costs.
Longer ducting or need for civil engineering works would increase costs.
Source: Hydro-Logic Ltd

Interactive road signs

The Environment Agency has trialled new vehicle activated flood warning signs at flood risk locations where flooding to roads and at fords has caused disruption or fatalities. Solar-powered signs, activated by oncoming vehicles and connected to river level telemetry, provide visual warnings once river levels exceed a predefined threshold. These signs aim to improve safety by providing timely warnings and ensuring that the public take appropriate action. They are designed to operate automatically without the need for mains power or user intervention.

The project was undertaken in conjunction with Dorset Highways Department and the signs were supplied by a specialist company (Scrimsign). The Environment Agency provided the telemetry and river level experience; Dorset Highways Department was responsible for maintaining the signs and the local authority was responsible for the public awareness aspects. Other systems may have different arrangements.

Figure 1.2 Example interactive road signs

The cost per sign was £5,000 including installation, with two signs usually required either side of a river crossing. A simple telemetry outstation cost a further £5,000 giving a total cost per site of £15,000 (Parker 2010). The design and trigger level assessment were made by the Environment Agency, but these could add additional costs if this was not the case.

The Environment Agency is currently improving the system to manage the data and to control and view warnings remotely. A limitation of the system is that the Environment Agency does not know what the sign is displaying, and an external management system is needed to allow remote control and to view warnings.

Alarm triggered from Environment Agency website warnings

Controlstar Ltd (www.controlstar.com) recently installed a warning sign as part of a requirement for a development in a flood risk zone identified as part of a Flood Management and Evacuation Plan. While the development and all egress and escape routes are above flood levels, the car park of the development is risk of flooding in extreme conditions. Controlstar developed an electronic warning board located in the basement and ground floor lobbies that displays the Environment Agency's warning symbols and advice (Figure 1.3). The symbols light up and issue a low intensity alarm sound when the warnings are triggered. The warning triggers are based on data read from the Environment Agency website linked to the internet via a broadband connection.

Figure 1.3 Example of alarm triggered from website warnings

The costs for these warning signs are approximately £1,100 for a standalone sign (which collects the required information from the internet) and a further £800 for each additional slave sign that links (wirelessly or wired) to the master sign (prices exclude VAT)[3]. The example above included one master sign and nine slave signs.

1.6.3 Computer-based automated dissemination

Regional or national computer-based flood forecasting and warning dissemination have recently been set up in the UK. Computer systems for real-time operation during flood events need to be robust with sufficient contingencies such as backup facilities for data and power failures.

Computer systems for automated direct dissemination of warnings can therefore be very expensive and require expensive high-specification computer hardware. Recent

[3] Personal communication from Richard Aldrich, Controlstar Systems Ltd

examples of these sorts of dissemination systems include the Environment Agency Floodline Warnings Direct service introduced in 2006 with a view to providing a nationally hosted warning dissemination, message and information handling system for all high risk properties with a direct flood warning service (approximately 1.8 million properties). The cost to implement the system was over £10 million plus ongoing maintenance costs (Andryszewski et al. 2005). More recently the Flood Forecasting Centre (FFC) was set up at a cost of £10.4 million[4] to allow collaboration between the Environment Agency and the Met Office.

The Scottish Environment Protection Agency (SEPA) implemented a new flood warning dissemination system in 2011 similar to that used by the Environment Agency. The dissemination system and funding for a joint Scottish Flood Forecasting Service (to set up a virtual flood forecasting unit between the Met Office's operations centre and SEPA's flood forecasting team) was provided for a total of £750,000 (Scottish Government 2010). The Service is responsible for providing daily statements for local authorities and emergency services. The costs also included a Flood Warnings Direct dissemination service that covered staff costs for a large programme team for a period of three years as well as the system and service provider. This is an opt-in scheme to provide direct warnings to the public based on the development of SEPA-dedicated infrastructure based on the similar Environment Agency solution.

1.7 Communication and dissemination training

Flood warning and forecast dissemination are vital to ensure that warnings reach users without delay and with sufficient lead time to permit response actions to take place. Ensuring that communication systems are reliable and that a forecast centre is capable of working collaboratively with other agencies effectively is essential.

A training programme for this at the national and local scale is required to ensure the correct procedures are in place. Training may be needed for:

- staff involved with forecasting model development (modelling and real time application of models)
- staff involved with setting targets or reviewing warnings (local knowledge, interpretation of results from a variety of models and studies)
- staff responsible for running forecast models (understanding of the forecast system, the data inputs, meteorology, hydrology and coastal processes)
- duty officers and staff responsible for issuing warnings
- staff responsible for flood warning dissemination systems

Much of these roles and training will already be available through existing staff. However, any expansion or new forecasting services could require additional staff and training in some circumstances, the costs of which would need to be considered.

1.7.1 National, regional and local training exercises

Complex multi-agency regional or national exercises require bespoke exercise management systems and specialist consultants to plan, assist and facilitate the delivery and review of the exercise. The main driver for national flood exercises is Recommendation 49 of the Pitt Review:

[4] http://www.ffc-environment-agency.metoffice.gov.uk/faq.html

> RECOMMENDATION 49: A national flooding exercise should take place at the earliest opportunity in order to test the new arrangements which central government departments are putting into place to deal with flooding and infrastructure emergencies (Pitt 2008, p. 233).

Exercise Triton was the first national flood exercise held in 2004. It was conducted in June 2004 and involved 1,000 players and directing staff. Costs for this were in the region of £1.5 million (Environment Agency 2005) for the cost of designing, implementing and reporting which included exercise scenario production, exercise documentation, a website for information sharing, the production of planning and overview reports, and a film of the exercise.

Exercise Watermark took place in March 2011 and involved around 10,000 people, 10 government departments, emergency services, utility companies and communities. The costs were approximately £1.8 million. The total costs include all costs associated with inception, designing, planning, conducting, reviewing and provision of the IT requirement.

A typical local flood exercise based on an Environment Agency Area/Region costs are likely to be in the region of £10,000 to £30,000 to develop a new exercise[5] depending on the number of players and time input required. This is based on the costs for planning, preparing scenarios and facilitating the exercise. Repeating or re-running an existing exercise would provide significant cost savings.

1.8 Public awareness campaigns

Appropriate investment in raising public awareness should be aligned with investment in a new flood forecasting and warning scheme/service to ensure that communities at risk are aware of:

- the risks and how they affect them
- how to interpret the warnings provided
- how to prepare, respond and recover from a flood

1.9 Other cost estimate requirements

In addition to the above cost estimates required, the following parameters are required to ensure whole life costs are correctly defined so as to incorporate these into an appraisal. The design life and discount rates are used to convert future costs over a scheme life to 'present values' so that they can be compared against the benefits.

1.9.1 Appraisal period/design life

The design life is typically defined as the minimum length of time that a scheme is required to perform its intended function. The design life for appraisals is typically taken to be 100 years, although alternative periods can be used.

The design life is an important consideration in whole life costing as component assets of a design may have a shorter service life and not be last as long as the design life. This has implications for cost estimates to ensure that a whole life cost estimate

[5] Personal communication from Ray Pickering

correctly identifies all long-term maintenance and asset replacement costs over the intended appraisal period.

Appraisal periods for flood forecasting will be linked to the availability of additional data and system/forecast upgrades. Computer hardware and software will need to be upgraded over the life of a forecast system as new, more advanced software becomes available and hardware systems become redundant and are replaced. These costs should be considered in a whole life cost estimate to ensure all relevant costs are included.

In addition to the software and hardware replacement costs, many existing and current forecast models are currently based on calibration from relatively short datasets that may not include the large flood events which these forecast systems are attempting to predict. Therefore, many forecast and warning models will need to be reviewed intermittently as new flood event data becomes available, new software and statistical methods to verify the outputs are developed and the spatial density of gauging station information increases. No information on the periodic review of forecast models is available, though it is expected that re-calibration of models would be required at least every 10 years.

1.10 Cost estimation methodology

The flow diagram in Figure 1.4 shows the key aspects required to provide a whole life cost estimate for a flood warning scheme.

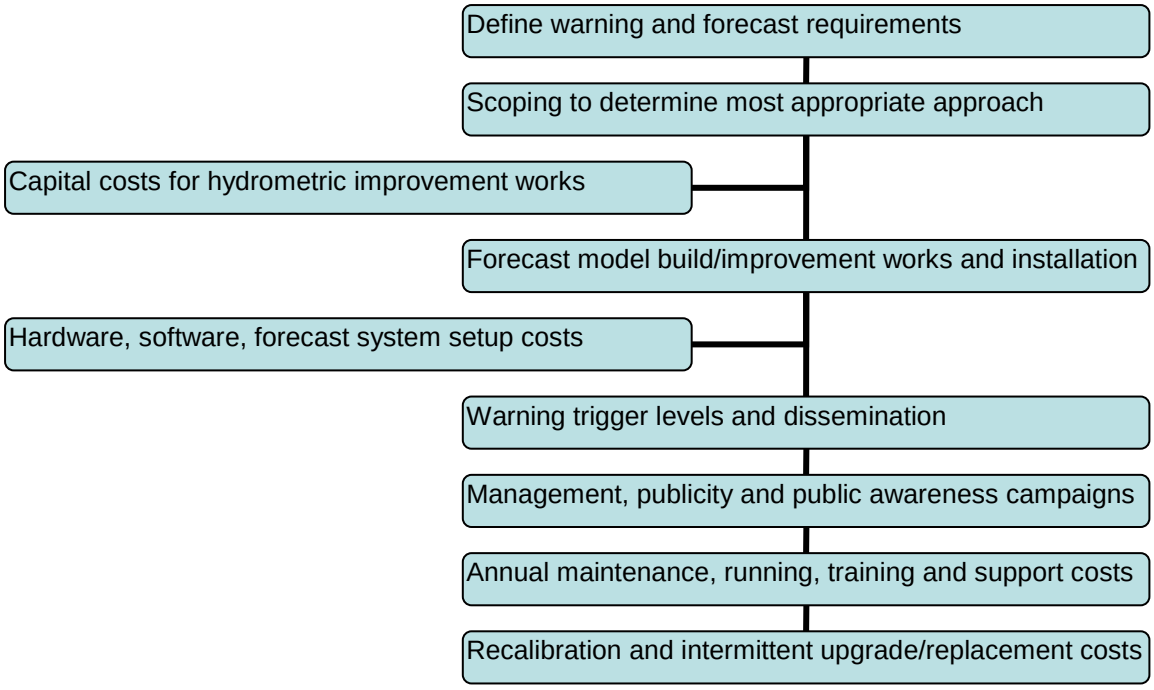

Figure 1.4 Flow diagram for flood warning whole life costs

1.11 Case study: Munster Blackwater Mallow Flood Forecasting System (Ireland)

The OPW's Preferred Flood Forecasting System (PFFS) for the Munster Blackwater at Mallow and Fermoy was developed between 2005 and 2009 but continues to undergo

improvements. The primary purpose of the system is to enable the erection of demountable barriers when necessary. However, it delivers more accurate forecasts than previous systems, providing forecasts of both river level and flow, with established longer warning times for specific locations. This case study may not be fully representative of typical setup costs due to the higher installation of river and rainfall gauge instrumentation than would normally be expected.

The system is based on a URBS (Unified River Basin Simulator) model, which is a hydrological model based on rainfall run-off and run-off routing. Data for the URBS model are provided by a telemetered river and rain gauge network, and the forecasting system is operated by Cork County Council through the FloodWorks data management system (produced by MWH Soft). The three main elements of the PFFS system are:

- telemetered river and rain gauge network
- rainfall run-off and routing model (URBS)
- data management system (or 'front end') – FloodWorks

The project rain gauges were installed in late 2005. Many of the project river stations were installed in 2005 and 2006. Rain gauge and river level gauge data are transferred by GSM.

The data management system, FloodWorks, is a modular software package designed for operational use in the control room, and is used for real-time simulation and forecasting of extreme hydrological and hydraulic conditions. It retrieves real-time rain and river data from the telemetry system, which it sends to the forecast models. It then allows the models to perform their function and obtains the model outputs, showing outputs in a hydrograph format.

Development of the system used four years' river flow and rainfall data. It took six months to implement the management system. Indicative costs for the setup and annual maintenance of the PFFS are shown in Table 1.4 and Table 1.5 respectively. Additional annual running costs are associated with OPW project management and Cork County Council operating costs. Staffing requirements include ongoing monitoring of the system. Cork County Council has a monthly rota of five staff to provide 24/7 on-call coverage.

Table 1.4 Set-up costs for PFFS

Item	Cost
River gauge loggers (18 @ €4,000 each)	€72,000
Rain gauges (32 @ €4,000 each)	€128,000
FloodWorks flood forecasting management software (includes long-term licence for 25 years)	€50,000
Hydrological model build and calibration	€13,000
Hydrological model licence cost (one-off)	€4,000
Training	€4,000
Reporting	€4,000
OPW project management cost engineer with expertise for one year	€60,000

Table 1.5 Annual Maintenance and Running Costs for PFFS

Item	Cost
Gauge operation and maintenance ((18+32) @ €4,000 each)	€200,000
Telemetry ((18+32) @ €400 each)	€20,000
FloodWorks system maintenance	€10,000

1.12 Checklist

The following checklist should be followed to ensure all relevant cost items are included and incorporated into a whole life cost estimate.

Whole life cost estimate checklist for flood forecasting and warning systems

Item	Description	Frequency	Comment
Planning costs			
Initial planning and procurement	To identify problems and options for improvements	One-off	
Scoping studies	To identify appropriate approach	One-off	
Capital costs			
Installing new or additional hydrometric equipment	Additional gauges or structural amendments. May also include rating review/alterations.	One-off	May not be required, or may be a requirement for the future.
Software and hardware	Any additional software or hardware required.	One-off	Existing system may already be in existence
Design, modelling, calibration	Development of new forecast models	One-off	
Configuration of forecast model	Setting up the forecast models on new or existing forecast system	One-off	Usually in-house costs but can be outsourced.
Staff training and running flood exercises	Local training on forecast model or training exercises. Regional or national training exercises may be on top of this.	One-off/ intermittent	
Management, liaison & publicity	Publicity campaigns or specific liaison with other stakeholders	One- off/ intermittent	
Operation costs			
Operating hydrometric	Operation of hydrometric	Continuous	If applicable

equipment	equipment and telemetry		
Running forecasting models	Generating and disseminating flood warnings	Continuous	
Inspection and maintenance costs			
Hydrometric gauge	Inspection and annual maintenance of gauge and telemetry	Annual	If applicable
Warning and model improvements	Forecast model improvements as new data and methods become available	Intermittent	If applicable
System hardware and software	Upgrades to software and hardware to retain reliability of system.	Intermittent	If applicable

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