Communities and Local Government

Improving the Flood Performance of New Buildings

Flood Resilient Construction

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Improving the flood performance of new buildings

Flood resilient construction

May 2007
Consortium managed by CIRIA
Department for Communities and Local Government: London

Acknowledgements

This guidance document was produced as part of the Department for Communities and Local Government Buildings Regulations (Sanitation) Research Framework, and the joint Defra/Environment Agency Flood Risk Management Research and Development programme. It is the main output from the research project "*Improving the Flood Resilience of Buildings through Improved Materials, Methods and Details*" (Ref CI71/8/5 BD2471).

This guidance document also constitutes Environment Agency Science Report SC040066/SR

The project was carried out by a consortium managed by **CIRIA** and comprising **HR Wallingford Ltd**, **Leeds Metropolitan University**, **WRc and Waterman Group**.

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ISBN 978 1 85946 287 4

Stock Code 61920

Further copies are available from:

RIBA Publishing
15 Bonhill Street
London
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Printed on material containing no less than 75% post-consumer waste

Product Code: 07 BD 04543

May 2007

Foreword

We are pleased to announce the publication of **Improving the flood performance of new buildings – Flood resilient construction**. This is the outcome of a joint research project between Communities and Local Government and the Environment Agency and has strong links to the Government's strategy for managing flood risk "Making space for water" that is co-ordinated by the Department for the Environment, Food and Rural Affairs. It is a true demonstration of joined-up Government on an important subject.

Flooding from rivers and coastal water or as a result of intense rainfall is a natural process that plays an important role in the shaping of the natural environment. However, flooding threatens life and causes substantial damage to property. Climate change over the next few decades is likely to mean milder wetter winters and hotter drier summers in the UK whilst sea levels will continue to rise. These factors will lead to increased and new risks of flooding within the lifetime of planned development.

Although planning policy avoids inappropriate new development in flood risk areas and directs development away from areas at highest risk, in order to maintain service or sustain communities, some development will be necessary in places that may flood. Planning deals with where to build. This guide explains how to build and describes how buildings should be constructed in order to minimise flood damage, as part of a package including flood awareness, warning and emergency planning.

This guide is the latest output in a series of information on flooding that has been published over the last 10 years, starting before the floods of autumn 2000. However, this project is different from earlier works in the UK and internationally in that it actually tested materials and assemblies in a hydraulics laboratory and subjected them to flooding for several days.

It is not always possible to provide defences to keep floodwater away from buildings and infrastructure, because they may not be the best option for people, wildlife or economically, and may increase flooding elsewhere. Increased demand for housing and limited available space means that in future it may be inevitable that properties will be built on sites that have some risk of flooding even after measures have been taken to reduce the risk. It is therefore important that these buildings are designed to be resistant or resilient to flooding.

Most homes are intended to last over 60 years; many will still be here in a hundred years. In that time it is expected that there will be real changes in the climate that will affect the water environment and increase flood risk. Resilient construction is therefore an important area for investment and one which we hope designers, developers, planners and building control bodies will treat with the seriousness it deserves. Furthermore, this form of construction is one of the adaptation strategies discussed in the Stern Review.

Baroness Andrews OBE
Parliamentary Under Secretary of State
Department for Communities and Local Government

Ian Pearson
Minister of State for Climate Change and the Environment
Department for Environment, Food and Rural Affairs

Sir John Harman
Chairman
Environment Agency

CONTENTS

Executive Summary

Aim of the Guidance

This document aims to provide guidance to developers and designers on how to improve the resilience of new properties in **low or residual flood risk areas** by the use of suitable materials and construction details. These approaches are appropriate for areas where the probability of flooding is low (e.g. flood zone 1 as defined by PPS 25) or areas where flood risk management or mitigation measures have been put in place. The guidance will also be useful to planners, building control officers and loss adjusters.

Specifically this guidance document provides:

- practical and easy-to-use guidance on the design and specification of new buildings (primarily housing) in low or residual flood risk areas in order to reduce the impacts of flooding
- recommendations for the construction of flood resistant and resilient buildings.

Background and government policy

Government policies in the UK do not advocate the building of dwellings in areas with a significant risk of flooding. However, where development is, *exceptionally*, necessary in such areas, national flood risk management policy requires that such developments are safe, do not increase flood risk elsewhere and, where possible, reduce flood risk overall.

It is critical that new buildings in these areas are designed appropriately to cope with floodwaters and minimise the time for re-occupation after a flooding event. Time to re-occupy properties is a principal consequence of flooding which can have a profound impact on the health and livelihoods of those affected.

In England, PPS 25 *Development and flood risk* (December 2006) and the associated Practice Guide takes a hierarchical approach to locating developments in the most appropriate location. This sequential approach (and the associated exception test) allows for resistance and resilience measures to be considered as part of this hierarchical approach.

The project supporting the development of the present guidance has also proposed changes to the Building Regulations for England and Wales (Approved Document C) to incorporate flood resistance and resilience. Once these changes are brought into effect, the links between planning and building control systems will be stronger.

This guidance offers a way in which planners and building control officers can assess the suitability of proposed resilience measures. However, this is not a checklist but a framework as there is no standard solution appropriate for all cases.

Hierarchy of building and site design

In line with the sequential approach to planning, the following are the range of construction measures that can be used to reduce the flooding risk at a site.

Flood avoidance Constructing a building and its surrounds (at site level) in such a way to avoid it being flooded (e.g. by raising it above flood level, re-siting outside flood risk area etc)

Flood resistance Constructing a building in such a way to prevent floodwater entering the building and damaging its fabric.

Flood resilience Constructing a building in such a way that although flood water may enter the building its impact is reduced (i.e. no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated).

Flood repairable Constructing a building in such a way that although flood water enters a building, elements that are damaged by flood water can be easily repaired or replaced. This is also a form of flood resilience.

Design approaches and flood resilient design and construction

This document, based on evidence from laboratory tests, technical evidence and industry experience, helps a designer to determine the best option or design strategy for flood management at a building site level from knowledge of basic flood parameters (e.g. depth, frequency and duration) which would normally be determined in a flood risk assessment at the planning stage. Depending on these parameters (in particular flood depth) and after utilising options for flood avoidance at site level, designers may adopt a **water exclusion strategy** or a **water entry strategy** as illustrated in the figure below:

	Design water depth*	Approach	Mitigation measures
Resistance/Resilience**	Design water depth above 0.6m	Allow water through property to avoid risk of structural damage. Attempt to keep water out for low depths of flooding *'Water Entry Strategy'******	• Materials with low permeability up to 0.3m • Accept water passage through building at higher water depths • Design to drain water away after flooding • Access to all spaces to permit drying and cleaning
Resistance/Resilience**	Design water depth from 0.3m to 0.6m	Attempt to keep water out, in full or in part, depending on structural assessment. If structural concerns exist follow approach above***	• Materials with low permeability to at least 0.3m • Flood resilient materials and designs • Access to all spaces to permit drying and cleaning
Resistance/Resilience**	Design water depth up to 0.3m	Attempt to keep water out *'Water Exclusion Strategy'*	• Materials and constructions with low permeability
Avoidance		Remove building/development from flood hazard	• Land raising, landscaping, raised thresholds

Notes:
* Design water depth should be based on assessment of all flood types that can impact on the building
** Resistance/resilience measures can be used in conjunction with Avoidance measures to minimise overall flood risk
*** In all cases the 'water exclusion strategy' can be followed for flood water depths up to 0.3m

- In a **water exclusion strategy**, emphasis is placed on ***minimising*** water entry whilst maintaining structural integrity, and on using materials and construction techniques to facilitate drying and cleaning. This strategy is favoured when low flood water depths are involved (up to a possible maximum of 0.6m). According to the definitions adopted in this Guidance, this strategy can be considered as a resistance measure but it is part of the aim to achieve overall building resilience

- In a **water entry strategy**, emphasis is placed on allowing water into the building, facilitating draining and consequent drying. Standard masonry buildings are at significant risk of structural damage if there is a water level difference between outside and inside of about 0.6m or more. This strategy is therefore favoured when high flood water depths are involved (greater than 0.6m).

Advice is provided on the suitability of common building materials, floor and wall constructions and other features and fittings for improving the flood resilience of buildings. The flood resilience characteristics considered are water penetration, drying ability and retention of pre-flood dimensions and integrity.

In all of the above options, build quality and workmanship are crucial to achieving the desired effect.

Purpose of this Document:

This document provides guidance on how flood resistance and resilience measures can be used to reduce flood damage, as part of an integrated portfolio of approaches.

It should be used when the principle of new development has been agreed and demonstrated to the satisfaction of the Planning Authority through application of the Sequential and Exception Tests in PPS25.

About the document

Part 1 introduces the concepts of flooding and resilience, within the UK planning and building regulation systems.

This part of the Guidance is particularly relevant to those with a limited knowledge of flooding and of the regulatory system.

Part 2 deals with the design approaches to managing flood risk.

This part of the Guidance will help designers, planners and building surveyors select appropriate design strategies. This may also be of interest to property insurers.

Part 3 gives guidance on flood resilient design and construction.

This part of the Guidance will be of particular relevance to building surveyors, designers and builders as well as property insurers.

Part 4 contains supporting information.

PART 1			PART 2		PART 3	PART 4	
Chapter 1 Introduction	**Chapter 2** Flooding considerations	**Chapter 3** Planning policy and Building Standards	**Chapter 4** Design Strategies	**Chapter 5** Avoidance and resistance design options	**Chapter 6** Guidance on flood resilient design and construction	**Chapter 7** The evidence base	**Chapter 8** References and sources of information
Why there is need to design for flood resilience How guide fits in with Government policy and existing guidance Scope of the guide What is not covered Intended users How to use the guide	Types and causes of flooding Definition of flood risk Ways to minimise flood risk Entry points of flood water into a building Types of damage caused by flood water	Overview of the planning system in England, Wales, Scotland and Northern Ireland General overview of Building Regulations in England, Wales, Scotland and Northern Ireland Interface between planning processes and Building Control	Description of strategies to manage flood risk Strategies for resilient building construction: 'Water exclusion strategy' 'Water entry strategy' Decision support flowchart for Avoidance, Resistance and Resilience design options	Description of avoidance and resistance measures such as: - site layouts (e.g. location of constructions on high ground) - landscaping - building options (e.g. raising floor levels) - drainage and incorporation of SUDS	Recommendations for specification of resilient building materials Advice and illustrative sketches on resilient design of: - foundations - ground floors - walls - doors and windows - fittings - services	Sources used to produce the guide: - published literature - review of existing practice - experiential information - laboratory test procedures and sample results	Key references and sources of information for resilient construction and planning

Glossary

Flood avoidance (at site level)	Constructing a building and its surrounds in such a way to avoid it being flooded (e.g. by raising it above flood level, re-siting outside flood risk area etc.)
Flood resistance	Constructing a building in such a way to prevent floodwater entering the building and damaging its fabric.
Flood resilience	Constructing a building in such a way that although flood water may enter the building its impact is minimised (i.e. no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated).
Flood repairable	Constructing the building in such a way that although flood water enters a building, elements that are damaged by flood water can be easily repaired or replaced. This is a form of flood resilience (see definition above).

The concepts of dry proofing and wet proofing (used widely in the USA) have been superseded in the UK by the above definitions

AD	Approved Document of the Building Regulations
ADC	Approved Document C of the Building Regulations
Damp proof course (d.p.c.)	Layer or coating of material placed in a wall to resist the passage of moisture from the ground.
Damp proof membrane (d.p.m.)	Layer or sheet of material placed beneath or within a floor to prevent passage of moisture. To be fully effective it should be lapped to the d.p.c. in the surrounding walls.
Differential head (dH)	Difference between water level outside and inside the building.
Exception test	The mechanism in PPS 25 which makes provision for the negative implications of developing in a flood risk area to be balanced against potential positive contributions to sustainable development that new development can bring. The exception test should be used only after the sequential approach has been applied and should not be used as a means of supporting inappropriate development.
Floodplain	Area of land that borders a watercourse, an estuary or the sea, over which water flows in time of flood, or would flow but for the presence of flood defences where they exist.

Flood risk	A combination of the probability and consequences of a flood event
Flood Risk Area	Any area liable to flood from any form of flooding
Flood Risk Assessment	A study to assess the risk to an area or site from flooding, now and in the future, and to assess the impact that any changes or development on the site or area will have on flood risk to the site and elsewhere. It may also identify, particularly at more local levels, how to manage those changes to ensure that flood risk is not increased. PPS25 differentiates between regional, sub-regional/strategic and site-specific flood risk assessments.
Freeboard	The difference between the flood defence level and the design flood level
Frogged brick	Brick with one or more indentations on the bed face, resulting from the pressing process.
Local flood defence	Infrastructure (e.g. earth bund) located close to the building which is intended to resist the passage of flood water and reduce the flood level adjacent to the building.
Perpends	Vertical cross joint in stone or brickwork.
Predicted flood level	Flood level estimated for a given frequency of occurrence.
PPS 25	Planning Policy Statement 25: Development and Flood Risk sets out the Government's policies on land use planning for development and flood risk
Residual flooding	This is the type of flooding that occurs when the existing flood management measures are exceeded or fail (e.g. breaching of defences or sewer surcharging).
Residual risk	The risk that remains after all risk avoidance, reduction and mitigation measures have been implemented, or where such measures fail.
Sacrificial materials	Materials used in house fittings that are likely to be damaged in case of flooding but can be easily replaced.
Sequential approach	The decision-making tool in PPS25 to ensure that sites at little or no risk of flooding are developed in preference to areas at higher risk
Sequential test	The application of the sequential approach by Local Planning Authorities in determining land uses that are compatible with the level of flood risk at each allocated development site within a Local Authority area.

SUDS	Sustainable Drainage Systems. A sequence of management practices and control structures used to attenuate run-off from development sites and to treat runoff to remove pollutants, thus reducing the negative impact on receiving water bodies
Tanking	Variety of methods used to prevent the infiltration of sub-surface water into a building, namely basements and walls and floors close to the water table.
TAN 15 Wales	Technical Advice Note 15: Development and Flood Risk (Wales) outlines the Welsh Assembly Government's policies for development in flood risk areas.
Water absorption	Ability of a material to incorporate water within its pore structure; it is usually defined as a percentage of weight.
Water penetration	Ability of a material/composite to allow passage of water through its body.
Water entry strategy	A design strategy based on allowing water to come inside a property rather than preventing its ingress.
Water exclusion strategy	A design strategy based on the use of impermeable materials/composite construction that will minimise the ingress of water into a property.

PART 1 – BACKGROUND

1 Introduction

1.1 Why design for flood resilience?

The Government's UK Climate Impacts Programme (UKCIP) and other research programmes have found that rising global temperatures are causing rainfall patterns to change. It is generally recognised that winters are becoming progressively wetter and warmer and summers drier. Research carried out as part of the Foresight Programme (DTI, 2004) has shown that climate change will play a major role in increasing the risk of flooding in the future. For example, short intense rain storms are becoming more frequent, often causing severe local flooding, particularly in urban areas with high-density development and under-capacity of drainage. Experiences of flooding in Carlisle in January 2005 show that the time to re-occupy properties is a principal consequence of flooding which can have a profound impact on the health and livelihoods of those affected.

Where application of the sequential approach in PPS 25 (or equivalent legislation in other parts of the UK) has shown that development is necessary in flood risk areas, new development on land that is at risk of flooding can sometimes be protected by flood defences. However, this may not be possible for technical or environmental reasons, or because they may increase flooding elsewhere. Where defences do exist there is always a possibility that they will fail or be overtopped by severe floods (referred to as *residual risk*). Whilst Government policies in no way advocate building of dwellings in flood risk areas, increased demand for housing and limited available space means that in future it may be inevitable that some properties will be built on sites where the residual risk is greater than elsewhere. It is therefore important that these buildings are designed to be more resistant or resilient to flooding to take account of residual risk.

Avoidance in the context of PPS25 means the allocation of development to areas of least flood risk and to apportion development types vulnerable to the impacts of flooding to areas of least risk. This document defines ***avoidance*** as measures that can be taken to prevent floodwater from reaching a property. For example, these can take the form of low defence mounds or barriers surrounding a development or individual property, or landscaping the ground surrounding a building to divert floodwaters away or into temporary storage. ***Resistance*** is defined here as measures taken at building level to prevent floodwater entering the building and damaging its fabric. For example, these measures can include the use of materials with low permeability.

Resilience is defined as sustainable measures that can be incorporated into the building fabric, fixtures and fittings to reduce the impact of floodwater on the property. This allows easier drying and cleaning, ensures that the structural integrity of the building is not compromised and reduces the amount of time until the building can be re-occupied.

Flood repairability involves the design and construction of building elements, to ensure the ease of replacement and repair, should they suffer flood damage.

1.2 Is flood resilience covered in Government policy?

The Department for Environment, Food and Rural Affairs (Defra) has overall policy responsibility for flood and coastal erosion risk management in England. Government strategy for flood and coastal erosion risk management in England, ‘Making Space for Water’ (Defra, 2005), aims to manage flood risk by a number of approaches based on national and local priorities. The overall aim is to manage the risks from flooding and coastal erosion by employing an integrated portfolio of approaches which reflect both national and local priorities, so as:

- to reduce the threat to people and their property; and
- to deliver the greatest environmental, social and economic benefit, consistent with the Government's sustainable development principles.

The strategy promotes sustainable and appropriate development and, where necessary, recommends constructing buildings, with appropriate flood resistant and resilient measures in areas that have a residual risk of flooding. It is not possible to defend and protect everywhere and people and property will still be at risk from severe, exceptional floods that are beyond the design standards of flood defences. It is clear, however, that the use of resilience should not be a means for by-passing the necessary planning requirements

In England, the Department for Communities and Local Government Planning Policy Statement PPS25 on Development and Flood Risk (2006) stipulates that flood risk is taken account at all stages in the planning process to avoid inappropriate development in areas of risk of flooding, and to direct development away from areas at highest risk. PPS25 (Annex D) also matches the types of development and their vulnerability to the probability of flood risk (this is called ‘the sequential approach’). For example, a nursing home should not be built in an area that will flood quickly, if it is not possible to efficiently evacuate residents, putting their lives at risk. However, constructing a cricket pavilion in that location may be acceptable because the risk to life would be much lower. Building in a high flood risk area would not be allowed. This ‘sequential’ approach allows for resistant and resilient techniques to be considered in areas with residual or low risk of flooding or where these cannot be protected by traditional defences. Departures from the sequential approach (the ‘Exception Test’) are only justified in circumstances where it is necessary to meet the wider aims of sustainable development. The development must be safe, without increasing flood risk elsewhere, and where possible reduce the flood risk overall.

In Wales, the Welsh Assembly Government has the overall policy responsibility for flood and coastal defence matters, and planning and development control. In July 2004 the Welsh Assembly Government issued ‘Technical Advice Note (TAN15) Development and Flood Risk’(Welsh Assembly Government web portal) which provides guidance on development in flood risk areas, and which should be read in conjunction with Planning Policy Companion Guide Wales 2006 (Welsh Assembly Government web portal). The aim of Planning Policy Wales (PPW) and TAN15 is to advise caution in respect of new development in areas at high risk of flooding by setting out a precautionary framework. New development should be directed away from areas designated as having the highest probability of flooding, with development only being permitted if determined by the planning authority to be justified in that area. Criteria for this justification include consideration of the consequences of a flooding event being deemed acceptable. In assessing the consequences, the use of resistance and resilience mitigation measures will be required as part of ensuring that the consequences are acceptable. The Environment Strategy sets out the Welsh Assembly Government's proposals for the move to flood risk management in Wales and the associated action plan identifies actions which will be undertaken to deliver this approach. Work is also being undertaken as part of the Environment Strategy action plan in Wales to refresh existing policy for flood risk management. This work includes identification and implementation of a series of measures for the management of flood risk, including resilience.

Scottish Planning Policy 7 (SPP 7) provides Scottish Executive policy on planning and policy issues and sets out its National Flooding Framework (The Scottish Executive web site). The Water Environment and Water Services (Scotland) Act 2003 has a requirement to promote a sustainable flood management approach.

Planning Policy in Northern Ireland is the responsibility of the Planning Service, an Agency within the Department of the Environment (NI). Planning policy on flood risk is expressed in Planning Policy Statement 15 (Planning and Flood Risk) and is predicated on the principle of avoiding development within river and coastal floodplains unless a proposal falls within certain expressly defined exceptions (Department of the Environment Northern Ireland web site). PPS15 does not currently include specific guidance on flood resilience.

Currently, the Building Regulations, common to both England and Wales, and the separate regulations covering NI, do not specifically cover flood risk management or flood protection issues, although Planning and Building Standards Advice on Flooding, Planning Advice Note (PAN) 69 (The Scottish Executive web site), includes guidance on water-resistant materials and forms of construction appropriate to Scotland.

Planning policy and Building Regulations are covered in more detail in Chapter 3.

> **About the Building Regulations**
>
> The principal purpose of Building Regulations (see Section 3.2 below) is to protect the health and safety of building occupants, with secondary considerations including sustainability and comfort. The Regulations do this by making Requirements and supporting these with Approved Documents that provide guidance on how to fulfil the requirements; other ways of meeting the requirements are also acceptable.

1.3 Why is resilience guidance required?

The Building Regulations and Approved Documents (covering England and Wales) do not currently advise on flood protection measures for buildings (The Building Regulations 2000). There is, however, existing guidance from the Government, construction management research bodies, and the insurance industry on post-flood repairs, which will help to improve the flood resilience of buildings. Apart from Scotland, there is currently no specific guidance on construction methods or details for new buildings to improve flood resistance or resilience. Therefore, one of the key aims of this document is to bring planning considerations and the Building Regulations together, where these relate to flood management through building resilience.

1.4 What is the aim of this guidance?

The aim of this document is to provide guidance to developers and designers on how to improve the resilience of new properties in **low or residual flood risk areas** by the use of suitable materials and construction details. These approaches are appropriate for areas where the probability of flooding is low (flood zone 1, PPS 25) or areas where new flood risk management or mitigation have been put in place. The guidance will also be useful to planners, building control officers and loss adjusters.

Specifically this guidance document aims to:

- provide practical and easy-to-use guidance on the design and specification of new buildings (primarily housing) in low or residual flood risk areas in order to reduce the impacts of flooding
- provide recommendations for the construction of flood resistant and resilient buildings.

This document does not endorse or facilitate development in areas of high flood risk.

1.5 Development of the guidance

Since 2003 there have been several initiatives, led by the European Commission (EC), the UK Government and the insurance industry to encourage the use of flood resilient measures, as a means to reduce the health risks and cost implications to people from further floods. For example, the document 'Preparing for Floods' (ODPM, 2003) provides some practical measures to minimise damage to buildings caused by floodwater. There is also recent good guidance on how to repair and refurbish properties that have been flooded (CIRIA, 2005a; BSI, 2005; Flood Repairs Forum, 2006). However:

- the majority of effort and interest is currently concerned with the retrofit of resilient measures for existing properties
- there has been limited research on deriving resilience standards for new build
- there have been several publications that provide guidance on resilience measures, since 'Preparing for Floods' in 2003, but the evidence is of a very similar nature and represents expert opinion and common sense; little being based on hard technical and physical evidence

- much of the existing advice relates to the fixtures and fittings, and post-flood repairs which are outside the scope of the Building Regulations (e.g. raising electric points, fitting check valves on service ducts, raising appliances and units above flood level, using plastic/ceramic/stainless steel fittings).

The advice given in this guidance is based on new laboratory testing, technical evidence, industry experience and literature review. The literature review and technical evidence showed that much of the information on resistant and resilient construction is unsupported with hard technical evidence but is based mainly on opinion and experience gained in the repair of existing buildings which have been flooded. Recent laboratory tests (see Chapter 7), undertaken specifically for the preparation of this guidance, provided new and valuable evidence on the behaviour of common building materials and techniques under flood conditions.

This guidance has been developed specifically for the design and construction of new buildings and extensions covered by the Building Regulations in England and Wales; however it may also be useful for advice on the refurbishment and repair of existing buildings.

1.6 Limitations of the guidance

This guidance does <u>not</u> cover the following aspects of resilient design and construction:

- structural damage from high velocity flow or debris impact
- effect of ageing of materials with time
- costs for materials and construction
- impact of changes in ambient conditions (e.g. freeze/thaw)
- effect of contamination within the flood water (e.g. silt, salt, sewage and pesticides)
- cleanability of materials and finishes
- moisture-induced growths (e.g. toxic mould)
- sewer flooding impacts in detail
- flooding from internal sources (e.g. burst water tank or boiler), although the recommendations in this guidance would reduce the impacts from such flooding
- problems caused by inadequate or defective roof drainage
- water-tight construction or modern methods of construction (including off site construction)

- interference and alterations by the occupier that might affect the building envelope
- detailed consideration of resilient internal fixtures and fittings.

1.7 How to use this guidance

Figure 1.1 helps navigation through the various parts of this document.

Part 1 introduces the concepts of flooding and resilience, within the UK planning and building regulation systems.

Specifically, Chapters 1 and 2 (Introduction and Flooding Considerations) provide a general introduction and some background information on flooding and flood risk.

Chapter 3 (Planning Policy and Building Standards) provides information on the planning and building control processes and explains where resilience measures are appropriate.

This part of the Guidance is particularly relevant to those with a limited knowledge of flooding and of the regulatory system.

Part 2 deals with the design approaches to managing flood risk.

Chapter 4 (Design Strategies) identifies different approaches to minimise the impact of floods on buildings and the occupants.

Chapter 5 (Avoidance and Resistance Options) provides information on design options aimed at keeping water away from buildings.

This part of the Guidance will help designers, planners and building surveyors select appropriate design strategies. This may also be of interest to property insurers.

Part 3 gives guidance on flood resilient design and construction.

Chapter 6 (Guidance on Flood Resilient Design and Construction) provides technical guidance on the forms of resilient construction that are most appropriate for developments at risk from flooding.

This part of the Guidance will be of particular relevance to building surveyors, designers and builders as well as property insurers.

Part 4 contains supporting information.

Chapter 7 (The Evidence Base) gives a brief summary of the data and information upon which this guidance is founded.

Chapter 8 (References and Contacts) provides useful background information and references.

Figure 1.1 Navigation guide for Guidance Document

PART 1			PART 2		PART 3	PART 4	
Chapter 1 Introduction	**Chapter 2** Flooding considerations	**Chapter 3** Planning policy and Building Standards	**Chapter 4** Design Strategies	**Chapter 5** Avoidance and resistance design options	**Chapter 6** Guidance on flood resilient design and construction	**Chapter 7** The evidence base	**Chapter 8** References and sources of information
Why there is need to design for flood resilience How guide fits in with Government policy and existing guidance Scope of the guide What is not covered Intended users How to use the guide	Types and causes of flooding Definition of flood risk Ways to minimise flood risk Entry points of flood water into a building Types of damage caused by flood water	Overview of the planning system in England, Wales, Scotland and Northern Ireland General overview of Building Regulations in England, Wales, Scotland and Northern Ireland Interface between planning processes and Building Control	Description of strategies to manage flood risk Strategies for resilient building construction: 'Water exclusion strategy' 'Water entry strategy' Decision support flowchart for Avoidance, Resistance and Resilience design options	Description of avoidance and resistance measures such as: - site layouts (e.g. location of constructions on high ground) - landscaping - building options (e.g. raising floor levels) - drainage and incorporation of SUDS	Recommenda-tions for specification of resilient building materials Advice and illustrative sketches on resilient design of: - foundations - ground floors - walls - doors and windows - fittings - services	Sources used to produce the guide: - published literature - review of existing practice - experiential information - laboratory test procedures and sample results	Key references and sources of information for resilient construction and planning

2 Flooding considerations

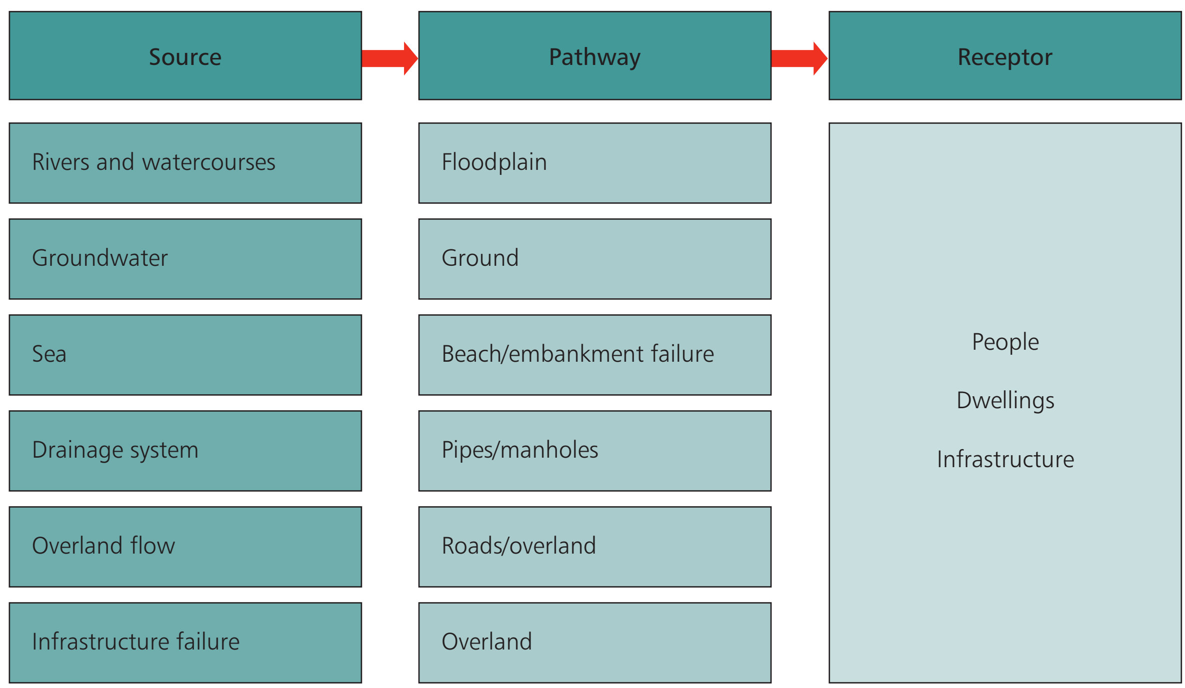
2.1 What are the causes of flooding?

The rationale behind flood risk management in the UK is based on the principle of source-pathway-receptor, as shown in Figure 2.1. This is a departure from previous approaches, in that more emphasis is given to addressing the impacts or consequences experienced by the receptors (people, buildings and infrastructure), rather than simply the actual hazard posed by a severe flood. Avoidance and resistance measures, such as permanent or temporary defences or landscaping, may be used along the 'pathway' to prevent floodwaters reaching a property. Resistance and resilience measures may be used at the 'receptor' stage, on or within a property, which addresses both the probability and consequence of flooding.

Although flooding can result from a single event, it more commonly occurs through a combination of events:

- rainfall fills rivers, streams and ditches beyond their capacity. Floodwater overflows river banks and flood defences
- coastal storms can lead to overtopping and breaching of coastal flood defences. Properties built behind these defences are therefore still at risk from flooding, although the 'residual' risk is lower. However, the consequences of this type of flood could be high.

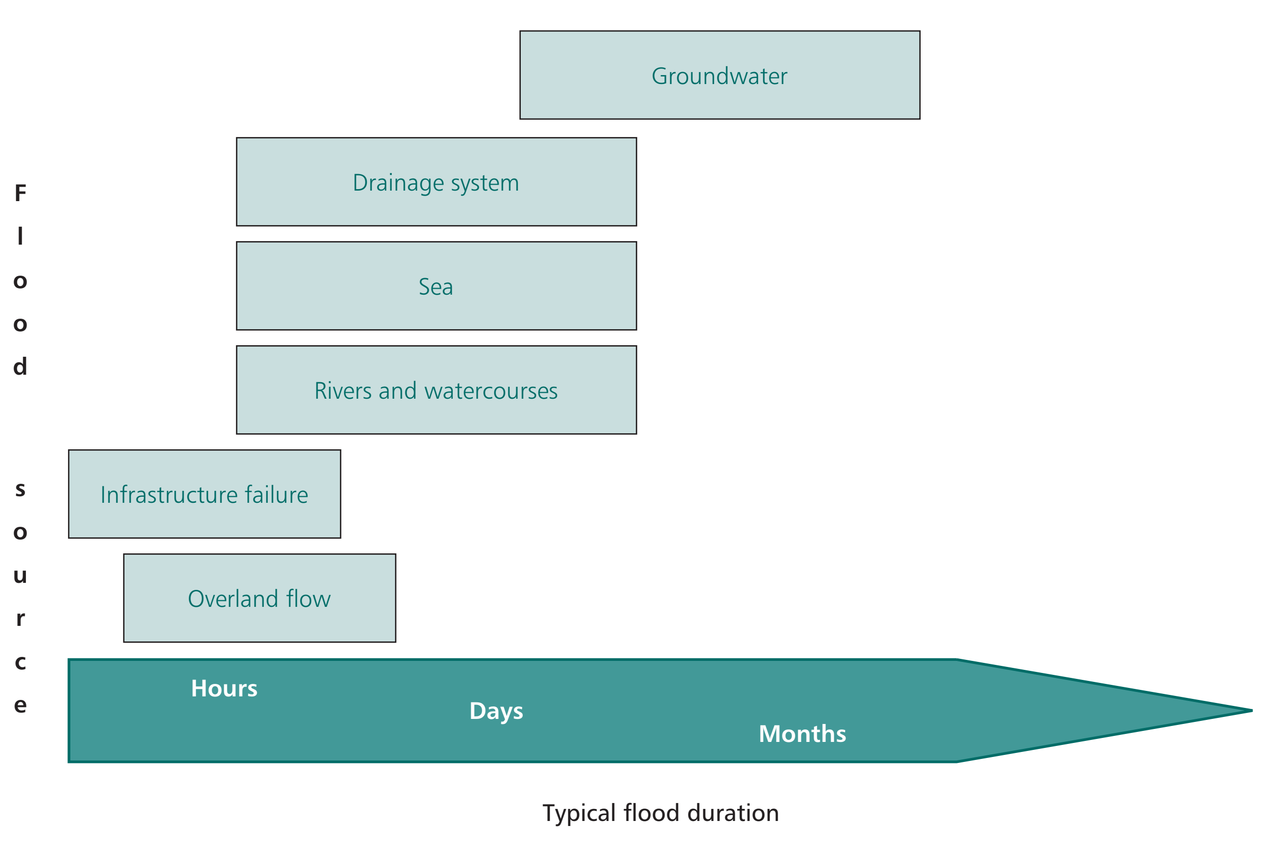
Figure 2.1 **Flood risk management – the concept of source-pathway-receptor**



- blocked or overloaded drainage ditches, drains and sewers may overflow across roads, gardens and into property
- overloaded sewers can sometimes back up into properties when they become blocked or too full
- rainfall can be so intense that it is unable to soak into the ground or enter drainage systems. Instead the water flows overland, down hills and slopes. Property at the bottom of hills or in low spots may be vulnerable. In urban areas floodwater may become contaminated with domestic sewage
- prolonged, heavy rainfall soaks into the ground and can cause the ground to saturate. This results in rising groundwater levels which leads to flooding above the ground. Floodwater may enter properties through basements or at ground floor level. Groundwater flooding may take weeks or months to dissipate
- a reservoir or canal may cause flooding either from overtopping or bank failure. This type of flooding (infrastructure failure) can result in rapidly flowing, deep water that can cause significant damage or loss of life.

Figure 2.2 provides typical durations for different types of flood. This is the length of time that the impact would be experienced by any receptors.

Figure 2.2 **Typical flood durations**



2.2 What is flood risk management?

All floods can be assessed in terms of flood depth, speed of flow, frequency of occurrence and duration (however, not all of these data are always readily available). This information can then be used to evaluate the flood risk to people and property at a particular location. Flood risk is a combination of the probability of the flood occurring and the consequence of the flood on people, property and infrastructure. A site specific Flood Risk Assessment (FRA) is required to support a planning application for sites larger than 1 ha in Flood Zone 1, and all proposals for new development in Flood Zones 2 and 3 in England. (In Wales, the requirements for a flood consequence assessment, FCA, will be determined as set out in TAN15).

Knowing the characteristics of a particular flood is essential when designing a building to be resilient or resistant to flooding as it enables selection of the most appropriate form of mitigation measures. For example, groundwater flooding can be prolonged, and therefore appropriate basement (e.g. CIRIA, 1995) and floor construction design is critical. Living accommodation below ground level is not recommended for new build in flood risk areas.

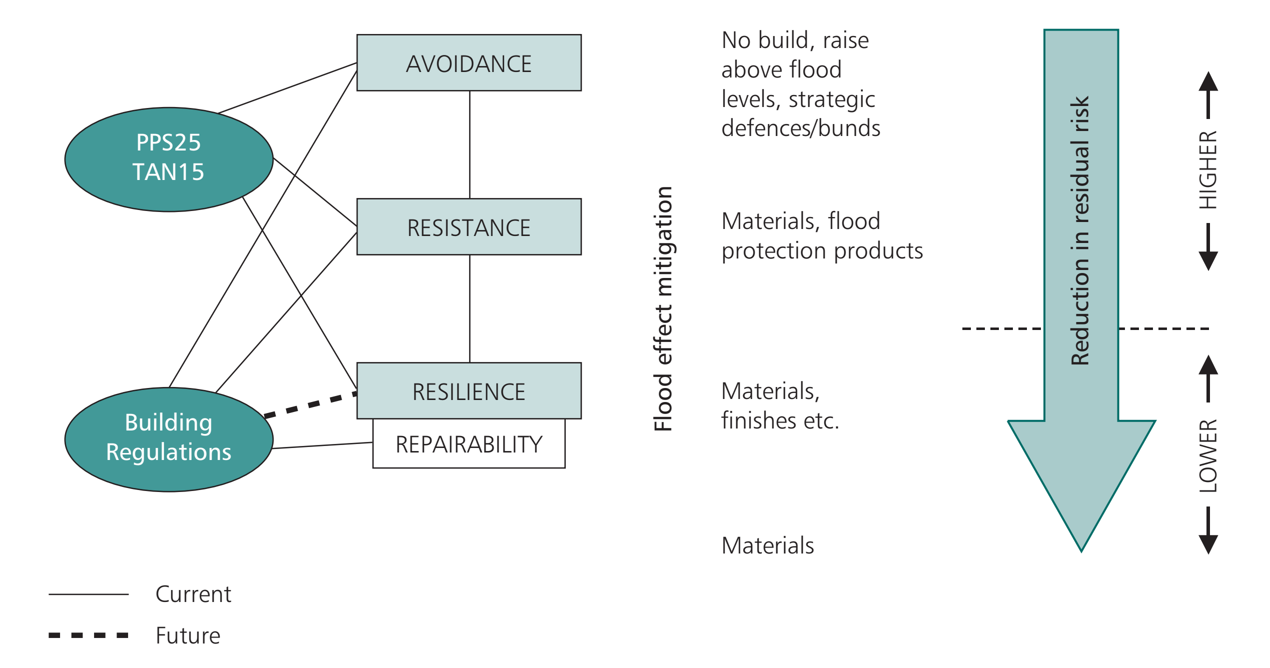
When determining the flood risk at a site, as required by PPS 25 and other UK planning requirements, it is important to:

- evaluate the possible source and frequency of flooding and the flood pathways
- estimate the depth, velocity and duration of flooding
- avoid adding to the source, cause or impact of flooding with inappropriate development
- ensure the development maximises the use of on-site storage/attenuation to minimise the effect on developments downstream; and
- design the building to reduce the consequences of flooding on people and property.
- reduce the flood risk overall

The above information forms part of a site-specific FRA. Advice on the preparation of these can be found in the Practice Guide Companion to PPS25 (Communities and Local Government, 2007).

It is possible to reduce the consequences of flooding to people and property by ***managing*** the flood risk. Flood risk should be managed in a hierarchical approach, by firstly considering developing outside flood risk areas (avoidance), secondly the use of resistance measures to prevent water from entering a building, through to use of resilient measures to reduce the impact of flood damage to a building. Figure 2.3 broadly illustrates the options to deal with different levels of risk to people and property, and where policy and guidance documents apply.

Figure 2.3 **Flood risk management hierarchy**



The best approach to flood risk management is ***avoidance***. Ideally this would mean building outside of areas known to flood (or likely to flood). If this is not possible it can be achieved by, building above the flood level or preventing floodwater from reaching a building by site layout.

There can be local permanent ***resistance*** measures such as low walls or mounds around development sites, contouring of the site to divert floodwater away from buildings, or sealed gates. These measures are often associated with pumps to deal with rainwater and any small amounts of water that manage to circumvent the defences. Flood barriers must be designed to withstand different water pressures, depending on the predicted depth of floodwater, and potential damage caused by floating debris.

Temporary building-level flood defence measures, such as installing flood boards on doorways or covers on service ducts, which can increase the flood resistance of a building, are however not a good solution for new buildings. It is preferable to design-in permanent flood resistance measures (such as low bunds around the development or building curtilage) than to rely on temporary solutions that require action by occupants to install, store and maintain them.

It is always preferable to keep floodwater out of buildings but it is not always possible. Water can enter through the junctions of components of construction materials, as well as cracks and joints, and service ducts. Even then, if the water depth is higher on the outside than on the inside of a masonry building (and possibly other types) by about 0.6m there is the possibility that water pressure will cause the structure to collapse (USACE, 1988). The difference in level is called 'differential head, dH'. Figures 2.4 and 2.5 illustrate these concepts.

Figure 2.4 **Definitions of flood depths**

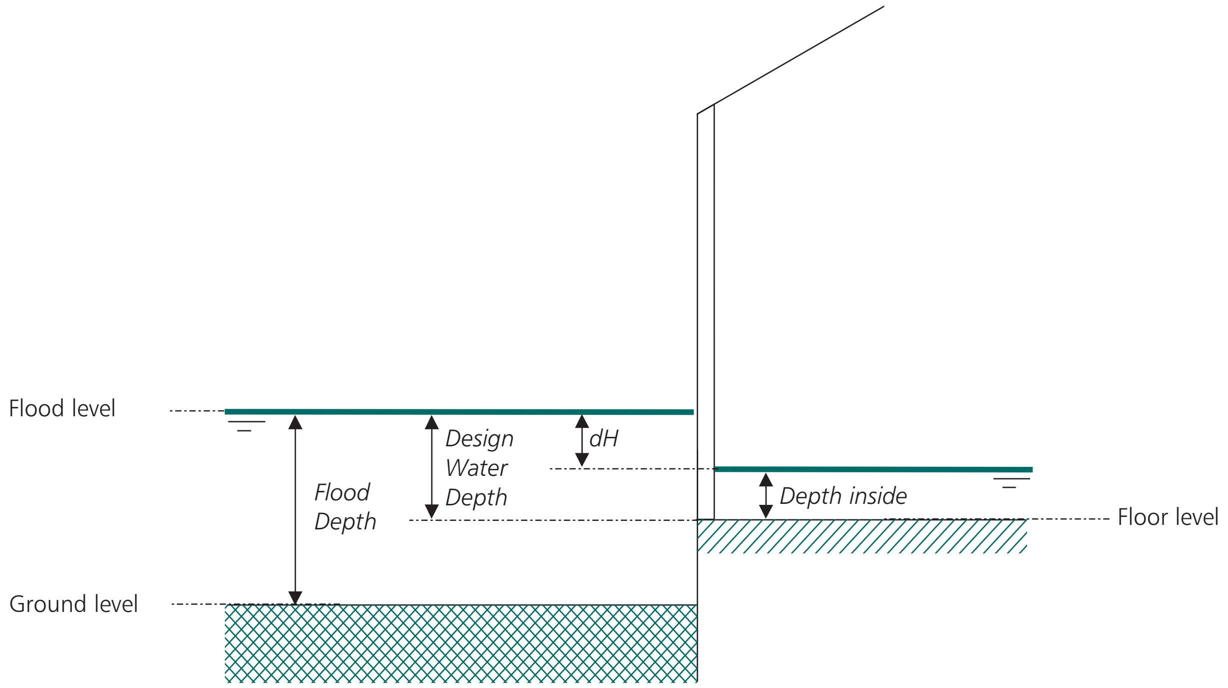
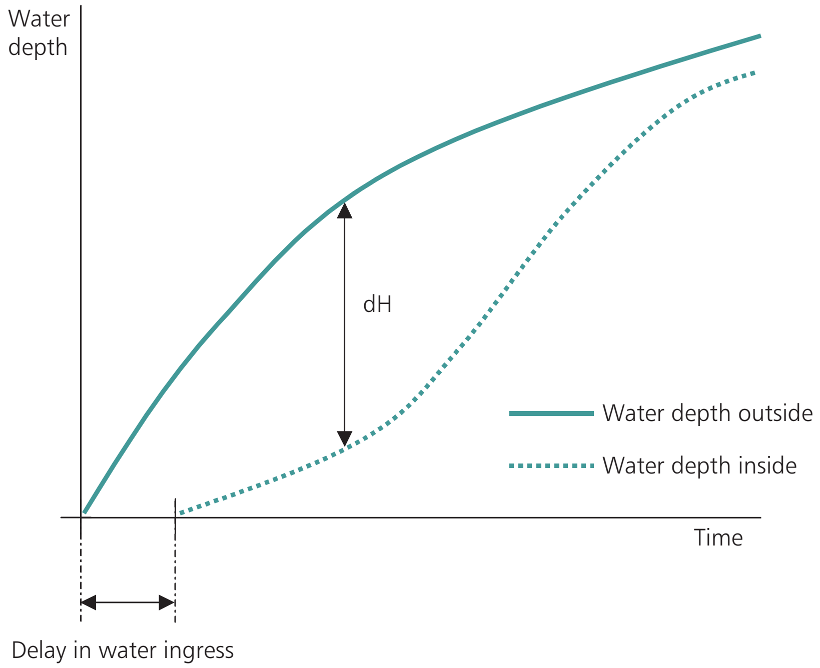


Figure 2.5 **Conceptual illustration of flood water depths outside and inside a building**



It is possible, using ***resilience*** measures as integral components of the building and/or inside the building, to reduce the risk of flood damage by careful selection of building materials, construction techniques and internal finishes. The use of appropriate resilience measures can also speed up recovery and repairs. This can only be achieved with careful design and good quality workmanship. Re-occupation of the building can then take place more quickly after a flood because less time, effort and cost will be required to repair the damage.

Resilience measures on their own are not suitable for areas with potential combined risk of high flood discharge rates, rapid rising levels and/or where speed of flow is likely to be high and dangerous to the stability of buildings and the safety of people. Speed of flow is one of the characteristics that should be considered in the preparation of the FRA.

Another aspect of flood risk management is the provision of ***flood warnings***. Designs for effective flood warning systems should also be included in the FRA, to allow occupiers sufficient time to remove or relocate valuables and evacuate. In many areas where properties are at risk from flooding, the Environment Agency provides a flood warning service. This works by using an automated message service to contact all people on the local flood-warning list by telephone, SMS message or fax to warn them of an impending flood.

Where the Environment Agency does not provide flood warning, or to provide additional security to the property owner, commercial flood warning devices can be purchased to indicate imminent or record past flood events. These systems must be calibrated to give occupants sufficient time to evacuate the premises and remove or relocate valuables.

Flood risk to people and property can be managed and reduced but it can never be completely removed (Defra, 2005). There will always be a *residual risk* even after flood management schemes or measures to reduce flooding have been put in place and even in apparently safe sites, for example behind flood defences.

Residual flood risk can be due to:

- failure of flood management infrastructure such as a breach of a raised flood defence, blockage of a surface water sewer or failure of a pumped drainage system
- a severe flood which causes a flood defence to be overtopped
- floods outside the known flood risk areas.

2.3 How does floodwater enter a building?

Floodwater will always follow a path of least resistance and will enter a building at the weakest points in the construction, particularly through masonry and construction joints, and any voids and gaps. The following summarises the main entry points.

Current building regulations and traditional construction do not require the use of materials and design details that can withstand long-term immersion in flood water. Water could enter via:

- brickwork and blockwork
- party walls of terraced or semi-detached buildings if the attached building is flooded
- expansion joints between walls where different construction materials meet or between the floor slab and wall
- suspended timber ground floors via the interface between timber and mortar for built-in joists or along the interface between timber and metal plate where a joist hanger is used. Water will be absorbed through the exposed end grain of a built-in timber joist.

Specific features encourage air flow and therefore may provide a pathway for water. Routes include:

- vents, airbricks
- inadequate seals between windows, doors and frames
- door thresholds

Cracks and openings due to settlement, poor construction, and services all provide water entry routes, such as:

- cracks in external walls
- flaws in wall construction
- cracks and gaps at the interface between brick, stone and block units and their bedding mortar due to inadequate bonding. These can be as a result of movement caused by thermal expansion/contraction, moisture or settlement
- damp proof course (d.p.c.), where the lap between the wall damp proof course and floor membrane is inadequate
- services entries e.g. utility pipes, ventilation ducts, electricity and telephone cables
- gaps in mortar in masonry, stonework and blockwork walls, usually at perpends.

Other entry routes include:

- seepage from below ground through floors and basements
- sanitary appliances from backflow from surcharged drainage systems.

Figure 2.6 Potential Routes for Entry of Flood Water into a Dwelling (courtesy of CIRIA, after CIRIA 2003)

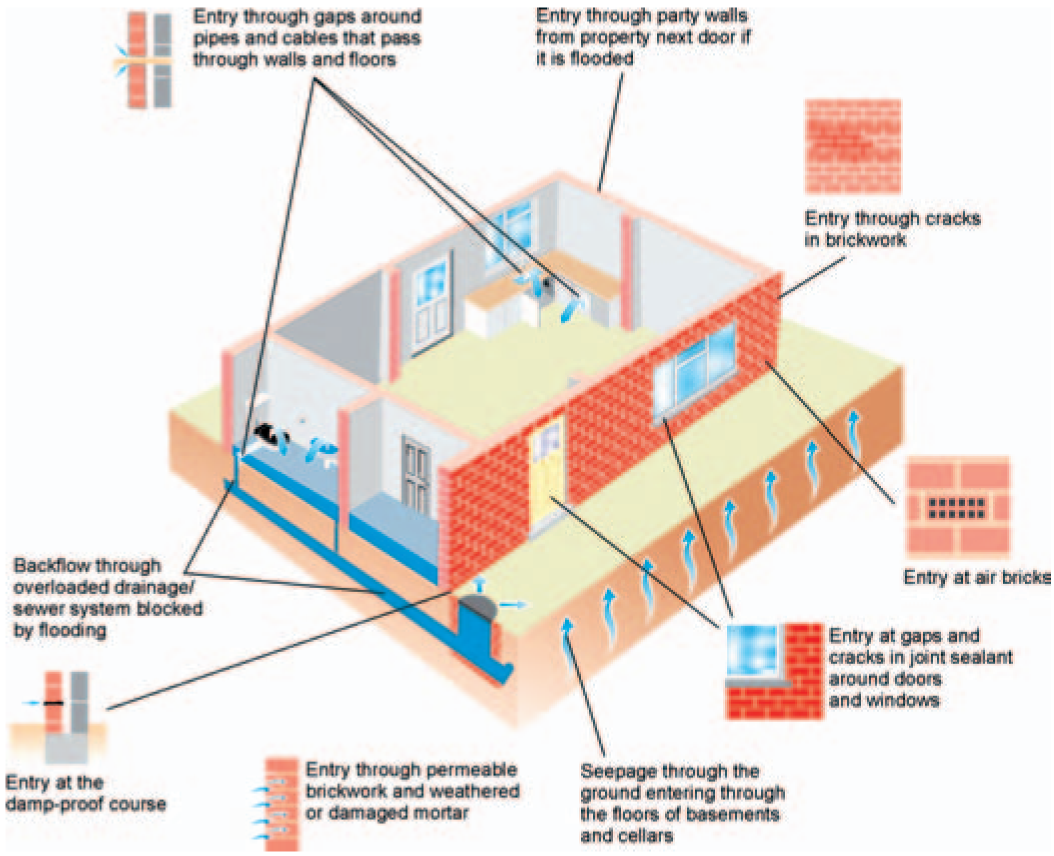


Figure 2.6 shows where floodwater can potentially enter a building.

2.4 What damage can a flood cause?

As well as having the potential to cause damage to the structure of a building, floodwater can also significantly impact the lives of the occupants. Fast flowing water or weakened structures could cause injury or even death. Physical health may suffer if floodwater is contaminated or if the building is re-occupied before it is allowed to dry effectively. Stress caused by the disruption to lifestyle and livelihood both during and after a flood is probably one of the main consequences of a flood.

This guidance does not cover the requirements for protection against structural damage caused by the weight and uplift forces due to the floodwater, nor impacts from water-borne debris. However a summary of the likely damage to property caused by floodwater at different depths and heights is provided in Table 2.7 for information. It is important that a structural assessment of the risks posed by flood water is considered by an experienced professional during the building design phase.

Table 2.7 **Possible flood damage for a typical residential property**

Depth of floodwater	Damage to the building	Damage to services and fittings
Below ground floor level	Possible erosion beneath foundations, causing instability and settlement Possible corrosion in metal components (e.g. joist hangers) Excessive moisture absorption in timber, causing warping Cracking of ground floor due to uplift pressures Accumulation of contaminated silt Structural and material weaknesses from inappropriate drying Rot and mould	Damage to electrical sockets and other services in basements and cellars. Damage to fittings in basements and cellars
Ground level to half a metre above floor level	Build-up of water and silt in cavity walls, with potential reduction in insulating properties, for some materials Immersed floor insulation may tend to float and cause screeds to debond Damage to internal finishes, such as wall coverings and plaster linings Floors and walls may be affected to varying degrees (e.g. swelling) and may require cleaning and drying out Timber-based materials likely to require replacement Damage to internal and external doors and skirting boards Corrosion of metal fixings Rot and mould	Damage to water, electricity and gas meters Damage to low-level boilers and some underfloor heating systems Damage to communication wiring and services Carpets and floor coverings may need to be replaced Timber-based kitchen units are likely to require replacement Electrical appliances may need to be replaced Insulation on pipework may need replacing
Half a metre and above	Increased damage to walls (as above) Differential heads of greater than 0.6m across walls could cause structural damage, although this will vary depending on the structure of the building. Damage to windows can be caused by much smaller differential pressures High speed flow around the building perimeter can lead to erosion of the ground surface; there is also the potential risk of damage to the structure from large items of floating debris, e.g. tree trunks	Damage to higher units, electrical services and appliances

2.5 The effects of contaminated floodwater on buildings

Most floodwaters carry contaminants, such as sewage, hydrocarbons, silt, salt and other biological and chemical substances, which can affect the health of the occupants and the performance of the building. Buildings may require further cleaning or extended drying times following a flood leading to increased costs and delays in re-occupation.

There is very little evidence of buildings being designed to deal with contaminated floodwater. However, an effective way of dealing with contamination is to use materials that minimise adsorption, ensure effective drying can be achieved (by providing access to all spaces to permit drying), and ensure units/fittings etc. can be easily cleaned.

This document does **not** advise on designs dealing with the particular characteristics of contaminated floodwaters, however good guidance on controlling and removing specific contaminants after a flood is readily available, e.g.

- 'Repairing flooded buildings' (Floods Repair Forum, 2006),
- 'Standards for the repair of buildings following floods' (CIRIA, 2005a),
- PAS 64 (a restoration code of practice) (BSI, 2005),
- BRE Good Repair Guides (BRE, 1997).

3 Planning policy and building standards

3.1 Overview of the planning system

England

The Government has revised and strengthened Planning Policy Guidance (PPG) 25 (DTLR, 2001), their planning policy on development and flood risk, as part of their approach to managing future flood and coastal erosion risks. This is now known as Planning Policy Statement 25 (PPS25) Development and Flood Risk, which applies to land use planning in England (Communities and Local Government, 2006).

The key planning objectives of PPS25 are to deliver sustainable development by:

- ensuring that flood risk is taken into account at all stages of the planning process
- providing a more strategic approach to managing flood risk, ensuring that this is considered as early as possible in the planning process
- clarifying the types of development that can be built in areas with a range of flood risks, and avoiding inappropriate development
- strengthen guidance on the need to include Flood Risk Assessments (FRA) at all levels of the planning process
- provide opportunities to reduce flood risk to communities by re-creating and safeguarding the flood plain
- promote more 'green space' and sustainable drainage systems within urban areas
- ensuring that new development takes climate change into account and does not increase flooding elsewhere.

An important section of PPS25 is the production of a site specific Flood Risk Assessment, which must accompany all planning applications, except for sites less than 1ha and not known to be in an area of flood risk. In addition to identifying the flood risk at the site and ensuring that flood risk is not increased for others, the FRA will consider ways to reduce the residual flood risk which can include, amongst other elements, incorporating resilience measures in the building design. A key role of the planning system is to ensure that flood risk is taken into account, and to regulate any measures taken to reduce the flood risk or residual risk. Through this 'sequential approach' avoidance, resistant and resilient techniques should be considered in certain areas with residual or low risk of flooding or which cannot be protected by traditional defences. However there can be justification for departures from the sequential approach (the 'Exception Test') where it is necessary to meet the wider aims of sustainable development.

The Government's flood risk management strategy for England is 'Making Space for Water' (Defra, 2005). Part of the strategy is considering resilience and resistance measures for both new and existing build, including in some circumstances for those properties that may not benefit from community schemes, and how uptake can be encouraged more generally, where appropriate.

Wales

Planning Policy Wales 2002 (PPW) provides the overarching policy guidance for development in Wales. TAN15 should be read in conjunction with the policies set out in PPW.

The general approach of PPW, supported by the TAN15, is to advise caution in respect of new development in areas at high risk of flooding, by setting out a precautionary framework to guide planning decisions. The overarching aim of the framework is, in order of preference, to:

- direct new development away for those areas which are at high risk of flooding
- to locate development in high risk areas (Zone C), only for those developments which can be justified on the basis of the tests outlined in Section 6 and 7 and Appendix 1 of TAN15.

Whilst the overall principles are similar to those in England and PPS 25, there are some specific detailed differences between the two planning approaches. For example, planning policy in Wales requires that development in flood risk area zone C should be constructed with floor levels above the 1% probability flood level (100 year event) and be designed to have no more than 600mm of flood water at the 0.1% flood level (1000 year event).

Scotland

In Scotland, Scottish Planning Policy 7 (SPP7) 'Planning and Flooding' sets out government policy and is supported by guidance in PAN 69 (The Scottish Executive web site) which explains the interface of planning and building standards. The PAN provides some guidance on water-resilient materials and recommended forms of construction.

Northern Ireland

Planning Policy Statement (PPS 15 – Planning and Flood Risk) was introduced in its final form in June 2006. This takes a precautionary approach with a strong presumption against any new development in the floodplain. Development may be considered by exception, in which case an FRA would be required.

3.2 Overview of the Building Regulations system

England and Wales

The Building Regulations set standards for the design and construction of buildings primarily to ensure the safety and health of people in or around those buildings. The Building Act 1984 (TSO, 1984) allows regulations for a wider purpose including:

> *'the health, safety, welfare and convenience of persons in and about buildings and others who may be affected by buildings or matters connected with buildings .....facilitating sustainable development'*

The Building Act 1984 is amended by the Sustainable and Secure Buildings Act (TSO, 2004), which allows environmental considerations to be addressed. The Regulations also cover energy conservation and pedestrian and vehicular access issues. The Government publishes guidance on ways of meeting these standards in what are known as Approved Documents. In the Building Regulations (England and Wales – The Building Regulations 2000 (SI 2000/2531) (as amended)) there are currently some provisions for flood mitigation in Approved Documents C, H and J.

Approved Document C provides practical guidance on site preparation and resisting contaminants and moisture. It does not provide information on preventing or reducing the impacts of flooding.

Approved Document H provides practical information on drainage and waste disposal and deals with the mitigation of flood risk associated with the surcharge of drains and sewers.

Approved Document J identifies the need for secondary containment where there is a significant risk of oil pollution but does not contain recommendations for ensuring storage above the predicted flood level.

Scotland

Building Standards in Scotland issued by Scottish ministers through the Scottish Buildings Standards Agency deal with mitigating the damage to buildings and removing the threat to the health and safety of occupants as a result of flooding. Guidance is given on the use of building materials that are not adversely affected by flood water. The following Standard is relevant to new buildings prone to flooding (Scottish Buildings Standards Agency, 1996):

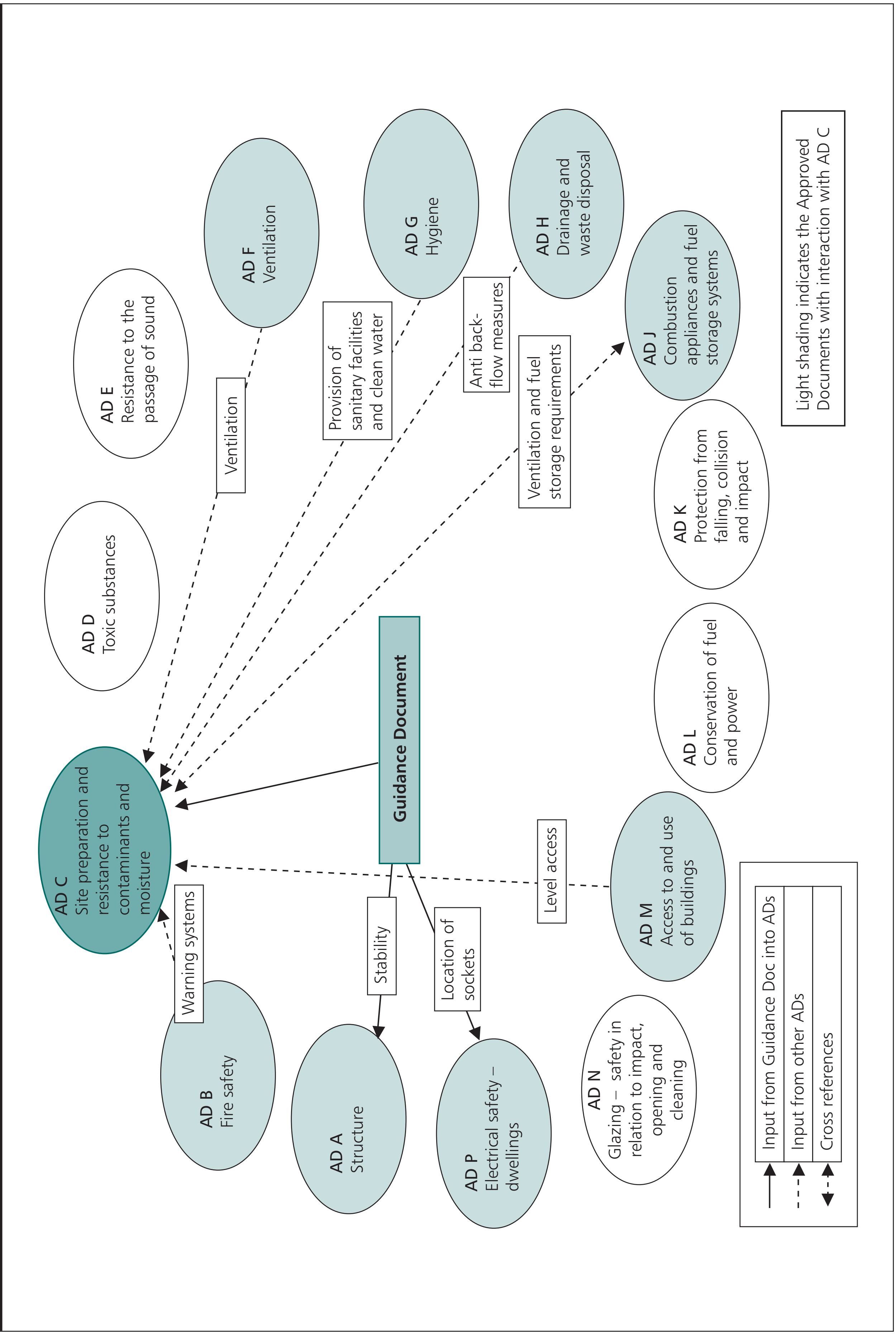
> BS3.3: *Every building must be designed and constructed in such a way that there will not be a threat to the building or the health of the occupants as a result of flooding and accumulation of groundwater.*

It should be stressed that the proposed amendments to the Buildings Regulations discussed elsewhere in this report relates to those for England and Wales, and not to the Building (Scotland) Regulations 2004.

Northern Ireland

The NI Building Regulations do not make specific mention of the use of flood resilience.

Figure 3.1 Interaction of present Guidance with Building Regulations Approved Documents



Proposed changes (England and Wales)

Existing guidance on flood-related issues in England and Wales is in a number of Approved Documents and for clarity and ease of use this needs to be brought together in one place, together with any new guidance. The most appropriate place is in Approved Document C. Any changes to the Building Regulations should be consistent with the requirements of PPS25/TAN15 and should concentrate on managing the residual risks insofar as they affect the health and safety of persons in and about buildings. The requirements should incorporate:

- a flood risk assessment (England)/flood consequence assessment (Wales)
- a requirement to incorporate measures to mitigate possible consequences.

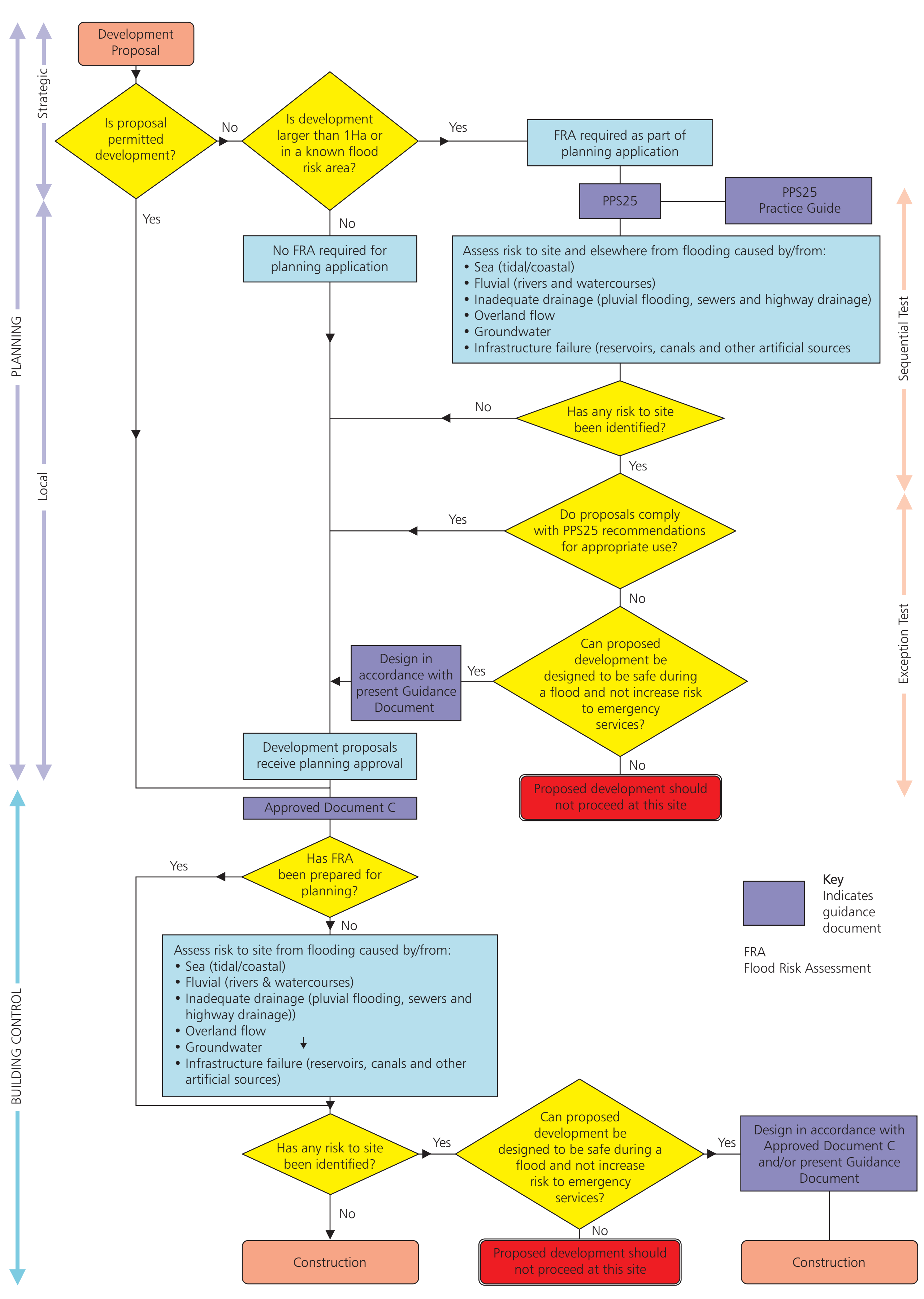
In order to minimise the costs to developers the requirements for flood risk assessments should mirror those in PPS25/TAN15 so that there is no unnecessary duplication of work. The guidance to support any requirement for flood mitigation should be consistent with the guidance in this report.

Figure 3.1 shows how this guidance may affect the Building Regulations (England and Wales), and also includes cross-referencing between the various Approved Documents.

3.3 Interface between planning processes and Building Control

Figure 3.2 shows the route a designer may need to follow during the planning application process and building control for a new property which is at some risk of flooding. It also shows where this guidance document and the changes proposed by this research to Approved Document C of the Building Regulations are relevant. This applies specifically to the processes and procedures in force in England, particularly for the requirement for a flood risk assessment. In Wales the procedure to be followed involves carrying out a flood consequence assessment if required by TAN15.

Figure 3.2 Decision tree for planning process and building control



PART 2 – DESIGN APPROACHES TO MANAGING FLOOD RISK

4 Design strategies

This chapter discusses the various factors to consider when undertaking a site specific Flood Risk Assessment (FRA) or a Flood Consequence Assessment (FCA) in Wales, and explains why they are important for the design of new buildings in areas with some risk of flooding. Knowledge and understanding of the potential flood characteristics together with information on predicted flood levels at a site will help designers of new buildings formulate a design strategy in order to achieve appropriate mitigation for any potential flood risk.

There are no definitive ways to design buildings to minimise flood damage. This guidance offers several design options, the choice of which will depend largely on the characteristics of flooding likely to affect a development site and the availability of space. It should be noted that this guidance does not cover operational flood measures such as the installation of temporary door guards since these are not considered the most appropriate measures for new buildings.

Figures 4.1 to 4.4 provide the rationale and guide the designer through the decision process for selection of the most appropriate strategy, i.e. flood avoidance, resistance and/or resilience. The process is described in detail below.

The first stage in the design strategy is to determine the types of flooding and their characteristics which are likely to impact the development site. In most cases this will have been considered in the FRA/FCA during the planning process (see Chapter 3). Where an FRA/FCA is ***not*** required as part of the planning process, estimates of these characteristics will still be required. The Environment Agency or Local Planning Authority should always be the first points of contact for information for FRA/FCA. It may also be necessary to seek historical data from other local sources of information e.g. libraries, existing residents, community associations and newspapers. Some areas have active local Flood Groups (refer to the National Flood Forum website).

Important factors to consider which will influence the design of new buildings are:

- *Potential sources of flooding*
  Various sources of flooding were listed in Chapter 2, Figure 2.1 and are included in PPS 25 . Flooding from seawater may expose building materials to saltwater damage particularly over prolonged periods. Although at relatively low probability of flooding, buildings behind sea or river defences could suffer severe structural damage from high water speeds and water borne debris from a breach in the defences. Flooding from overloaded sewer systems could result in contaminated floodwater infiltrating the building fabric causing cleaning and drying problems during refurbishment. Groundwater flooding could damage foundations, floors and walls.

- *Predicted flood level*
  The normal output from an FRA/FCA is a range of predicted flood levels for different frequencies of occurrence (or return period) and for all relevant flood

sources. This enables the calculation of the most appropriate depth of floodwater at the development site or building for design purposes.

- *Duration*
  Flooding from large rivers which exceed their capacity or from rising groundwater can often be of long duration, sometimes taking several days/weeks (or months, in the case of groundwater) to drain away, so that pumping may be required. Inundation of a building by floodwater for long periods could damage the building fabric and lead to structural problems. For long duration flooding, a strategy to keep water out at the building level may not be a viable option. Mitigation measures may only delay the time before water enters a building to enable ground floor contents to be moved. In terms of the costs of damage, a limit of 12 hours can be used to differentiate between short and long floods (Flood Hazard Research Centre, 2005).

- *Frequency*
  In areas where flooding is frequent but shallow, an effective strategy may be to consider avoidance or resistant measures to restrict water reaching or entering the property. If avoidance or resistance is not possible, or the flood depth is significant, then incorporation of resilient measures may be the only option. In this case, the design strategy should be to maximise the use of resilient material, to reduce the damage and subsequent costs of repair and refurbishment. The decision on whether a design flood is considered to be frequent would be made in consultation with the planning authority and the relevant regulatory authority.

- *Depth*
  Tables of typical flood damage associated with different flood depths are given in Chapter 2, Figure 2.7. Flood depth is considered to be the main parameter in the design strategy, since this will dictate whether it is feasible to try to exclude and/or delay floodwater from entering the property. For design purposes it is assumed that additional freeboard will used in setting the floor level of a property, to take into account uncertainties in data, estimates and irregularities in ground and water surfaces (e.g. waves resulting from wind or traffic). For example, the Environment Agency requires that floor levels are set 300mm above the predicted 100 year flood level plus climate change allowance, for river flooding.

The second step of a strategy is to calculate a design flood depth at a building from knowledge of the predicted flood level and the ground level and to set a practical design floor level (Figure 4.2). This may require an iterative process as issues such as level access and cost need to be considered.

If the floor level is below the predicted flood level then a decision has to be made as to whether it is appropriate or possible to:

Avoid building in a flood risk area or where this is not possible, raising ground level and/or floor level. This form of avoidance may not be possible for many reasons:

- not economically viable

- ground instability

- unacceptable aesthetics
- planning concerns for level access or for safe evacuation.

If the above is not possible, the next step is to consider whether any practical measures such as local bunds, landscaping or construction of boundary walls will be a worthwhile option to try to keep floodwaters away from new buildings (Figure 4.3). It must always be remembered that any measures adopted must not make flooding worse for any surrounding areas and ideally should reduce the overall flood risk. Compensatory flood storage areas may not be a feasible option.

Avoidance measures include:

Not building in flood risk areas wherever possible

Raising ground or floor level or re-designing to a location outside the flood area, and provision of replacement storage.

Local bunds can be designed to protect individual or groups of buildings from flooding. It is unlikely that these can be made fully watertight and pumps may be necessary to remove or re-direct any seepage water within the protected area. Bunds may be effective where the predicted duration and depth of flooding is low. Advice should be sought from a Qualified Engineer/Professional to ensure the bunds can withstand predicted water pressures.

Landscaping of a development site or building curtilage to direct or divert floodwater away from buildings can be effective particularly where the predicted duration of flooding is short i.e. hours rather than days. Landscaping is an integral component of sustainable drainage systems (SUDS). They can be designed to manage flood risk and water quality, and also environmentally acceptable to communities.

Boundary walls and fencing could be designed with high water resistance materials and/or effective seals to minimise water penetration for low depth, short duration floods (but not for groundwater flooding).

Resistance measures are aimed at preventing floodwater ingress into a building; they are designed to minimise the impact of floodwaters directly affecting buildings and to give occupants more time to relocate ground floor contents. They will probably only be effective for short duration, low depth flooding i.e. less than 0.3m.

They include the use of low permeability materials that reduce the rate of water ingress into a property. Details of these materials and their use are given in Chapter 6.

More details on avoidance and resistance measures can be found in Chapter 5.

This guidance is aimed at buildings constructed of traditional materials. However, it is possible that some individual properties or commercial buildings could be designed to be highly resistant to floodwater by construction with water resistant materials such as boundary/retaining walls in waterproof concrete.

Avoidance and resistance measures are only likely to delay the floodwaters reaching a development or entering a building so it would always be prudent not to rely solely on them. Having considered these measures, an associated step in the design strategy is to consider making the buildings themselves more resilient to floodwater (Figure 4.4).

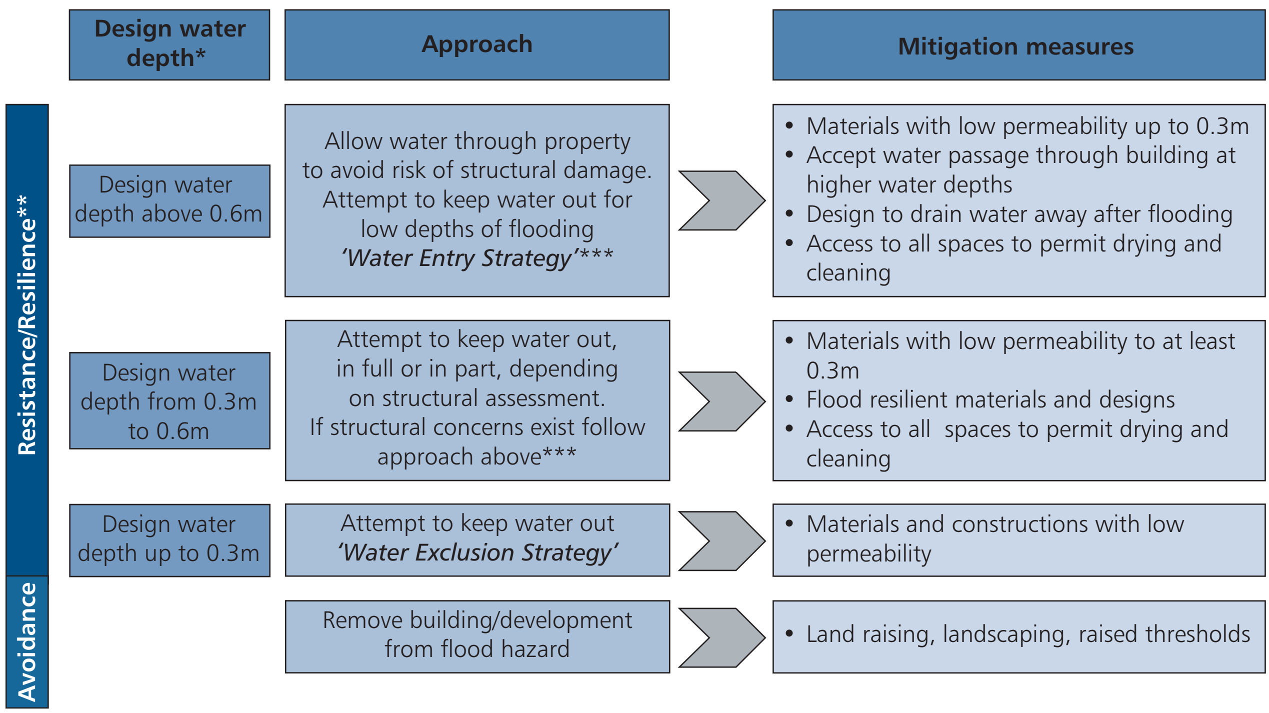
> **Resilience measures** are either an integral part of the building fabric or are features inside a building. These can be considered in combination with resistance measures or where resistance measures are not an option.

In order to decide which resilience measures would be effective it is necessary to know the potential depth and duration of flooding that is likely to occur. For the purpose of producing a *simple* design strategy, guidance on resilience measures is applicable to flood depths outside of a building of:

- less than 0.3m
- above 0.3m but less than 0.6m
- above 0.6m.

Figure 4.1 summarises the overall rationale behind the design strategies.

Figure 4.1 **Rationale for design strategies**



Notes:
* Design water depth should be based on assessment of all flood types that can impact on the building
** Resistance/resilience measures can be used in conjunction with Avoidance measures to minimise overall flood risk
*** In all cases the 'water exclusion strategy' can be followed for flood water depths up to 0.3m

The following boxes summarise the main elements of the design strategy for resilience. Guidance on the choice of resilience measures is given in Chapter 6.

At predicted depths less than 0.3m, and for short duration floods, the strategy is to adopt a 'resistant' approach and try to keep water out of a building i.e. ***water exclusion strategy***. Under this strategy, the aim would be to build walls and floors with low permeability materials, with associated minimal (or no) damage or deformation. In addition, the materials should be easy to clean and dry out, e.g. engineering bricks, water resistant renders.

Under this scenario, people may safely leave their houses as there is a low possibility of flood water flowing at speeds greater than 2m/s, which could present a danger to the most vulnerable.

However, it is likely that if the flood is prolonged i.e. more than a few days, such as may occur from rising groundwater or from a major watercourse, it will penetrate the building due to settlement or to cracks developing in the fabric of the building.

For flood depths between 0.3m and 0.6m a decision needs to be taken as to whether it is feasible or practical to adopt the water exclusion strategy. If this is the case, then low permeability materials can be used up to 0.6m. If structural integrity of the building is an issue or concern, then it will be advisable to allow for partial water entry as set out below. In this case, measures can be again used to minimise water ingress up to 0.3m.

It is important that a structural assessment of the risks posed by flood water is considered by an experienced professional during the building design phase

For flood depths greater than 0.6m, it is likely that structural damage could occur in traditional masonry construction due to excessive water pressures (differential head between outside and inside of the property); this can be worsened by impact from water-borne debris. In these circumstances, the strategy should be to allow water into the building, i.e. the ***water entry strategy***. This should apply irrespective of the flood duration or frequency. The key consideration here is the use of materials that retain their structural integrity, but allow passage of water. Materials should also have good drying and cleaning properties. Use of sacrificial materials can be considered as internal or external finishes; e.g. gypsum plasterboard. A secondary design consideration is whether to use measures to minimise water ingress up to 0.3m with the aim of 'buying time' for removal of valuables and safe evacuation. This approach is most suitable when the rate of rise of flood water is relatively slow, i.e. several hours.

For flood depths above 0.6m, the likely flood velocity should be assessed as this can pose a danger, particularly in cases where people need to leave their homes. Velocities in excess of 0.5m/s can pose a problem to the most vulnerable.

Figure 4.2 **Design strategies; decision flowchart – Avoidance (1)**

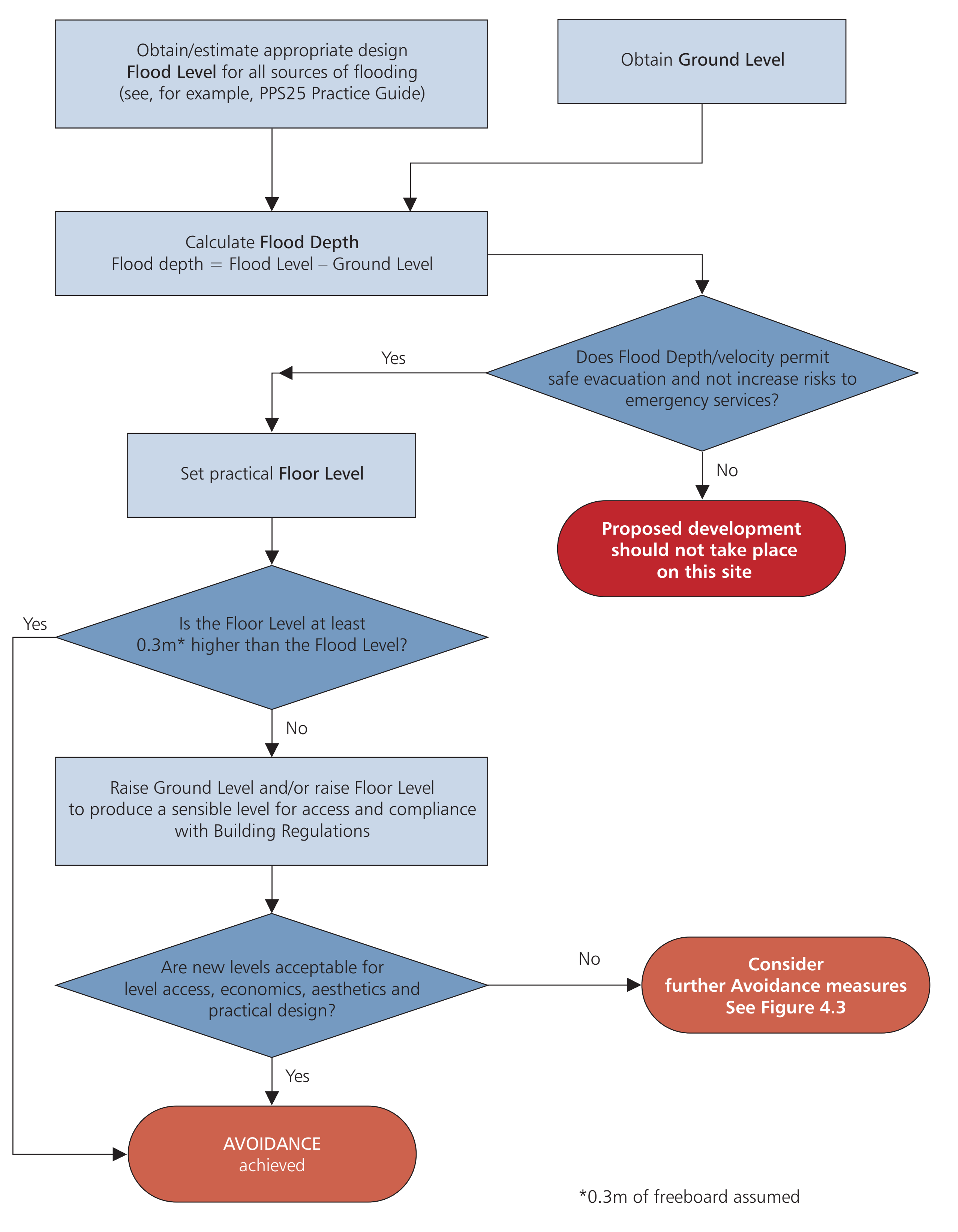


Figure 4.3 Design strategies; decision flowchart – Avoidance (2)

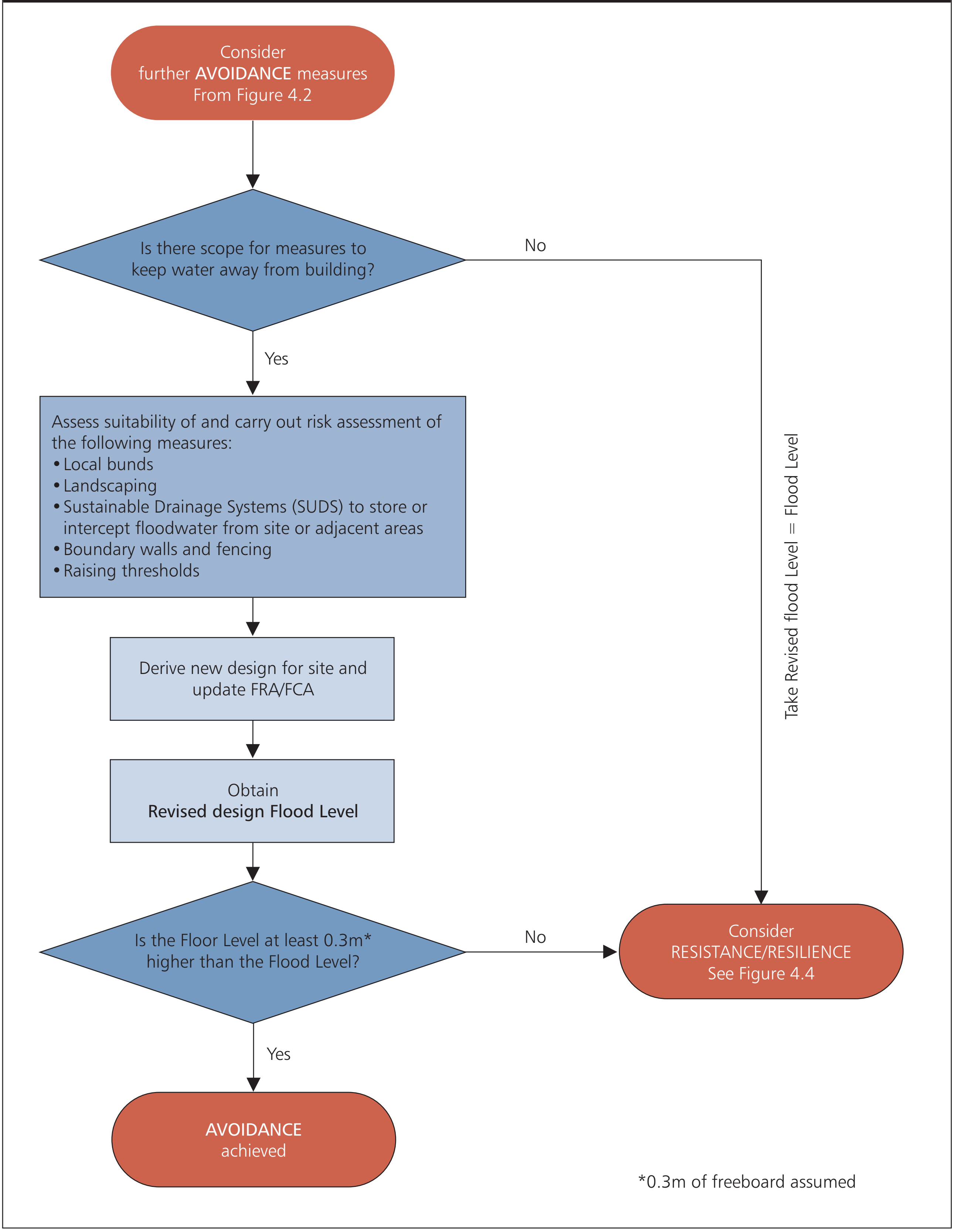
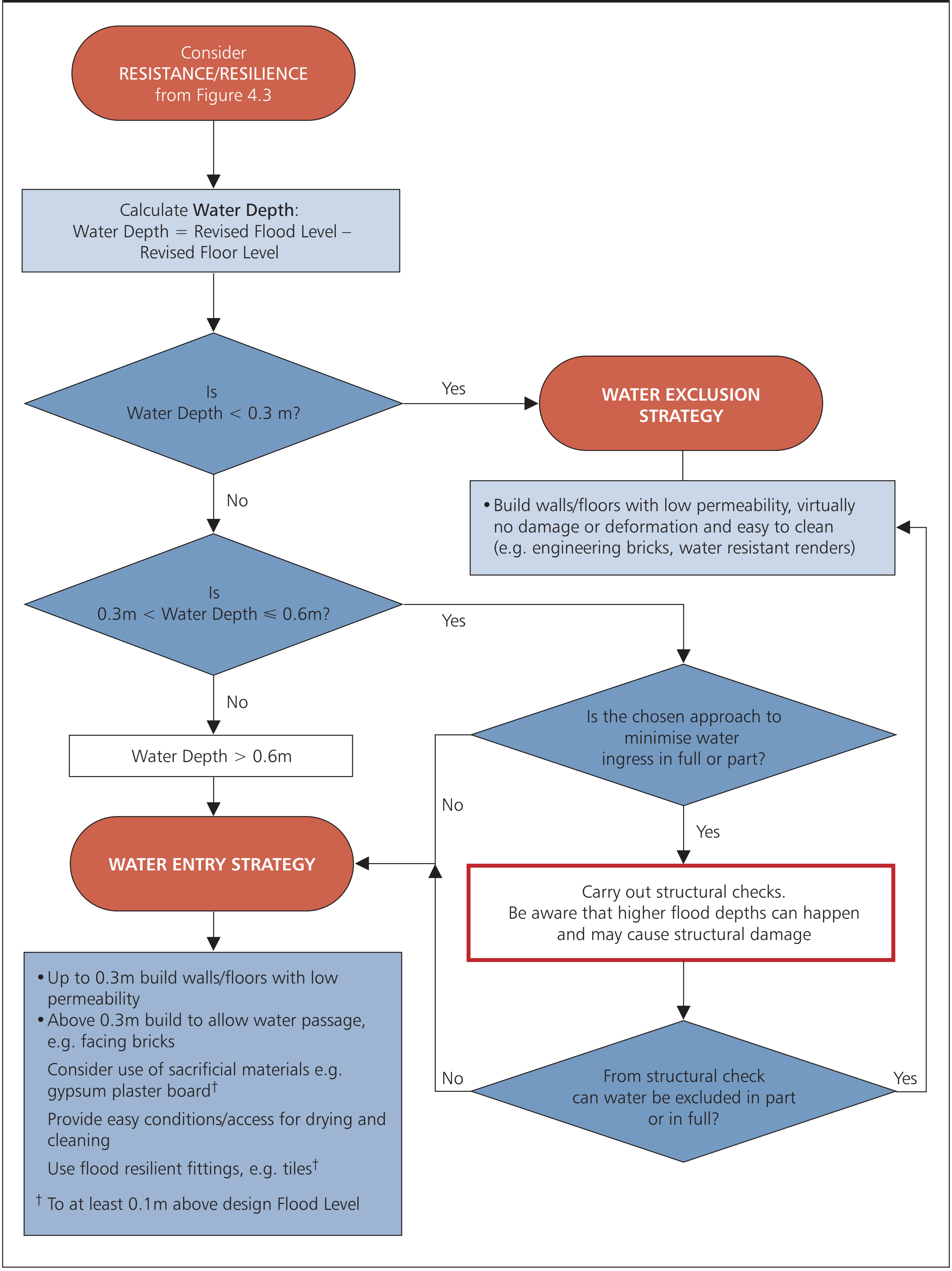


Figure 4.4 **Design strategies; decision flowchart – Resistance/Resilience**



Two example design scenarios are presented below to illustrate the advantages of incorporating resilient construction materials and methods.

Example A – Property at the edge of a floodplain likely to be flooded to a low depth of water

Consider a domestic property to be built close to the edge of a river floodplain (which has been defined for the 100 year return period). The predicted flood depth was estimated as 0.2m with a medium probability of occurrence of 1 in 100 years. According to Figure 4.4 a "water exclusion strategy" is recommended because the predicted flood water depth is below 0.3m. Recent laboratory tests have shown that engineering bricks on the external face of a property greatly enhance its ability to prevent water ingress through the walls. In this hypothetical case therefore, engineering bricks would be appropriate as a resilient construction up to 0.3m above ground.

If the building walls were constructed as a traditional masonry cavity wall with facing bricks on the external face and Aircrete blocks on the internal face, with mineral fibre cavity insulation and an internal lining of gypsum plaster board it is estimated that the flood depth inside a 3m by 3m room would be 30mm after 5 hours, but could be higher due to ingress through openings such as doors and service ducts. After 12 hours it is estimated that the depth of water would be around 53mm. However, using resilient engineering bricks on the external face of the wall, (with all other components remaining the same), would lead to a flood depth of only 3mm inside the property after 5 hours (or 7mm after 12 hours), assuming that every effort has been made to minimise ingress through all openings.

Example B – Property likely to be flooded to a high depth of water

Consider a domestic property to be built in masonry in an area where the predicted flood depth is estimated as 0.9m. According to Figure 4.4 a "water entry strategy" should be adopted to avoid any potential structural instability and to allow water passage through the fabric of the house.

Materials that can dry quickly while retaining their integrity should be specified. Soft hand-made bricks would not be appropriate but standard cavity masonry wall construction ('brick – concrete block – gypsum plasterboard') is likely to be adequate provided closed cell insulation is used. The gypsum plasterboard up to 1m above floor level, if fixed horizontally, could be removed after the flood to aid the drying process.

Based on laboratory measurements, it is estimated that a 'brick-concrete block' cavity wall would take approximately only 5 days to dry naturally. If Aircrete blocks are used in the internal face instead of concrete blocks then it is likely to take over 26 days to dry naturally.

5 Avoidance and resistance design options

This chapter considers in more detail the measures that can be adopted for avoidance and resistance, on site and at building level. Chapter 4 dealt with the design strategies that involve avoidance, resistance and resilience measures. Chapter 6 gives the detailed guidance on overall building resilience.

5.1 Avoidance

5.1.1 Site layout

One of the primary means of avoiding the impacts of a flood is a sensible development layout (a key element to cover in the FRA), which minimises the need for resistance and resilience measures. In designing the layout of the development, it is important to consider the safe movement of people in or out of the area, especially near areas of potentially flowing water. It may be necessary to determine the location of overland flow routes and either design to divert floodwater away from property or design to build elsewhere. Existing drainage channels must be assessed as to the likelihood of overtopping.

In general, above ground flood escape routes should be kept to publicly accessible land, as safeguarding these is difficult if they are located within private property. Such routes should be signed, and other flood awareness measures taken to inform local communities of the impacts of flooding. The location of the most suitable access routes will be decided from the results of the flood risk assessment (CIRIA, 2006a).

An appropriately designed development can be achieved by:

- applying the sequential approach at the site level e.g. locating housing developments on lower flood risk areas, where the profile of the site makes this possible, utilising lower ground for non-emergency access roads, amenity areas and other associated land uses

- raising land to create high ground, without adversely affecting existing flood management

- setting the ground floor level, where practical/feasible, sufficiently high not to be affected by the flood.

It is important that **land raising** is not carried out in areas, which will result in increased flood risk elsewhere. Typically, this would be in the areas alongside watercourses or poorly-drained areas. The potential impacts of land raising could be to reduce flood storage capacity and displace flood water, thus increasing flow speeds and water depths in adjacent areas. Essential land raising will have to be compensated by the provision of additional flood storage areas or improved flood routes, designed as part of the flood risk assessment. These aspects would be considered in the detailed FRA produced to support a planning application, which would be assessed by the local planning authority.

Creating an island effect with surrounding areas inundated by floodwater is not usually acceptable to a local planning authority as there must be safe access for emergency vehicles and evacuation. Essential and emergency access routes should be designed above predicted flood level, which could be achieved by land raising.

When designing and engineering for land raising, careful consideration must be given to:

- top soil stripping, storage and reinstatement
- existing ground conditions (e.g. underlying soft or highly permeable ground);
- type of material (inert, granular/cohesive e.g. clay)
- slope or embankment stability
- compaction and settlement of infill material
- possibility of mobilising contaminants
- impact on existing hydrology.

Fuel storage containers, private pumping stations and any other external service installations with mechanical or electrical parts, should be raised and secured above predicted flood levels. Guidance on fuel storage is given in Approved Document J of the Building Regulations (*Combustion appliances and fuel storage systems*) – The Building Regulations 2000.

5.1.2 Landscaping

Landscaping the land surrounding individual or groups of buildings to encourage drainage away from a property is an effective measure. In some locations it may be possible to re-contour the land at the edges of flood plains to allow for new development without increasing flood risk, by carrying out flood plain compensation works as part of a development. Further guidance on landscaping is given in CIRIA (2006a).

A conventional low-cost **earth bund** may provide an effective local flood defence to floodwater around the site or building curtilage where practical and acceptable to the planning authority. There may be a need to provide pumping arrangements to remove potential rainwater or floodwater seepage. An assessment should be carried out during the design stage to ensure that any earth bund does not increase flood risk elsewhere.

5.1.3 Drainage

The site drainage system and the management of surface water runoff are important considerations in reducing the flood risk to people and property. Consideration needs to be given, in both the FRA/FCA and for the site layout, to the surface water and foul drainage systems.

Flood hazards, affecting either the site or the associated surface water and foul systems may be caused by:

- overland flow across the site from uphill areas. This risk should have been identified in the FRA/FCA

- misconnections of surface water to the foul sewer system within the development, creating a risk of surcharging

- overloading of existing downstream systems, which may cause them to back-up under extreme storms

- close proximity to an existing system, which suffers from poor performance (e.g. overloading, severe infiltration).

Foul and surface water sewer systems, and the development site layout should be designed to satisfy the requirements of the Sixth Edition of Sewers for Adoption (SfA) – a design guide for developers published in 2006 on behalf of Water UK (WRc, 2006). It should be noted that each Sewerage Undertaker has its own variations. Drainage within the curtilage of individual properties should be designed in accordance with Approved Document H (The Building Regulations 2000). There will still be a need for provision of measures for dealing with flows that exceed the design capacity of the systems (see, for example, CIRIA C635 – 'Designing for exceedence in urban drainage – good practice' (CIRIA, 2006a).

Current planning requirements for drainage encourage the use of sustainable drainage systems (SUDS), which manage surface water runoff and minimise impacts on the environment in a more sustainable manner compared to traditional pipe-based systems. Best practice guidance on the design and construction of SUDS is given in CIRIA manuals C522 and C609 (CIRIA, 2000, and CIRIA, 2004, respectively). A new SUDS Manual for the UK is due to be published by CIRIA in Spring 2007.

The Environment Agency also produces good practice guides (Environment Agency web site), which provide advice on flood risk and drainage within new developments. These include:

- addressing flood risk in new development, Good practice note 1: provides practical steps in considering flood risk when selecting a development site and when deciding the mix of uses, layout and design of the development

- designing drainage schemes, Good practice note 2: provides an overview of best practice in providing drainage for new developments. It highlights the use of the modern approach to install sustainable drainage systems

- achieving positive gains from watercourses in new development, Good practice note 3: This guidance note provides information on watercourses in developments. The main drive of this document is the achievement of a sustainable development in union with the watercourse.

The philosophy of SUDS is to mimic as closely as possible the surface water flows arising from a site prior to the proposed development and to treat runoff to remove pollutants, thus reducing the negative impact on receiving water bodies. Certain site characteristics mean that certain sustainable drainage functions may have a greater emphasis than the others. The variety of SUDS components and design options available allows designers and planners to consider local land use, land take, future management scenarios, and the needs of local people when undertaking the drainage design.

SUDS can be designed to intercept floodwater that may enter a development site from uphill adjacent areas and to either store or divert storm water for release at a later stage when floodwaters have receded. SUDS can also be used closer to buildings, even incorporated into individual gardens or local infrastructure (pavements and roads), diverting rainwater away from buildings into storage areas.

Careful consideration should be given to the type of surface water drainage system that can be incorporated effectively in areas prone to groundwater flooding, which is often of long duration (days to months). Drainage systems should be designed to cope with high water table levels during extreme conditions.

New buildings and infrastructure can be designed in sympathy with the existing topography, to manage the passage of water along specific flow routes, e.g. around or underneath the property. Examples are given below in Figures 5.2 to 5.4.

Figure 5.1 **Drainage relief openings (courtesy of HR Wallingford Ltd.)**

The openings in the property wall and road on the new estate in Figure 5.1, which is in a known area of flood risk, were specifically designed to convey flood flows away from the property and into temporary underground storage.

Figure 5.2 **Use of SUDS in a new housing development (courtesy of HR Wallingford Ltd.)**

Figure 5.2 shows a swale used to deal with surface water drainage in a housing development in England.

In Figure 5.3 a residential development next to an existing watercourse utilises raised floor levels and channels underneath the house to convey excess water in times of flood.

Design of the above drainage solutions needs to consider the full range of flood water flow, depth, duration and frequency at the site, to optimise their performance.

5.1.4 *Boundary walls and fencing*

Boundary walls and fencing can be designed to create flood resistant barriers. Options include solid gates with discreet waterproof seals and where possible, integral drains, or fencing where the lower elements are constructed to be more resistant to flooding (see Figures 5.4 to 5.6). These are effectively used by some sewerage undertakers to combat low depth flooding from sewers.

Figure 5.3 **Flood management system (courtesy of Leadbitter Construction)**

Figure 5.4 **Example of property boundary wall and lower sealed gate (courtesy of Severn Trent Water)**

Figure 5.5 Example of sealed gate (courtesy of Severn Trent Water)

Figure 5.6 Example of protection of fence base with impermeable material (courtesy of Severn Trent Water)

5.1.5 Threshold and floor levels

When designing an extension or modification to an existing property, which is covered by the Building Regulations, an appropriate avoidance measure would be to ensure the threshold levels into a property are above the design flood level. Account must be taken of providing level access for compliance with Regulations governing access to buildings. Porches, conservatories and patio doors constructed with a high doorstep level provide an added barrier to floodwater.

Approved Document M of the Building Regulations (England and Wales) states that reasonable provision shall be made for people to gain access to and use the building and its facilities. Building Standard 4.1 (Scotland) states that every building must be designed and constructed in such a way that all occupants and visitors are provided with safe, convenient and unassisted means of access to a building. Level or ramped access is therefore required to nearly all buildings. However, the requirement for level access can conflict with land raising measures to prevent potential flooding.

The Scottish Guidance PAN 69 (Scottish Executive, web site) advises that potential conflicts between the need for level access and flood risk should be discussed with planning and building regulation officers at an early stage. It may be reasonable for a proportion of dwellings in a development to be provided with disabled access. Where level or ramped access is provided, careful consideration should be given to appropriate detailing of damp-proofing, weather-proofing and drainage, particularly on and around the accessible entrance and to the landing immediately adjacent. Guidance on level thresholds is provided in ‘Accessible Thresholds in New Housing’ (Stationery Office, 1999). Ramps, if required, can be incorporated sympathetically in a driveway/garden design.

5.2 Resistance

When constructing new properties, permanent flood resistance measures (e.g. use of low permeability materials) are always preferable to temporary measures, such as flood resistance products (e.g. door flood guards) as they do not require intervention by the property occupants. Materials providing resistance to water ingress are evaluated in Chapter 6. Some information on temporary measures is given below.

Flood resistance products for buildings are relatively new. Following the autumn 2000 floods in the UK and more recent floods in Europe, there has been a development of temporary barrier ‘products’ and permanent building techniques to reduce the impacts of flooding on property. Whilst new quality standards have been developed for temporary barriers, such as the BSI Kitemark Scheme for Flood Protection Products, this guidance does not consider that temporary measures (door boards, airbrick covers etc) are appropriate for new buildings. This is mainly for the following reasons:

- home owners have the responsibility to store, maintain and install the products
- durability and sustainability are not proven in most products

- all future homeowners must be made aware of the use of temporary products as the chosen flood mitigation measure.

The quality standards for certified flood protection products comprise PAS 1188-1 (for building apertures) and 1188-2 (for temporary or demountable types). PAS 1188-3 covers building flood skirt systems. They are currently under review.

Details of Kitemark licensed temporary flood defence products are given on the Environment Agency website and on the National Flood Forum website (NFF website).

5.3 Other design considerations

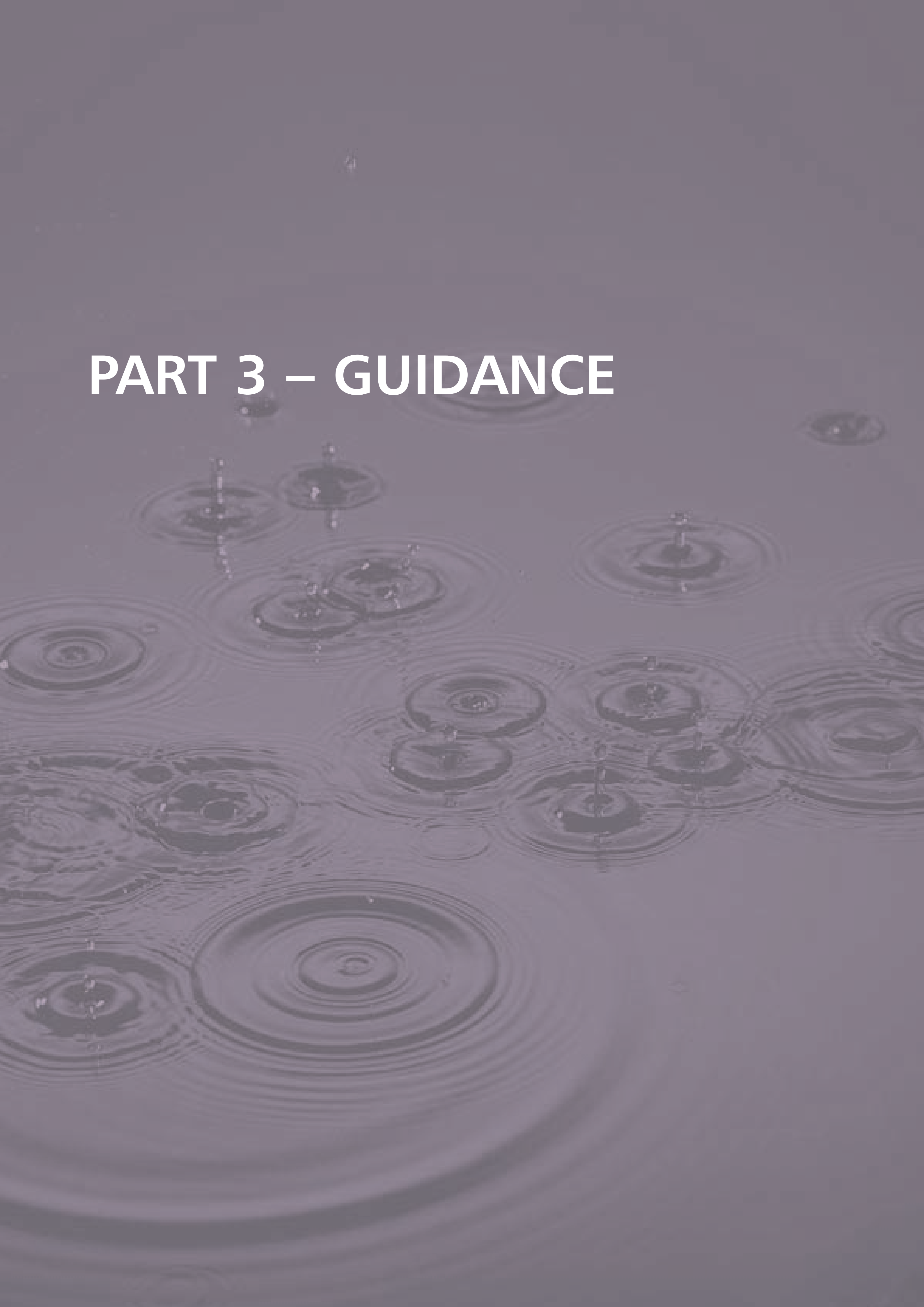
There are some measures that can be taken at the building level to reduce the impact of floods; some are based on architectural choices, such as the layout of the internal space, elevated construction or imaginative designs, whereas others relate to the use of warning systems. A brief description of some of these measures is given below.

Careful **layout of internal space** can be an effective measure to minimise the impact of floods. Living accommodation, essential services, storage space for key provisions and equipment should be designed to be located above predicted flood level. Siting of living accommodation above flood level, where possible, is the appropriate design option in areas at risk of flooding. The use of ground floor areas will normally be agreed at planning stage, but options could include designs for provision of additional flood storage or conveyance areas and car parking.

Single storey accommodation is not appropriate where predicted flood levels are above design floor level. PPS25 gives further guidance on the requirements for safe access, refuge and evacuation in flood risk areas.

A discussion of appropriate selection of **house fittings** is covered in Section 6.7.

PART 3 – GUIDANCE



6 Guidance on flood resilient design and construction

6.1 General principles

Management of flood risk can be achieved during the planning and outline design stages for any new development as discussed in Chapters 3 (Planning Policy and Building Standards) and Chapter 4 (Design Strategies). This chapter is concerned with measures aimed at achieving flood resilience that can be applied at the building design level. This chapter provides technical guidance on building materials and forms of construction (and to a lesser extent, on fittings) that are appropriate for improving the flood resilience of buildings. It is the result of a synthesis of information from a number of different sources: published literature, review of existing practice, experiential information, and laboratory testing. Some recommendations in this Guidance naturally differ from current standards, such as those contained in the NHBC, in order to address the severity of exposure to flood water which hitherto has not been considered.

Any resilience measures should be designed so that the building can be occupied safely over its proposed lifetime taking climate change into account.

It is generally accepted that total prevention of water ingress or 'dry proofing' to a building is very difficult to achieve. The strategies that are recommended to minimise flood impact to buildings and their occupants are described in Figures 4.2 to 4.4 of Chapter 4. In terms of achieving resilience, there are two main strategies, whose applicability is dependent on the water depth the property is subjected to (see Chapter 4).

- **Water exclusion strategy** – where emphasis is placed on ***minimising*** water entry whilst maintaining structural integrity, and on using materials and construction techniques to facilitate drying and cleaning. This strategy is favoured when low flood water depths are involved (not more than 0.3m). According to the definitions adopted in this Guidance, this strategy can be considered as a resistance measure but it is part of the aim to achieve overall building resilience

- **Water entry strategy** – where emphasis is placed on allowing water into the building, facilitating draining and consequent drying. Standard masonry buildings are at significant risk of structural damage if there is a water level difference between outside and inside of about 0.6m or more. This strategy is therefore favoured when high flood water depths are involved (greater than 0.6m).

Other important factors that should be considered for resilient design and construction, but not addressed in this guidance, are:

- cost

- durability

- ease and practicability of construction
- environmental, social and aesthetic acceptability.

Guidance is provided in the following sections:

Section 6.2 – building materials

Section 6.3 – foundations

Section 6.4 – floors

Section 6.5 – walls

Section 6.6 – doors and windows

Section 6.7 – fittings

Section 6.8 – services.

In each section dealing with construction elements (e.g. materials, foundations, floors, and walls) there is a brief discussion of the design issues, followed by general advice on resilience. Some illustrative sketches are also included which provide information on general arrangements but do not cover construction details.

6.2 Building materials

The recommendations given in this section on building materials are based primarily, but not exclusively, on recent laboratory investigations (permeability and drying tests on 13 typical building materials subjected to 1m head of flood water). An illustrative example of testing is given in Figure 6.1.

Figure 6.1 **Pressed facing bricks being tested**

Although this guidance covers the main types of building material commonly in use in the UK for typical domestic construction, it should be borne in mind that other materials also may prove to be suitable for resilient constructions. It should also be noted that there is variability within materials that may affect their resilience performance. As expected, the denser materials such as concrete and engineering bricks were found to have good resilience characteristics. In general, the findings of the materials testing confirmed existing knowledge and experience but provided new quantitative data on construction material behaviour.

Table 6.1 presents the characteristics of common building materials, tested in the laboratory, classified as having good, medium or poor performance with regard to water penetration, drying ability and integrity.

Definitions of the characteristics used in Table 6.1 are:

- water penetration – the seepage (rate and volume) through the material (note that this is different from "water absorption")
- drying ability – the capability to regain its original moisture condition (assessed by the average drying rate and the time taken to reach the original value)
- retention of pre-flood dimensions, integrity – the lack of deformation or change in form or appearance of the material

Table 6.1 **Flood resilience characteristics of building materials (based on laboratory testing)**

Material	Resilience characteristics*		
	Water penetration	Drying ability	Retention of pre-flood dimensions, integrity
Bricks			
Engineering bricks (Classes A and B)	Good	Good	Good
Facing bricks (pressed)	Medium	Medium	Good
Facing bricks (handmade)	Poor	Poor	Poor
Blocks			
Concrete (3.5N, 7N)	Poor	Medium	Good
Aircrete	Medium	Poor	Good
Timber board			
OSB2, 11mm thick	Medium	Poor	Poor
OSB3, 18mm thick	Medium	Poor	Poor
Gypsum plasterboard			
Gypsum Plasterboard, 9mm thick	Poor	Not assessed	Poor
Mortars			
Below d.p.c. 1:3(cement:sand)	Good	Good	Good
Above d.p.c. 1:6(cement:sand)	Good	Good	Good

* Resilience characteristics are related to the testing carried out and exclude aspects such as ability to withstand freeze/thaw cycles, cleanability and mould growth

Clearly other factors affect the choice of resilient building materials, namely their insulating properties, ease of handling, availability, aesthetics, cost, etc. and these should also be considered when specifying materials for construction in flood-prone areas.

Building materials that are effective for a 'water exclusion strategy' include: engineering bricks, cement-based materials including water retaining concrete and dense stone.

Building materials that are suitable for a 'water entry strategy' include: facing bricks, concrete blocks, sacrificial or easily removable external finishes or internal linings.

6.3 Foundations

Foundations are designed to suit site conditions, namely the local geotechnical characteristics and the building design. Strip and trench-fill foundations are generally used where no special problems are identified, whereas raft, pile, pier and beam foundations may be necessary in other cases. In general, the choice of foundation type will be dictated by ground conditions, rather than resilience considerations. However, improvements can be made to increase the resilience.

For typical two-storey dwellings shallow footings are likely to be appropriate in most cases. It is common practice to use concrete blocks as substructure elements in typical cavity wall buildings but laboratory work has shown that groundwater can penetrate through the blocks into the wall cavity (and from there into the building) if care is not taken to minimise the passage of water. There is a general recommendation in the NHBC Standards, 2006) to allow a clear cavity of at least 225mm below damp proof course (d.p.c.) to prevent the build up of any mortar dropped during construction from having a detrimental effect on the performance of the wall. However, this unsealed void may be an entry point for rising ground water into the property via the blockwork.

Basements are a separate category of construction which can benefit from various types of tanking methods to provide an effective barrier to flood water. Guidance on tanking can be found, for example, in publications such as CIRIA Report 139 'Water-Resisting Basement Construction – A Guide' (CIRIA, 1995), NHBC Standards (2006). It is not advisable to design for living accommodation in basements, where there is a risk of flooding.

6.3.1 Water exclusion strategy

A general principle for flood resilient design where predicted flood water depths are relatively small (no greater than 0.3m above floor level) is to minimise the entry of water through permeable elements of the foundation. Any concrete blocks placed below ground-bearing concrete floor slabs provide a potential path for water to ingress into wall cavities, as these blocks are considerably more permeable than concrete slabs. Figures 6.2 and 6.3, illustrating a ground bearing slab and a concrete suspended floor slab, show a potential flow path from the ground adjacent and under a dwelling, through porous substructure and into the wall cavity. The use of concrete or another impermeable material to seal the blocks may resolve this problem. The figures highlight the fact that measures taken above ground level may not fully prevent the ingress of water.

Figure 6.2 **Water ingress into properties through the ground – ground bearing floor**

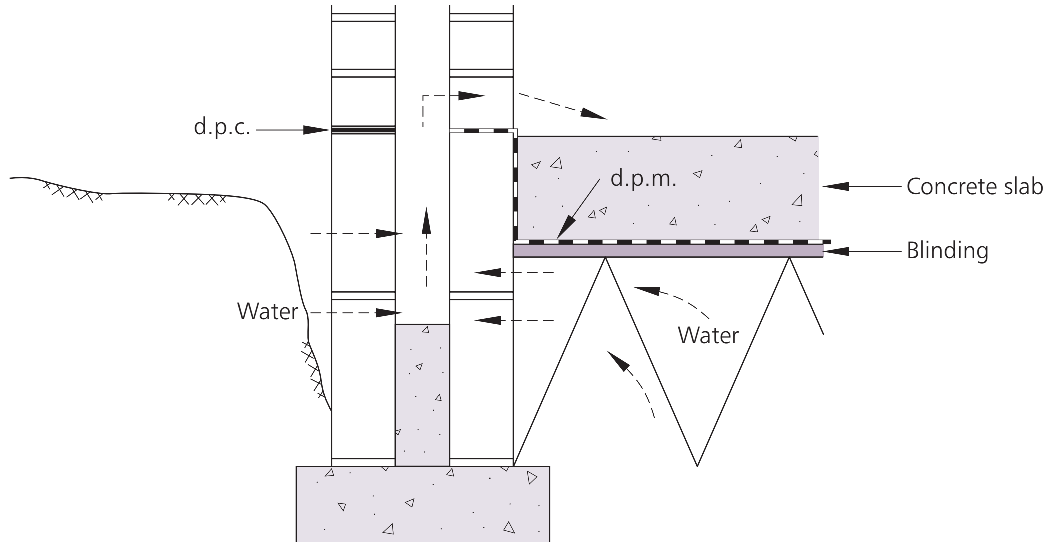
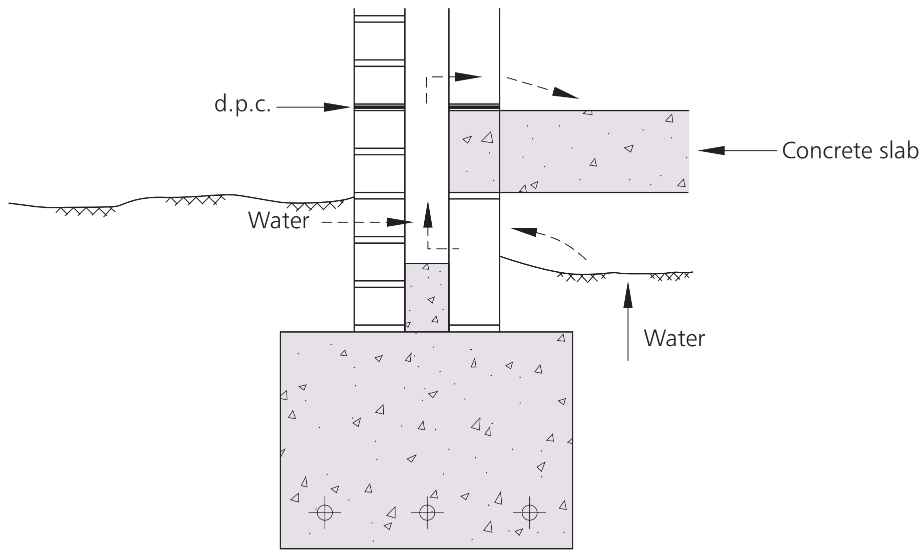


Figure 6.3 **Water ingress into properties through the ground – suspended floor**



> **General advice for resilient design**
>
> Where concrete ground floor slabs are used, the blockwork substructure is often the weakest point in terms of water penetration from the ground into a dwelling. Whereas there is a general perception that water can ingress through the blockwork structure of the external face of a wall into the property, it is less apparent, but equally possible, that water will penetrate from the ground on the inside of the property. Figures 6.2 and 6.3 illustrate these flow paths for two types of ground floor (ground bearing floor and suspended concrete floor), and different types of foundation (typical for construction in England).
>
> Concrete blocks used in foundations should be sealed with an impermeable material or encased in concrete to prevent water movement from the ground to the wall construction.

6.3.2 *Water entry strategy*

> **General advice for resilient design**
>
> A general principle for flood resilient design where predicted flood water depths are high is to provide durable materials that will not be affected by water and use construction methods and materials that promote easy draining and drying.
>
> Standard methods and good quality building materials will generally comply with these requirements but good workmanship is essential.

6.4 Floors

The behaviour of ground floors in floods can be influenced by two different conditions:

- water ingress from the ground (potentially resulting in uplift pressures), and
- exposure to standing water.

Of the above two situations (which can occur simultaneously), water ingress from the ground is potentially more severe as it is more likely to affect the structural integrity of the floor. Structural calculations may need to be carried out to ensure that the floor (including any lateral support provided at the perimeter) has the necessary strength to resist uplift forces without excessive deformation or cracking.

6.4.1 *Water exclusion strategy*

When applying a "water exclusion strategy" (i.e. minimising water ingress through ground floor slabs), for predicted water depths above the floor of greater than 0.3m, it is important to carry out structural checks assuming a flood depth of 1m minimum above the slab, even in areas where the design flood water depth is lower. Usual safety factors must be applied in all such calculations (floors and walls). Laboratory evidence on small slabs (0.5m by 0.5m) indicated that 150mm thick concrete slabs on supporting soil can withstand such forces without allowing water ingress. However, for larger slabs, uplift forces may cause deformation and induce cracking and lead to preferential paths for water ingress.

General advice for resilient design

Ground supported floors are the preferred option and concrete slabs of at least 150mm thickness should be specified for non-reinforced construction. Hollow slabs are not suitable if the elements are not effectively sealed.

Suspended floors may be necessary where ground supported floors are not suitable, namely in shrinkable/expanding soils (e.g. clay) or where the depth of fill is greater than 600mm. Uplift forces caused by flood water may affect the structural performance of a floor. Suspended floors are generally not recommended in flood-prone areas, for the following reasons:

- the sub-floor space may require cleaning out following a flood, particularly a sewer flood. In order to aid this process and where accumulation of polluted sediment is expected, the sub-floor space should slope to an identified area and be provided with suitable access
- if cleaning is required, floor finishes may need to be removed to provide access to the sub-floor space. Cheaper, sacrificial, finishes would be the best option.
- the steel reinforcement in the concrete beams of 'beam and block' floors may be affected by corrosion and its condition may need to be assessed following repeated or prolonged floods.

Suspended timber floors, particularly when including timber engineered joists, are not generally recommended in flood prone areas because most wooden materials tend to deform significantly when in contact with water and therefore may require replacement. Rapid drying can also cause deformation and cracking.

Reinforced concrete floors are acceptable but may be prone to corrosion of any exposed steel in areas of prolonged flooding.

Hardcore and blinding: good compaction is necessary to reduce the risk of settlement and consequential cracking.

Damp Proof Membranes (d.p.m.) should be included in any design to minimise the passage of water through ground floors. Impermeable polythene membranes should be at least 1200 gauge to minimise ripping. Effective methods of joining membrane sections are overlaps of 300mm, and also taping (mastic tape with an overlap of 50mm minimum). Care should be taken not to stretch the membrane in order to retain a waterproof layer. Experience in Scotland has indicated that welted joints in the d.p.m. are an effective jointing solution.

Insulation materials: Water will lower the insulation properties of some insulation materials. Floor insulation should be of the closed-cell type to minimise the impact of flood water. The location of insulation materials, whether above or below the floor slab, is usually based on either achieving rapid heating of the building or aiming for more even temperature distribution with reduced risk of condensation. Insulation placed above the floor slab (and underneath the floor finish) rather than below would minimise the effect of flood water on the insulation properties and be more easily replaced, if needed. However, water entry may cause insulation to float (if associated with low mass cover) and lead to debonding of screeds.

No firm guidance can be provided on best location for insulation where the primary source of flooding is from groundwater. For other types of flooding, placing insulation below the floor slab may be adequate but it is important to recognise that the characteristics of the insulation may be affected by the uplift forces generated by the flood water.

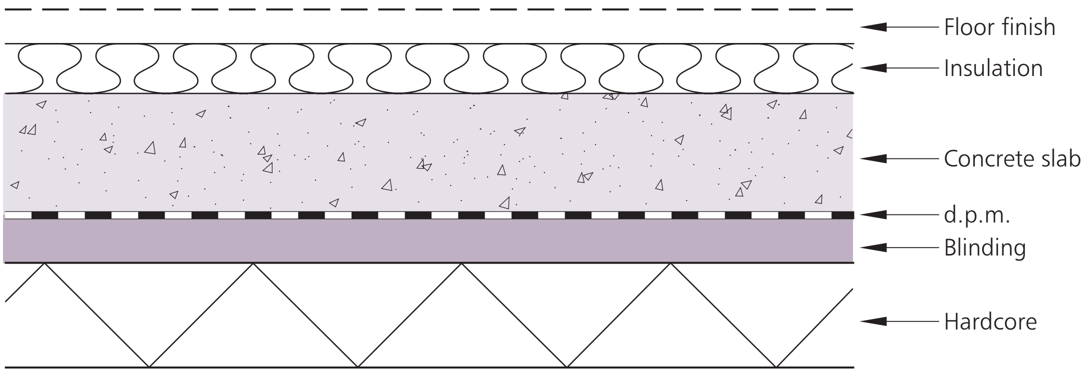
Floor finishes: suitable floor finishes include ceramic or concrete-based floor tiles, stone, and sand/cement screeds. All tiles should be bedded on a cement-based adhesive/bedding compound and water resistant grout should be used. Concrete screeds above polystyrene or polyurethane insulation should be avoided as they hinder drying of the insulation material. Suitable materials for skirting boards include ceramic tiles and PVC. Ceramic tiles are likely to be more economically viable and environmentally acceptable.

Floor sump: provision of a sump and small capacity automatic pump at a low point of the ground floor is recommended in cases where the expected probability of flooding in any one year is 20% or a frequency of flooding of more than once in five years (see Section 4). This system will help the draining process and speed up drying but it may only be effective for shallow depth flooding. The dimensions of the sump and its operational procedure would be calculated and agreed with the planning authority based on the predicted volumes of water to be drained.

Services: under floor services using ferrous materials should be avoided.

Recommended ground-supported and acceptable suspended floor arrangements are presented in Figures 6.4 to 6.6. If suspended timber flooring is a favoured option, then a combination of construction elements that is likely to minimise problems associated with flooding is shown in Figure 6.6. This is referred to as a “Restricted option”

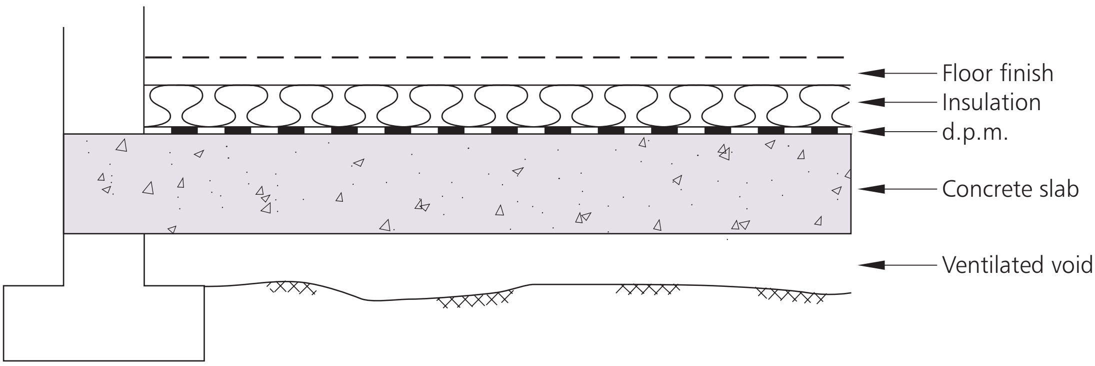
Figure 6.4 **Ground-supported floor – Preferred option**



- Hardcore bed at least 100mm thick of well compacted inert material, blinded with fine inert material to provide a smooth base
- Damp proof membrane of polythene at least 1200 gauge
- Concrete slab at least 150mm thick
- Insulation as rigid closed-cell material
- Ceramic tiles or stone floor finishes and skirting boards.

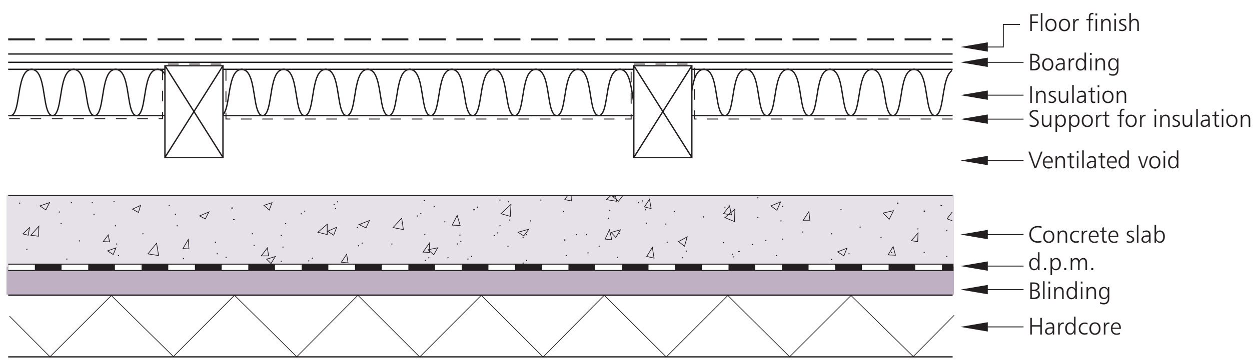
Figure 6.4 shows floor insulation above slab and there is laboratory evidence to support this location but there is currently no sound evidence to prevent the use of below slab insulation.

Figure 6.5 **Suspended Concrete Floor – Acceptable option**



- Reinforced concrete slab at least 150mm thick and complying with structural requirements for uplift forces
- Damp proof membrane of polythene at least 1200 gauge
- Insulation as rigid closed-cell material
- Ceramic tiles or stone floor finishes and including skirting boards.

Figure 6.6 **Suspended Timber Floor – Restricted option**



- Hardcore bed at least 100mm thick of well compacted inert material, blinded with fine inert material to provide a smooth base
- Concrete slab at least 150mm thick
- Insulation as rigid, closed cell material and supported with battens, plastic mesh or corrosion-resistant fixings
- Boarding consisting of WBP Plywood and preservative treated timber
- Stainless steel hangers

6.4.2 Water entry strategy

General advice for resilient design

Materials that retain their integrity and properties when subjected to flood water (such as concrete) or those that can be easily replaced (sacrificial materials), should be specified. Construction should allow easy access for cleaning, (e.g. below suspended floors), and drainage.

Concrete ground-supported floors are the preferred option and concrete slabs of at least 100mm thickness should be specified.

Suspended floors may be necessary where ground-supported floors are not suitable, namely in shrinkable/expanding soils (e.g. clay soils) or where the depth of fill is greater than 600mm. In cases of prolonged floods, where flood water is heavily silted, or from sewer flooding, the sub-floor space may require cleaning out following a flood; to aid this process, it should slope to an identified low point and be provided with suitable access. If cleaning is required, floor finishes may need to be removed to provide access to the sub-floor space and therefore cheaper, sacrificial, finishes would be the best option. Alternatively, external access to the sub-floor space can be considered as a design option.

Suspended steel floors may be adequate provided they incorporate resilient features such as anti-corrosion properties and comply with required structural capability.

Suspended timber floors, particularly when including timber engineered joists, are not generally recommended in flood prone areas because most wooden materials tend to deform significantly when in contact with water and therefore may require replacement. Rapid drying can also cause deformation and cracking.

Hardcore and blinding: good compaction should be achieved to reduce the risk of settlement and consequential cracking.

Damp Proof Membranes (d.p.m.) should be included in any design to minimise the passage of water through ground floors. Impermeable polythene membranes should be at least 1200 gauge to minimise ripping. Effective methods of joining membrane sections are: overlaps of 300mm or taping with mastic tape with an overlap of 50mm minimum. Care should be taken not to stretch the membrane in order to retain a waterproof layer. Experience in Scotland has indicated that welted joints in the d.p.m. are an effective jointing solution but the quality of the welts is very dependent on workmanship.

Insulation materials: Water will lower the insulation properties of some insulation materials. Floor insulation should be of the closed-cell type to minimise the impact of flood water. The location of insulation materials, whether above or below the floor slab, is usually based on either achieving rapid heating of the building or aiming for more even temperature distribution with reduced risk of condensation. It is recommended that insulation be placed above the floor slab (and underneath the floor finish) rather than below would minimise the effect of flood water on the insulation properties and be more easily replaced, if needed.

Floor finishes: there are two possible approaches that depend on an assessment of the likely frequency of flooding and cost of material and installation: use of sacrificial materials or reliance on high quality durable materials – see Section 4. Sacrificial floor finishes can include timber flooring and soft furnishings such as carpets. Materials that are likely to withstand exposure to floodwater without significant deterioration are ceramic or concrete-based floor tiles, marble or stone. All tiles should be set on a bed of sand and cement render and water resistant grout should be used. Concrete screeds above polystyrene or polyurethane insulation should be avoided as they hinder drying of the insulation material due to the relative impermeability.

Suitable materials for skirting boards include ceramic tiles and PVC. Ceramic tiles are likely to be more economically viable and environmentally acceptable. Replacement timber may be a suitable option, for cases where a strategy to use of sacrificial materials is adopted.

Floor sump: provision of a sump and small capacity pump in the floor at a low point of the ground floor is recommended in cases where the expected frequency of flooding is high; this system will help the draining process and speed up drying but it may only be effective for shallow depth flooding. The dimensions of the sump and its operational procedure would be calculated and agreed with the Planning Authority based on the predicted volumes of water to be drained.

Services: under floor services using ferrous materials should be avoided.

Figures 6.4 and 6.5 illustrate recommended floor designs for the water-entry strategy.

6.5 Walls

The recommendations given in this section on wall construction are based primarily on recent laboratory investigations, but are supported by expert opinion and experience from the building industry – see Chapter 7. The laboratory tests covered 16 wall panels (approximately 1.1m high by 1m wide) of composite construction subjected to 1m head of water and then allowed to dry naturally. This is not an exhaustive list of constructions and other wall designs may also have adequate resilience characteristics.

Table 6.2, based on the laboratory evidence, classifies wall components as good, medium or poor with regard to water penetration, surface drying and structural integrity.

Definitions of the characteristics used in Table 6.2 are:

- water penetration – the leakage (rate and volume) through the entire wall thickness (note that this is different from “water absorption”)
- drying ability – the capability to regain its original surface moisture condition (assessed by the average drying rate and the time taken to reach the original value)
- retention of pre-flood dimensions, integrity – the lack of deformation or change in form or appearance of the wall panel.

Table 6.2 **Flood resilience characteristics of walls (based on laboratory testing)**

Material	Resilience characteristics*		
	Water penetration	Drying Ability	Retention of pre-flood dimensions, integrity
External face			
Engineering bricks (Classes A and B)	Good	Good	Good
Facing bricks (pressed)	Medium	Medium	Good
Internal face			
Concrete blocks	Poor	Medium	Good
Aircrete	Medium	Poor	Good
Cavity insulation			
Mineral fibre	Poor	Poor	Poor
Blown-in expanded mica	Poor	Poor	Poor
Rigid PU foam	Medium	Medium	Good
Renders/Plaster			
Cement render – external	Good	Good	Good
Cement/lime render – external	Good	Good	Good
Gypsum Plasterboard	Poor	Not assessed	Poor
Lime plaster (young)	Poor	Not assessed	Poor

* Resilience characteristics are related to the testing carried out and exclude aspects such as ability to withstand freeze/thaw cycles, cleanability and mould growth

6.5.1 Water exclusion strategy

This strategy is applicable to design flood depths of up to 0.3m or up to 0.6m, if allowed by the structural assessment of the design.

General advice for resilient design

Ensure high quality workmanship at all stages of construction.

Masonry walls:

Ensure mortar joints are thoroughly filled to reduce the risk of water penetration. If frogged bricks are used, they should be laid frog up so that filling becomes easier and coverage more certain. Bricks manufactured with perforations should not be used for flood resilient design.

Where possible, use engineering bricks up to predicted flood level plus one course of bricks to provide freeboard (up to maximum of 0.6m depth above floor level); this will increase resistance to water penetration. Blocks (and dense facing bricks) have much improved performance when covered with render.

Aircrete blocks allow less leakage than typical concrete blocks but concrete blocks dry more quickly. Therefore, design of blockwork walls needs to take into account these two opposite types of behaviour and consider whether drying or resistance to water is most relevant in each situation. For a "water exclusion strategy", the expected amount of leakage is minimal and therefore, Aircrete blocks are recommended, although they may retain moisture for longer than concrete blocks, Compared with heavier blocks, Aircrete may offer less restraint to floor/slab edges which under the action of uplift forces could promote the opening up of floor/wall junctions.

Do not use highly porous bricks such as hand made clay bricks.

Solid masonry walls are a good option but will need to be fitted with internal or external wall insulation in order to comply with Building Regulations.

Clear cavity walls, i.e. with no insulation in the cavity, have better flood resilience characteristics than filled or part filled cavity walls as they dry more quickly. The requirements for insulation can be satisfied by external insulated renders or internal thermal boards.

There is evidence that thin layer mortar construction (or thin joint, as it is also commonly known) is a good flood resilience option.

Framed walls: Avoid timber framed walls containing construction materials that have poor performance in floods, for example oriented strand board and mineral fibre insulation. Timber framed walls are not recommended in a "water exclusion strategy". Steel framed walls may offer a suitable alternative option but specialist advice needs to be sought on how to incorporate resilient materials/construction methods in the design, in particular with regard to the insulation.

Reinforced concrete wall/floor construction should be considered for flood-prone areas, i.e. where the frequency of flooding is predicted to be high (see Chapter 4). This form of construction is effective at resisting forces generated by floodwater and will provide an adequate barrier to water ingress (provided service ducts and other openings into the building are adequately sealed). Design details for this type of construction are beyond the scope of this document.

External renders are effective barriers to water penetration and should be used with blocks (or bricks) at least up to the predicted flood level plus the equivalent of a course of bricks as freeboard. Structural checks may be necessary to ensure stability, because of the external water pressures that could occur for design flood depths above 0.3m. External cement renders with lime content (in addition to cement) can induce faster surface drying.

Insulation:

External insulation is better than cavity insulation because it is easily replaced if necessary.

Cavity insulation should preferably incorporate rigid closed cell materials as these retain integrity and have low moisture take-up. Other common types, such as mineral fibre batts, are not generally recommended as they can remain wet several months after exposure to flood water which slows down the wall drying process. Blown-in insulation can slump due to excessive moisture uptake, and some types can retain high levels of moisture for long periods of time (under natural drying conditions).

Internal linings:

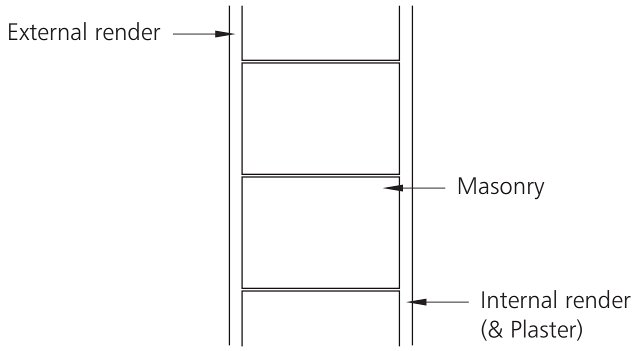
Internal cement renders (with good bond) are effective at reducing flood water leakage into a building and assist rapid drying of the internal surface of the wall. The extent to which render prevents drying of other parts of the wall is not currently clear. This may be important, particularly for solid wall construction. This applies also to external renders.

Avoid standard gypsum plasterboard as it tends to disintegrate when immersed in water. Splash proof boards do not necessarily offer protection against flood waters, which may remain for some time and exert pressure on the board.

Anecdotal evidence suggests that internal lime plaster/render can be a good solution. Lime plaster depends on contact with the air to set and harden. Because of this, full strength lime plaster, which typically requires over 6 months, was not possible to test. Consequently, no assurance can be given for its performance. Tests performed when young showed that it crumbles very easily under high water pressure.

Examples of recommended wall arrangements are presented in Figures 6.7 to 6.9 below.

Figure 6.7 Solid External Walls



– External cement based render, preferably with lime content. Composition depends on masonry. The following mixes have good resilient properties:

1 cement : 6 sand on bricks;

1 cement : 4 sand: 1/2 lime on concrete blockwork or bricks;

1 cement : 6 sand: 1 lime on Aircrete blocks.

– Masonry with minimum thickness of 300mm (thin mortar joint construction using Aircrete blocks is effective as demonstrated in laboratory tests) or alternatively reinforced concrete wall

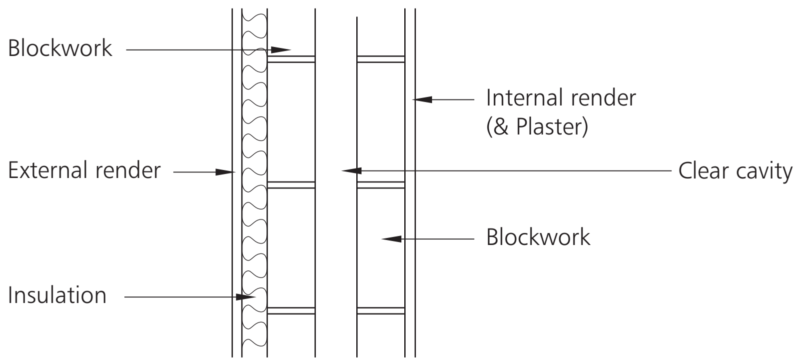
– Internal cement-based render, preferably with lime content. Composition depends on masonry; the following mix is effective for flood resilience:

1 cement : 6 sand: 1 lime on Aircrete.

Apply external and internal renders, following good practice guidance, ensuring minimum total thickness of 20mm and at least two coats.

– Use external insulation in preference to internal insulation.

Figure 6.8 Cavity External Walls – Clear cavity



Clear cavity

– External cement based render, preferably with lime content. Composition depends on masonry; the following mixes are effective for flood resilience:

1 cement: 4 sand: 1/2 lime on concrete blockwork (or bricks);

1 cement: 6 sand: 1 lime on Aircrete.

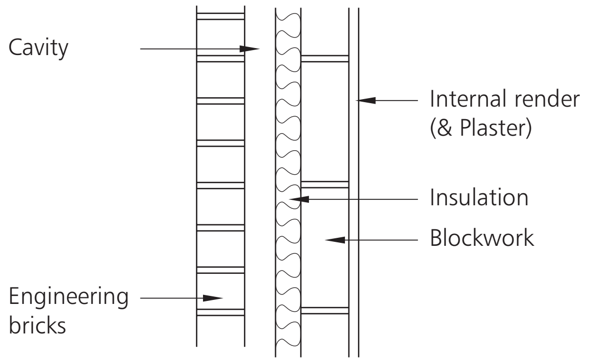
Apply render following good practice guidance, ensuring minimum total thickness of 20mm and two coats.

– Internal cement based render, preferably with lime content. Composition depends on masonry. The following mix works well:

1 cement: 6 sand: 1 lime on Aircrete.

– Stainless steel wall ties should be used to minimise corrosion and consequent staining.

Figure 6.9 Cavity External Walls – Part-filled cavity



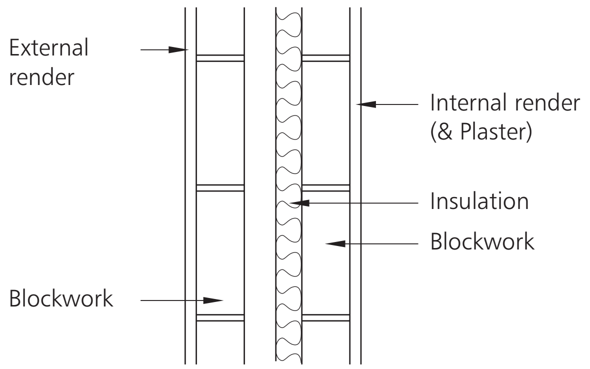
Option A

Part-filled cavity

Part-filled cavity – Option A

- External face consisting of engineering bricks up to required level for flood protection (up to 0.6m maximum above floor level plus one course). Other external facing materials can be used above this level, but ensure interface is watertight.
- Rigid insulation.
- Internal face consisting of blocks.
- Internal cement based render, preferably with lime content. Composition depends on masonry; the following mix is effective:

  1 cement : 6 sand: 1 lime on Aircrete.
- Ensure stainless steel wall ties are used to minimise corrosion and consequent staining.
- Sacrificial plasterboard can be used, but it needs to be removed between ground floor and flood level. The board should be fitted horizontally to make removal easier. In some cases a dado rail can be used to cover the joints.



Option B

Part-filled cavity – Option B

- External cement based render, preferably with lime content. Composition depends on masonry; the following mixes are effective:

  1 cement : 4 sand: $^{1}/_{2}$ lime on concrete blockwork

  1 cement : 6 sand: 1 lime on Aircrete.
- External face consisting of blocks.
- Rigid insulation.
- Internal face consisting of blocks.
- Internal cement based render, preferably with lime content. Composition depends on masonry; the following mix is effective for flood resilience:

  1 cement : 6 sand: 1 lime on Aircrete.
- Ensure stainless steel wall ties are used to minimise corrosion and consequent staining.

6.5.2 *Water entry strategy*

This strategy is applicable to design flood depths above 0.6m, or above 0.3m if the structural assessment of the design shows that the integrity of the building would be compromised by a "water exclusion strategy".

General advice for resilient design

Ensure high quality workmanship at all stages of construction.

Masonry walls:

Use good quality facing bricks for the external face of cavity walls.

Do not use soft bricks, such as hand made clay bricks, which can easily crumble when subjected to water.

Concrete blocks dry more quickly than Aircrete blocks. However, Aircrete blocks allow less leakage. Therefore, design of blockwork walls needs to take into account these two opposite types of behaviour and consider whether drying or resistance to water is most relevant in each situation. For a "water entry strategy" which is aimed at allowing water passage through the property, concrete blocks are recommended.

Clear cavity walls, i.e. with no insulation, have better resilience characteristics than filled or part filled cavity walls as they dry more quickly.

Framed walls: Avoid timber framed walls containing construction materials that have poor performance in floods, namely oriented strand board and mineral fibre insulation. Timber framed walls are generally not recommended, unless a sacrificial approach is adopted whereby some materials will be stripped to allow drying.

Steel framed walls may offer a suitable alternative option but specialist advice needs to be sought on how to incorporate resilient materials/construction methods in the design. The possible use of bituminous paint on steel plates may be a means of preventing corrosion.

External renders should not be used as they provide a barrier to water penetration and may induce excessive differences in depth between outside and inside of the property resulting in possible structural problems.

Insulation:

External insulation is better than cavity insulation because it is easily replaced if necessary; however it is generally protected by rigid lining which may create a barrier to water.

Cavity insulation should incorporate rigid closed cell materials as these retain integrity and have low moisture take-up. Other common types, such as mineral fibre batts, are not generally recommended as they can remain wet several months after exposure to flood water which slows down the wall drying process. Blown-in insulation can slump due to excessive moisture uptake, and some types can retain high levels of moisture for long periods of time (under natural drying conditions).

Internal linings:

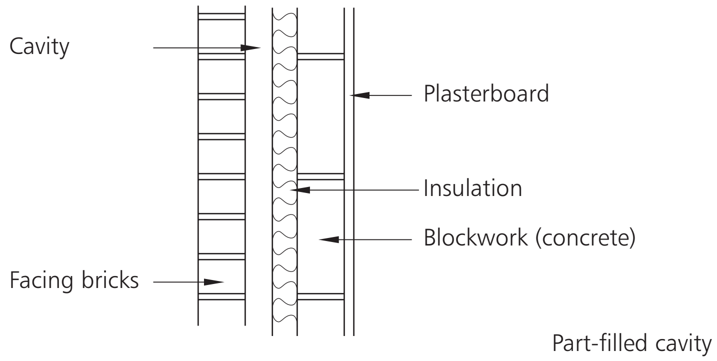
Avoid internal cement renders as these can prevent effective drying.

Use standard gypsum plasterboard up to the predicted flood level (plus freeboard of 50mm) as a sacrificial material. For this purpose, the use of a dado rail to separate the above and below flooded area may be useful. Splash proof boards do not necessarily offer better protection against flood waters, which may remain for some time and exert pressure on the board.

Above predicted flood level (plus freeboard) the use of plasterboard or internal cement renders is appropriate.

Anecdotal evidence suggests that internal lime plaster/render can be a good solution. Lime plaster depends on contact with the air to set and harden. Because of this, full strength lime plaster, which typically requires over 6months, was not possible to test. Consequently, no assurance can be given for its performance. Tests performed when young showed that it crumbles very easily under high water pressure.

Figure 6.10 **Cavity External Walls – Part-filled cavity with sacrificial plasterboard**



Part-filled cavity

- External face consisting of engineering bricks up to required level for flood protection (up to d.p.c.). Other external facing materials can be used above this level, but ensure transition is watertight.
- Rigid insulation
- Internal cement based render, preferably with lime content. Composition depends on masonry; the following mix is effective:

  1 cement : 6 sand: 1 lime on concrete blocks.
- Stainless steel wall ties should be used to minimise corrosion and consequent staining.
- Sacrificial plasterboard can be used, but it needs to be removed between ground floor to flood level. The board should be laid horizontally to make removal easier.

6.6 Doors and windows

Doors, windows and air vents are potential flow paths into properties.

General advice for resilient/resistant design

Doors: Raising the threshold as high as possible, while complying with level access requirements, should be considered as the primary measure. In addition, sealed PVC external framed doors should be used and, where the use of wooden doors is a preferred option, all effort should be made to ensure a good fit and seal to their frames.

Hollow core timber internal doors should not be used where the predicted frequency of flooding is high. Where sufficient flood warning is given, butt hinges, that allow internal doors to be easily removed and stored in dry areas prior to a flood, should be used. Where the frequency of predicted flooding is low or where there is no warning (e.g. overland or sewer flooding) it may be necessary to replace the doors after the flood.

Windows/patio doors: Windows and patio doors are vulnerable to flood water and similar measures to those used for doors should be taken. Special care should be taken to ensure adequate sealing of any PVC window/door sills to the fabric of the house. Of particular concern would be excessive water pressure on the glazing of patio doors. Double glazing conforming to the relevant standards would in principle adequately resist the pressures generated by flood waters; debris carrying flows may cause damage.

Air vents: special designs of air vent are available in the market to prevent water ingress in circumstances where the predicted flood depth is low (i.e. < 0.3m); e.g. periscopic air vent, see Figure 6.11. Careful consideration should be given to effectively sealing any associated joints.

Figure 6.11 **Periscopic air vent (courtesy Severn Trent Water)**

6.7 Fittings

6.7.1 Water exclusion strategy

General advice for resilient design

The main principle is to use durable fittings that are not significantly affected by water and can be easily cleaned (e.g. use of plastic materials or stainless steel for kitchen units). The cost of these units may need to be balanced against the predicted frequency of flooding.

Place fittings (e.g. electrical appliances, gas oven) on plinths as high as practicable above floor so that they are out of reach of flood water.

Ensure adequate sealing of joints between kitchen units and surfaces to prevent any penetration of water behind fittings.

Ensure high quality workmanship in the application of fittings.

An illustrative example of a resilient kitchen is given in Figure 6.12, e.g. raised oven and fridge/freezer on plinth and use of ceramic tiles on the floor. In this figure it can be seen that the kitchen units are made of stainless steel. Due to its relatively high cost this is a suitable solution only in cases where the predicted frequency of flooding is high (see Chapter 4).

More details are given in 'Standards for the repair of buildings following flooding' (CIRIA, 2005a) or in web sites such as the 'Guide to flood resilient repairs', promoted by Norwich Union (Norwich Union, web site).

Figure 6.12 **Main kitchen appliances (such as oven and fridge/freezer) placed above floor level (courtesy of Norfolk County Council and FLOWS Project)**

6.7.2 *Water entry strategy*

General advice for resilient design

Although a sacrificial approach can be adopted whereby fittings are designed to be replaced after a flood, it is advisable to specify durable fittings that are not appreciably affected by water and can be easily cleaned (e.g. use of plastic materials or stainless steel for kitchen units). The cost of these units may need to be balanced against the predicted frequency of flooding. Avoid wood fibre based carcases and use easily removable solid wood doors and drawers.

Place fittings (e.g. electrical appliances, gas oven) as high as practical above floor to minimise the risk of being affected by flood water.

When allowing water in, it is important to provide means for effective drainage and cleaning. Providing gaps behind kitchen units will facilitate drainage and will allow access for forced drying, if proved to be necessary.

Ensure high quality workmanship in the application of fittings.

More details are given in 'Standards for the repair of buildings following flooding' (CIRIA, 2005a) or in web sites such as the 'Guide to flood resilient repairs', promoted by Norwich Union (Norwich Union web site).

6.8 Services

General advice for resilient design

Where possible, all service entries should be sealed (e.g. with expanding foam or similar closed cell material).

Pipework: Closed cell insulation should be used for pipes which are below the predicted flood level.

Drainage services: Non-return valves are recommended in the drainage system to prevent back-flow of diluted sewage in situations where there is an identified risk of the foul sewer surcharging. Maintenance of these valves is important to ensure their continued effectiveness.

Water, electricity and gas meters: should be located above predicted flood level.

Electrical services: electrical sockets should be installed above flood level for ground floors to minimise damage to electrical services and allow speedy re-occupation (see Figure 6.13. Note a dado rail which provides a limit for replacement of any wall covering). Electric ring mains should be installed at first floor level with drops to ground floor sockets and switches.

Heating systems: boiler units and ancillary devices should be installed above predicted flood level and preferably on the first floor of two-storey properties. Underfloor heating should be avoided on ground floors and controls such as thermostats should be placed above flood level. Conventional heating systems, e.g. hot water pipes are unlikely to be significantly affected by flood water unless it contains a large amount of salts. The less common, hot air duct heating would remain effective provided it is installed above the design flood level.

Communications wiring: wiring for telephone, TV, Internet and other services should be protected by suitable insulation in the distribution ducts to prevent damage. Any proposed design solution for flood insulation on all potentially vulnerable wiring should be discussed with the relevant service providers.

Figure 6.13 **Raised sockets (courtesy of Norfolk County Council and FLOWS project); note also PVC skirting board and tiled floor**

PART 4 – SUPPORTING INFORMATION

7 The evidence base

This guidance document has been produced by a project carried out under the Communities and Local Government Building Regulations Research Programme and the Defra/Environment Agency Flood and Coastal Erosion Research Management Programme, aimed at incorporating flood resilience into the Building Regulations and providing advice for new buildings. It is the result of a synthesis of information from different sources: published literature, review of existing practice, experiential information and laboratory testing. This supporting information is contained in three reports listed in the table below. These reports are available via the CIRIA flooding website:

Work Package	Content	Reference
WP2	Literature review	CIRIA 2005b
WP5	Laboratory testing	CIRIA 2006b
WP6	Collation and analysis of post-flood observational data	CIRIA 2007

The *literature review* found general agreement on the factors and techniques that need to be considered for flood resilient building design (CIRIA 2005a, 2005b), based on expert opinion and common sense. However, much of this advice was based on extrapolations of known behaviour and anecdotes, lacking scientific underpinning. There is little published scientific research into the performance of construction materials under flood conditions, and no significant efforts to collate and analyse experiential data. This was addressed by the project, in the form of new laboratory testing of building materials and constructions, and the collation of experiential evidence from industry. This new evidence supports this guidance.

The *experiential evidence* on flooded properties was collated from personal views based on experience and observation, technical data from the flood damage industry on the drying of properties and appropriate methods of construction from the building industry (CIRIA, 2007). The majority of effort and interest has been concerned with the retrofit of resilient measures for existing properties, in response to the severe flooding since 1998. It is only more recently that consideration has been given to the incorporation of resilience measures for new build. Much of the recent best practice guidance relates to the fixtures and fittings, and post-flood repairs.

An extensive programme of *laboratory tests* produced for the first time quantitative baseline information on the behaviour of building materials and composites (floors and walls) when subjected to flood conditions (CIRIA, 2006b). Detailed time-varying data for water leakage/seepage and surface drying were collected. Examples of the data collected and of the testing work carried out are given in Figures 7.1 to 7.5. Note that the water penetration data shown for individual materials are given as "seepage", whereas the term "leakage" is used for composite walls given the number of different materials present in this latter case.

Figure 7.1 Example of data collected on building materials: variation of seepage rate with time

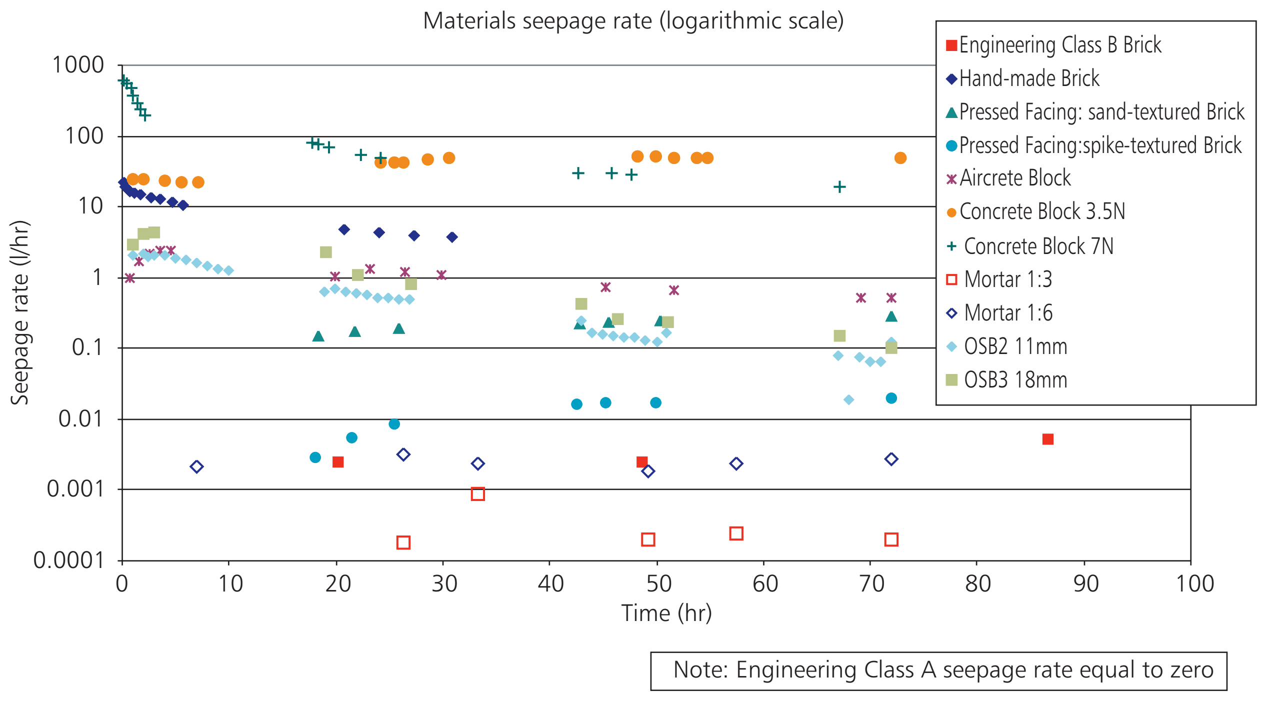


Figure 7.2 Example of effect of render on leakage rate through brick wall

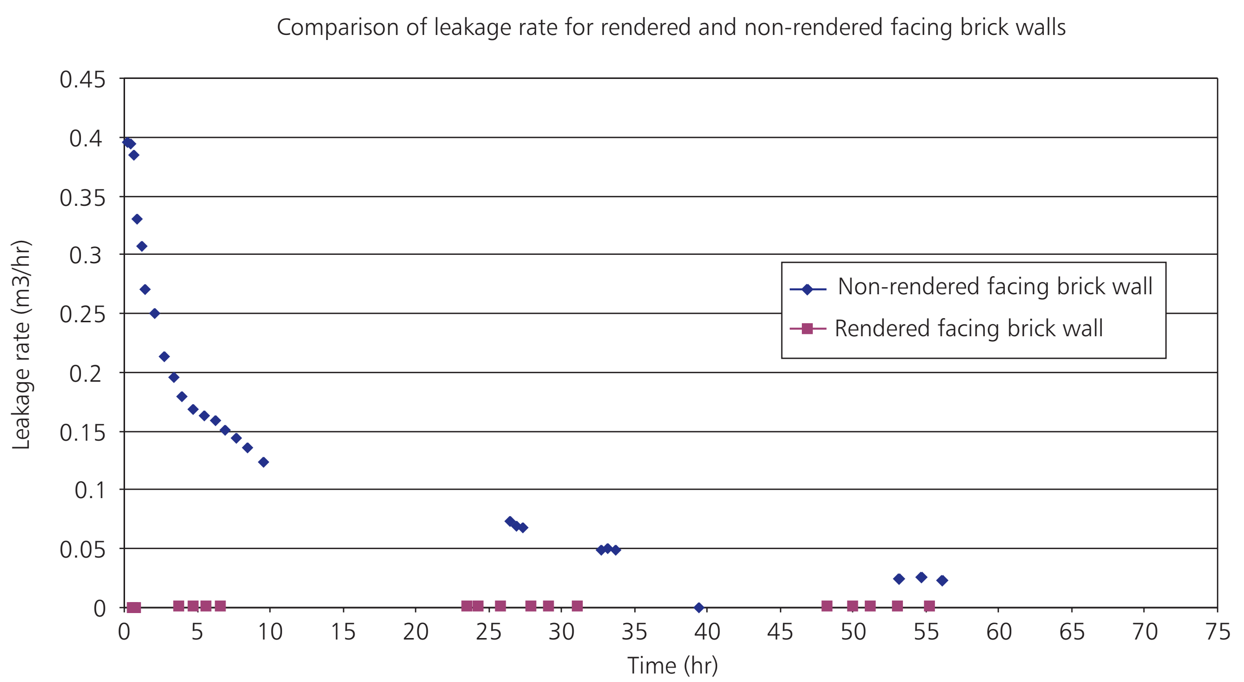


Figure 7.3 **Example of effect of render on surface drying of external brick wall (reduction in surface moisture; 1.0 equivalent to pre-flood condition)**

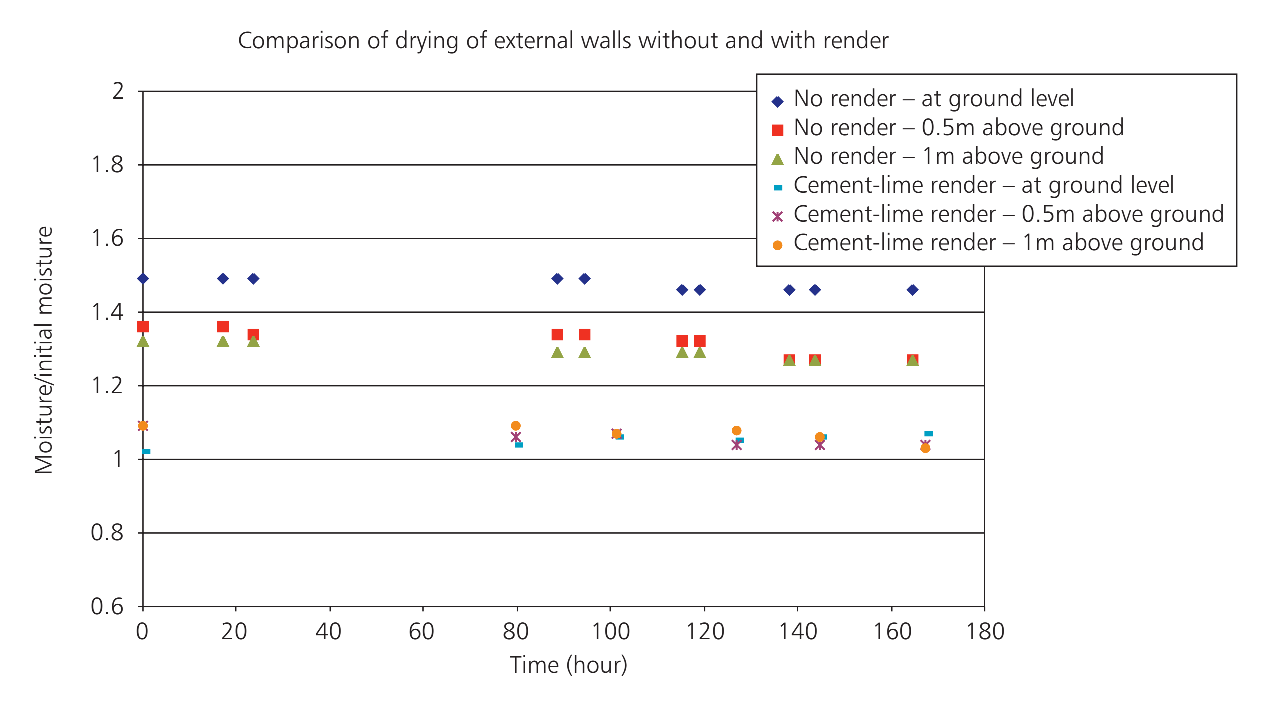


Figure 7.4 **Constructing wall test panels in the laboratory test rigs**

Figure 7.5 Testing a cavity masonry wall

The conditions under which the materials, walls and floors were investigated were as realistic as possible to mimic severe floods, but did not include the effects of high sediment loads, debris impacts, strong currents or waves. For example, sample walls of 1.1m by 1m were exposed to 1m depth of water for four days (flooding on the external face for three days, followed by one day flooding on the internal and external faces) to simulate typical flooding of a property. This was followed by six days natural drying in the laboratory environment.

Walls with different characteristics showed widely varied behaviour. For example, in terms of leakage, a typical masonry cavity wall consisting of pressed facing bricks on the external face and concrete blocks on the internal face when subjected to 1m head of water can leak at a rate of 400 litres/hour (or 360 litres/hour/metre of wall). It was found that leakage rates tend to reduce significantly with time but if this rate were maintained, a 3m by 3m room would reach a water depth of over 0.2m in only five hours (assuming water could not enter the property through other surfaces). If engineering bricks were used on the external face (with all other characteristics remaining the same) the depth of water inside the room would only be 0.02m. This illustrates the importance of incorporating flood resilient materials.

Given the wide range of building materials and types of wall and floor construction, it was necessary to limit testing to the types most commonly in use in England and Wales for domestic new build. Inevitably, there may be other materials and methods of construction which are resilient to flooding, which have not been considered.

It is worth noting that the testing of walls involved young wall panels, typically seven days old. As such, they may not have reached their full strength, and their resilience properties could still improve with time. Conversely, older walls may experience settlement and thus develop cracks, which could reduce their resilience properties. This was a limitation imposed by the number of test walls and the time allocated for the testing programme.

In spite of the above limitations, the test programme carried out was instrumental in providing much scientific data which was lacking. In many cases, it confirmed general perceptions; in others it highlighted the importance of verifying existing assumptions on material behaviour.

8 References and sources of information

BRE (1997). Repairing flood damage. Good repair guide 11. Parts 1 to 4, Construction Research Communications Ltd., ISBN 1 86081 1507

BSI (2003) PAS 1188 Flood Protection Products (1188-1: building apertures; 1188-2: temporary and demountable products; 1188-3: building skirt systems). BSI, London May 2003

BSI (2005). PAS 64 Professional water damage mitigation and initial restoration of domestic dwellings, BSI, London, May 2005

CIRIA (1995). Water-Resisting Basement Construction – A Guide. Report 139. Construction Industry Research and Information Association, UK

CIRIA (2000). Sustainable urban drainage systems – design manual for England and Wales, C522, by P. Martin et al, Construction Industry Research and Information Association, UK

CIRIA and EA (2003). Flood protection products – a guide for homeowners. CIRIA, London and Environment Agency, London

CIRIA (2004). Sustainable drainage systems. Hydraulic, structural and water quality advice, C609, by S Wilson, R Bray, P Cooper. Construction Industry Research and Information Association, UK

CIRIA (2005a). Standards for the repair of buildings following flooding, C 623, by S. Garvin, J. Reid, M. Scott Construction Industry Research and Information Association, UK

CIRIA (2005b). Improving the Flood Resilience of Buildings through Improved Materials, Methods and Details. Report Number WP2c – Review of Existing Information and Experience (Final Report), by J. Wingfield, M. Bell and P. Bowker, June 2005

CIRIA (2006a). Designing for exceedance in urban drainage – good practice, C635, by D. Balmforth, C. Digman, R. Kellagher and D. Butler, Construction Industry Research and Information Association, UK

CIRIA (2006b). Report no. WP5C Final report – Laboratory tests, by M. Escarameia, A. Karanxha and A. Tagg, July 2006

CIRIA (2007). Report no. WP6 – Collation and analysis of post-flood observational data, by A. Tagg, M. Escarameia, J. Molinero Ortiz, 2007

CIRIA Flooding web site www.ciria.org/flooding/

Department for Communities and Local Government (2006). Planning Policy Statement 25: Development and Flood Risk, TSO, December 2006

Department for Communities and Local Government (2007). Development and Flood Risk: A Practice Guide Companion to PPS25 'Living Draft' 19 February 2007, www.communities.gov.uk

Defra (2005). Flood Risks to People Phase 2. R&D Guidance Document, FD2321/TR2, April 2005

Defra (2006). Making Space for Water. Update Newsletter, July 2006

Department of the Environment Northern Ireland web site: www.doeni.gov.uk. Planning Policy Statement 15, 2006

DTI (2004). Foresight Future Flooding Report, Office of Science and Technology, London

DTLR (2001). Planning Policy Guidance Note 25 - Development and Flood Risk, TSO, London

Environment Agency web site: www.environment-agency.gov.uk.

Flood Hazard Research Centre (2005). The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques, Middlesex University Press

Flood Repairs Forum (2006). Repairing flooded buildings, Flood Repairs Forum

National Flood Forum web site: www.floodforum.org.uk/flood_forum/floodprotection

NHBC Standards (2006). Published by NHBC, UK

Norwich Union web site www.floodresilienthome.co.uk (accessed in September 2006). A Guide to Flood Resilient Repairs

ODPM (2003). Preparing for floods. Interim guidance for improving the flood resistance of domestic and small business properties. 2003 Reprint

The Building Regulations 2000. The Stationery Office
- Approved Document A 'Structure'
- Approved Document C 'Site preparation and resistance to contaminants and moisture'
- Approved Document H 'Drainage and waste disposal'
- Approved Document J 'Combustion appliances and fuel storage systems'
- Approved Document M 'Access to and use of buildings'

The Scottish Building regulations
- Standard 3.3 Flooding and ground water

The Scottish Executive web site: www.scotland.gov.uk
- Scottish Planning Policy (SPP 7): Planning and flooding
- Water Environment and Water Services (Scotland) Act 2003, The Stationery Office Ltd
- Planning Advice Note (PAN 69): Planning and building standards

Scottish Buildings Standards Agency
- Design guidance on flood damage to buildings (1996)

Stationery Office (1999). Accessible Thresholds in New housing: guidance for house builders and designers. March 1999

TSO (1984). Building Act 1984. The Stationery Office, London, 1984

TSO (2004). Sustainable and Secure Buildings Act 2004. The Stationery Office, London, 2004

USACE (1988). Flood Proofing Tests – Tests of Materials and systems for Floodproofing structures. US Army Corps of Engineers, USA

Welsh Assembly Government web portal. www.planningportal.gov.uk/wales

WRc (2006). Sewers for adoption – a design and construction guide for developers. 6th Edition, WRc, ISBN 1 898920 57 3

Appendix: Project details

The project was carried out by a consortium managed by **CIRIA** and comprising **HR Wallingford Ltd, Leeds Metropolitan University, WRc and Waterman Group**.

Authors	**Pam Bowker BA (Hons)** Pam Bowker has over 35 years' experience working at HR Wallingford in the river engineering environment, specialising in flood risk management and flood protection. She is now an independent consultant in flood management.
	Manuela Escarameia MSc CEng MICE EurIng Manuela Escarameia is a chartered civil engineer and Principal Engineer at HR Wallingford with 20 years' experience in hydraulic engineering with particular experience in hydraulic structures and drainage.
	Andrew Tagg BSc MSc CEng MICE MCIWEM Andrew Tagg is a Principal Engineer with HR Wallingford, and has over 25 years' experience working in all aspects of the water environment, particularly flood management, water resources and catchment management.

The research project was guided by a steering group, which comprised:

John Blanksby (Chair)	University of Sheffield
Michael Johnson	Communities and Local Government
Jonathan Chapman	Environment Agency
Neil Smith	NHBC
Margaret Burrup	Severn Trent Water Ltd.
Steve Ball	English Partnerships
Jackie Bennett	Council of Mortgage Lenders
Geoff Bayliss	Welsh Assembly Government
Robin Thompson	Defra

The members of the project consortium producing the other Work Packages leading up to and alongside this guidance were:

Malcolm Bell	Leeds Metropolitan University
Jez Wingfield	Leeds Metropolitan University
Nick Orman	WRc
Nick Price	WBC

Pam Bowker	Flood Risk Management Consultant (previously with HR Wallingford)
Andrew Tagg	HR Wallingford
Manuela Escarameia	HR Wallingford

This project was managed by Sarah Reid and Paul Shaffer and initiated by Marianne Copeland (nee Scott).

Project Funders

Department for Communities and Local Government
Environment Agency
English Partnerships
NHBC
Scottish Building Standards Agency
Council for Mortgage Lenders
Concrete Block Association
CIRIA Core Programme

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The following organisations also contributed either directly to this guidance document or to the earlier stages of the project, and their input is gratefully acknowledged.

ActionDry Emergency Services
AEA Technology (Communities and Local Government Project Officer)
Barratt Homes
Belfor
BRE
Brick Development Association
British Damage Management Association
Ceram Building Technology
Chartered Institution of Water and Environmental Management (CIWEM)
Countryside Properties Plc
Defra
Department of the Environment Northern Ireland
Elmhurst Energy Systems
Gravesham Borough Council
HBF
H & H Celcon Ltd
Jim Barrack Consulting
Wolverhampton University
Leadbitter Construction
Lincolnshire CC
Local Authority Building Control (LABC)
Munters
National Flood School
North Cornwall DC
Norwich Union
Oxford City Council
Rameses Associates Ltd
RIBA
Royal Haskoning
Swansea City Council
Tarmac Topblock Ltd
Tellinglime Products
The Concrete Centre
Trada Technology Ltd
UCL Centre for Sustainable Heritage
University College London
Xella
Welsh Assembly Government

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