



Federal Ministry for the  
Environment, Nature Conservation,  
Building and Nuclear Safety

# A Primer on Flood Protection

Protecting property and building wisely



# Imprint

## Published by

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)  
Public Relations Division · 11055 Berlin · Germany  
Email: [service@bmub.bund.de](mailto:service@bmub.bund.de) · Website: [www.bmub.bund.de/english](http://www.bmub.bund.de/english)

## Edited by

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)  
Division B I 5 (Civil Engineering, Sustainable Construction, Building Research) · Dipl.-Ing. (FH) Frank Cremer  
Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) within the Federal Office for Building and Regional Planning (BBR)  
Division II 6 Construction and Environment · Dr. Bernhard Fischer  
Ruiz Rodriguez + Zeisler + Blank GbR, Wiesbaden · Peter Zeisler  
Leibniz Institute of Ecological Urban and Regional Development (IOER), Dresden · Dr. Thomas Naumann, Sebastian Golz

## Design

Design Partner, Stuttgart

## Printed by

Bonifatius GmbH, Paderborn

## Picture credits

See page 63

## Date

August 2016

## First Print

1,000 copies

## Where to order this publication

Publikationsversand der Bundesregierung  
Postfach 48 10 09 · 18192 Rostock · Germany  
Tel.: +49 30 / 18 272 272 1 · Fax: +49 30 / 18 10 272 272 1  
Email: [publikationen@bundesregierung.de](mailto:publikationen@bundesregierung.de)  
Website: [www.bmub.bund.de/en/service/publications](http://www.bmub.bund.de/en/service/publications)

## Note

This publication is part of the public relations work of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. It is distributed free of charge and is not intended for sale. Printed on recycled paper.

# A Primer on Flood Protection

Protecting property and building wisely

This primer is not a textbook, and it is expressly not intended to serve as a regulation within the meaning of a building code or standard. In keeping with requirements to take own precautionary measures, as set forth in Article 5 of the Federal Water Act (WHG), it provides information conducive to well-founded decisions during and after flood events, made with a view to preventing or reducing damages.

Use of its information will not absolve anyone of their responsibility for their own decisions and for conscientious action.

We explicitly note that the explanations the primer offers on the behaviour of building materials and composite materials under the impacts of floods neither constitute / certify, nor eliminate / negate, any suitability of such materials under building law. Their purpose instead is to provide a basic understanding of the structurally relevant physical principles involved.

# Contents

	<b>Introduction</b> .....	<b>6</b>
<b>1</b>	<b>Summary</b> .....	<b>7</b>
	1.1 Floods – natural events .....	8
	1.2 Flood records and statistics.....	8
	1.3 Impacts of climate change on the flood situation .....	9
	1.4 Heavy rainfall events.....	11

## Part A: Aspects of precautionary flood protection

<b>2</b>	<b>Strategies for flood prevention and preparedness</b> .....	<b>12</b>
<b>3</b>	<b>The legal framework under water law</b> .....	<b>13</b>
<b>4</b>	<b>Area-related precautions and flood management</b> .....	<b>18</b>
<b>5</b>	<b>Technical flood protection</b> .....	<b>19</b>
	5.1 How technical flood protection systems function .....	19
	5.2 Cost-effectiveness of flood protection measures .....	20
	5.3 Possible ways in which protection systems can fail.....	20
	5.4 Flood protection in sewer systems / assuring proper drainage of wastewater and rainwater in inland areas.....	21
	5.5 Coastal protection .....	22

## Part B: Information for affected citizens and property owners

<b>6</b>	<b>Potential flood hazards, and building precautions</b> .....	<b>24</b>
	6.1 Precautionary building strategies .....	24
	6.2 When water enters buildings .....	25
	6.3 Water pressure and buoyancy.....	25
	6.4 Checking the structural stability of existing buildings.....	26
	6.4.1 Adequate building loads, wall / foundation dimensions .....	26
	6.4.2 Emergency flooding of buildings.....	27
	6.5 Currents.....	28
<b>7</b>	<b>Design recommendations for flood-adapted construction</b> .....	<b>29</b>
	7.1 Protecting buildings against entry of groundwater .....	29
	7.2 Protecting buildings against entry of sewage water (backwater).....	31
	7.3 Protecting buildings against entry of surface water .....	32
	7.4 The adaptation strategy – structural precautions in buildings.....	36
	7.4.1 Heating and electrical systems .....	36
	7.4.2 Protecting heating-oil tanks against flotation / buoyancy forces .....	37
	7.4.3 Storage and handling of other substances hazardous to water.....	38
<b>8</b>	<b>Flood resistance of building materials and layered / composite constructions</b> .....	<b>39</b>
	8.1 Basic principles .....	39
	8.2 Types of damage.....	39
	8.3 The behaviour of common building materials when exposed to flooding .....	41
	8.3.1 Natural stone.....	41
	8.3.2 Bricks and other ceramic products .....	42
	8.3.3 Cement-bound building materials.....	42
	8.3.4 Lime-bound building materials.....	43

8.3.5	Gypsum-bound building materials.....	43
8.3.6	Aerated concrete .....	43
8.3.7	Insulating materials.....	44
8.3.8	Wood and wood materials.....	44
8.3.9	Metal and glass materials.....	44
8.4	Walls, ceilings and floors .....	45
8.4.1	Exterior- / interior-wall structures.....	45
8.4.2	Ceiling and floor structures .....	47

## Part C: Flood preparedness and flood management

<b>9</b>	<b>Information provision.....</b>	<b>48</b>
9.1	Flood hazard maps: “Know the hazards” .....	48
9.2	Online information systems.....	49
9.3	Flood forecasting.....	50
<b>10</b>	<b>Behavioural precautions .....</b>	<b>51</b>
10.1	Personal alarm and action plans (flood checklist).....	51
10.2	Organising neighbourhood assistance .....	51
10.3	Flood-preparedness equipment .....	51
10.4	Moving furniture out of harm’s way .....	52
10.5	Emergency luggage and documents; emergency lodgings.....	52
<b>11</b>	<b>Flood management and recovery .....</b>	<b>53</b>
11.1	Protecting yourself.....	53
11.2	Documentation.....	53
11.3	Pumping water out of affected areas.....	53
11.4	Sludge .....	53
11.5	Drying.....	53
11.6	Oil damage .....	54
11.7	Rebuilding .....	54
<b>12</b>	<b>Risk provisioning.....</b>	<b>55</b>
<b>13</b>	<b>Additional materials.....</b>	<b>56</b>

## Annexes: Precautions that private persons can take

<b>Annex 1: Checklist: Planning your own flood preparedness.....</b>	<b>58</b>
What you can do today .....	58
Final preparations before a flood .....	59
After a flood .....	59
<b>Annex 2: Checklist: “The right flood-preparedness equipment” .....</b>	<b>60</b>
<b>Annex 3: Checklist: “Cars and floods” .....</b>	<b>61</b>
<b>Cited laws, directives and standards .....</b>	<b>62</b>
<b>Picture credits .....</b>	<b>63</b>

# Introduction

Floods are, first and foremost, natural events that occur within the natural environment. Regularly flooded floodplains, for example, provide habitats for many plant and animal species. On the contrary, hardly a year goes by in which floods fail to cause significant damages to buildings and infrastructure.

Along with river floods, heavy rainfall, usually limited to small geographical areas, now frequently contributes to flood-related damage. Human impacts – and, not least, the impacts of climate change – tend to intensify these effects. The latest assessment report of the Intergovernmental Panel on Climate Change (IPCC) confirms that further increases in the intensity and frequency of floods have to be expected as a result of climate change. Extreme weather events such as strong heat waves and torrential rainfall are occurring frequently, and, in all likelihood, will occur even more often, and with even greater intensity, in the future. Sea levels are expected to rise by several tens of centimetres by the end of the century, thereby posing a serious threat for low-lying coastal areas and islands.

As a result we can expect to continue having to face natural flood events, in spite of all our progress in early detection, forecasting and mitigation of floods. For this reason, major efforts to counter the threats from flooding need to be made in all relevant areas. Flood

protection strategies have changed profoundly in recent years. The strategies sought under the old approach tended to be local, aimed, after a flood had occurred at a particular place, at ensuring that no comparable damage would ever occur in that same location. Today, we combine the technical flood protection we need at specific locations with precautionary strategies oriented to extensive areas. As we do so, we need to look carefully at the pros and cons of construction in flood-prone areas, taking account of the different relevant uses and requirements.

And apart from such efforts, each individual's own legal obligation to take the necessary precautions continues to play an indispensable role in all efforts to prevent or minimise damages from natural hazards. This primer on flood protection offers building and home owners, and renters, valuable information in these areas. In addition, it might serve as a valuable planning aid for architects and engineers, who develop protection concepts in connection with building planning. Consequently, it might support efforts to prevent major damage and unnecessary financial burdens.

Besides, this primer on flood protection might help raise awareness of the need for effective precautions even in areas that have had no experience with floods to date.



# Summary



Water everywhere

Over the past few years, extreme precipitation events in the central European region have brought about floods that have caused major economic damage. The impacts of the floods have been such that many of the affected households, companies and communities have been able to recover from them only with the help of outside assistance.

The areas affected by such extreme meteorological events have included the North Sea and Baltic Sea coastlines. Since 1962, when Germany's North Sea regions were battered by a devastating storm surge, a range of extensive technical measures have been taken, however, to protect population centres on the German North Sea coast against comparable floods. The flood protection options available to individual persons in coastal areas are very limited in comparison to the options available in inland areas. Nonetheless, the information in this brochure could still be of use for persons threatened by storm surges within receding-coastline areas (coastal sections that, in the absence of protective measures, continually change naturally) or within cities such as Hamburg and Bremen.

This primer on flood protection provides information and precise strategies that might help prevent or reduce the harmful impacts of most of the flood events expected in the future. Its guidelines are especially relevant for owners and residents of residential buildings. In principle, however, all of the information it presents can also be applied to public and commercial areas and structures. That said, however, it must be noted that every commercial / production facility is unique, with special aspects to consider that are beyond the scope of this brochure.

Part A of the primer focuses on the basic principles and general facts to be aware of with regard to flood threats and flood prevention. Part B is addressed to pertinent building precautions, and it presents detailed examples of suitable precautionary measures. Part C discusses additional aspects of flood-related precautions, such as information provision, behavioural precautions and measures to guard against risks. A final, additional chapter discusses flood management and the steps to take in recovering and rebuilding after a flood event.

The annex provides information relative to organising and implementing private flood-preparedness measures.

## 1.1 Floods – natural events

At irregular intervals, out-of-the-ordinary weather situations lead to floods. Like the seasons, floods are continually recurring natural events. Floods are part of the natural environment. Many species and species communities have gone beyond simply adapting to recurring floods. They have come to need regular flood events tending to choose floodplains as their habitats. However, people cannot so easily adapt their lives and living environments to the dynamics of flood regimes. What people can do is to be informed about floods, and to take the necessary precautions to minimise flood-related damage.

Floods can be differentiated in terms of the ways in which they originate and manifest themselves:

**Heavy rainfall events** occur especially in summer months, as the result of storm fronts. Heavy rainfall events exhibit maximal precipitation intensities, are spatially limited and of relatively short duration. Streams and rivers with small catchment areas react with extremely rapid increases in their flow rates and water levels. Normally, they swell so rapidly that affected people have little or no time to take protective measures. Such rapid changes in watercourses cannot be precisely forecast. For this reason, buildings in potentially affected areas need to have structural protection. This plays a key role in keeping damage to a minimum.

**Floods** in rivers occur whenever widespread rainfall, continuing over long periods of time, and even occurring in conjunction with snowmelts, swells river flow to the point at which rivers burst their banks. Water levels in connection with such events can fluctuate by meters. The flood forecast systems now in place along many rivers are able to reliably predict the development and maximum water levels of floods. Due to the reaction time such systems allow, the behavioural precautions taken by individuals play an especially important role in minimising damage. Needless to say, good structural precautions and flood-adapted construction methods play an indispensable protective role as well.

**Backwater flooding** can occur as the result of either heavy rainfall or river flooding. When excessive

amounts of rainfall overload sewers, or large quantities of river water or high-level groundwater enter sewer systems, such systems can back up. Such backups can drive water into cellars, via home service connections, and cause considerable damage.

**Groundwater flooding** can occur as the result of long-lasting precipitation, climatically wet periods or extensive flood events. Such flood events tend to cause groundwater levels to rise, via a delayed effect – first in floodplains, and then in areas further inland.

**Drifting ice** in rivers can, in combination with minor flood events, lead to high local water levels. Drifting chunks of ice can wedge together and lock up in front of man-made barriers such as bridges, thereby blocking water flow and creating upriver backwater. When such ice barriers then suddenly break open, they can release flush waves that can cause severe downriver damage.

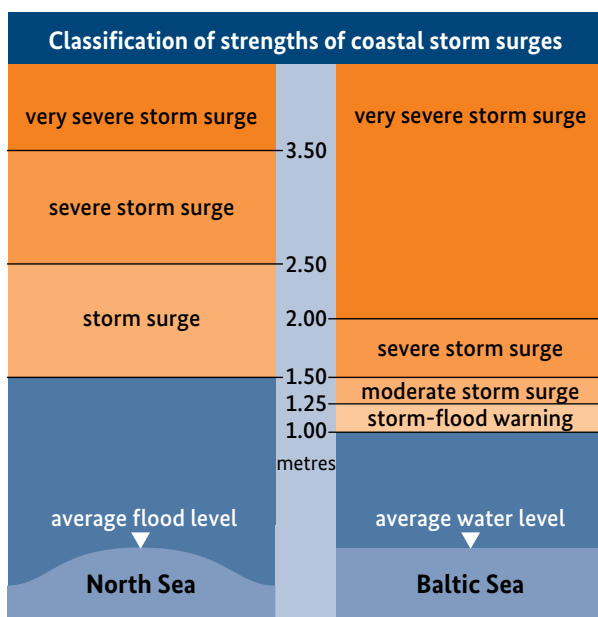
**Storm surges** can occur along coastlines when strong, persistent winds blowing from the sea combine with tides to raise water levels more than 1.5 meters above the mean high water (MHW) level. The Federal Maritime and Hydrographic Agency (BSH), the competent provider of maritime services in Germany, has developed a storm-surge-severity classification.

Pursuant to that classification, along North Sea coastlines, water levels of 1.5 to 2.5 meters above MHW are considered “storm surges,” levels of 2.5 to 3.5 meters above MHW are considered “severe storm surges” and levels of more than 3.5 meters above MHW are considered “very severe storm surges.” For the Baltic Sea, the BSH issues storm-flood warnings when water levels exceed 1.0 meters above mean sea level (MSL). Along Baltic Sea coastlines, water levels of 1.25 to 1.5 meters above MSL are considered “average storm surges”, levels of 1.5 to 2.0 meters above MSL are considered “severe storm surges” and levels of more than 2.0 meters above MSL are considered “very severe storm surges.”

## 1.2 Flood records and statistics

Floods have occurred since time immemorial. Quantitative records of historical flood events have only been available for about 150 years, however. Early “records” tend to be references to extreme flood events, such as





Source: Federal Maritime and Hydrographic Agency (BSH)

lines denoting historic high-water marks and references in chronicles. Records of water-level data can be statistically analysed to determine how often specific water levels were exceeded. Each new flood event, and each new long period with no floods, changes the overall statistical picture. To evaluate a storm-surge event, one ideally should be able to assess the specifics of the associated sea-water rise, of the prevailing currents, of the wave energies and of the various storm-related events.

### 1.3 Impacts of climate change on the flood situation

Climate change is one of the greatest challenges we face in our time and will continue to face in the future. As the current Fifth Assessment Report (of early 2014) of the Intergovernmental Panel on Climate Change



Rhine River water level in Cologne

(IPCC) has confirmed, it is now clear, without any doubt, that we are undergoing a process of climate change. The primary indicator of climate change is global warming, which is already manifesting itself and will continue to intensify in the coming years. While the overall process is slow, we are already noticing its initial impacts.

Average global temperatures are now expected to rise by one to two degrees Celsius in the coming decades. And we must expect average global temperatures to rise considerably higher, unless greenhouse-gas emissions are significantly reduced. Such trend predictions from climate projections should not be viewed as weather forecasts, however. Weather forecasts, which are based on current measurements and observations and take account of experience gained with weather records, cover periods of days into the future. By contrast, climate projections, which are based on predictive scenarios that integrate data on atmospheric greenhouse-gas concentrations, changes in land sealing, population trends and use of energy resources, extend decades into the future.

To obtain a picture of potential climate trends over large areas, one has to combine the results of multiple scenarios. Significantly, climate projections look at large-scale weather patterns. They do not make specific predictions regarding the occurrence of small-scale events such as heavy rainfall or thunderstorms. All climate models have one thing in common: no model can take account of all aspects and details of climate, which is complex in the extreme. Additionally to model future climatic conditions, one must make assumptions and simplifications that introduce uncertainties into pertinent calculations. In addition, differences between different models' underlying assumptions hamper any comparisons of different models' results.

Floods in inland areas result from rainfall. In principle, the following applies: more heat means more energy, and that, in turn, means more moisture transport.

The regional climate models available for Germany indicate that the seasonal progression of precipitation is going to shift. Winter months will probably bring more precipitation, but less precipitation in the form of snow. Summer months, by contrast, will be drier overall in many areas, and that is expected to create



Extreme weather: a drought

additional problems. The forecasts relative to precipitation refer to long-lasting precipitation from low-pressure systems. Changes in the frequencies and intensities of heavy summer rainfall have already been observed and are expected to continue growing in future. Interestingly enough, the regional-level climate forecasts for Germany differ – considerably, in some cases – from region to region. And large-scale weather patterns are expected to change or shift. For this reason, it is difficult to make general predictions regarding the ways in which climate change will affect flooding in Germany.

With regard to flood events in southern Germany that are frequently expected from a statistical standpoint, the project “Climate change and consequences for water management” (KLIWA), an effort of the Länder Baden-Württemberg, Bavaria and Rhineland-Palatinate, and of Germany’s National Meteorological Service (DWD), has found that floodwater flow levels could increase by up to 75 percent by the end of the century. With regard to rare events that, statistically speaking, occur no more than once every 100 years, floodwater flow levels could increase by up to 25 percent. The smaller the recurrence interval – or the larger the probability of occurrence – the higher such increases are expected to be. This suggests that critical water levels in the area studied will be more frequently attained and exceeded in the future.

It is important to note, however, that a given percentage increase of floodwater flow does not mean one and the same water-level increase for every starting water level. Every water level has its own characteristics. As water levels rise, a water body’s discharge can increase in different ways, depending on the form of the water body’s cross-section. The relationship between water



Flooded street and sewer backwater as a result of heavy rainfall

level and discharge is referred to as the “stage discharge curve.” A sample evaluation of various stage discharge curves, representing various different water bodies in southern Germany, indicated that water levels could rise by an average of about 0.5 to 1.2 meters during the frequently recurring flood events that, statistically, occur every 5 to 20 years, and by an average of 0.2 to 0.6 meters during rare flood events with recurrence intervals of one hundred years or more.

In their current flood protection planning, planners are already taking climate trends into account – via such measures as addition of suitable surcharges and integration of suitable preparations for later adaptations. This does not mean, however, that all protective facilities are automatically going to be upgraded as necessary in the coming years. In some areas, the level of protection in place will actually decrease – at least from a calculatory standpoint.

Along coastlines, a range of changes are expected, as a result of emerging climate change trends, that could have impacts on the flood situation. Such changes include increases in sea levels, increases in wave energy, changes in flow and current conditions, tidal changes and intensifying storm activity. Today, planners are already carefully considering and taking account of the possible impacts of climate changes. For example, as a safety precaution, coastal protection systems are being designed to withstand sea-level rises of 30 to 50 centimetres over the next 100 years, even though the rise observed over the last century amounted to only 10 to 20 centimetres. The developments that actually occur are continually being monitored and evaluated, so that the measures necessary to maintain current protection levels can be taken promptly as needed.

The Federal Government’s “Impacts of climate change

on waterways and navigation” (KLIWAS) research project is working to generate scientifically reliable data on the range of hydrological changes expected along Germany’s waterways and coastlines. The results of that effort will provide an important foundation for the further development of appropriate strategies in the areas of protection, urban development and construction.

#### 1.4 Heavy rainfall events

In recent decades, heavy rainfall events have frequently caused severe – but locally confined – floods. Overloading of sewage networks within settled areas – networks that, primarily for operational and economic reasons – have often not been designed and sized for such events, can lead to severe flooding. Not infrequently, such flood situations are compounded by large amounts of mud flow. The damages resulting directly from heavy rainfall itself – such as heavy, torrential cloudbursts can account for significant fractions of the overall resulting damage.

Furthermore, very sudden flooding of low-lying sections of buildings, such as underground car parks, undercrossings and cellars, can present serious hazards. Housing areas built on low-lying ground can be suddenly exposed to severe flooding. Interestingly enough, the names of streets and land parcels (such as ravine road, mill road, or valley road) can indicate possible flood hazards.

Effective protective measures are usually out of the question in such cases, since the times and places of rainfall events are difficult or impossible to predict in the short term, and since such events usually allow very little time to react. However, proper advance planning can indeed help reduce or even prevent damage.

In some catchment areas of watercourses, maps of areas at risk from torrential cloudbursts are already available. Such maps show the locations – usually small depressions, but sometimes also entire streets – where rainfall can collect and be unable to run off rapidly enough.

Although hydrological calculation methods quickly run up against their technical limits in such applications, such maps can provide initial assessments of whether certain buildings might be flooded when heavy rainfall events occur. In addition, they can help to identify areas that offer potential for holding or diverting rainwater.

Germany’s National Meteorological Service (DWD), for example, provides district-specific warnings, nationwide, of possible extreme weather events. Thunderstorms, which are often referred to as “thunderstorm cells” or “severe rainfall cells” when they bring heavy rainfall, can be limited in area to just a few square kilometres. As a result, a thunderstorm will normally not affect an entire district in the same way. When the DWD issues a warning for a specific district, however, all persons in the district have a high probability of being affected in some way. Such warnings can be provided at very short notice when extreme weather situations begin to manifest themselves.

The weather portals available on the Internet, which often offer both time-specific forecasts and weather-radar data, are also helpful in this regard. Such sites can show the pathway a storm cell has taken over time, consequently supporting forecasts regarding the cell’s further development.



Street names can indicate flood hazards



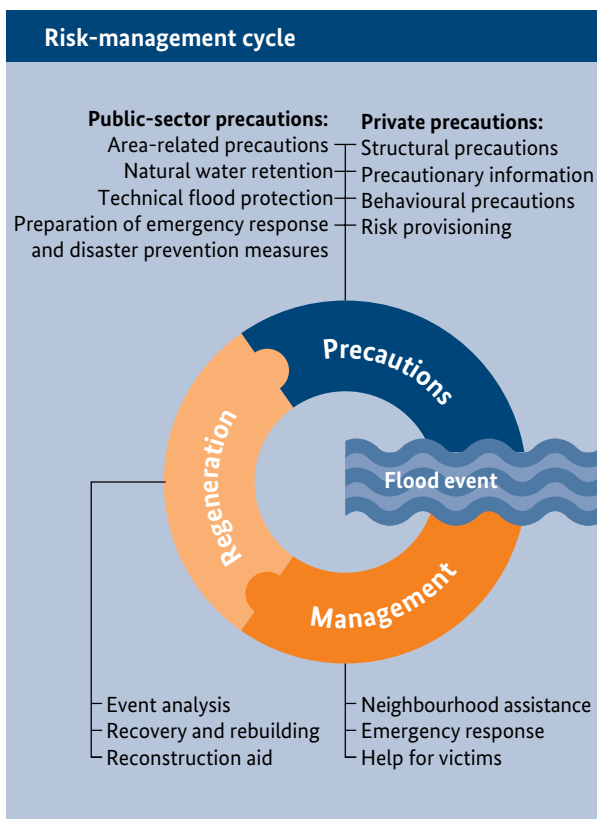
## 2 Strategies for flood prevention and preparedness

As a result of economic growth and settlement pressures, river meadows and coastal areas have frequently been appropriated for industrial and commercial facilities, housing developments and agricultural and forestry cultivations. The protection provided by technical flood protection facilities, such as walls, dikes, coastal barriers and floodwater-retention systems in inland areas, can be effective only up to the flood levels for which the facilities have been designed. Any floods that exceed those levels will completely inundate the so-protected areas. No flood protection can be perfect and complete at all times.

As early as 1995, the “Guideline for forward-looking integrated flood protection“ of the Federal / Länder Working Group on Water (LAWA) noted that any comprehensive flood protection must consist of both technical protection and extensive, additional precautions.

With the implementation of the European Floods Directive (Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks), a range of new perspectives and approaches have become established. The process of managing flood risks is now viewed as a cycle that comprises both precautions prior to floods and management measures during floods. Also, as a rule, flood events are followed by a regeneration phase.

Many persons affected by floods may wait until they have been hit by a flood event before they consult this primer. In addition to such aspects and the planning and modernisation of buildings, this primer thus covers the recovery and rebuilding that necessarily follow a flood. In the area of precautions, the competent authorities, and citizens and homeowners, can all help, via suitable combinations of the following individual strategies, to reduce flood damage:



Source: Modelled after work of Federal / Länder Working Group on Water (LAWA)

- **area-related precautions**, involving efforts to designate / use as little land as possible, in flood-prone areas, for construction
- allowing **natural water retention** on areas that can store rainwater and then release it later, in a gentle manner, to rivers and streams
- **technical flood protection**, which, where technically and economically feasible, can keep floodwaters away from buildings and other facilities
- **preparations for emergency response and disaster prevention**, which can ensure that measures taken to address floods proceed smoothly
- **structural precautions**, which, via flood-adapted-construction methods and uses, can enable buildings to withstand flooding without suffering any damage
- **information provision** such as identification of all relevant information channels, warning of approaching floods and assistance in proper interpretation of all provided information
- **behavioural precautions**, involving advance development and teaching of proper behaviour in the event of floods, can reduce or even eliminate the risks of injury and death and of property damage
- **risk provisioning**, the making of financial provisions for cases in which flood damage occurs in spite of application of the above strategies.

### 3 The legal framework under water law

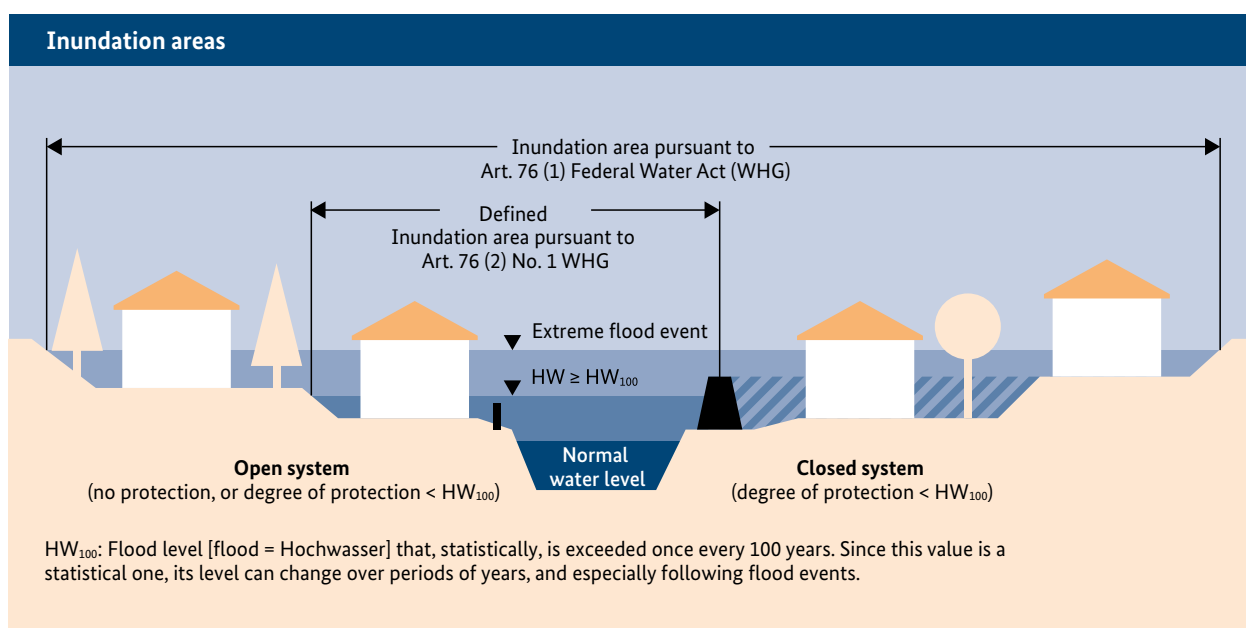
The new version of the Federal Water Act (WHG) of 31 July 2009 transposed the EC Directive on the “assessment and management of flood risks” (2007/60/EC of the European Parliament and of the Council of 23 October 2007, also referred to in the following as the “European Floods Directive”) into national law. That directive focuses both on inland floods caused by rivers that burst their banks and on coastal floods caused by storm surges. Along with human health, the goods that it lists as needing protection against adverse consequences of floods include the environment, economic activity and the cultural heritage.

Its central provisions mandate the preparation of flood hazard maps (FHM) and flood risk maps (FRM) in areas with significant flood risks (flood risk areas). The directive also mandates the preparation of flood risk management plans (FRMP) on the basis of findings gained with FHM and FRM. The Federal Water Act thus now contains complete regulations on flood protection and flood precautions – on flood preparedness that, in general, is referred to as “flood risk management.” Work on flood risk management takes place in a coordinated manner, in the context of “units of management” such as river basin districts and coastal areas, and with international coordination as necessary.

The term “flood risk management” covers all existing protective strategies, including technical flood protection, floodplain management (including setting aside and preparing areas and providing for natural water retention) and other types of flood precautions (building precautions, precautions taken by local authorities and potentially affected citizens, behavioural precautions, information provision and risk provisioning). The WHG requires that flood hazards and risks be identified and described in connection with the following flood scenarios:

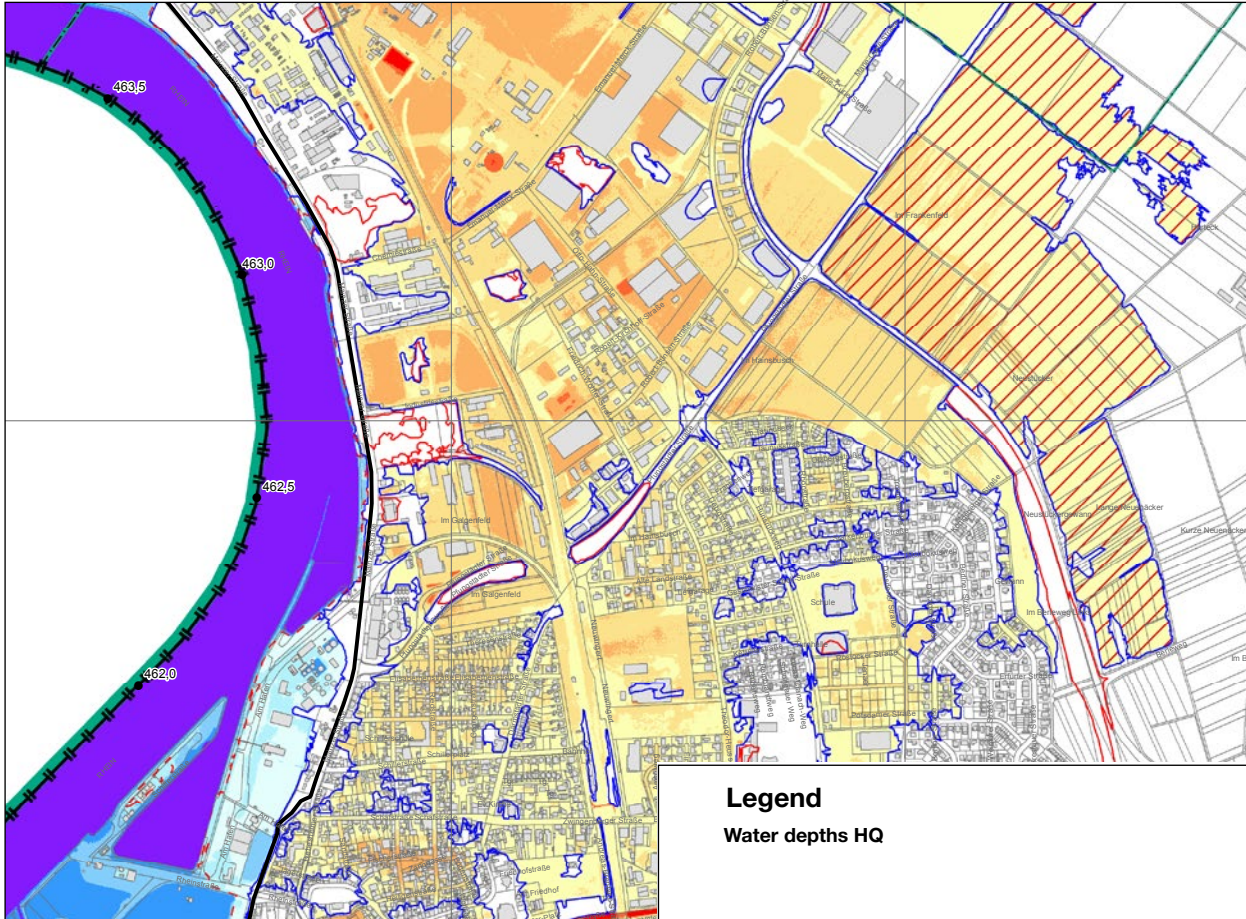
1. **floods with a low probability**, or extreme event scenarios
2. **floods with a medium probability** (likely return period  $\geq 100$  years)
3. **floods with a high probability** (where appropriate)

The significant sections of water bodies for which FHM and FRM are to be prepared have been defined by the Länder. As a result, area coverage can differ from region to region. Whereas some Länder have only considered water bodies of the highest category (water bodies that lie within the responsibility of Länder (state) administrations, and federal waterways), others have also taken extensive account of smaller water bodies.



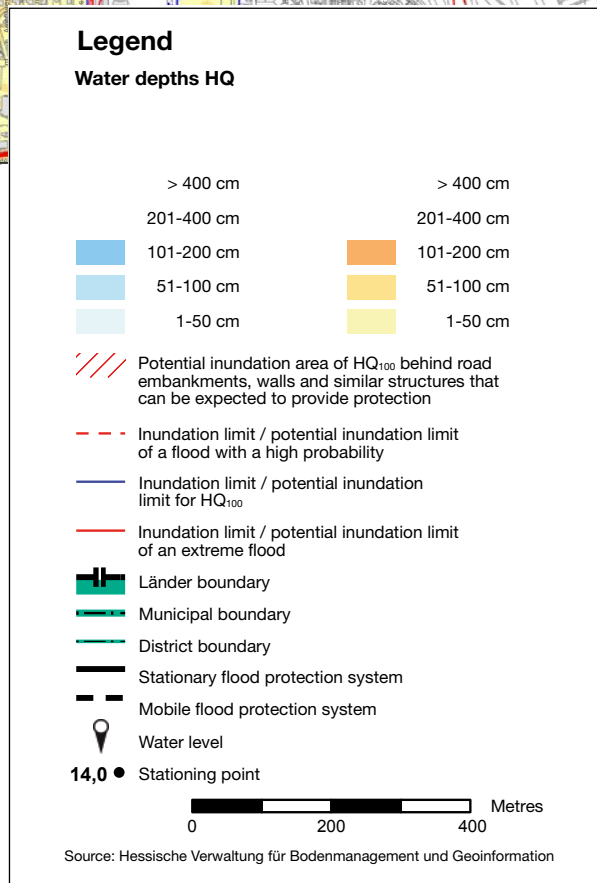
Source: Pursuant to Federal Water Act (WHG) of 31 July 2009



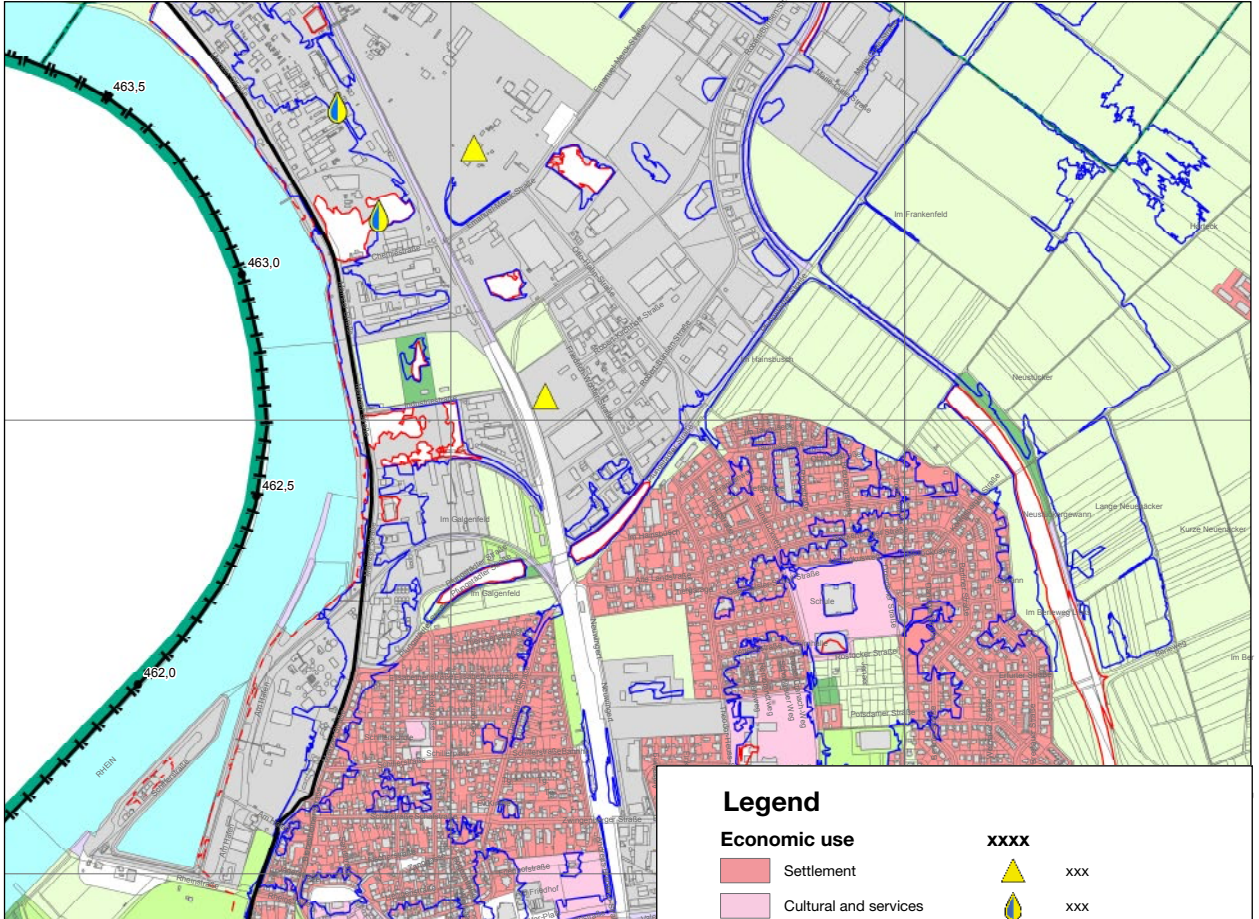


The Federal / Länder Working Group on Water (LAWA) has published recommendations relative to the preparation of such maps and flood risk management plans. The maps are drawn to suitable scales (usually 1:5,000 or 1:10,000). The key parameters applied in flood hazard maps include inundation areas and inundation depths, considered in combination with flow speeds. In steeper areas, flow speed is an especially significant parameter.

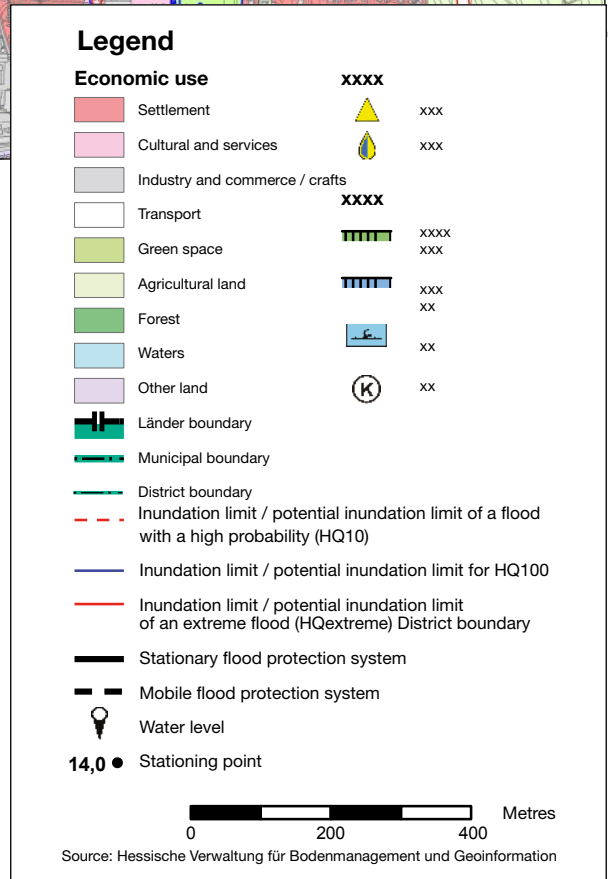
For cartographical representation of inundation depths, LAWA recommends the use of a five-shade, blue colour scale, for all readily floodable areas without flood protection (open systems), and the use of a yellow-orange scale for areas protected by dikes (closed systems). Additional shades can be added as necessary – for example, when especially deep inundation is expected. Since these design recommendations have not been imposed at the national level, relevant representations can vary from region to region.



Example of a flood hazard map for 100-year flood event, with legend



The information shown in flood risk maps includes the numbers of affected inhabitants. The types of economic activity concerned, installations pursuant to Directive 96/61/EC (IPPC installations, since 2013, IED installations pursuant to Directive 2010/75/EU). The potentially affected protected areas pursuant to Annex VI No. 1 numerals i, iii and v of Directive 2000/60/EG (Water Framework Directive), including areas used for the abstraction of drinking waters, and Natura 2000 areas along with any additional information that a Member State considers it useful to provide.



Example of flood risk map, with legend





Heating oil spill

Within flood risk areas, the Länder define inundation areas, via either ordinances or Länder water laws. The basis for such definitions consists of floods that, statistically, occur once every 100 years.

In general, designation of new building areas in defined inundation areas is prohibited. This has the purpose of preventing new construction that would create potential for additional flood damage. Exceptions to this prohibition are permitted only subject to compliance with strict conditions. For further information, cf. Art. 78 (2) WHG. The applicable conditions in this context include: no other options for settlement development are available (for instance for an affected municipality); no life-threatening hazards, and no significant health or property risks, are expected; and measures would not compromise existing flood protection.

In general, the construction and expansion of structures are prohibited in inundation areas that fall into the following categories: areas for which legally binding land-use plans have already been prepared (Section 30 Federal Building Code (Baugesetzbuch – BauGB)), areas for which current development plans have been prepared (Section 33 BauGB); built-up areas (Section 34 BauGB); and undesignated outlying areas (Section 35 BauGB). In derogation thereof, the competent authority may approve structures in individual cases, if, pursuant to Art. 78 (3) Sentence 1 WHG, the

following conditions are cumulatively fulfilled:

- flood retention is not, or not significantly, diminished or impaired, and any losses of retention space are simultaneously compensated for
- the project does not change the relevant water level and flood discharge in an adverse manner
- the project does not impair existing flood protection, and
- the project is carried out in a manner adapted to flood risks

Alternatively, adverse impacts can be offset via imposed requirements and conditions.

The Länder may issue provisions governing a) flood-safe construction of new facilities that use heating oil, and b) flood-safe retrofits of facilities that use heating oil, in inundation areas. In individual cases, the Länder may also issue prohibitions on new oil-fired heating systems. Again and again in the past, spills of heating oil have damaged buildings and polluted water bodies.

In defining inundation areas, authorities are required to inform the public appropriately – appropriately, acting early to raise public awareness of flood hazards. The Länder issue provisions on how residents in affected areas are to be informed, promptly, about flood hazards, about suitable preparedness measures and

rules for proper behaviour and about any expected floods.

As a preface to its special provisions on flood protection, the Federal Water Act (WHG) (Art. 5 (2)) establishes a general obligation to act in a careful and responsible manner. Under this obligation, all persons who could be affected by floods are required to take all possible and reasonable protective and precautionary measures in the respective extent for the person involved

#### Art. 5 (2) WHG

“Every person, who could be affected by floods is required, within the framework of what is possible and reasonable for him or her, to take suitable precautionary measures to protect himself / herself against adverse flood impacts and to reduce damages and, in particular, to use land in ways that take due account of the possible adverse consequences of floods for human beings, the environment or property.“

The legal provisions relative to coastal protection are enshrined within the Länder (state) laws of Germany's five coastal Länder. In the framework of the constitutionally defined joint task “improvement of agrarian structures and coastal protection,” the Federal Government participates financially in the coastal protection measures of the Länder. At present, the Federal Government assumes 70 percent of the relevant investment costs of the Länder. The Länder remain responsible for the planning and execution of the measures. And they are solely responsible for all pertinent maintenance costs.



Unadapted settlement development



Flood-adapted construction, with raised ground floor



## 4 Area-related precautions and flood management

Flood damage occurs only where goods and assets are affected by flooding. Floodplain management is thus an important component of flood preparedness. Legal provisions are already in place to control further development on floodplains and in coastal areas. On the contrary, floodplain management measures cannot – and should not – include driving existing settlements out of such areas. Where settlements are located in such areas, strategies for preventing and reducing damage have to rely on behavioural precautions and on technical flood protection measures.

In addition to protecting existing retention areas, the task spectrum in floodplain management includes reclaiming former retention areas along water bodies – for example, through dike relocations.

In inland areas, floodplain management is not limited to the riverside areas in which floods can cause damages. It also – and especially – has to consider those areas in which floods originate. In this context, a distinction is made between long-lasting precipitation that slowly, but steadily, leads to flooding throughout a large river catchment area, and heavy rainfall events that lead to sudden flooding of roads and houses in smaller catchment areas.

In both types of cases, decentralised flood protection measures play an important role. The key principle is to find ways to retain rainwater in specific areas. In general, rainwater can be retained either in open areas or in settlement areas.

In open terrain, forests provide the best buffers against floods. Forest soils have an excellent capacity to absorb and temporarily store rainfall. Agricultural areas can also be effective in collecting and retaining rainwater. The decisive factors with such areas are a) what crops are being cultivated on them, and b) how intensively the rainfall hits the areas. Grassland, for example, is very good at retaining rainwater.

Unlike soils protected by a grain-crop or grass cover – which form tight webs of roots – bare soils, if steep enough and if hit by heavy rainfall, release soil particles into the water flowing over them, creating soil mud in the water. In such cases, no mat of roots absorbs and slows the water flow, and the resulting water-mud mixtures run off unhindered. When such mixtures



Soil erosion after heavy rainfall

strike developed areas, they often cause considerable damage, even if the nearest water body is actually a long distance away.

What is more, the positions and orientations of roads can further intensify the run-off process. Paved roadside channels, with no sludge traps or other checking structures, and with oversized and fully cleared embankments, channel water very rapidly into settlements and into water bodies. This can cause downstream flooding and damages.

In settled areas, as part of measures for decentralised flood protection, more and more roof- and land-drainage systems are being disconnected from sewage networks. This reduces loads on sewage networks and on wastewater-treatment plants. With such disconnected systems, rainwater is channelled into depressions in the terrain, or into special infiltration ditches, where the water can seep into the ground. While such systems are effective only over very small areas, they do help to reduce damage.



## 5 Technical flood protection

Technical flood protection plays an important role in all flood protection strategies. The most important elements of technical flood protection include:

- retention measures: reservoirs, flood retention basins, polders (discharge areas);
- river engineering measures: dikes and dams;
- coastal protection measures: dikes, barriers, groynes, breakwaters, waterfront structures, dunes, earthwork in forelands and beach replenishment;
- property-protection measures: walls, barriers and mobile flood protection systems; and
- flood forecast systems.

### 5.1 How technical flood protection systems function

Reservoirs and flood retention basins are normally sited in the upper sections of water bodies, and they have their greatest impacts in areas immediately downstream. Polders, or discharge areas for flood retention, are normally placed in the middle and lower sections of water bodies.

Their water retention reduces water levels in areas located further downstream, and delays the arrival of flood waves.

River-engineering and property-protection measures have impacts right where they are sited. However, if the retention areas their construction has removed are not compensated for, they can actually exacerbate flood situations. As a rule, river-engineering measures include building of earthwork dams. Steel sheet piles and reinforced concrete are used to build fixed flood protection walls or to provide dense, stable foundations for mobile protection systems.

All technical flood protection facilities are designed to include a safety margin, known as the “freeboard.” Freeboard is a safety factor included to take account of wave action, wind effects or any root penetration in earthworks. The amount of freeboard included will vary, depending on the protection system and structural height involved. It usually amounts to several decimetres.



Flooded Rhine River polder near Ingelheim

## 5.2 Cost-effectiveness of flood protection measures

Prior to the construction of a flood protection facility, the following criteria are weighed against each other in the framework of a cost-effectiveness study:

- the investment and reinvestment costs for the flood protection facility (the construction costs for the included systems, for land use, for dike repair, for replacements of damaged mobile components, etc.)
- the operating and maintenance costs for the flood protection facility (costs for dike maintenance measures, operating and maintenance costs for special structures such as pump systems, costs for set-up and dismantling of equipment, costs for care and storage of mobile systems)
- the benefits accruing in the form of reduced damages, throughout the calculated lifetime of the protection facility.

It must be ensured that the benefits derived from the facility justify the costs. In selection of the degree of protection to be provided, in the context of the state's public assistance / welfare obligations, high priority is placed on protecting human life and improving the quality of life for people.

## 5.3 Possible ways in which protection systems can fail

Flood protection facilities are technical systems that are designed to guard against certain types of events. Such systems can fail when they are affected by events that exceed their design criteria. What is more, under unfavourable conditions, systems can fail even in the face of events that do not exceed their design criteria. The following basic mechanisms for the failure of protection systems have to be differentiated in the planning and operation of such systems:

### Failure when the target / flood height for which systems have been designed is exceeded

**In the case of retention basins and reservoirs:** Water is released via the spillway for the basin or reservoir, to prevent further backwater accumulation. Spillways are dimensioned so that such releases will not damage the dam or other structure involved. The water discharged



Closing structure for a flood retention basin



Flood protection dike along the Elbe River

via the spillway causes downstream water levels to rise. And such discharges can amount to several times the normal discharge level.

**In the case of dikes and dams:** When water flows over earthworks, there is always a risk of surface erosion, even when the earthworks have a protective vegetation cover. High flow speeds and wave action can exacerbate this risk. Erosion – for example, erosion that begins at the dam crest – will gradually increase the inflow cross-section. That, in turn, causes the erosion to increase. Such erosion can cause dike / dam breaks several hundred meters long.





Flood protection wall built with steel sheet piles

**In the case of flood protection walls and pre-installed mobile protection systems:** Water flows over the protection systems and inundates the land behind them. As a rule, there are no risks that the systems themselves will be destroyed in the process.

**Sandbag barriers and sandbag-substitute systems** can be destroyed when they are subjected to overflow. That possibility needs to be taken into account in the design of such protection systems.

If a suitable flood forecast system is in place in a water body's catchment area, the time at which a flood will crest can be precisely predicted. The measures to take once such a prediction has been provided, and in keeping with the protection system involved, need to be defined in the relevant alarm and action plans.

**Failure before the target / flood height for which systems have been designed is exceeded**

When protection systems fail before the targets / flood heights for which they have been designed are exceeded, such failures may be considered technical failures. Even when good engineering practice is followed, such scenarios have to be taken into account in the planning of preparedness measures.

**In the case of retention basins and reservoirs:** Failures of such systems leads to sudden increases in discharges, and of downstream water levels, often in connection with mudflow-like bedflow discharge.



Flood protection wall made of safety glass

**In the case of dikes and dams:** The most frequent causes of failure are a) regressive erosion within or below the dam body and b) stability failures. Unless countermeasures are taken, both factors will always lead to breaks. To prevent such types of failure if at all possible, the dikes and dams along our water bodies are continually monitored as soon as water begins collecting behind them. At the first indications of possible failure, dike-protection personnel take "dike-defence" action.

**In the case of flood protection walls and pre-installed mobile protection systems:** The stability of such protection systems is assured by requirements to provide proof of structural strength, and by careful maintenance and proper erection. During floods, unforeseen stresses (such as flotsam impacts) can damage such systems, however. In selection of such systems, care must be taken to ensure that failure of parts of a protection system will not cause the entire system to fail (through a domino effect).

#### 5.4 Flood protection in sewer systems / assuring proper drainage of wastewater and rainwater in inland areas

Above-ground flood protection measures always have to be seen in connection with the relevant sewer system. In the absence of suitable precautionary measures and / or constructive measures for sewer systems, flood protection measures can remain ineffective. The following needs to be studied and considered in this regard:



Integrated flap gate for flood protection

**Floodwaters have to be prevented from overwhelming and spreading through sewer systems.**

- Stormwater-overflow systems in sewer systems are “short circuits” leading directly to water bodies. Such systems need to be closed off, with check valves, to floodwater that enters the sewer network.
- When parts of a settlement areas experience above-ground flooding, floodwater will enter the sewer system via manholes and street inlets. Pressure-tight manhole covers, and slide valves that can close off sewers by sections, can prevent the flooding of the remaining sewer network. Once sewer systems are flooded, check valves in residential service lines, located within residential buildings or in shaft structures placed in front of buildings, and pumping systems, protect building drainage systems.
- Manhole covers and sewer sections located in front of flood protection facilities have to be protected with special care.

**Drainage behind protection systems has to be assured.**

- It has to be ensured that wastewater and rainwater, within sewer systems, can continue to drain even when floods occur. Sewer networks can handle only limited amounts of backwater.
- When flood events persist for long periods of time, groundwater levels rise and can reach the level of sewer beds. When that occurs, the infiltration-water



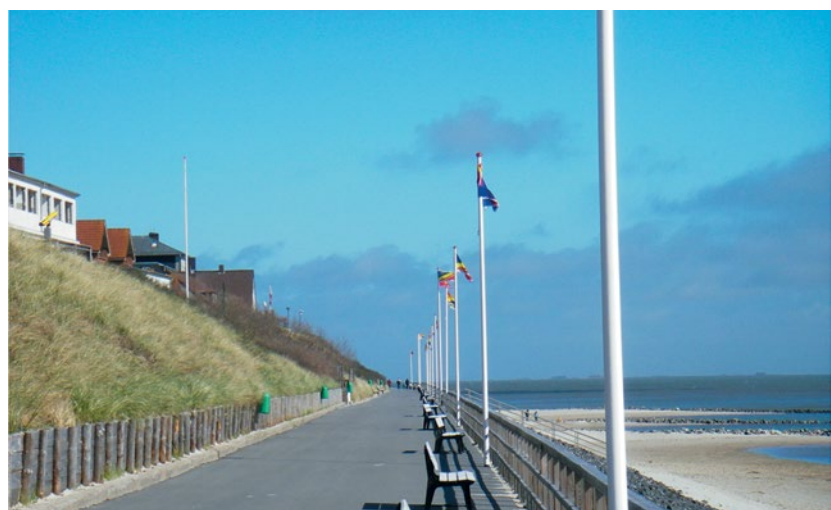
Mobile flood protection with bulkheads

fraction in sewer systems increases and has to be drained.

- Drainage of lateral tributary streams must not be allowed to back up if at all possible. The pumping stations needed to prevent such backups should have adequate capacity.

**5.5 Coastal protection**

In the absence of coastal protection measures, the some 1.1 million hectares of lowlands in the catchment areas of Germany’s North Sea and Baltic Sea coastlines would be inundated every time a severe storm surge occurred. It would no longer be possible to use and develop these lands for housing and economic activity. Coastal protection dikes, barriers, reinforced dunes and steep



Coastal protection dike



embankments and regular beach replenishment now protect these areas, with very high levels of safety and reliability. Following the catastrophic flood of 1962, Germany's five coastal Länder developed general plans for coastal protection, comprising all measures that would be needed to guard against such extreme storm surges. They have been continually implementing these plans since then. Due to the high investment costs involved, it has not yet been possible to implement the general plans completely. Nonetheless, the measures taken to date have been highly successful; the defences successfully withstood the North Sea storm surges of 1976, 1990, 1994, and 2013, and the Baltic Sea surges of 1995 and 2006, all of which had water levels exceeding those of 1962.

Monitoring and maintenance of coastal protection systems have to be carried out on a continual basis. In the coming years, it will be necessary to implement the measures remaining within the general plans. What is more, the assessment bases for the coastal protection systems will have to be carefully observed and ana-



Tetrapods protecting the coastline on the island of Sylt

lysed, with regard to now-emerging climate change, and to enable early implementation of any necessary adaptations. Coastal protection remains an important ongoing task – and certain residual risks for protected areas will persist.



Coastal protection with groynes and a flood control dike



# 6 Potential flood hazards, and building precautions

## 6.1 Precautionary building strategies

To be able to take effective precautions – in construction, and in raising awareness and cultivating proper behaviour – one must understand a) how water affects structures and their furnishings and equipment and b) how floods behave in the region concerned. Most of the recommendations provided in this primer are oriented to existing buildings. Wherever possible, flood-prone areas should be avoided as sites for new housing and business developments. And flood-prone areas can include all areas that can become “wet” when floods occur, potentially including land that lies outside of legally defined inundation areas. The following technical descriptions present illustrative possibilities. In specific, individual cases, expert planners should be consulted.

Three basic protective strategies for preventing and reducing flood damage have become adopted in practice:

**Avoid:** The most effective way to reduce flood damage is to simply avoid flood hazards. This can be accomplished spatially, by avoiding flood-prone land, or structurally, by providing higher foundations for high-value sections of buildings.

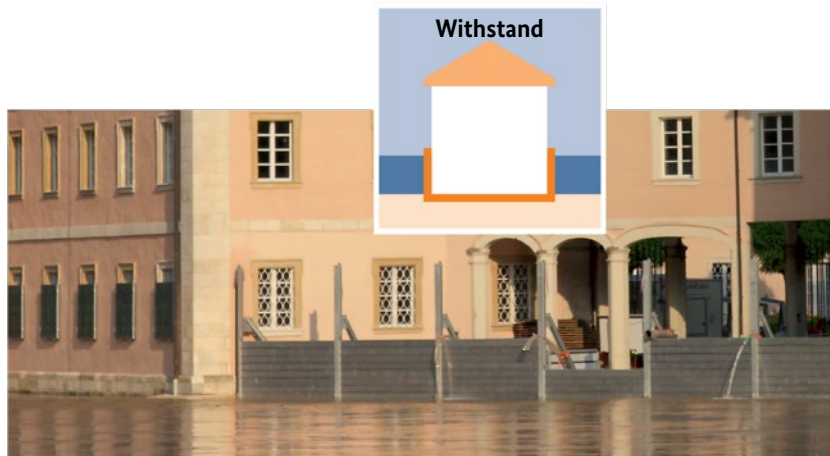
**Withstand:** Where avoidance is not feasible, technical protection systems – operating within the load limits for which they have been designed – can keep rainwater, floods and groundwater away from buildings and keep water from penetrating into them.

**Adapt:** Where situations can occur that would overwhelm the aimed-for protection, or where protection systems cannot be provided cost-effectively, uses can be adapted to flood hazards in such a manner as to reduce any expected flood damage. In some cases, it can make more sense, as one adaptation strategy, to simply allow water to enter structures or areas. Such an approach can sometimes limit damage more effectively than can attempts to prevent any and all water penetration.

None of the above strategies should be considered “best,” in and of itself, or chosen as a sole answer. Very frequently, the best approach will combine all three strategies.



Avoid: for example, by placing buildings on supports

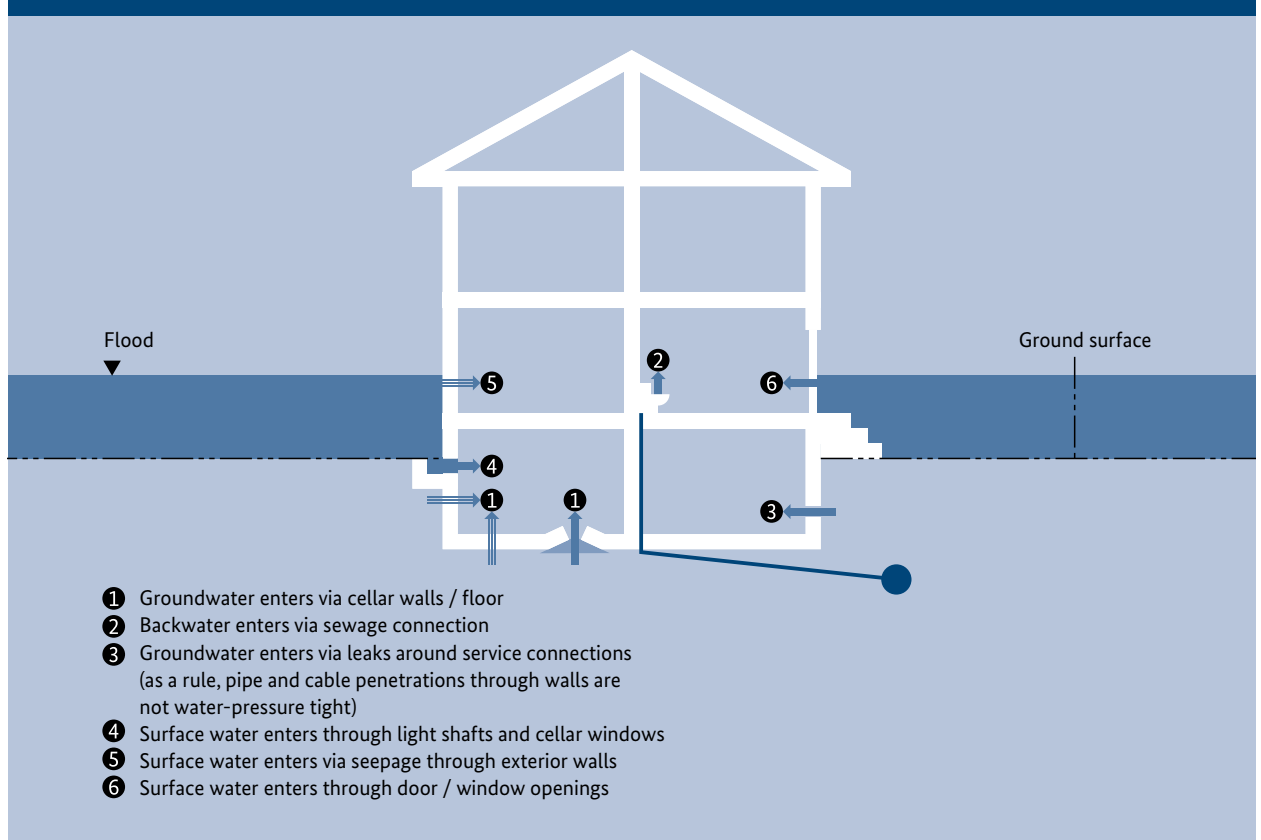


Withstand: for example, by protecting structures with bulkheads



Adapt: for example, by securing tank systems

## Different ways that water can enter buildings



Source: Planen und Bauen von Gebäuden in hochwassergefährdeten Gebieten – Hochwasserschutzfibel, BMVBW, 2003 (Planning and construction of buildings in flood-prone areas – primer on flood protection, Federal Ministry of Transport, Building and Urban Affairs (BMVBS), 2003)

### 6.2 When water enters buildings

In general, water entry into buildings does not necessarily threaten their structural stability. It does, however, cause lasting damage – to such as doors, windows, building systems, plaster, wallpaper, floorings, and to interior furnishings.

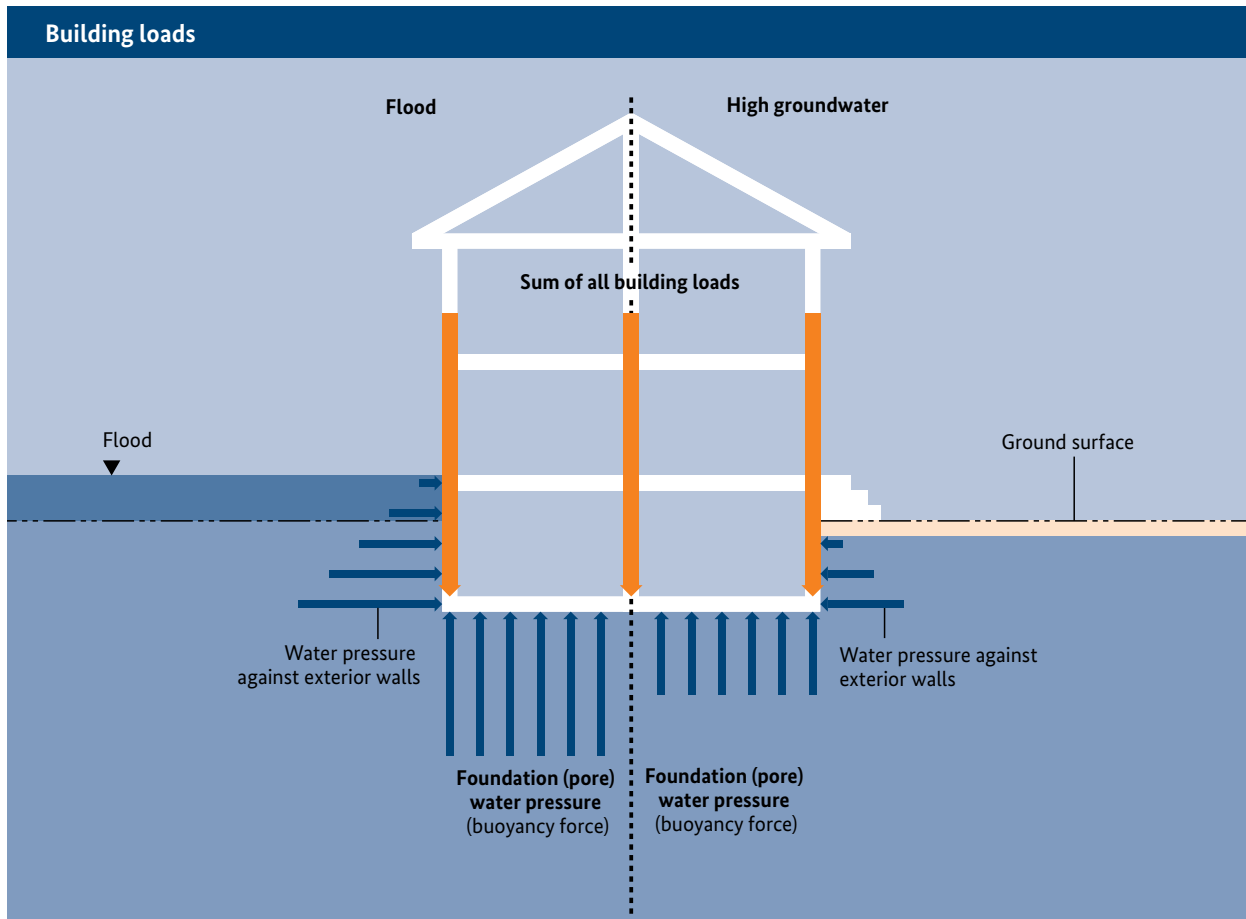
The aim of building-related protective measures should thus be to prevent water entry into buildings – or at least limit water entry as long as this would not compromise their structural stability. The figure above shows the general different ways in which water can enter into a building when a flood occurs.

### 6.3 Water pressure and buoyancy

When groundwater rises above a building's foundation level, the building becomes subject to water pressure and buoyancy forces. In each case, the strength of such buoyancy forces depends on the water volume that a building is displacing. It thus depends on the water level. The buoyancy forces increase as water levels rise and the displaced water volume increases.

When the total buoyancy force exceeds the total building load, the building will begin to float. In unfavourable cases, this can destroy the building. For this reason, it is vital to ensure that buildings remain structurally stable at all times – even in the presence of the most severe flood events.

Critical situations can arise when a building is being built, and its total building load is still small. For this reason, construction must be planned in an ensuring



Source: Foundations of Hydrostatics (Archimedes, 287 – 212 B.C.)

way that construction phases that present risks in this regard – such as phases immediately following the completion of the foundation – do not coincide with seasonal flooding, such as the flooding that often occurs in winter and spring months. As a precaution, the possibility of (partially) flooding the building, with fresh water if necessary, should be planned for.

**Attention:** Water-tight buildings with just a few stories normally lack the weight they need in order to resist buoyancy forces.

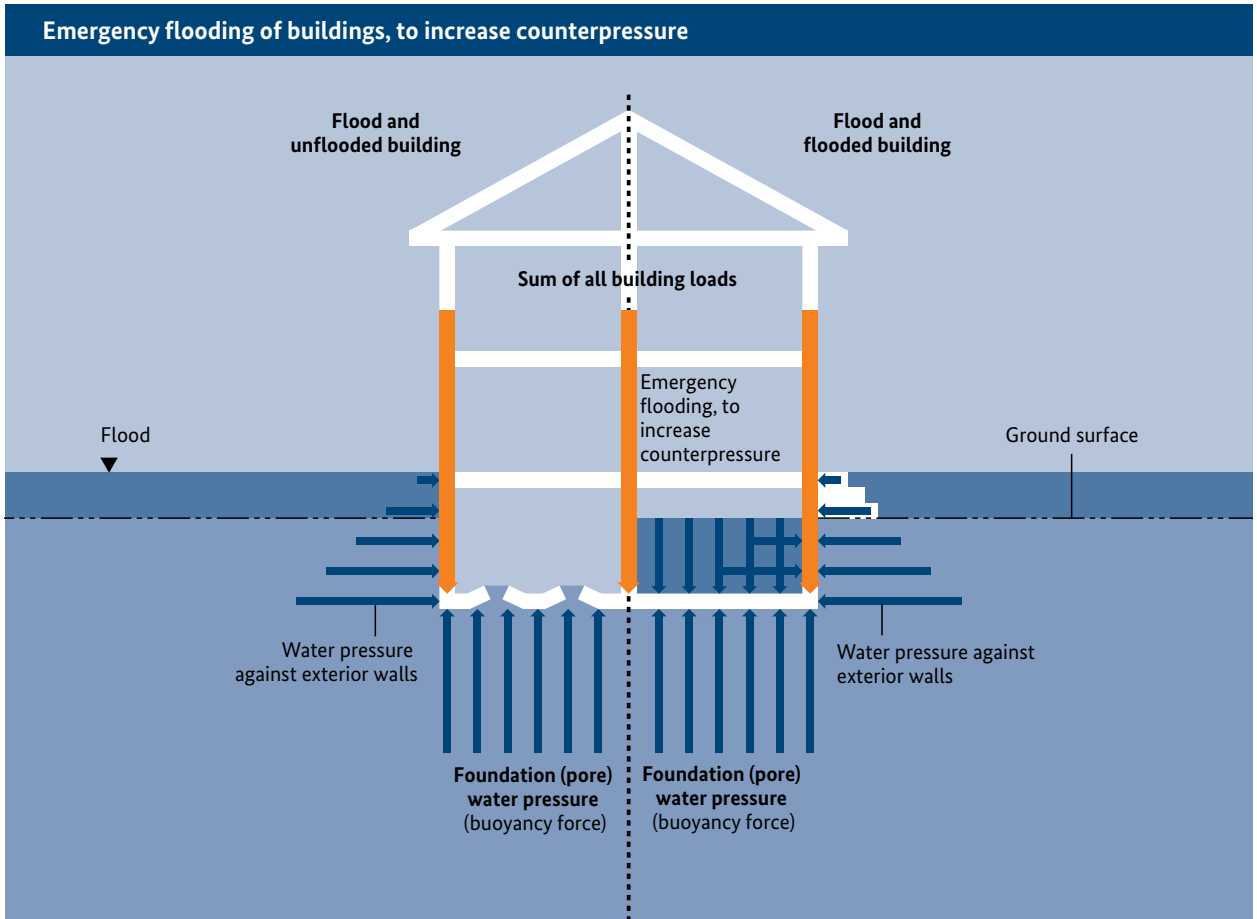
Moreover, floods bring additional stresses in the form of water pressure on foundation beds and on walls. In many cases, buildings are not designed to withstand such stresses. Floods, therefore, can damage their walls and / or foundations.

## 6.4 Checking the structural stability of existing buildings

### 6.4.1 Adequate building loads, wall / foundation dimensions

As a rule, a building's buoyancy safety will be sufficient only as long as the water level around the building is not overly high. Planners should carry out static checks of all at-risk buildings to ensure that they have adequate buoyancy safety.

And while a building as a whole needs to have adequate buoyancy safety, its various parts and sections must be designed to withstand expected increases in water pressure. For this reason, cellar walls and foundations should normally be made of reinforced concrete. In addition, foundations should be adequately anchored so they can resist flotation and breakaway.



Source: Foundations of Hydrostatics (Archimedes, 287 – 212 B.C.)

### 6.4.2 Emergency flooding of buildings

When buoyancy or water pressure threaten a building's structural stability, the simplest and most effective immediate countermeasure can be to flood the building, either partially or completely. In preparation for such eventualities, buildings should be equipped with water-level marks that show the emergency-flooding level needed to protect the building.

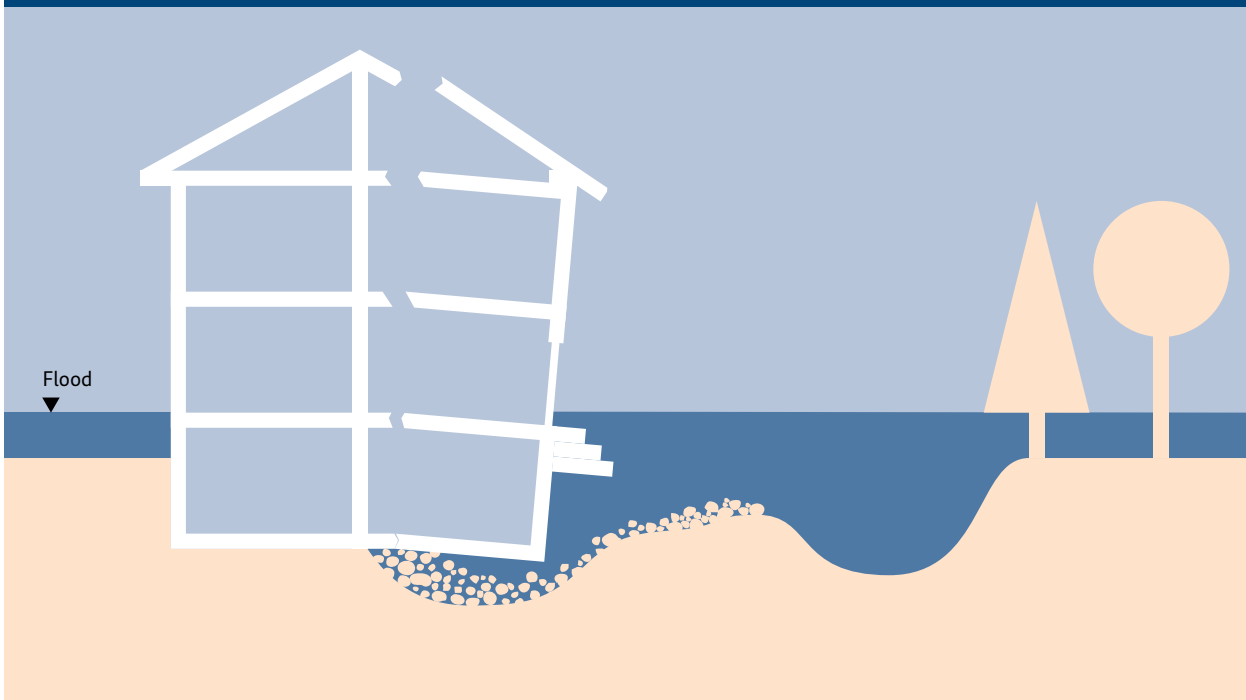
Flooding with clean water can reduce damage due to dirt or pollutants. The above figure shows the force relationships involved when flooding is used to counter water displacement. Flooding creates counterpressures, in the interior of the building, that can considerably reduce the effects of the forces being exerted on the building from the outside. In addition, the weight of the so-introduced water adds to the building's total load.

**In sum:** Emergency flooding reduces the total stresses on the building.

In some cases, it may be useful to use other materials to provide an additional load (imposed load). In addition to sandbags, any types of heavy materials may be used that can be placed over entire areas. Point loads – such as those exerted via table legs – are unsuited for this purpose.

In general, it is wise to have an expert planner check the buoyancy safety and static strength of your building's exterior walls and cellar floors in the context of likely or possible water pressures. In each case, the planner will estimate the load being exerted by your building or rather the weight, and then consider that load in relation to the weight of the volume of water that the building would displace in the event of any

## Buildings located near rivers are susceptible to being destroyed through undermining of their foundations



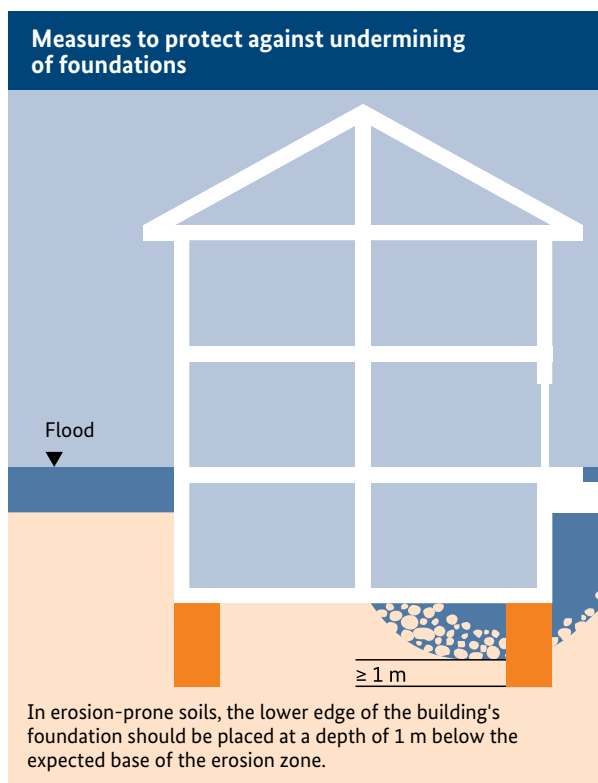
Source: Foundations of Hydrostatics (Archimedes, 287 – 212 B.C.)

expected flooding. Through a pressure-distribution analysis, a planner can then also determine which structural components would be prone to failure when subjected to static water pressures.

### 6.5 Currents

Buildings located near rivers can also be subject to additional stresses from river currents. In particular, small buildings, with relatively shallow foundations, are especially at risk of collapsing and being carried away when they are hit by strong currents. Fast-moving flotsam can worsen this problem. Where surfaces are not paved or otherwise reinforced, currents can strip soil particles from soil structures, thereby creating hollows in foundation soil. This, in turn, can damage buildings by causing subsidence and undermining and even breaking foundations.

For this reason, in erosion-prone soils, the base of the foundation should be placed a full metre lower than the base of any expected erosion. To protect an existing building in this regard, one can add a fronting concrete wall that will reduce the risk of the foundation's being undermined.



Source: in keeping with DIN 4123



# 7 Design recommendations for flood-adapted construction

## 7.1 Protecting buildings against entry of groundwater

Where soils are highly water-permeable, predominately areas with sandy or gravelly soils, floods can be expected to involve rapid rises in groundwater levels. Near to rivers, the following simplified relationship may be assumed to apply: the flood level = the groundwater level.

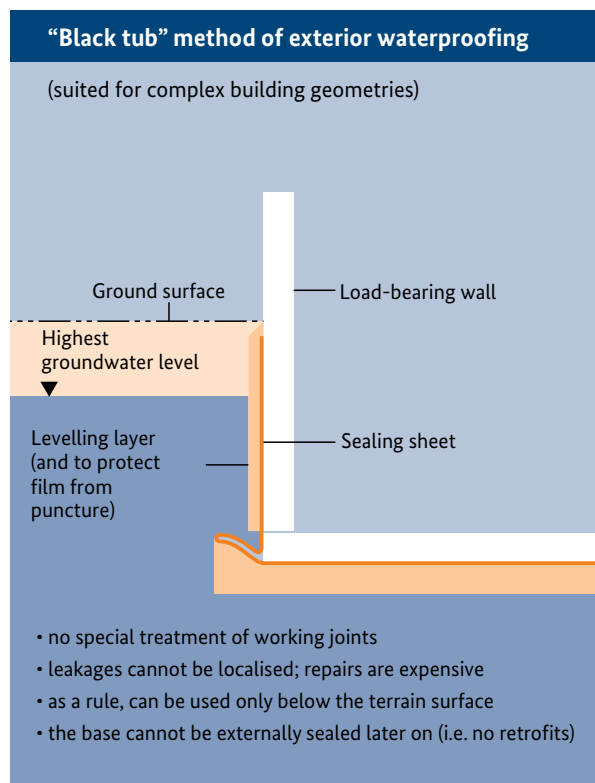
When the groundwater level rises above a building's foundation level, water pressure creates additional stresses on the base of the structure and on its walls. The groundwater is then referred to as "pressing groundwater." With regard to such situations, the DIN 18195 (Waterproofing of buildings) standard provides technical information on how waterproofing structures should be dimensioned and installed. The following requirements apply in the case of pressing groundwater:

- As a rule, the structural waterproofing should be applied to the exterior sides of exterior walls. In addition, it has to form a closed "tub" or enclose the structure on all sides. Where it is not feasible to apply such exterior waterproofing, the interior of a structure can be waterproofed.
- Where water-permeable, non-cohesive soils (sand, gravel) are involved, the waterproofing has to extend at least 30 centimetres above the highest expected groundwater level. With cohesive soils (loam, clay), the waterproofing should extend at least 30 centimetres above the planned terrain surfaces.
- It must be ensured that the waterproofing does not lose its protective function when expected structural deformations (shrinkage, subsidence) occur.

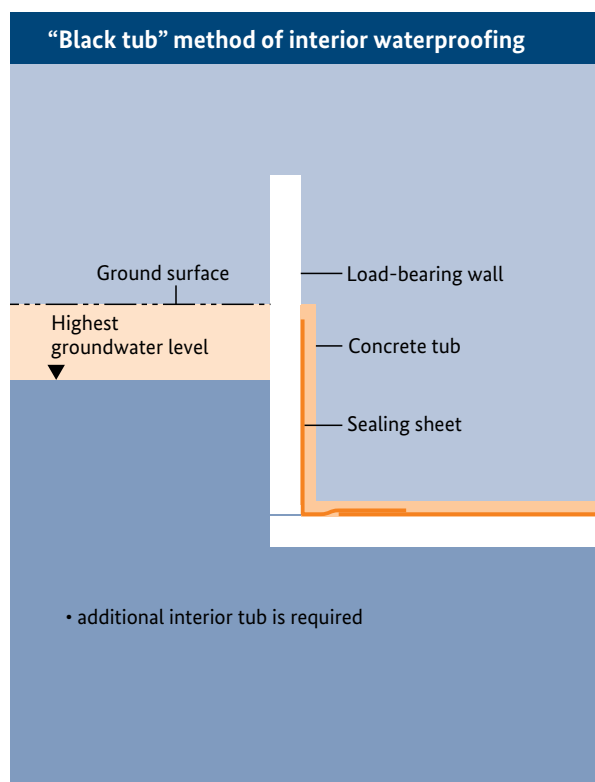
Two basic types of structural waterproofing are differentiated: "black tub" and "white tub."

With "black tub" waterproofing, all sides of affected building sections are covered with bituminous or plastic sheeting. As a rule, such waterproofing is applied on the exterior; the waterproofing sheeting is arrayed on the building's exterior and then affixed to the building's walls or foundation.

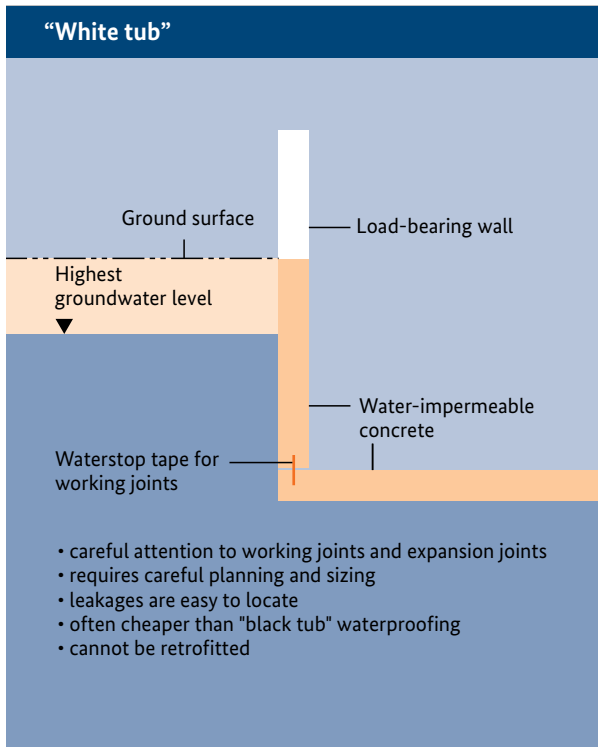
It is much more difficult, from a technical standpoint, and much more expensive, to apply such waterproofing



Source: DIN 18195



Source: DIN 18195

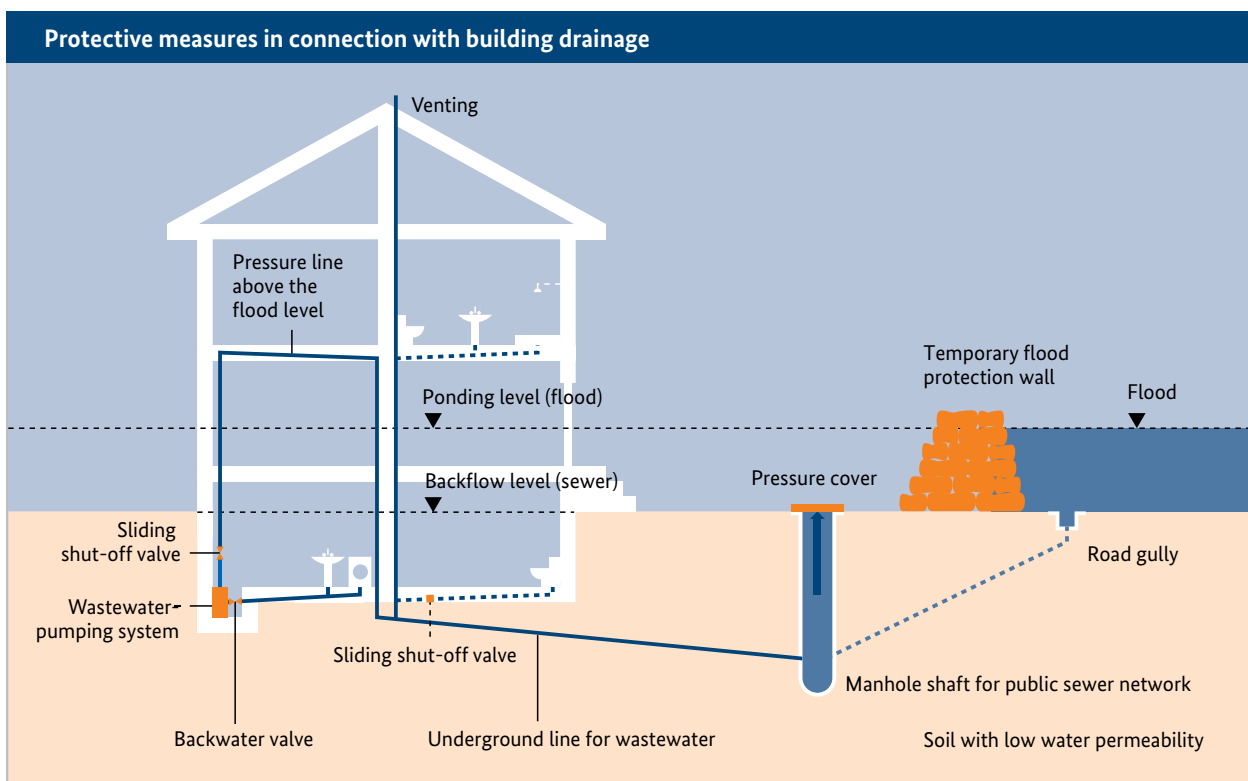


Source: DIN 1045, DIN EN 206, DafStb “WU-Richtlinie” (Water-impermeability guideline of the German committee for steel-reinforced concrete (DafStb))

(after the fact) to the interior of a building (waterproofing from the inside). With interior waterproofing, an additional inside tub or tray has to be installed that has the static strength to withstand the water pressures to which the waterproofing can be exposed. For this reason, interior waterproofing, designed to guard against pressing water, should be used only in certain individual cases involving retrofitting of old structures.

In “white tub” waterproofing, a building’s exterior walls and base plate are built of water-impermeable concrete, as a closed tub, in keeping with the applicable technical regulations and standards. Such structures require no additional sealing sheeting. In construction of such structures, special attention must be given to the proper execution of working joints.

“Working joints” refer to the transitions between fresh concrete and concrete sections that have already hardened. One manner of ensuring that working joints are water-tight is to use plastic waterstop tape to connect already hardened concrete to fresh concrete, with half of each tape segment bound within hardened concrete and half inserted in a new, adjoining section of



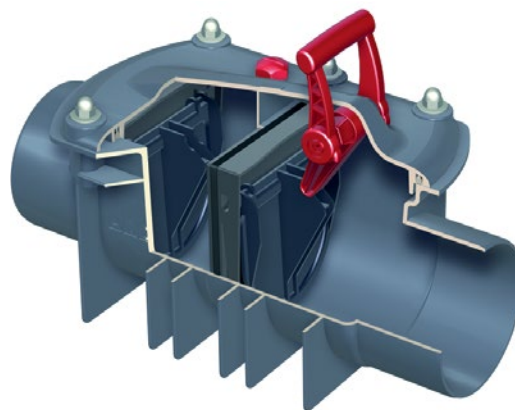
Source: DIN 1986, DIN EN 12056, DIN EN 13564

fresh concrete. Regardless of what sort of waterproofing is used, the base and walls of the structure have to be designed and dimensioned so as to be able to withstand the expected water-pressure stresses. In general, this means that base plates made of reinforced concrete require an additional upper reinforcement layer.

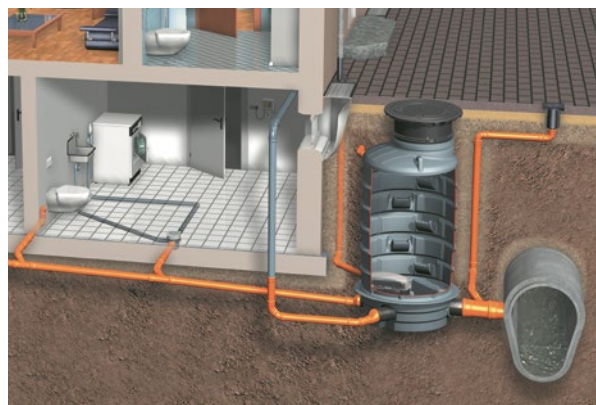
## 7.2 Protecting buildings against entry of sewage water (backwater)

During floods, water levels often rise in sewer networks because sewers become overloaded with large quantities of rainwater and groundwater (if they are not sealed off from such water), or because they back up when their receiving waters reach high levels. Such water-level rises in sewer networks propagate themselves through drainage lines and service connections – and even into the interiors of buildings.

When a building’s wastewater network is not equipped with closure mechanisms such as check valves, slide valves and wastewater pumping systems, the water level within it will rise until it matches the water level in the sewer network. This can then lead to water



Backflow-prevention system for buildings, for wastewater that does not include human waste

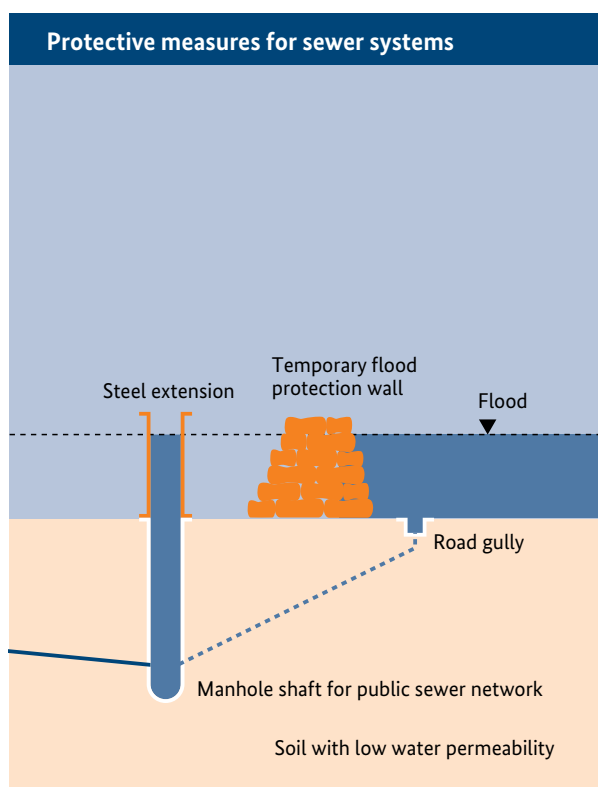


Backflow-prevention system installed outside of a building

discharges from drains of sanitary systems or other systems.

In flood-prone areas with long water-retention periods, sliding shut-off valves provide a greater measure of safety and reliability than check valves do. Their use requires suitable advance warning, however, since they can function properly only if they are closed in time.

The term “backflow level” is used in connection with wastewater systems. With regard to a sewer network in non-flood-prone areas, that level refers to the highest-possible water level that can occur when the network backs up. In each case, the local authorities will normally define a definitive backflow level. If a backflow level has not been so defined, the backflow level at a connection point is considered to be the road surface height at that point. In inundation areas, water levels in sewer lines can be expected to rise to the flood-water level, that means higher than the backflow level.



Source: DIN 1986, DIN EN 12056, DIN 13564

**In sum:** In inundation areas, the water level that floods can reach – and not the backflow level – is the level to consider in addressing the possibility of sewer backups. Every structure in such areas must be protected with backflow-prevention systems and / or pumping systems. And such systems must be regularly serviced.



A backup can also lead to unexpected flooding in outside, supposedly “flood-protected“ areas around structures (such as areas behind flood protection walls). Water from inundated areas can be pressed through sewage networks and directly onto properties. If a sewer network cannot be closed off with the help of sliding shut-off valves, water overflow from the network can be prevented with overflow-protection systems such as pressure covers and steel-cylinder extensions. It must be remembered that backflow problems often can affect not only individual buildings, but also entire, large “protection zones.“

### 7.3 Protecting buildings against entry of surface water

Buildings in flood-prone areas can be protected in different ways (structural and behavioural strategies) against entry of surface water:

- protection systems (water stops) in outside areas, to prevent inflow of water to buildings (useful only when no groundwater can penetrate)
- waterproofing and protective measures applied to buildings themselves, to prevent water penetration into buildings

One way of preventing water from flowing to a building is to surround the building with a flood protection structure.



A simple sandbag wall can be surprisingly effective.

Depending on the type and location of the building to be protected, and in keeping with the expected flood levels, stationary flood protection systems, or partly or fully mobile flood protection walls, can be used.

Stationary flood protection systems, such as earthwork dams, walls or sheet pile barriers, are separate flood protection structures that have to be specially planned and designed for the site in question. What is more, they tend to reduce options for using the property in question, they lastingly change the appearance of the municipalities and landscapes in which they are placed and they can hinder the flow of traffic.

In general, partly mobile flood protection walls consist of “mobile“ stop-plank systems combined with stationary support systems such as embedded, anchoring foundations or securely installed supports with guide rails to accept the planks. With such systems as well, the resulting flood protection will be effective only if no flow around them occurs (surface water or rising groundwater) and the sewer network does not back up in the manner described above.

Mobile flood protection walls consist of transportable protective elements – usually planks – that, for reasons of static stability, should be erected, or stacked, only to a maximum wall height of 2.5 meters. In most cases, they are buttressed with steel structures on their rearward sides (away from the water). High wall heights are technically inadvisable, due to the increasing water-pressure stresses involved. Where such flood protection walls are used to protect individual buildings, they can be braced directly against the buildings themselves.

Stationary and partly mobile systems tend to be used primarily in connection with public or industrial flood protection, due to their high investment costs. Mobile flood protection structures consisting of planks and guide rails, structures which also suitable for protecting door and gate openings, are an exception in this regard.

For protection of private structures, property enclosures employing walls or small earthen embankments can be useful, depending on buildings' locations. When only slight water overflow levels are expected, the simplest, and cheapest solution can be to protect



Flood protection with mobile, water-filled tube system

buildings with small dams consisting of sandbags. Systems consisting of water-filled tubes can provide quick, temporary protection. With such systems, one must always ensure that suitable protection is in place to prevent water from flowing underneath guarding structures, at ground level. Where water-filled protection systems are flooded to and beyond the maximum water levels they are designed to guard against, they present a risk of sudden failure.

With flood protection walls, one must expect the possibility of minor leakages and underflow. For this reason, pumps should normally be kept available, both outside and within buildings, to pump out water that enters by such means.



Circumferential flood protection with partly mobile wall elements

**A basic rule:** Flood protection walls make sense only in combination with adequate protection against groundwater and backflow from sewage networks.

In general, waterproofing and other protective measures applied directly to buildings are easier to implement and thus more cost-effective than such measures in outdoor areas. For measures in and on buildings to be effective, buildings must have adequate structural stability and water resistance, and their exterior walls must be water-tight. The following options are available for preventing water from entering via door and window openings:



Flood protection with protective panels made of plastic





Flood protection for building openings

- when overflow levels are minor (centimetres or decimetres), sandbags can provide adequate protection
- stop-log / plank systems placed directly in front of entryways can provide effective water stoppage even in the face of higher water levels (decimetre or meter range)
- in addition, other types of waterproofing systems are available on the market (such as custom-fitted inserts for entryways and windows that means bulkheads, with profile seals) that also offer adequate protection against water penetration, up to certain water levels
- as an alternative, pressure-tight and highly stable windows and doors can be installed



Flood protection for window openings

As the term suggests, pressure-tight doors and windows are designed to resist water pressure – and, thus, air pressure. While they prevent water from flowing into structures, they also block room ventilation when they are closed.

Doors and windows are termed “flood-resistant” when they withstand flood pressures and allow only small amounts of water to enter.

Since water pressure increases as water levels rise, attention should always be given to the maximum permissible ponding depths for which such systems are designed. Manufacturers normally indicate such depths as heights above the windowsill (lower edge of the window). This aspect is particularly important in connection with cellar windows. Light shafts around



Automatically closing outer panel for windows





Pressure-tight window



Foil seals for building openings

cellar windows can also be made flood resistant. This involves installing specially ruggedized light-shaft boxes directly on the building. To ensure that no groundwater can enter via bottom outlets, such systems include backflow-prevention systems.

Buildings should be waterproofed to ensure that no water can seep through their exterior walls. When this is done, it must be remembered, however, that the aims of flood protection and thermal insulation basically conflict when seen from the standpoint of building physics. What is good with regard to flood protection (such as dense materials, and a lack of openings) tends to have negative impacts on thermal-insulation / energy efficiency (no ventilation – poor water vapour diffusion; good thermal conductivity – poor thermal-insulation performance). The following criteria should be considered, or weighed against each other, in the designing of exterior facades:

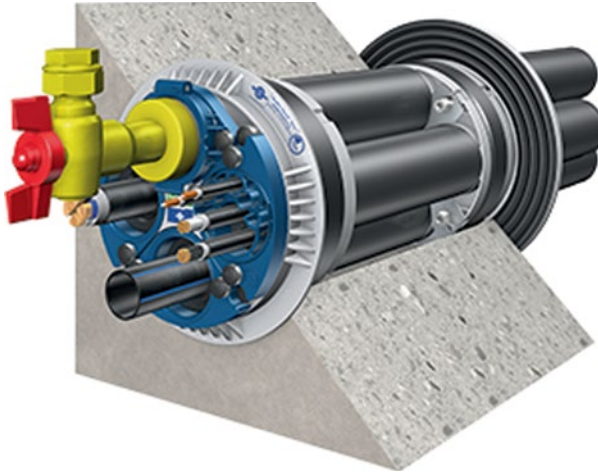
- maximum expected flood levels
- flood probability / frequency
- requirements pertaining to thermal insulation / energy saving
- drying speeds following soaking
- expenses involved in repairing systems
- aesthetic criteria for facades

These criteria apply to both old and new buildings. Decisions relative to the design of structural flood protection measures have to be made on an individual-case basis, however.



Pressure-tight door

Where buildings' exterior walls are not adequately waterproofed, water seepage into buildings must be expected. In particular, leakages in joints or wall connections can lead to significant water seepage.



Wall penetration designed to withstand water pressure

Chapter 8 focuses on the durability of construction materials and various structural designs under the influence of floods.

## 7.4 The adaptation strategy – structural precautions in buildings

Structural precautions should begin during the planning phase. For example, significant damages can be ruled out simply by eliminating a basement / cellar level, or opting for a black or white “tub.” By moving a ground-level story to a higher level, or placing a structure on stilts, one can ensure that floods will not affect a home’s living areas. Where buoyancy risks apply, suitable buoyancy safety must be ensured. And if a building is flooded in spite of all “withstand”-strategy measures, or if the protection targets for which protection systems were designed are exceeded, suitable adaptations in the areas of building materials, building systems and building furnishings, taking account of the possibility of flooding, can help prevent damages.

It must be remembered that technical building systems not only can suffer damage – they can also pose serious and even life-threatening hazards for people and can create environmental problems.

### 7.4.1 Heating and electrical systems

Heating systems, and electrical installations such as current distribution boxes, should be located on upper floors where they will be safe from floods. Subordinate electrical installations should be kept out of home areas likely to be affected by flooding (cellars, ground floor), if at all possible, or at least installed high above floor levels. The relevant electrical circuits should have separate circuit breakers and protective devices.

Heating systems should be designed so they can be quickly dismantled in the event of flood threats or, alternatively, should be equipped with added protection so they can withstand flooding.

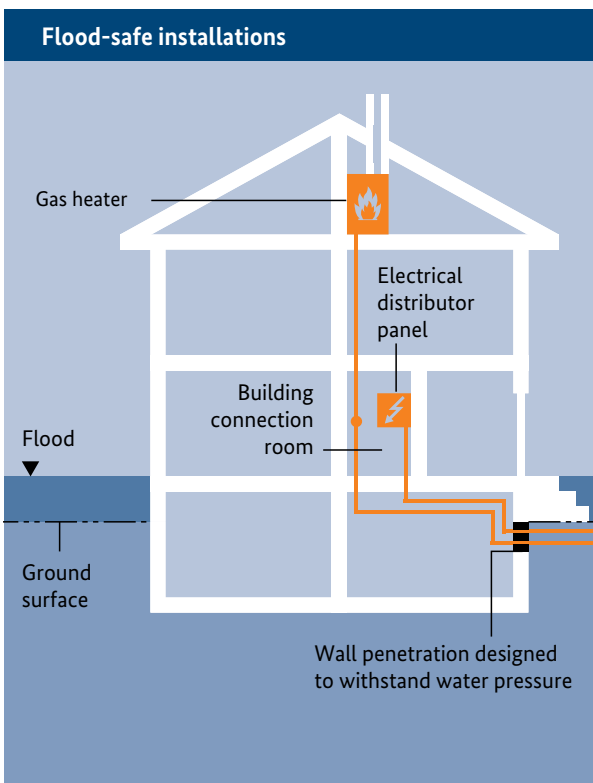
Fuel-storage areas and units present additional problems. Heating oil is discussed in the following chapter, as a special issue. Storage areas and units for other types of fuel (wood chips, wood pellets) can be



Flood-resistant door insert



Protection for a heating burner



Source: Ruiz Rodriguez + Zeisler + Blank GbR

damaged by flooding. Gas tanks should be protected against buoyancy and impacts.

#### 7.4.2 Protecting heating-oil tanks against flotation / buoyancy forces

Releases of oil, via leaks in heating systems or heating-oil tanks, can seriously damage buildings and their furnishings. What is more, oil spills can pollute above-ground and subterranean water bodies.

Where conversions to other fuels are not feasible, tanks, along with all connections and openings (filler tubes, vents), must be protected against all water penetration. In addition, tanks must be secured, with the help of suitable anchors or upward supports, against flotation. The “critical load case” with regard to tank dimensions and characteristics relative to flotation is the empty tank. In designing and dimensioning anchors and supports for guarding against buoyancy, one must thus focus on the “empty-tank” case. This also applies for outdoor tanks.





Heating-oil tanks with buoyancy safeguards

Where heating-oil tanks cannot be secured against buoyancy, filling tanks with water, to provide the necessary counterweight, can be a suitable emergency measure. Later, one can have a specialist company separate the resulting heating oil / water mixture; the relevant costs are miniscule in comparison to the costs of the damages that oil spills within and around a building can cause. Tank connections and connecting lines, in the case of tank arrays, always need to be shut off and secured.

But note that not all tanks are designed to withstand the water pressures that floods can apply. Tank manufacturers are required to provide proof (certification) relative to their tanks' characteristics in this regard. In some cases, static calculations may have to be carried out to ensure that tanks are properly secured against buoyancy. For these reasons, the following principle applies:

Oil-fired heating systems should not be used in flood-prone areas.

### 7.4.3 Storage and handling of other substances hazardous to water

Substances that pose hazards for health, water resources and the environment need to be moved out of the danger zone, in keeping with a predefined plan. The questions of which substances need to be moved, and where they need to be moved to, must be clarified in advance. Substances should be properly labelled in this regard, to facilitate allocations when such moves are required.

A number of different measures can be carried out – some before, some during and some after flood events – in order to reduce damage to electrical and heating systems. It is recommended that such measures be planned in cooperation with the relevant specialist companies. On-the-spot planning while a flood is approaching often fails to produce the desired results. The following points should be observed:

- secure tanks in cellars and underground tanks (against spills, and against flotation)
- dismantle technical equipment if necessary or appropriate
- remove electrical systems, or at least switch them off
- shut off the main valves / switches for gas, water and electricity



# 8 Flood resistance of building materials and layered/composite constructions

## 8.1 Basic principles

In contrast to the precautionary strategies “Avoid” and “Withstand,” which are aimed at keeping flood water away from buildings, or preventing water from entering buildings, flood-adapted construction strategies seek to limit the flood damage that occurs when flooding of a structure can no longer be prevented.

Flood-adapted construction, therefore, represents a third precautionary strategy, one that is becoming increasingly important. This strategy seeks to reduce the structural damage that buildings can suffer when they are flooded. When it is successful, the strategy thus reduces the scope of the structural repairs that are needed after the flood is over, and it enables buildings to be quickly returned to their intended uses. In the case of commercially used properties, fast repairs and fast resumption of normal utilisation can play an important economic role.

In support of this strategy, therefore, building materials should be chosen that are insensitive or resistant to water, and such materials should be used especially in ceiling, floor, exterior-wall and interior-wall structures that are normally particularly at risk of suffering flood damage. Alternatively, structural designs can be optimised in ways that keep the cost of later renovations, in terms of both time and materials, to a minimum. Above those sections of buildings that are particularly at risk from floods, the customary construction methods may be used, without restrictions.

The task of designing flood-adapted structures is a complex one, normally requiring the involvement of specialist planners. Such planners can ensure, both prior to initial construction, and after flood damage has occurred, that all necessary work is specified, in terms of type and scope, and that no unnecessary tasks are carried out. The following three sections are presented to help give readers an overview of the broad spectrum of flood-adapted construction:

- the typical types of damage that one finds in buildings following flood events,
- the behaviour of common building materials when exposed to flooding, and
- special aspects to take into account in adaptation of special structural combinations of layers.

## 8.2 Types of damage

All of the main types of damage that buildings can suffer as a result of flooding can be grouped into the following three main groups:

- moisture and water damage,
- damage as a result of contamination,
- structural damage.

Any building, if not specially adapted for flooding, will suffer moisture and water damage as soon as it and its various parts come into contact with ponding and / or penetrating floodwater. The characteristic types of damage that then occur in this category include visible traces of moisture penetration and water levels, efflorescence on structural surfaces, moisture- and frost-related deformation and volume changes and detachment of coatings. The subsequent damages that can occur include reductions of structural strength,



Soaked exterior wall, following a flood

impairment of thermal-insulation performance, infestations by microorganisms (fungus, bacteria) and corrosion.

Floodwater can dissolve and transport substances hazardous to waters (such as heating oil). When such substances come into direct contact with structures, they usually significantly contaminate / pollute them or leave them irreversibly damaged. Such damage also frequently causes highly unpleasant smells that building users then notice. As a rule, the tasks of satisfactorily removing such contaminations, and restoring structures to a safe condition for their occupants, are technically involved and financially costly. The required structural measures may even include the complete replacement of contaminated parts and structures. It can be a good idea, depending on the scope of damage in each relevant case, to have a technical expert assess the damages.



Flood-caused detachment, via floating, of cement screed laid in the “floating” manner

Many different types of damage are structural in nature. The severity of building damage can depend on the height that floodwaters reach and on their impacting flow speeds. Such damages can reach the point at which a structure’s structural stability, or the stability of parts of the structure, is threatened. The main types of damages in this category include:

- foundation damages
- damages from hydrostatic pressures or buoyancy
- other flood-related stresses on structural components

Foundation damages in existing buildings occur, in floods, especially when sections of foundations, such as parts of base plates, and of foundation walls, are undermined via erosion and scouring. The scope of foundation damages also includes subsidence of buildings, or of parts of buildings, that can occur when foundation soil becomes heavily soaked and softened. The typical types of damage in this area include cracks in walls and deformation and tilting of parts of buildings.

In buildings, or parts of buildings, structural damages caused by water pressure (hydrostatic forces) or by buoyancy occur primarily during flooding when large, non-flooded rooms are surrounded by groundwater or



Undermined house along the Weißeritz river

surface water, with the result that significant buoyancy forces counter the forces exerted by the building.

Buoyancy risks also have to be considered in connection with other parts of buildings. For example, floorings, in particular, can be damaged when the buoyancy forces exerted by inundated, hidden thermal floor insulation exceed the weight loads of floor layers





Buoyancy-caused detachment of a floor construction

over the insulation and of furnishings, for instance. When that occurs, the entire floor structure will float, and thereby normally be irreparably damaged. Other types of flood-related stresses on structural components include impact damage caused when debris strikes a building's facade.

### 8.3 The behaviour of common building materials when exposed to flooding

In floods, building materials can be exposed to strong temporary stresses from pressing water, and their moisture content can increase very sharply as a result. Building materials' properties with regard to water absorption, water transport and water storage can vary, in keeping with the materials' composition, the means by which they have been manufactured and processed and the purposes for which they are being used in a relevant structure.

And building materials' specific properties in each case play a central role in determining how likely, and how severely, they will be damaged in the event of a flood. The process of assessing the ability of typical building materials, and of typical constructions / combinations / composites of materials, to withstand flood damage (adverse impairment) is a highly complex one. Such assessment must especially take account of

- building materials' stability with regard to their strength properties,
- their stability with regard to their forms and volumes,
- their water-absorption behaviour,
- their suitability for natural or technically boosted drying on site,
- their reusability, and

- their resistance to fungal and microbial infestation, and their resistance to corrosion.

By assessing a material's properties with regard to these criteria, an experienced planner can determine the material's suitability for use in flood-adapted structural components. It must be remembered that additional damage mechanisms may apply, however. Such mechanisms may include transport, within materials, of harmful, stored water-soluble salts that can lead to efflorescence or plaster crumbling. Additionally, high moisture loads increase building materials' thermal conductivity, thereby increasing structures' heating-energy requirements. In general, buildings that, following a flood, have not yet dried out adequately are at increased risk of incurring microbial infestation or corrosion.

The following section describes the moisture properties of various building materials, including natural stone, brick and other ceramic products, materials incorporating bound cement, lime or gypsum, insulating materials, wood and wood materials and various types of metal and glass materials.

#### 8.3.1 Natural stone

The moisture properties of natural stones, which in earlier time were commonly used in building construction, are determined primarily by the processes via which the stones formed. Some sedimentary rocks, for example, such as sandstone and limestone, have porous



Natural-stone wall

structures that can absorb, store and transport water via capillary action. Many types of magmatic rocks, such as basalt or granite, are practically free of pores and thus have no structures that could absorb water. Clayey shale and gneiss, which are metamorphic rocks, also have very few pores, and thus have very low water-absorption capacity.

### 8.3.2 Bricks and other ceramic products

In general, bricks are grouped into the major categories of facing bricks and common bricks. Facing bricks (clinker) have a high bulk density – and thus low water-absorption capacity. They are thus often used for the outer shells of multi-shell masonry structures. Common bricks, on the other hand, have lower bulk density, and thus high water-absorption capacity. They are used for load-bearing and non-load-bearing masonry walls, including both interior walls and exterior walls.

The strength properties of fired bricks, like the strength properties of other masonry building materials, are not adversely affected by exposure to flooding.



Wall of vertically perforated bricks with low bulk density

Other ceramic materials of relevance for construction include thin clinkers for exterior-wall coverings, ceramic facade plates and wall and floor tile. All of these materials have very dense structures. They thus have low water-absorption capacity.

### 8.3.3 Cement-bound building materials

The group of frequently used building materials that are minerally bonded with cement, an inorganic binding agent, include concrete – with either normal or lightweight aggregate – and the great majority of masonry and plastering mortars.



Waterproofed cellar with thermal-insulation layer

Building materials that have porous structures can readily absorb, transport and store water. But by carefully controlling their pore structures during production, one can use them to make water-repellent and even water-impermeable materials that are tailored for specific applications.

That said, it must be remembered that “water-impermeable concrete” is not really a material as such but the result of a building technique whereby concrete components, in addition to having a load-bearing function, acquire a sealing function against pressing water. The planned functional cohesion of

- concrete with low pore volumes
- stress-adapted, specially planned reinforcement, for limiting crack widths
- special measures for sealing joints and penetrations; and
- assured, component-specific minimum thicknesses

is what produces components with high water-penetration resistance. The areas in which water-impermeable-construction techniques are used include produc-



tion of water-impermeable foundation structures – so-called “white tubs.”

The cement-bound building materials also include the group of lightweight concretes, which have pore structures that slow water penetration.

#### 8.3.4 Lime-bound building materials

Under moisture stresses, the behaviour of sand-lime bricks and lime-bound, granulated-slag bricks is similar to that of aerated concrete. Their pore-size distribution gives them low capillary activity, and thus they absorb water only slowly. (Their low water-absorption capacity also results from their high bulk density.) But since these materials basically have high



Sand-lime bricks

pore volumes, ultimately they will absorb large amounts of water if they remain in contact with water for long periods of time.

#### 8.3.5 Gypsum-bound building materials

The group of building materials that can readily suffer damage when exposed to floods includes gypsum-bound materials such as calcium sulfate screeds (formerly: anhydrite screeds), gypsum plasters and gypsum fibreboards. In general, such building materials have a relatively high water-absorption capacity – and



Gypsum-bound building materials

also tend to be especially sensitive to moisture. When they experience moisture penetration for prolonged periods, gypsum-bound building materials tend to suffer irreversible swelling, followed by losses of strength.



Wall built of aerated-concrete blocks

#### 8.3.6 Aerated concrete

Aerated concrete (formerly: gas concrete) is a building material with very high porosity (with pores accounting for up to 90 percent by volume). It is often used to make precision blocks, or large precision-formed elements, for masonry construction, as well as reinforced wall and ceiling elements in prefabricated construction. The structure of aerated concrete includes both capillary pores, which facilitate water absorption near the surface, and closed, bubble-shaped macro-pores, which have lower water-absorption capacity, since their enclosed air delays water penetration.



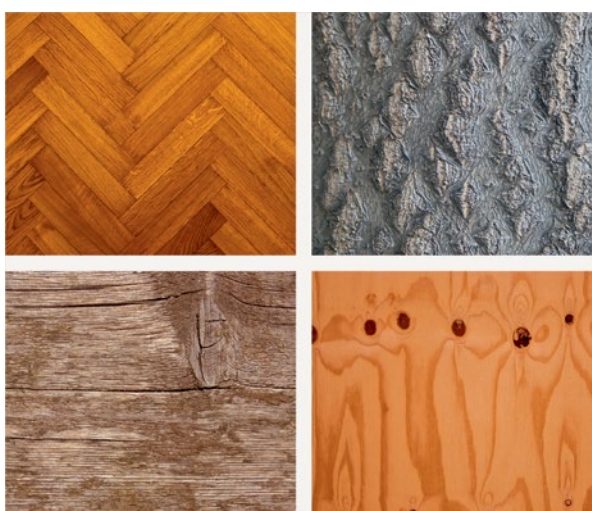
Wood-fibre insulation

### 8.3.7 Insulating materials

The many different types of insulating materials that are used for thermal and / or sound insulation can also be susceptible to damage. In general, insulating materials, in keeping with their primary purpose, need to have low thermal conductivity. That, in turn, always means they have low bulk density and high porosity. When exposed to floodwater, some insulating materials absorb large quantities of water and lose their dimensional stability. They then either cannot be dried or can be dried only at unreasonable expense. The group of commonly used insulating materials that normally have to be replaced following flood exposure includes rock wool, wood fibre panels, cellulose flakes (blow-in insulation) and all plant-based fibre insulation materials. When exposed to normal moisture loads, rigid foam panels such as expanded polystyrene (EPS) and polyurethane (PUR) panels absorb only small amounts of water. When they remain in contact with water for long periods of time, however, they can experience strong moisture stresses. As a rule, rigid foam boards made of extruded polystyrene (XPS) absorb very little water even during prolonged water contact. Insulating boards made of foam glass are not sensitive to water. Because foam plastics are subject to buoyancy forces when they are inundated, non-anchored and non-glued panels made of such materials (and laid horizontally, for example, under screeds) can suffer damage when flooded. When incorporated in interior- / exterior-wall structures, insulating materials may be exposed to different types of impacts during flood events. Such structures are discussed in section 8.4.1.

### 8.3.8 Wood and wood materials

When exposed to prolonged moisture loads, wood is especially at risk of rotting and of incurring microbial



Wood building materials

infestations. As a result, following a flood, all wooden parts and structures need to be immediately uncovered and exposed and then properly dried. This means, as a rule, that claddings and other coverings, and other surrounding elements, have to be removed.

Wood materials such as particle board, OSB boards, veneer-laminate boards and plywood boards suffer irreversible deformations when exposed to floodwaters and normally then have to be replaced.

### 8.3.9 Metal and glass materials

As a result of their material structures, homogeneous construction materials made of metal or glass, including foam glass with closed cells, do not swell, are impervious and absorb no water.

For this reason, they do not exhibit deformation due to swelling or shrinking. In practice, metals and glass are normally used in complex construction products. In such applications, they do require certain kinds of care



Metals and glass as building materials



following flood exposure, in spite of their basic robustness, such as cleaning, checking and – in some cases – measures to restore their proper function and corrosion protection.

## 8.4 Walls, ceilings and floors

In planning flood-adapted buildings, one must consider not only the specific characteristics of building materials, but also the best ways to integrate materials within typical types of structural designs – which now always call for multi-layer structures that even have multiple shells. Both in construction of new buildings and modernisations of existing ones, such combinations of layers now play indispensable roles in simultaneously meeting combinations of different types of utilisation requirements – for wall, ceiling and floor structures.

A key aim is to prevent critical levels of water collection in components, via careful choices of materials, of layer combinations (tailored for intended uses and likely stresses) and of defined layer thicknesses. During the planning phase for a structure, therefore, the behaviour of such combinations of layers of different building materials, under flood stresses, has to be taken into account.

### 8.4.1 Exterior- / interior-wall structures

Floods can subject wall structures to intensive stresses, as long as no waterproofing or barrier systems are in place to protect them from direct water contact. Flood-adapted construction strategies take account of the fact that floodwater can affect both sides of walls, exterior-wall and interior-wall structures.

As walls have to fulfil a range of different requirements in the areas of thermal insulation, sound insulation and moisture protection, most traditional types of wall structures – and all modern wall types – are multi-layer structures. Some wall types even have multiple shells. Multi-shell wall structures have hollows and air layers between their various shells. Floodwater can find its way into such spaces, with the result that a wall structure's innermost shell can come into contact with ponding water. Wall structures should offer adequate drainage options for such cases.

Flood-adapted construction strategies can include the following, for example, for wall structures that have hollows and air layers, between layers of different materials, that can allow water to flow and collect: in wall sections at levels up to the expected maximum flood level, other construction techniques can be used,



Multi-shell exterior-wall structure



Back-ventilated facade construction

employing materials and structures that are resistant or insensitive to water; or structures can be optimised for maximally rapid and cost-effective repairs and renovations following floods.

In this connection, it must be remembered that moisture in wall structures can be transported, via capillary action, up to 50 centimetres above the actual flood level.

In the interest of minimising water collection in exterior- / interior-wall structures, the capillary water-absorption capacity of the outermost structural layer in particular should be as low as possible. Ideally, building materials in exterior layers will be water-impermeable.

In layering thermal insulation within multi-shell exterior-wall structures (core insulation), one must remember that, as experience has shown, it can be very difficult to dry such insulation reliably, as such drying can be a time-consuming, complicated process. If at all possible, insulation layers should remain easily accessible, so that they can be rapidly replaced if damaged. External thermal insulation composite systems (ETICS) are more accessible than are core

insulation systems. They can often be redried, following flood events.

To ensure that thermal-insulation layers will retain their proper function and structural stability after being soaked, one must select the materials and structural techniques for such composite systems carefully, paying special attention in each case to the insulating material's dimensional stability in contact with water, and to the stability of the adhesive that binds the insulation to the substrate.

In addition, in flood-prone areas of buildings, one can take such measures as placing thermal-insulation layers behind easily removable wall claddings (back-ventilated facade constructions). It is also useful, in planning, to include systematic arrays of structural joints in facade sections above the expected maximum flood level. Such joints facilitate rapid dismantling of soaked areas – and, thus, rapid drying of wall materials. The insulating materials selected for such sections can then be less water-resistant than they would otherwise need to be. It can be more cost-effective to include such “disposable” layers than to use only water-resistant building materials.



As a rule, interior and exterior plaster layers have to be removed, following prolonged flooding, to enable significantly faster drying of walls and insulation layers. In some cases, such drying may need to be accelerated with the help of drying units.

Lightweight partition walls with panelling (stud walls) made of plasterboard or other non-water-resistant materials always have to be opened up following flooding, so that at least their panels and insulation layers can be replaced. In general, it must be remembered that when water enters a building at a specific point, while floodwaters are spreading, the water levels on opposite sides of light partition walls can differ considerably. Such level differentials can cause severe damage in such partitions and even cause them to fail suddenly.

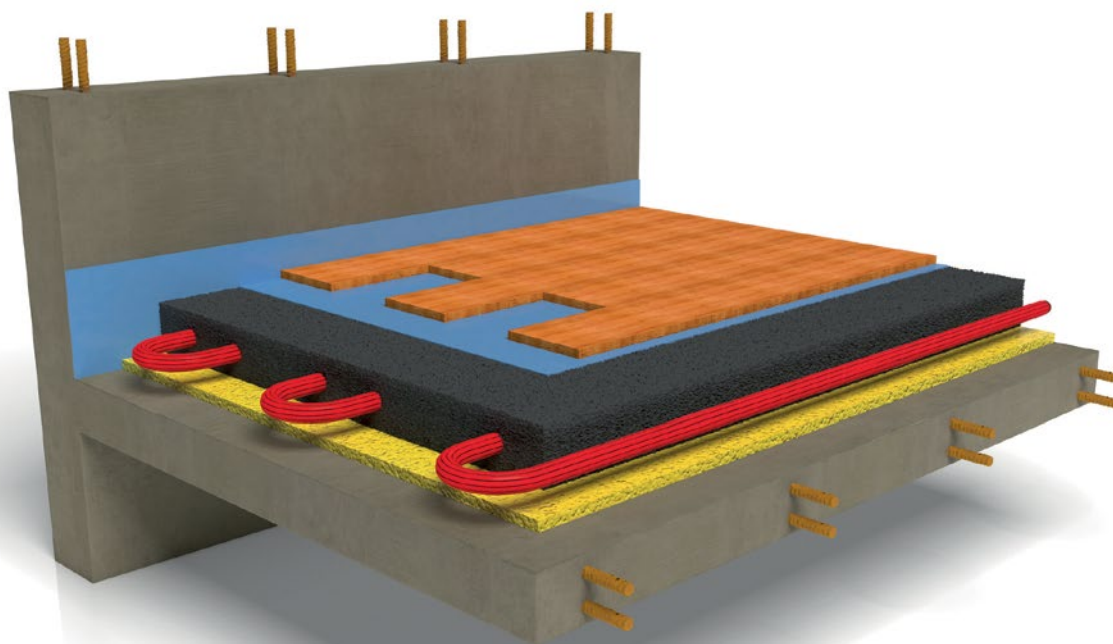
In the case of timber-frame and half-timbered constructions, all affected solid-wood sections have to be exposed to enable rapid and complete drying. In addition, panelling, insulating materials, vapour barriers, etc. in the damaged area normally have to be removed and replaced. When solid-wood timbers are properly dried, any swelling they have undergone usually disappears. Wood materials used in wall

structures are usually deformed irreparably when flooded, however, and then have to be replaced.

#### 8.4.2 Ceiling and floor structures

Inundation of ceiling and floor structures also often leads to extensive and severe damage. In considering such eventualities, one must view all the layers of a ceiling structure – normally including the raw ceiling and an overlying floor construction, with footfall sound insulation and thermal insulation, and possibly also including technical systems (such as under-floor-heating systems) – as one structural component.

In selecting materials and layering sequences for such constructions, one must always ensure that all layers can be accessed if they need to be dried. Here as well, the most cost-effective overall solutions may provide for the planned removal of individual layers. Hollows and absorbent materials in ceiling constructions facilitate water pooling during floods and can present additional hazards when ceiling structures experience static overloads. The different buoyancy forces that individual layers experience must always also be taken into account.



Schematic view of a floor structure

# 9 Information provision

## 9.1 Flood hazard maps: “Know the hazards”

To be able to assess flood safety precautions, and to be able to properly inform the public, one must have a thorough understanding of the prevailing flood hazards.

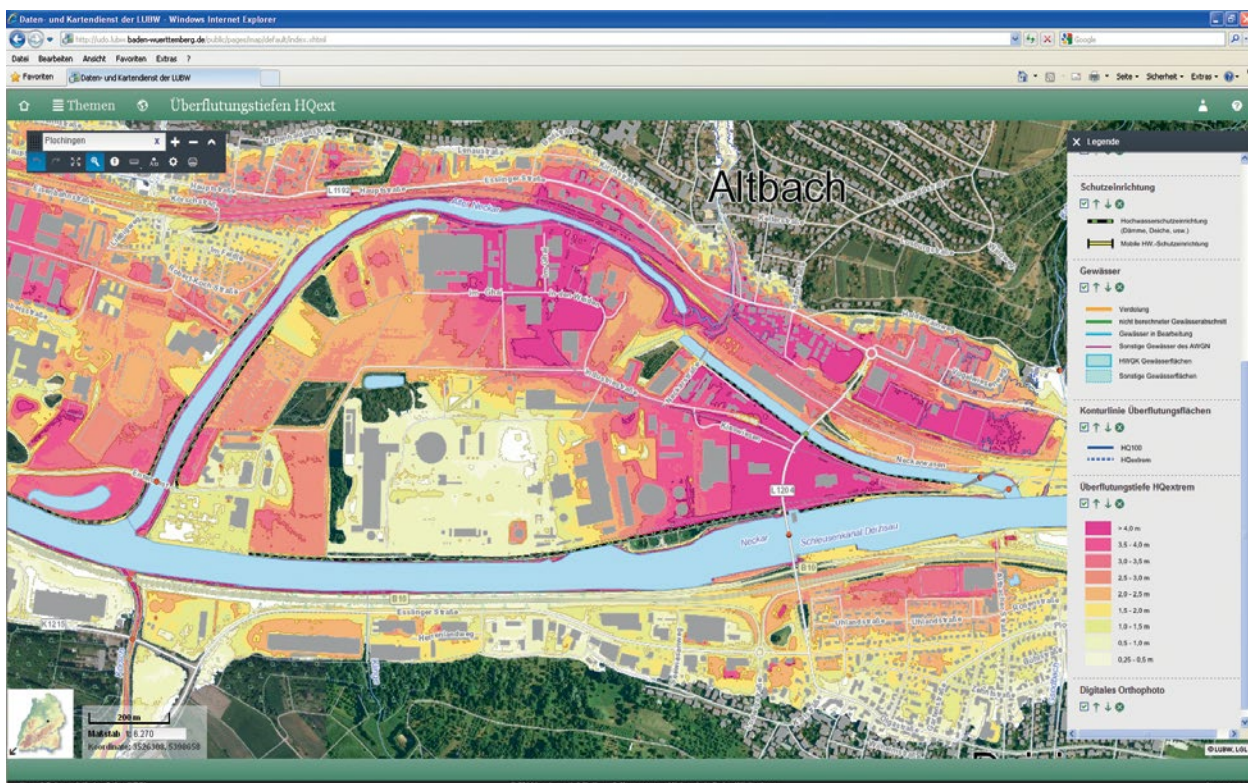
Flood hazard maps play an important role in enhancing awareness of specific flood hazards. They open up new options for managing tasks in connection with flood protection and flood preparedness.

Flood hazard maps give citizens (such as building owners and residents), and industry and commercial sectors, useful information that enables such potentially affected parties to take the necessary precautions in construction planning, building protection, behavioural planning and risk provisioning with the help of flood

insurance. The different ways in which citizens, industry and commercial operations can use flood hazard maps include the following:

- as a basis for planning behavioural precautions (information channels, and escape and evacuation routes)
- as a basis for taking precautions relative to structures, including adaptation of utilisations, usage of flood-adapted building materials and proper storage of substances hazardous to water
- as a basis for planning specific types of building protection (such as waterproofing for doors and windows)

Flood hazard maps also serve as an important basis for city planning.



Example of a flood hazard map available online



## 9.2 Online information systems

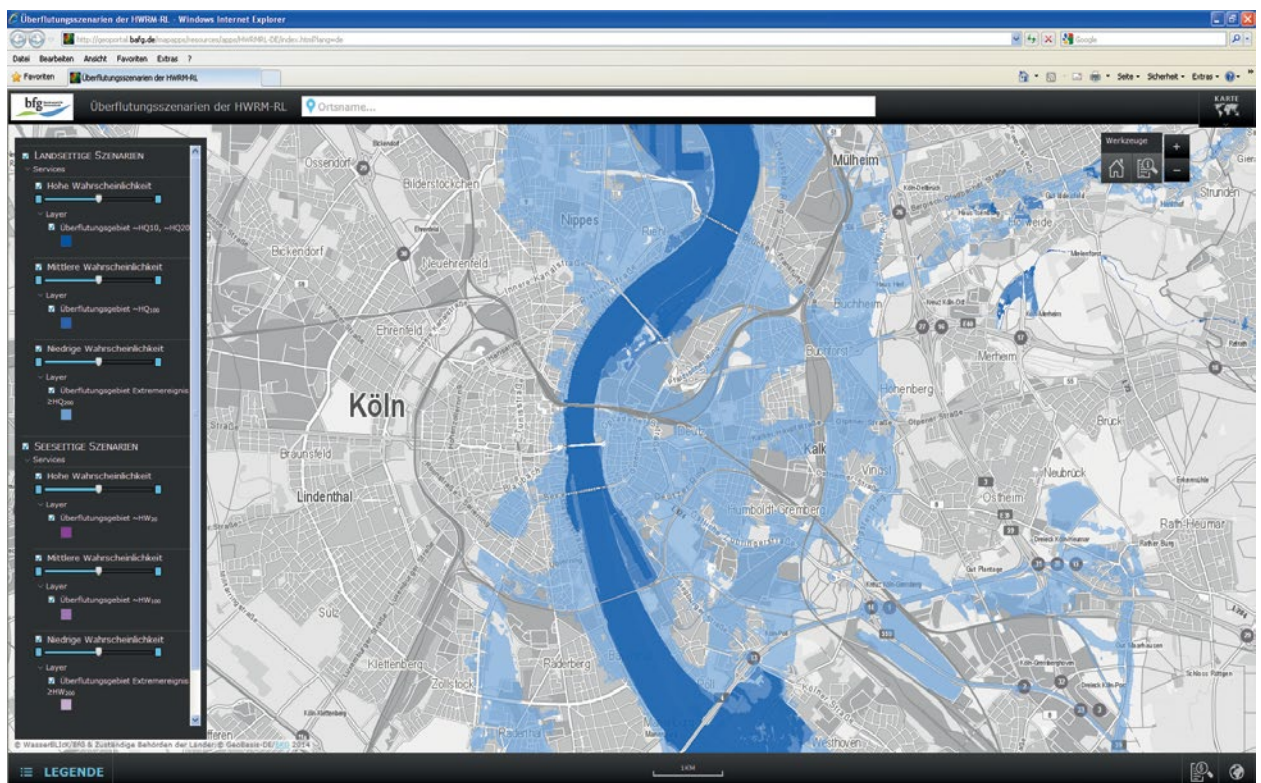
In addition to relying on printed flood hazard and flood risk maps, users can also inform themselves via map services available on the Internet. The advantage of such systems is that they can be rapidly updated. New information can be provided immediately, as needed, at no additional expense.

When floodwaters rise, the demand for relevant information grows – and not only on the part of persons directly at risk. If an information-provision system then fails, due to overload, some important information might not be communicated. Persons potentially at risk or otherwise interested are thus urged, as part of their own preparedness measures, to regularly check flood hazard and flood risk maps for their areas, to print them out, store them in a safe place and to consult them as necessary.

Users are also urged to familiarise themselves with the options available with online systems and any special

aspects of such systems. What information is available? What symbols are used, that means how do the maps show information? What types of searches – such as address-based searches – are possible? The Federal Government's portal [www.wasserblick.net](http://www.wasserblick.net) is operated by the German Federal Institute of Hydrology (BfG). That portal provides nationwide information about flood hazards along important sections of rivers and along coastlines. It supports searches by place names, thereby enabling users to inform themselves about the specific situations in their own communities and to obtain relevant data. The online portals of the Länder and of major cities also provide detailed information. The portal [www.hochwasserzentralen.de](http://www.hochwasserzentralen.de) presents current measurements, and forecasts and warnings, for all parts of the national territory.

Familiarise yourself with information systems on time – do not wait until a flood occurs to obtain key information.



The Federal Government's web portal [www.wasserblick.net](http://www.wasserblick.net)





Satellite image of 12 August 2002

### 9.3 Flood forecasting

In many major river-system areas, and along the country's coastlines, efficient flood forecast systems play a vital role in flood protection measures. For a flood forecast system to function effectively and properly, the following basic requirements must be fulfilled:

- its forecasts are heard
- its forecasts are heard on time
- listeners give credence to its forecasts
- residents in the affected areas know how to behave and respond – thanks to advance drills – during floods, including their early approach phases

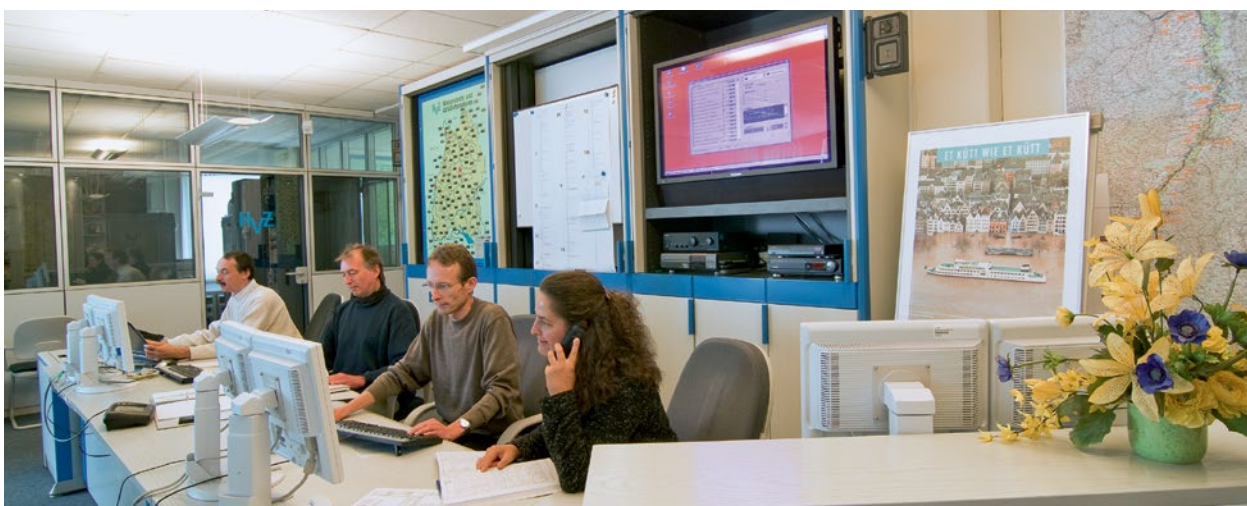
Behavioural precautions cannot function effectively unless a forecast system is in place, and a forecast system will be of little value if the public does not know how to respond to the forecasts and warnings it issues.

The two basic aspects of preparedness are interdependent. Flood forecast systems and behavioural precautions are equally important in terms of priority. Ongoing measures need to be taken in both areas.

Behavioural precautions can be supported by placing flood-level markers on bridges and building walls. Such markers keep the public aware of flood threats, and they serve as an important reference in consideration of expected water levels.



Eye-catching flood mark along the Zwickau Mulde in Colditz



Flood forecasting centre of Baden-Württemberg's State institute for the environment, measurements and nature conservation

## 10 Behavioural precautions

Taking proper behavioural precautions means using the period between the time a flood begins to mount and the time it reaches critical, damage-inducing water levels in a way that helps to minimise damages. Along major rivers, floods can be predicted one to two days in advance, and reliable, specific forecasts can be made several hours in advance. Along smaller rivers in central upland areas, the prediction periods may be reduced to just a few hours.

Similar time periods apply to storm-surge forecasts in coastal areas. In Hamburg and Bremen in particular, behaviour and evacuation measures, based on storm-surge forecasts, play an important role in coastal protection concepts.

Flood information and forecasting need to lead to useful, rapidly implemented behaviour.

When flood warnings are not heard or heeded, the best precautions are useless.

### 10.1 Personal alarm and action plans (flood checklist)

Many different types of tasks need to be carried out before, during and after flood events. Families and groups of neighbours need to agree on task assignments in advance, prior to any flood. Ideally, they should conduct practice drills to test such assignments in advance.

### 10.2 Organising neighbourhood assistance

Neighbourhood assistance arrangements can be of use in addressing emergency situations and many related problems. By meeting regularly, neighbourhood assistance groups can enhance neighbourhoods' interactions and their sense of togetherness. Such groups should coordinate tasks among themselves. For vacation periods, they should appoint representatives to take responsibility for providing flood warnings and taking necessary action.

New residents of flood-prone areas should consult with long-time residents to learn about floods and the proper responses.



A simple tool for filling sandbags



Pump

### 10.3 Flood-preparedness equipment

Persons in flood-prone areas should collect flood-preparedness equipment before floods take place. Emergency-response organisations such as fire departments and the THW technical assistance organisation need to be able to use their own equipment and thus cannot lend out any equipment. Neighbourhood assistance groups can make necessary major procurements jointly.





The best way to move furniture out of harm's way?

## 10.4 Moving furniture out of harm's way

Persons in flood-prone areas should prepare plans (in both list and sketch form) for moving furniture and other furnishings as necessary. Significantly, people often give high priority to possessions that, in retrospect, turn out to have low priority and could have been moved much later. The important things to consider first include documents and possessions with sentimental value (memorabilia) that either are irreplaceable or can be replaced only with great difficulty.

Furthermore, it may be infeasible to move heavy and bulky objects out of the danger zone. To prepare for such eventualities, one should have adequate number of supports available with which one can raise such objects.

## 10.5 Emergency luggage and documents; emergency lodgings

The police and disaster prevention authorities may order a mandatory evacuation. Such an order is given only when the population in the affected area is at considerable risk of injury or even death. Normally, when such orders are given, very little time remains to act. The following rules should be observed in any case:

- be sure to pack your emergency luggage well in advance
- your community's action plan will provide such information as:
  - “flood-free” routes (escape, evacuation and supply routes)
  - “flood-safe” assembly areas from which the public, in the event of an evacuation, can be

transported to emergency shelters

- Location of emergency shelters;
- be sure to take heed of loudspeaker announcements issued from emergency-response vehicles
- be sure to take heed of radio announcements

Providing care and assistance for evacuated persons:

- local authorities provide basic assistance for evacuated persons (shelters, mobile kitchens, etc.)
- other assistance organisations provide additional assistance (such as social assistance)

Be sure to remember your important medications. They may be difficult or impossible to obtain during an emergency situation. It is also wise to include a one-day's supply of food and drink, and sanitary articles, in your emergency luggage.



A selection of flood-preparedness equipment



# 11 Flood management and recovery

If you are affected by a flood, you should keep the following important points in mind as you prepare to clean up and repair the damages.

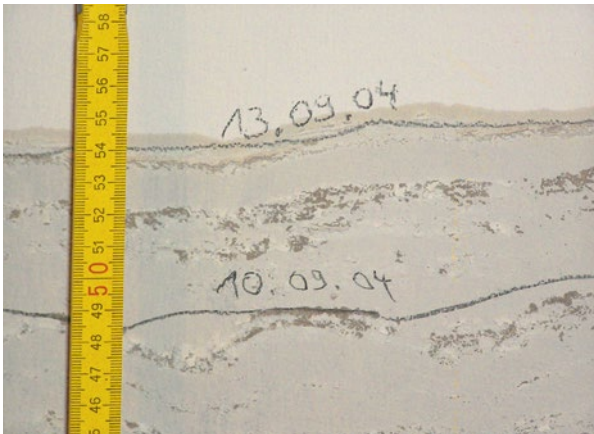
## 11.1 Protecting yourself

Before you enter buildings that have been strongly affected by floods, be sure they are not in danger of collapsing. Always remember to protect yourself. Enter inundated areas only if you are sure that you will have safe footing in them and that the structures surrounding you are structurally stable (such as stairs, for example). Remember that electrical devices and equipment may be electrically live.

Protect yourself and your health by wearing suitable protective clothing. This especially applies to the damage-repair phase. Always wear safety glasses and protective gloves. A protective breathing mask can be advisable if mould spores have appeared following the retreat of the floodwaters. In warm temperatures, mould can appear within just a few days.

## 11.2 Documentation

Before you begin repairing damages, make photo or video records of all damages. Mark the water level within the building and on the outside. Prepare a list of damaged property items before you begin disposing of anything. Be sure to consult promptly with your insurance company on how to proceed.



A photo records details of the event

## 11.3 Pumping water out of affected areas

If the building is partly or completely under water, and if the water is unable to drain by itself, you can begin pumping water out of the building as soon as the outside water level is lower than the inside water level. To prevent buoyancy-caused damage, do not begin pumping water out of the cellar until the flood wave has passed. In the process, always remember to consider the water pressure caused by groundwater.



Sweeping sludge out as the floodwaters recede

## 11.4 Sludge

Floodwaters often sweep sludge and debris into buildings and onto surrounding areas. When such sludge dries, it can be very difficult to remove. Remove sludge from your building, using shovels and buckets, as soon as the floodwater begins retreating. If drainage is possible, it is a good idea to hose away sludge with clean water.

## 11.5 Drying

Wet objects and structures should be dried as quickly as possible. When a structural component consists of multiple layers, proper drying of all layers must be ensured. In some cases, outer layers will have to be removed so that drying can take place. Hollow spaces between layers may be filled with water.



Oil pollution from a nearby heating-oil spill

For drying, one should ensure that air can flow through the building. Often, special drying equipment will have to be used to accelerate the drying process. The drying process following a flood can take several weeks. Many companies specialise in providing drying services and equipment for buildings.

### 11.6 Oil damage

When cleaning up building damage from a heating-oil spill, be sure to bind the oil before you begin pumping. Since oil floats on water, the pumping process can leave an oil film on walls, thereby causing serious damage.

Therefore, do not begin pumping the water out until the oil film on the water surface has been secured (when it has been bound and removed by the fire department or a specialist company). If you plan to carry out the binding process yourself, with the help of binding agents, be sure to use only approved binding agents, and be sure to dispose of all waste oil and chemicals properly afterwards. Similar precautions apply in the case of releases of other substances hazardous to water.

Always notify your fire department when oil or other substances have been released during a flood.

Any walls, floors or ceilings that have been contaminated with oil should immediately be stripped of their plaster and / or any other wall coverings. If the oil has seeped deep into masonry, it may be necessary to replace or even demolish the wall.

### 11.7 Rebuilding

Before you begin repairs and rebuilding, review all existing structures with regard to their flood resistance. Other types of structures and materials may be less susceptible to damage. It may be useful to consider moving to a different location.



## 12 Risk provisioning



Insure yourself before it is too late!

When flood damage occurs, all necessary precautions and response measures notwithstanding, and the damage exceeds the flood victims' regular financial resources, private savings or insurance policies can help reduce the overall economic impacts. However, insurance policies may cover only those losses that would have a substantial impact on insured parties. In addition, insurance policies can apply restrictions or staggered deductibles that increase the need for personal provision.

A key risk for insurance companies in this regard is that usually only those building owners seek to insure themselves against flood damage who could obviously be affected by floods. Extreme flood events can simultaneously cause considerable or serious damage in many buildings. Unlike the situation with fire insurance, insurers' costs for flood insurance payouts to large numbers of policyholders have to be split among relatively small numbers of policyholders. This usually deters insurance companies from insuring buildings that are particularly at risk. Besides, the insurance sector has introduced risk zones that all insurers apply in the same manner.

In general, insurance companies differentiate the following different types of damage:

- **damages caused by floods** when ponding above-ground water enters buildings
- **damages caused by sewer backwater** when sewer water backs up into buildings, or floodwater enters buildings via sewer lines
- **damages caused by groundwater** when underground water flows into buildings via walls or wall penetrations

Although the three types of cases are the same in terms of the level of damage that buildings and household goods can suffer, they differ in terms of insurance companies' readiness to provide compensation for damages.

In the first case, involving floodwater that has pooled above ground, an expanded natural-hazard insurance policy may cover damage to the building itself, including all installations such as heating or sanitary systems and to household goods. The two categories of property may have to be insured separately, however.

In the case of sewer backwater, insurance companies provide compensation only if the failure of permanently installed protective mechanisms – such as pump systems or check valves – has led to the damage. In this light, such damages are thus comparable to the water damage caused by damage to water pipes. As a rule, one cannot insure oneself against damages caused by groundwater infiltration.

Damages to vehicles are covered by partial coverage insurance, oriented to current value. Insurers do not pay for various types of accessories, such as first-aid kits and child seats. No compensation is provided for items being transported within vehicles, such as CDs and purchased goods. Travel luggage can be covered by baggage insurance.

Check whether, and how, you are insured against floods.

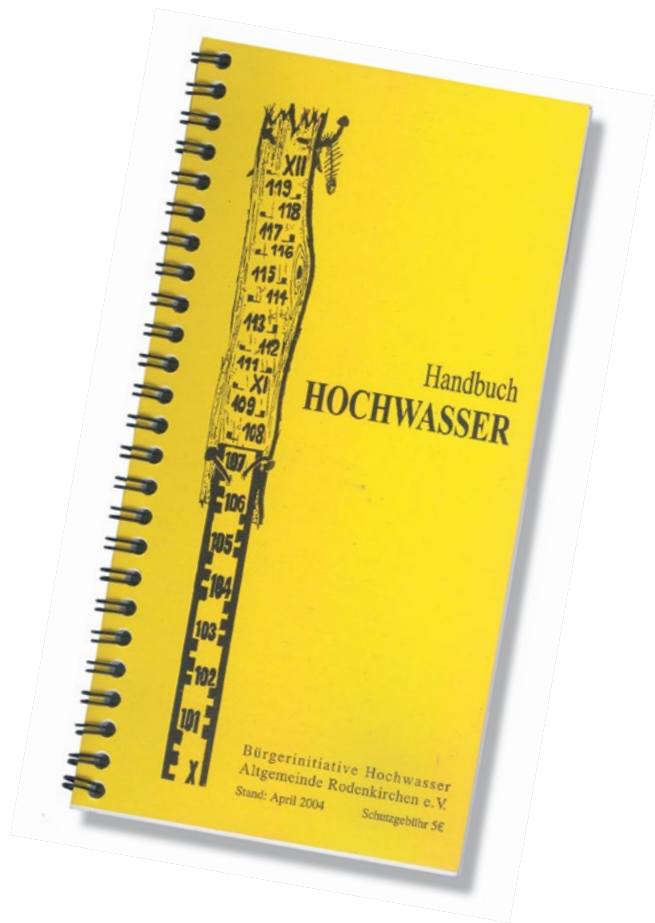


# 13 Additional materials

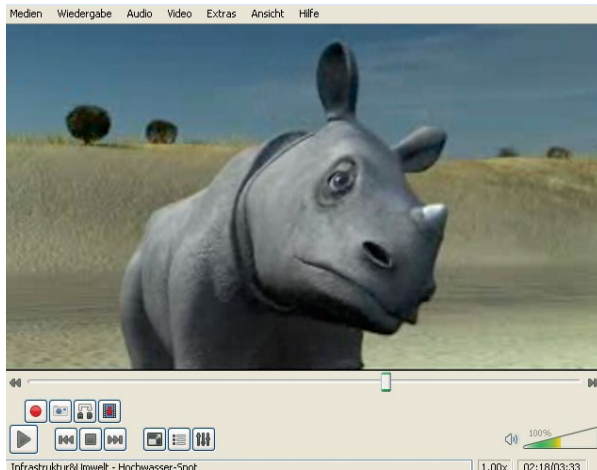
Active, ongoing public-awareness measures are the key to successfully reducing damage in connection with floods. The aim of such measures are to strengthen (potentially) affected citizens' awareness of flood hazards and risks and to provide them with specific information relative to flood hazards and ways of reducing damage. Municipalities can offer their citizens specific information that is adapted and optimised in keeping with local flood conditions.

The whole topic of floods and flood hazards concerns both individual citizens and local authorities. In most cases, local authorities provide information, advice and instructions to support and assist flood victims. Such services help citizens protect their property and live more safely.

In any case, public-relations and public-awareness measures should take account of efforts of interest groups formed by (potentially) affected persons. In general, the more directly that information can be provided to citizens, the more effective and trustworthy information exchanges will be.



Practice makes perfect: sandbag-filling contest for youngsters



A clip about floods and flood issues ([www.ella-interreg.org](http://www.ella-interreg.org))

Joint drills can encourage affected citizens to practice the proper behaviour well in advance of the next flood.

Different types of campaigns can motivate children to respond properly. For example, a sandbag-filling competition can promote team spirit and athletic ambition – and quickly become an educational experience in the process.

Art competitions are especially popular with younger children. By painting pictures following a flood event, children can express their hopes and concerns and help their local group deal with what has occurred.

The following information media have become established at the municipal level:

- flood-information sheets, with the following content:
  - tips on how to behave before, during and after a flood (cf. the annex),
  - flood hazard maps,
  - sources of information before and during a flood event.
- Informational events held in connection with emergency response drills run by local disaster prevention authorities.

Digital media also play an important role in explaining flood hazards and measures for reducing flood risks. Short, entertaining clips can call attention to flood risks.



The SchaVIS flood-simulation game



The SchaVIS flood-simulation game

Various aspects of precautionary measures can also be communicated in entertaining ways. Simulation games, such as those in which one can pretend to be an excavator operator, bus driver or operator of agricultural machinery, can train people in how to respond effectively in the case of floods. In such games, players reduce their virtual damage by acting properly and efficiently moving their valuables out of the danger zone. The games can also include special shorts on subjects such as what tools and equipment can be useful in the event of floods.

# Annex 1: Checklist: Planning your own flood preparedness“

## What you can do today

- Discuss the potential hazards and risks with your family; define rules for proper behaviour in the event of floods. Know how to communicate “Where is each of us at any given time?” Define tasks for each family member: “Who is going to do what?” Remember that not all members of the family will necessarily be home when a flood strikes. Be sure that your children know where they should go in the event of a flood. The shortest, least-dangerous route might lead to the home of a relative or friend. In general, be sure to consider the following: “Where should we go if we have to leave the house?” (The authorities may order an evacuation).
- Know how family members will all be informed about the key decisions that have been made.
- Make children aware of special dangers (remember your supervisory responsibilities).
- Check your own premises and property to determine whether your structural measures could increase the hazards for your neighbours (measures such as the building of special retaining walls, establishing special types of biotopes, etc.).
- Remember that drinking water supplies could be affected (contact your water utility for information about the drinking water supply in relevant situations).
- Remember to take precautions with regard to pets and / or livestock on agricultural land (find housing options, have feed supplies available).
- Where might you have hazardous substances that have to be promptly secured? – Environmental hazards.
- Organising neighbourhood assistance – who is going to help whom? Staying in contact and exchanging information with your neighbours can help you stay abreast of relevant news. Remember that floods can disrupt telephone service (via both fixed-line and mobile networks), and mobile networks can easily become overloaded.
- Label your possessions.
- Regularly clean storm drains and outlets.
- Regularly check non-return valves and sliding valves.
  
- Organise protective measures in companies (during and outside of working hours).
- Pack emergency luggage and important documents so they will be ready and at hand if you have to suddenly leave the house.
- Review possibilities for temporarily moving in with relatives or friends.
- Every member of the family should know where the main switches / valves for water, electricity, heating, gas, oil, etc. are located.



## Final preparations before a flood

- Every flood is different. The conclusions you draw from past flood events can be wrong with regard to the latest flood. Be sure to pay attention to information issued by flood monitoring centres.
- Follow the weather situation.
- Stay tuned to radio and TV broadcasts.
- Take note when construction of catwalks begins.
- Pay attention to loudspeaker announcements.
- Follow instructions issued by authorities.
- Take the measures that have been ordered.
- Stay in touch with the authorities in your community, so you will know how the situation is developing.
- Inform yourself regarding special regulations for communities located in valleys and downstream from dams.
- Move livestock out of the danger zone.
- Secure cellar tanks, dismantle technical systems if necessary.
- Remove electronic systems, or at least switch them off.
- Remember that roads and pathways can be flooded. Avoid driving in flooded areas if at all possible. Be aware of the potential hazards (hydroplaning, flotsam, falling rock). Remember that normally safe traffic routes can suddenly prevent life-threatening hazards.
- Take note of hazards from accumulations of flood debris (= potential for sudden releases).
- Prepare, carry out and regularly check procedures for shutting off, closing and sealing off systems and structures.
- Move vehicles out of garages / away from parking areas and into safe areas.
- Organise and carry out neighbourhood assistance. Encourage persons unaffected by flooding to help affected persons wherever possible, and without being specially asked.
- Shut off the main valves / switches for gas, water and electricity. (Attention: remember to switch off freezers).
- Move any objects that should not get wet out of cellars.
- Be sure to have emergency luggage ready and at hand.
- Remember to pay attention to your own safety, especially in cellars.

## After a flood

- Begin clean-up measures right away (animal corpses present risks of disease and infection, mud can harden in drying, etc.).
- Disinfect private wells, and have their water quality checked (follow all applicable regulations).
- Exercise caution when opening garage and hall doors.
- In order to prevent buoyancy-related damage and water-undermining, wait until outside water levels have dropped before you begin pumping water out of cellars.

# Annex 2: Checklist: “The right flood-preparedness equipment”

Act in advance to put together your own set of flood-preparedness equipment. Emergency-response organisations such as fire departments and the THW technical assistance organisation need to be able to use their own equipment and thus cannot lend out any equipment. If you are a new resident in a flood-prone area, and have just started thinking about flood preparedness, consult with long-time residents in the area and let them advise you on what your “flood kit” should include. Take part in neighbourhood assistance.

Equipment	Location:	Checked on:							
<b>Packaged drinking water</b>									
<b>Day's ration of storable food</b>									
<b>Eating utensils, knives, scissors, etc.</b>									
<b>Portable radio receiver</b>									
<b>Important documents</b>									
<b>Cell phone with additional battery</b>									
<b>Spare batteries</b>									
<b>Battery-powered lights and non-electrical, portable stove</b>									
Thick candles, lighter, matches									
Flashlight, and spare batteries									
Oil lamp, with oil (as an alternative)									
Camping lantern (such as lanterns using gas cylinders) (as an alternative)									
Camping stove, with fuel									
<b>Heating</b>									
Gas cylinder with heating attachment									
Hot water bottle									
Wool blankets, sleeping bag, sleeping mat									
<b>Portable medicine chest</b>									
Hygiene articles (if no wastewater drainage is possible)									
Washing bowl									
Toilet bucket with cover; camping toilet									
Toiletry bag, hygiene products and towels									
<b>Equipment for moving in water</b>									
Rubber boots, waders									
Life vest									
Sandbags, with filling material									
Submersible pump, with residual-current device (RCD) and tube									
Waterproof extension cords									
Connecting sleeves, hose clamps									
Adhesive tape									
Thick protective foil									
Ladder									
<b>Tool chest</b>									
<b>Other equipment</b>									
Emergency generator									
Fuel (observe regulations for storage)									
Inflatable boat									
Rope									
Bucket									
Drinking water container									

This list can be expanded as necessary.

## Annex 3: Checklist: “Cars and floods”

- If a flood threatens, move vehicles out of garages (better too soon than too late).  
Move vehicles that are parked outdoors out of the danger zone.
- Attention vacationers. Unforeseen critical situations can also arise in your vacation spot. Check the situation before you park a vehicle and leave it unattended for several hours.
- If you need to cross a flooded area: “Feel your way” slowly (even a walking speed may be too fast); water can cause major damage if it floods the engine compartment.
- If you have been driving for some time, shut off the engine so that your catalytic converter can cool before you drive through the flooded area. Catalytic converters reach temperatures of about 700 degrees. If they are cooled very suddenly, their ceramic cores can burst.
- If your vehicle has stood in water that reached up to its oil pan or even above its wheels, do not attempt to restart your engine. Have the car towed to the nearest automobile repair shop for an inspection (and have the brake fluid and oil changed).



## Cited laws, directives and standards

BauGB: Federal Building Code (Baugesetzbuch) of 23 September 2004 (Federal Law Gazette I, p. 2414), last amended by Article 1 of the Act of 20 November 2014 (Federal Law Gazette I, p. 1748)

WHG: Federal Water Act (Wasserhaushaltsgesetz) of 31 Juli 2009 (Federal Law Gazette I, p. 2585), last amended by Article 2 of the Act of 15 November 2014 (Federal Law Gazette I, p. 1724)

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive)

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (European Floods Directive)

Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)

LAWA – Länder Working Group on Water (1995): Guidelines for Forward-Looking Flood Protection: Floods – Causes and Consequences. August 1995

LAWA – Federal/Länder Working Group on Water (2013): Recommendations for the Establishment of Flood Risk Management Plans. Last revision: September 2013

DAfStb WU Guideline (2003-11): Water-impermeable concrete structures (Wasserundurchlässige Bauwerke aus Beton); Berlin: German committee for steel-reinforced concrete (Deutscher Ausschuss für Stahlbeton) (DAfStb) within the German Institute for Standardization (DIN)

DIN EN 206: (2012-03) Beton – Festlegung, Eigenschaften, Herstellung und Konformität (Concrete – definitions, properties, production and conformity)

DIN 1045: Tragwerke aus Beton, Stahlbeton und Spannbeton (Bearing structures made of concrete, steel-reinforced concrete and pre-stressed concrete): – Teil 1 (Part 1): Bemessung und Konstruktion (Dimensioning and design) (2001-07); Teil 2 (Part 2): Beton – Festlegung, Eigenschaften, Herstellung und Konformität (Concrete – definitions, properties, production and conformity); Anwendungsregeln zu DIN EN 206-1 (Application rules relative to DIN EN 206-1) (2008-08); Teil 3 (Part 3): Bauausführung (Structural execution) (2012-03); Teil 4 (Part 4): Ergänzende Regeln für die Herstellung und die Konformität von Fertigteilen (Supplementary rules for the production and conformity of prefabricated parts) (2012-02)

DIN 1986 (2008-05): Entwässerungsanlagen für Gebäude und Grundstücke (Drainage systems for buildings and plots of land) – Teil 100 (Part 100): Zusätzliche Bestimmungen zu DIN EN 752 und DIN EN 12056 (Additional provisions relative to DIN EN 752 and DIN EN 12056)

DIN 4123 (2013-04): Ausschachtungen, Gründungen und Unterfangungen im Bereich bestehender Gebäude (Excavations, foundations and underpinnings in connection with existing buildings)

DIN EN 12056-4 (2001-01): Schwerkraftentwässerungsanlagen innerhalb von Gebäuden (Gravity-driven drainage systems within buildings) – Teil 4 (Part 4): Abwasserhebeanlagen; Planung und Bemessung (Wastewater pumping systems; planning and dimensioning); Deutsche Fassung (German version)

DIN EN 13564-1 (2002-10): Rückstauverschlüsse für Gebäude (Anti-flooding devices for buildings) – Teil 1 (Part 1): Anforderungen (Requirements)

DIN 18195: Bauwerksabdichtungen (Normreihe) (Waterproofing of buildings (standards series)) – Teil 1 (Part 1): Grundsätze, Definitionen, Zuordnung der Abdichtungsarten (Basic principles, definitions, classification of types of waterproofing) (2011-12); Teil 6 (Part 6): Abdichtungen gegen von außen drückendes Wasser und aufstauendes Sickerwasser, Bemessung und Ausführung (Sealing against water pressing in from the outside and against standing seepage water) (2011-12); Teil 8 (Part 8): Abdichtungen über Bewegungsfugen (Sealing layers over expansion joints) (2011-12); Teil 9 (Part 9): Durchdringungen, Übergänge, An- und Abschlüsse (Penetrations, joints, connections and closures) (2010-05); Teil 10 (Part 10): Schutzschichten und Schutzmaßnahmen (Protective layers and protective measures) (2011-12)

## Picture credits

Cover:	Peter Zeisler	Page 39:	Sebastian Golz
Page 7:	Jens Vogelsang, Pressestelle des Kreisfeuerwehrverbands Herford e. V.	Page 40:	both: Sebastian Golz
Page 9:	Peter Zeisler	Page 41:	above: Sebastian Golz below: Bergfee, <a href="http://www.fotolia.com">www.fotolia.com</a>
Page 10:	left: Uwe Wittbrock, <a href="http://www.fotolia.com">www.fotolia.com</a> right: swa182, <a href="http://www.fotolia.com">www.fotolia.com</a>	Page 42:	left: Gina Sanders, <a href="http://www.fotolia.com">www.fotolia.com</a> right: Kara, <a href="http://www.fotolia.com">www.fotolia.com</a>
Page 11:	Jürgen Gerhardt	Page 43:	above: view7, <a href="http://www.fotolia.com">www.fotolia.com</a> middle left: strubel, <a href="http://www.fotolia.com">www.fotolia.com</a> middle right: zdshooter, <a href="http://www.fotolia.com">www.fotolia.com</a>
Page 14:	Regierungspräsidium Darmstadt	Page 44:	above left: Ingo Bartussek, <a href="http://www.fotolia.com">www.fotolia.com</a> above right: Tommy, <a href="http://www.fotolia.com">www.fotolia.com</a> below: elxeneize, <a href="http://www.fotolia.com">www.fotolia.com</a>
Page 15:	Regierungspräsidium Darmstadt	Page 45:	Alterfalter, <a href="http://www.fotolia.com">www.fotolia.com</a>
Page 16:	Stefan Daller, RegioWiki Bayern e. V., CC BY-NC-SA 3.0-Lizenz	Page 46:	djama, <a href="http://www.fotolia.com">www.fotolia.com</a>
Page 17:	above: Marco Kaschuba below: Peter Zeisler	Page 47:	patatmac, <a href="http://www.fotolia.com">www.fotolia.com</a>
Page 18:	Peter Zeisler	Page 48:	<a href="http://udo.lubw.baden-wuerttemberg.de/public/">http://udo.lubw.baden-wuerttemberg.de/public/</a>
Page 19:	Peter Zeisler	Page 49:	<a href="http://geoportal.bafg.de/mapapps/resources/apps/HWRMRL-DE/index.html">http://geoportal.bafg.de/mapapps/resources/apps/HWRMRL-DE/index.html</a>
Page 20:	above: Jürgen Gerhardt below: Peter Zeisler	Page 50:	above: DWD middle: Peter Zeisler below: Landesanstalt für Umwelt, Messungen und Naturschutz (State institute for the environment, measurements and nature conservation), Baden-Württemberg
Page 21:	left: ThyssenKrupp GfT Bautechnik GmbH right: AQUA-STOP „Hochwasser-Service“ Dienstleistungs GmbH	Page 51:	above: Lobbe Holding GmbH & Co KG below: Spechtenhauser Hochwasser- und Gewässerschutz GmbH
Page 22:	above left: IBS Technics GmbH, above right: AQUA-STOP „Hochwasser-Service“ Dienstleistungs GmbH below: Dorothee Zeisler	Page 52:	above: victor zastol'skiy, <a href="http://www.fotolia.com">www.fotolia.com</a> below: Jürgen Gerhardt
Page 23:	both: Peter Zeisler	Page 53:	left: Peter Zeisler right: Enrico Di Cino, <a href="http://www.fotolia.com">www.fotolia.com</a>
Page 24:	above: Peter Zeisler middle: vieraugen, <a href="http://www.fotolia.com">www.fotolia.com</a> below: Peter Page Tankanlagen-Service GmbH	Page 54:	GaryButtle, <a href="http://www.istockphoto.com">www.istockphoto.com</a>
Page 31:	above: ACO Passavant GmbH middle: KESSEL AG	Page 55:	AlbanyPictures, <a href="http://www.istockphoto.de">www.istockphoto.de</a>
Page 32:	mhp, <a href="http://www.fotolia.com">www.fotolia.com</a>	Page 56:	above: Bürgerinitiative Hochwasser, Altgemeinde Rodenkirchen e. V. ( <a href="http://www.hochwasser.de">www.hochwasser.de</a> ), below: Peter Zeisler
Page 33:	above left: Ludwig Trauzettel above right: IBS Technics GmbH below: Christian H. Wirz	Page 57:	left: INFRASTRUKTUR & UMWELT, Professor Böhm und Partner (IU) above right and below: Hochschule RheinMain, <a href="http://www.hs-rm.de">www.hs-rm.de</a>
Page 34:	above: IBS Technics GmbH middle: RS Stepanek KG below: Rank Wasserschutzsysteme		
Page 35:	above left: IBS Technics GmbH above right: DiGeWa Lothar Zache below: AQUA-STOP „Hochwasser-Service“ Dienstleistungs GmbH		
Page 36:	above: Doyma GmbH & Co below: Hermann Reitthaler GmbH		
Page 37:	above: AQUA-STOP „Hochwasser-Service“ Dienstleistungs GmbH		
Page 38:	Peter Page Tankanlagen-Service GmbH		

The pictures and representations of flood protection structures and equipment are intended to serve as examples of the possibilities for taking precautions and providing protection.

