Bund/Länder-Arbeitsgemeinschaft
Wasser

# Flood hazard map guidelines of the German Working Group of the Federal States on Water Issues (Bund / Länder-Arbeitsgemeinschaft Wasser (LAWA))

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Issued by the

Ad-hoc Flood Committee of the German Working Group of the Federal States on Water Issues (LAWA), Matthias Löw, chairman

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# Contents

# 1 Introduction

The dissemination and publication of flood hazard information is becoming increasingly important since this is the only way responsible authorities and the public can obtain information that will allow all concerned to take appropriate flood control measures.

The revised Federal Water Act (WHG; Wasserhaushaltsgesetz) of 3 May 2005 defines new requirements for the dissemination of flood hazard information, by virtue of the Act's provisions concerning flood prone areas (§ 31c) and the statutory deadlines for the identification of such areas (§ 31b).

According to the German flood control document entitled *Instrumente und Handlungsempfehlungen zur Umsetzung der Leitlinien für einen zukunftsweisenden Hochwasserschutz* issued by Länderarbeitsgemeinschaft Wasser [German Working Group of the Federal States on Water Issues] (LAWA 2004), flood hazard maps are an integral element of all dimensions of flood control. Some of Germany's Bundesländer (federal states) have already devised flood hazard maps (MUNLV 2003, MUV 2003, 2005).

On 18 January 2006 the European Commission proposed a directive to help Member States prevent and control floods via a three step process. One of the key measures included in the proposed directive is the development of flood hazard maps and flood risk management plans.

To this end, LAWA has compiled the present guidelines for the development of flood hazard maps.

## 2 Definitions of terms

These guidelines contain recommendations concerning the development of flood hazard and flood hazard zone maps. There are also other types of maps such as flood hazard potential maps and flood risk maps, which are defined in the glossary.

- *Flood hazard maps* provide flood hazard information in terms of the relationship between the flood probability and flood intensity. Such maps should be produced for areas where flooding could cause considerable damage.

  Statistical flooding probability is expressed in terms of flooding recurrence, whereas intensity is generally measured in relation to water depth. However, other characteristics such as water velocity are also used.

- *Flood hazard zone maps* are the result of the interpretation of flood hazard maps from the perspective of specific disciplines. They are used to apply water management data to regional planning processes and should be developed insofar as necessary. These maps are to show the probability and intensity of flooding in specific danger zones, which are generally assigned one of the following classifications: high, medium, low, and very low.

The various types of flood hazard maps are described in detail in section 4.

## 3 Potential flood hazard map users

Past experience has shown that interdisciplinary collaboration is beneficial when it comes to managing the aftermath of extreme flood events. It is recommended that collaboration of this type be applied to the realization of flood hazard maps and other flood control measures, since this would fulfil the following criteria for multi-purpose projects:

- All users benefit from the realization of flood hazard maps.
- The various users contribute their data, expertise, and experience to the realization of the maps.
- All users are equally committed to ensuring that flood hazard maps gain acceptance as a flood damage reduction tool.

The needs of all users should be taken into account in developing flood hazard maps.


Figure 1: Flood hazard map users

The flood hazard map users shown in Figure 1 are as follows:

- Water management agencies
- Regional/land use planning agencies
- Local planning agencies
- Disaster and emergency planning agencies
- Insurances
- Stakeholders affected by flooding

### 3.1 Water management agencies

The water management agencies of Germany's Bundesländer can use flood hazard maps as a basis for the following:

- developing and prioritizing flood protection plans
- planning the reactivation of existing water retention areas
- formulating the relevant policies
- developing guidelines for handling substances that pose a risk to water resources, by mapping at-risk areas
- identification of floodplains.

### 3.2 Regional/land use planning agencies

Regional/land use planning agencies manage and monitor the demands on and uses of space. Flood hazards constitute a natural factor that matter in spatial terms. Planners must take this factor into account in finding a workable and sustainable land use equilibrium between built-up areas and open space.

On 14 June 2000, a conference on land use held by the ministers of Germany's Bundesländer adopted a series of flood protection guidelines for implementation in Bundesländer land use plans (MKRO 2000). In these guidelines, the Bundesländer unanimously agreed to pursue the following flood related land use management goals:

- Preservation and recovery of natural floodplains
- Risk prevention for floodplains and flood prone areas
- Water retention in the catchment

The guidelines further state that flood prone areas can be effectively protected in due time through the identification of so called Priority Areas (*Vorranggebiete*) and Reserve Areas (*Vorbehaltsgebiete*), pursuant to § 4 of the Regional Planning Act (Raumordnungsgesetz (ROG)).

Stakeholders need complete flood related information in order to weigh the merits of the various land use modalities in a comprehensive and transparent manner that is acceptable to all concerned and that reveals the effects of preventive flood control measures. Hence flood hazard maps can be an invaluable source of information for land use planners in defining specific regional goals, principles and guidelines for land development processes with built-in flood event safeguards.

The MKRO guidelines call upon regional and state land use planners to translate the flood protection principles defined in § 2(8)(sentence 6) of the Regional Planning Act (Raumordnungsgesetz (ROG)) into objectives or principles in the land use plans. To this end, the MKRO recommends that the following area classifications be applied:

- *Priority Areas:* Inhabited areas where floods could potentially pose a threat to life and limb, or where hazard reduction with flood control structures would be unduly costly. All residential and commercial uses that could potentially lead to or exacerbate flood damage or flood hazards or that could increase the risk of flooding should be avoided in such areas.

- *Reserve Areas:* Areas where (a) a low to high risk of flooding exists; (b) structural and planning measures should be implemented with a view to reducing flood damage; and (c) high-risk inhabited areas should be identified. After this information has been developed, planning and construction activities are to take into account the known flood risks in the affected areas, and the relevant flood control measures are to be defined.

The MKRO recommendations leave it up to the individual Bundesländer to define and realize technical assessments of the terms "high risk," "risk to life and limb," "manageable" and "non-manageable." Flood hazard zone maps could be particularly useful for these processes.

The following data in flood hazard maps allows for their use as land use management tools:

- *Intensity:* as measured by water depth, water velocity and so on.
- *Statistical probability of flooding:* flooding recurrence/flood frequency

Technical evaluations of flood hazard zone maps (see section 4.2) provide a preliminary indication as to whether specific areas should be classified as Reserve Areas or Priority Areas. The recommended scale for flood hazard maps is 1:50,000 up to 1:100,000.

### 3.3 Local planning agencies

Pursuant to § 1 of the Federal Building Code (Baugesetzbuch), the task of local planning agencies is to do the preparatory work for, and coordinate land use in, municipalities. The Federal Building Code also stipulates that in their capacity as the responsible urban land use planning authority, municipalities are entitled and obliged to realize the following two types of urban land use plans:

- A *land use plan* for the municipality as a whole, but whose provisions are not legally binding in terms of building codes (preparatory urban land use plan pursuant to § 5 of the Federal Building Code (Baugesetzbuch)).
- A *development plan* that is based on the land use plan and pertains solely to specific parts of the city. This plan defines legally binding regulations (binding land use plan pursuant to § 8 of the Federal Building Code (Baugesetzbuch)) and governs construction modalities in built-up and development areas.

Pursuant to § 5(4) of the Federal Building Code (Baugesetzbuch), designated floodplains are to be integrated into land use and development plans; and floodplains not yet designated, as well as flood prone areas, are to be listed in such plans as well.

Bundesland and regional land use plans provide land use planners with basic best practice guidelines for urban development. Flood hazard maps could potentially provide additional information of this nature. For example, flood depth information can initiate appropriate planning and use of buildings. Such measures can greatly reduce flood damage in that development plans can integrate flood-related specifications such as floor elevation, or information about the use of oil heating.

Flood hazard maps can serve as a basis for the following within the framework of land use plans:

- best practices for urban development
- land use management
- protective measures for buildings.

Water management information developed and gathered by subject experts should be factored into local planning processes. Insofar as possible, measures aimed at reducing and avoiding flood damage should be implemented. Flood hazard maps provide information that can enable communities, homeowners, businesses, and other stakeholders to do the following:

- identify and assess the relevant risks
- implement safeguards against flooding
- take efficient and prompt action in the event of flooding.

The recommended map scale for local planning purposes is 1:1,000 up to 1:25,000.

### 3.4 Flood fighting and disaster control agencies

Flood fighting and disaster control agencies are the main users of flood hazard maps in the event of flooding. The disaster control laws of the various Bundesländer require disaster control agencies to develop, update and optimize preparatory emergency alert and action plans. These plans are to be reviewed, updated if necessary and regularly optimized on the basis of flood hazard maps.

Flood hazard maps provide information concerning flood conditions (water depth, flood water velocity) in a specific area, and thus allow for planning and implementation of strategic action plans for specific scenarios. Specific analyses of data sets comprising an amalgamation of flood hazard map information and additional empirical data allow for the following:

- Hazard identification
- Optimized use of human and material resources
- Identification and optimization of evacuation routes
- Identification of the need for additional flood barriers (horizontal structures) and secondary lines of defence against floods so as to avoid or delay the inundation of other areas when primary flood barriers fail.

Flood hazard maps also provide emergency personnel with an overview of flood scenarios during scheduled flood/disaster control procedure exercises, and form the basis for the realization of these exercises.

### 3.5 Insurance companies

Insurers need precise and accurate flood hazard information in order to define realistic premiums for flood damage insurance. To this end, Germany's insurance industry association *(Gesamtverband der Versicherungswirtschaft (GdV))* has adopted a flood-hazard zone classification system known as ZÜRS (Falkenhagen 2005) comprising the following flood hazard categories:

Table 1: Flood-hazard zone categories as defined by *Gesamtverband der Versicherungswirtschaft (GdV)*

| **Hazard category** | **Description** |
|---|---|
| Hazard class 4 | An area where there is a statistical probability that flooding will occur more than once every ten years |
| Hazard class 3 | An area where there is a statistical probability that flooding will occur more than once every 50 years but less than once every ten years |
| Hazard class 2 | An area where there is a statistical probability that flooding will occur more than once every 200 years but less than once every 50 years |
| Hazard class 1 | An area where there is a statistical probability that flooding will occur less than once every 200 years |

Flood hazard maps can be used to validate the GdV system. Maps that provide flood intensity information are a vast improvement over current flood hazard zone maps.

### 3.6 Stakeholders affected by flooding

Flood hazard information is indispensable when it comes to (a) determining which measures are needed for effective flood protection; and (b) providing businesses and the general public with relevant flood hazard information.

If flood hazard maps are distributed efficiently, they can greatly enrich the knowledge about flood hazards. The information contained in flood hazard maps enables all stakeholders - from property owners and residents to corporate decision makers - to make sound decisions for construction planning, building protection, action plans and other precautionary measures, by providing the basis for the following:

- flood preparedness (communication of emergency information, escape routes and evacuation procedures)
- protecting buildings against inundation through the use of (a) construction materials in a manner that safeguards buildings against floods and (b) water-resistant materials
- safe and proper storage of water-hazardous substances
- building protection through the use of door and window seals.

# 4 Map content and typology guidelines

## 4.1 Flood hazard maps

Flood hazard maps show the physical factors that make floods a threat, and in doing so, depict flood hazards in terms of the interplay between flood intensity and the statistical probability of flooding.

### 4.1.1 Statistical probability of mapped flooding

The statistical probability of mapped flooding should be determined on the basis of the requirements of each user's specific local parameters and conditions.

Flood events with a statistical recurrence of at least 100 years are to be used for the maps. If frequent flooding is likely to pose a severe threat, flood events with a statistical recurrence of more than once every 100 years (e.g. every 20 or 50 years) can be used as a basis for the flooding intervals shown on the map (see section 6.1.1). On the other hand, even extreme flood events with a return period of 200 to 1000 years should be represented so as to illustrate exceptional flood hazards.

For maps that are used as a basis for flood protection measures, only one probability of flooding should be depicted in terms of surface area. Several statistical probabilities of flooding can be depicted (in accordance with the aforementioned ZÜRS flood-hazard zone classification system) on a single map for other purposes.

### 4.1.2 Flood intensity

Since water depth is the most important flood damage parameter, it is represented in all flood hazard maps; albeit on the basis of different classifications (see Figure 8 in section 7.2.1 for a proposed standard water depth classification system).

Water velocity is another key flood intensity parameter. Areas with relatively steep slopes are particularly prone to high flow rates that can result in severe damage to buildings and infrastructures. Flow rates of 0.5 m/s and more, combined with the water depth, are associated with an increased risk of injury and fatalities (BWW 1997).

In Switzerland, the arithmetic product of water velocity and depth is used as a parameter for flood risk in steeply sloping areas, whereas water depth alone is sufficient for areas with only slight sloping.

The duration of flooding is a third flooding parameter, which can lead to dike failure. Moreover, the rate of water level rise determines the amount of time remaining for the realization of ad hoc flood barriers.

In most cases, water depth should be the only intensity parameter shown on flood hazard maps, since otherwise information overload can undermine the maps' practicality.

### 4.1.3 Additional contents in flood hazard maps

In addition to flood characteristics, the following hot spots and other key flood related information can also be integrated into flood hazard maps, pursuant to guidelines published by the Bundesland of North Rhine-Westphalia (MUNLV 2003):

Table 2: Hot spots and other key flood related information (MUNLV 2003)

| | |
|---|---|
| **Hot spots** | Bridges |
| | Culverts and pipes |
| | Weirs; back dikes |
| | Dams and detention reservoirs |
| **Key information** | Flow direction in water bodies and the locations of hydrometric stations |
| | Road and highway networks |
| | Topographical background (see section 7.2.3) |
| | Grids in the required coordinate system |
| | Levels in water bodies , benchmark levels and high-water marks |

Other information such as the location of hospitals, factories, power plants, waterworks and waste dumps can also be integrated into flood hazard maps for disaster preparedness purposes.

## 4.2 Flood hazard zone maps

Flood hazard zone maps show area-specific flood hazard categories based on the interplay between probability and intensity. Figure 2 shows the relationship between flood intensity and the probability of flooding, based on the following flood hazard categories:

- Extreme hazard (red)
- Moderate hazard (blue)
- Low hazard (yellow)
- Residual hazard (hatched)

The fact that fields 2, 4 and 6 comprise two overlapping hazard categories is meant to indicate that allocation of a flood hazard category is a subject-specific weighting process that under some circumstances cannot be based on standard zoning approaches.

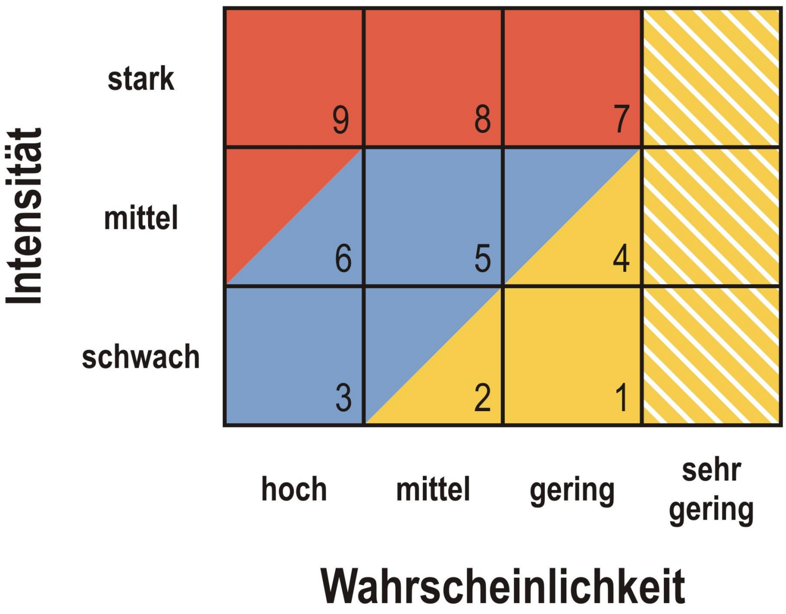


Figure 2: Hazard categories based on the interplay between probability (horizontal) and intensity (vertical), categories: high, medium low, very low

### 4.2.1 Intensity classifications

The following flood intensity levels for water depth, water velocity and the like in specific areas are meant to be guidelines that users should adapt to their specific conditions:

- *High intensity* refers (for example) to settings where humans and animals indoors are at risk and/or where buildings may sustain damage or be destroyed.
- *Medium intensity* refers (for example) to settings where (a) humans and animals are at risk outdoors, but incur only residual risk if they are indoors; and/or (b) buildings may sustain damage.
- *Low intensity* refers (for example) to settings where (a) human and animals located both outdoors and indoors incur only residual risk; and/or (b) some parts of buildings such as basements may sustain damage.

This qualitative classification system is subject to the classifications of physical parameters shown in table 3. Users of flood hazard zone maps should assess the technical aspects of these classification thresholds and should modify them insofar as necessary.

Table 3: Examples of intensity classifications

| | **Flat areas** | **Steep areas** |
|---|---|---|
| **Intensity** | **Water depth (h)** | **Water velocity (v)** |
| High | >2.0 m | > 2 m/s |
| Medium | 0.5 to 2.0 m | 0.5 to 2.0 m/s |
| Low | < 0.5 m | < 0.5 m/s |

### 4.2.2 Probability classifications

Classifications have also been devised for probability, in addition to intensity. According to published results, the following classification thresholds appear to be most useful:

- Flood events with a return period of 20 years: high probability.
- Flood events with a return period of 20 to 100 years: medium probability.
- Flood events with a return period of 100 years: low probability.
- Flood events with a return period of 200 years: residual risk.

## 5 Flood hazard map development procedures in Germany's Bundesländer

Four of Germany's Bundesländer are currently developing flood hazard maps. The procedures employed for these various projects will now be described.

### 5.1 North Rhine-Westphalia

The Bundesland of North Rhine-Westphalia intends to develop flood hazard maps for virtually all river courses with catchment areas that are greater than 10 square kilometres in size. In the interest of establishing a single Bundesland-wide standard for flood hazard maps, the North Rhine-Westphalia Ministry of the Environment has published guidelines for the development of flood hazard maps (MUNLV 2003).

North Rhine-Westphalia's flood hazard maps are based on floodplains with a return period of 100 years. The maps also contain information discharges at top-of-bank level and floodplains that are prone to high water flooding with a return period of 10 to 50 years (depending on when inundation damage begins at specific locations), as well as the statistical probability of extreme flood events (once every 300 years). The North Rhine-Westphalia maps also show the following: water depth in flood plains; water velocity and flow time; and hot spots such as bridges, weirs and bottlenecks.

North Rhine-Westphalia has not enacted any statutory regulations concerning the publication of flood hazard maps.

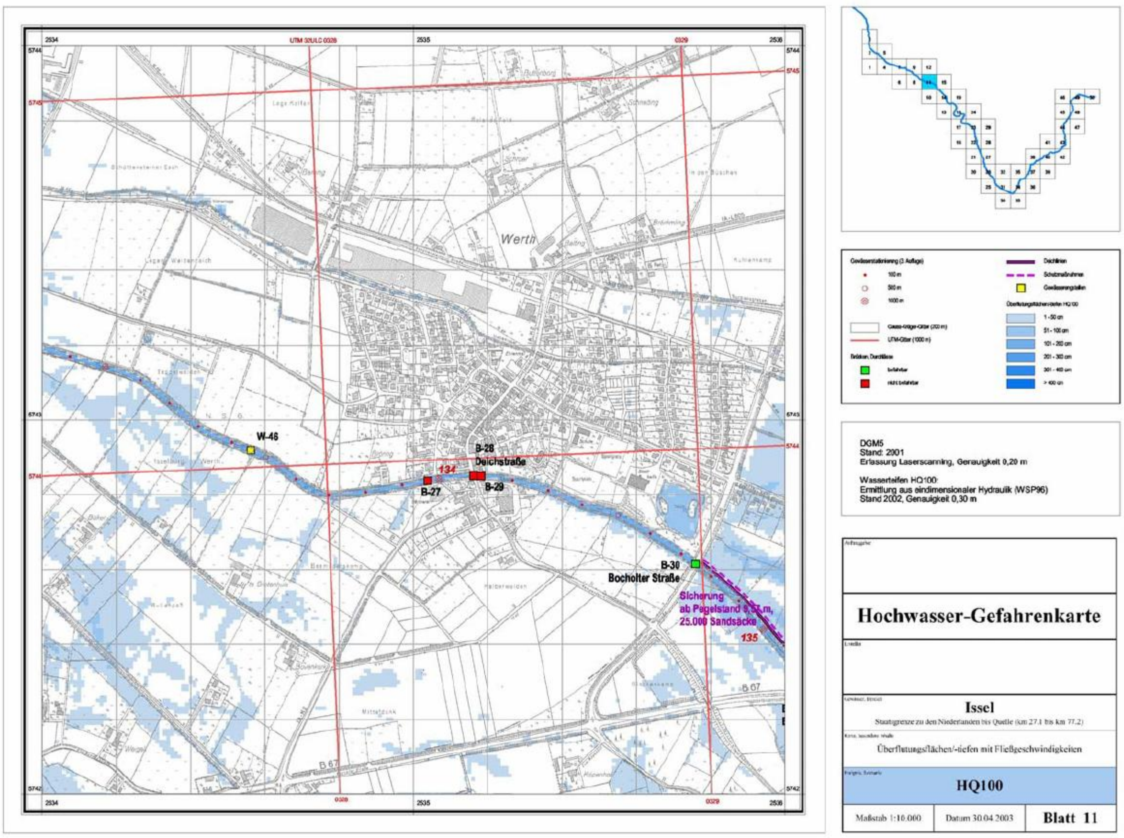


Figure 3: Flood hazard map Issel River in North Rhine-Westphalia (MUNLV 2003)

Translation:

| | |
|---|---|
| *Legende:* | *Legend:* |
| Gewässerstationierung | River kilometre marking |
| Durchlässe<br>Passierbar | Bridge underpasses<br>Passable |

| | |
|---|---|
| Nicht passierbar | Non-passable |
| Deichlinien | Dikes |
| Schutzmaßnahmen | Protective structures |
| Gewässerengstellen | Narrows |
| Überflutungsflächen/-tiefen HQ 100 | Flood areas and depths for 100 year flooding |
| | |
| *Plankasten:* | *Plan box:* |
| Hochwasser-Gefahrenkarte | Flood hazard map |
| Überflutungsflächen/-tiefen mit Fließgeschwindigkeiten | Flood areas and depths, with water velocity |
| HQ 100 | 100-year flooding |
| Maßstab | Scale |
| Datum | Date |
| Blatt | Map no. |

## 5.2 Baden-Württemberg

Flood hazard maps will have been realized by 2010 for all watercourses in Baden-Württemberg with catchment areas exceeding 10 square km. The maps are mainly intended as information sources for the public, and to demarcate the statutory boundaries of floodplains, and will also provide a basis for the identification of Priority Areas and Reserve Areas for review purposes and further implementation of regional plans (MUV 2003, 2005).

The maps will be produced on the basis of a joint Bundesland and municipal government project, and will be distributed to users via a Bundesland-wide water management database system that is to be implemented by Baden-Württemberg's Agency for Environment (Landesanstalt für Umweltschutz). Two different types of standardized maps have been defined for Baden-Württemberg. Type 1 maps show floodwater depths in open-system watercourses in 50 cm increments for flood events with a return period of 100 years; and for closed systems, flooding status after the design flood level has been exceeded. Areas prone to flooding with a return period of 1000 years (extreme flood events) are also delineated. Type 2 flood hazard maps show - according to area and in a single map - floodplains and flood areas with flood return periods of 10, 50, and 100 years, as well as extreme flood events.

Publication of flood hazard maps is required by article 77 of the Baden-Württemberg Water Act (Baden-Württembergisches Wassergesetz), which also stipulates that the public is to be made aware of the maps' existence by displaying them in public venues. The maps can also be viewed at www.hochwasser.baden-wuerttemberg.de (Reich 2005).

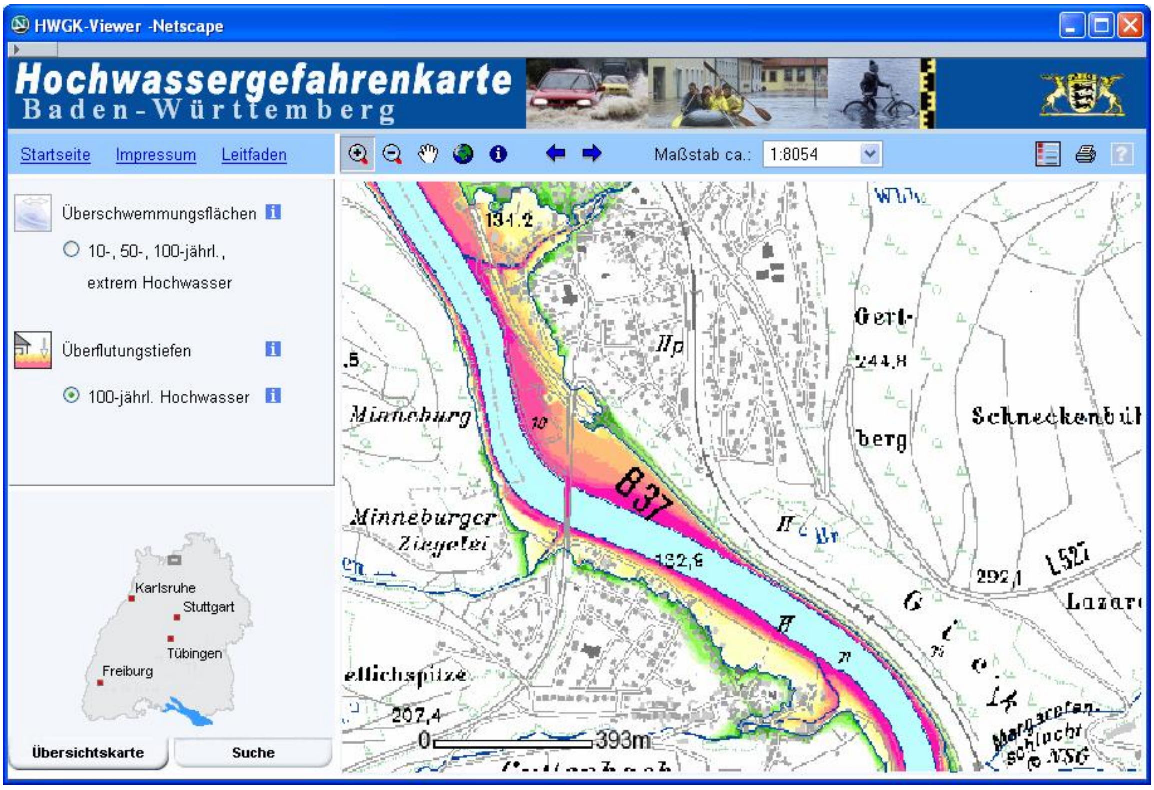


Figure 4: Type 1 web-based flood hazard map for the Neckar River in the Bundesland of Baden-Württemberg (http://www.hochwasser.baden-wuerttemberg.de/)

Translation:

| | |
|---|---|
| Hochwassergefahrenkarte | Flood hazard map |
| Startseite | Homepage |
| Impressum | Contact |
| Leitfaden | Guidelines |
| Überschwemmungsflächen<br>10-, 50-, 100-jährl., extrem Hochwasser | Inundation areas<br>10, 50, 100 year, extreme flooding |
| Überflutungstiefen<br>100-jährl. Hochwasser | Water depths<br>100 year flooding |
| Übersichtskarte | Overview map |
| Suchen | Search |
| Maßstab | Scale |

## 5.3 Saxony

The Bundesland of Saxony has produced a flood hazard potential map in an overview scale showing the risk of flooding for the Bundesland's largest rivers on the basis of the following intensity factors: (a) water depth or specific discharges during severe flooding; and (b) areas prone to extreme floods with a return period of 100 years. Flood area simulations were carried out without regard for any protective structures, so as to identify flood prone areas and potential floodplains. In addition to potential flood areas, potential damage in the event of severe flooding was identified. The information contained in flood hazard maps is used for regional and land use planning. This information also serves to identify risks and existing conflicts, thus providing the basis for (a) the realization of further reaching and more precise analyses in the form of flood hazard maps; and (b) increasing risk awareness for residents in flood hazard zones.

Flood hazard maps were realized in the Bundesland of Saxony on the basis of the aforementioned preliminary work, as well as the flood protection plan that was elaborated in the wake of the August 2002 flooding. The maps show all flood prone areas that border primary watercourses, including adjacent residential, commercial and industrial areas. Elaboration and publication of the maps is mandated by Saxony's Revised Water Act (Elze 2005).

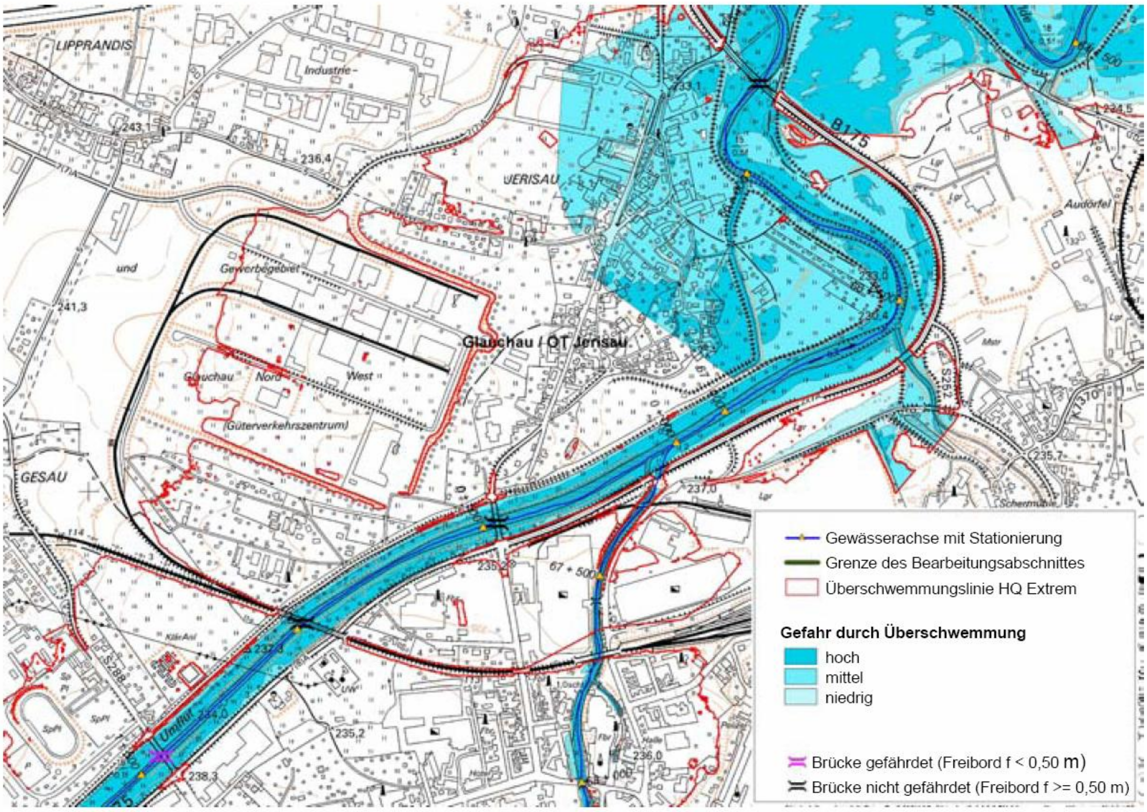


Figure 5: Flood hazard map for the Mulde River in Saxony

Translation:

| | |
|---|---|
| Gewässerachse mit Stationierung | River with kilometre marking |
| Grenze des Bearbeitungsabschnittes | Section boundary |
| Überschwemmungslinie HQ Extrem | Inundation line for extreme flooding |
| Gefahr durch Überschwemmung<br>hoch<br>mittel<br>niedrig | Flood hazard<br>high<br>medium<br>low |
| Brücke gefährdet (Freibord f < 0,50 m) | Bridge at risk (freeboard less than 0.5 m) |
| Brücke nicht gefährdet (Freibord f >= 0,50 m) | Bridge not at risk (freeboard 0.5 m or greater) |

Saxony's flood hazard maps show flooding intensity for a statistical recurrence of 20, 50, 100, 200, and 300 years. The maps also show extreme flood events, which are defined by a recurrence of up to once every 500 years, or is calculated on the basis of 150-200 percent of 100 year flooding. In the case of extreme flooding, it can be assumed that protective structures would fail. The impact of flotsam and bed-load discharge on water level was factored into the hydraulic simulations.

Following a test phase in which two types of maps were piloted, it was decided to forego the flood hazard zone maps since Saxony's flood zones are not defined by law. The flood hazard map approach was selected for reasons of practicability. Each type of flood hazard is depicted on a separate map sheet, and extreme flood events are shown as a line chart on each map. Flood intensity is shown on the basis of three different classifications (see table 3, section 4.2.1), which are allocated on the basis of maximum high-water mark or specific water velocity (product of depth and velocity).

The flood hazard maps are distributed to municipalities and district governments. Publication of flood hazard maps is required by law in the Bundesland of Saxony (pursuant to article 99b of the Saxony Water Act), which stipulates that the maps are to be published in municipalities and are to be permanently posted in adequate public places.

## 5.4 Rhineland-Palatinate and Luxembourg

Flood hazard maps for the Moselle River and its tributaries were produced by Luxembourg and Rhineland-Palatinate under the auspices of the Interreg IIC program and were published in *Grenzüberschreitender Atlas der Überschwemmungsgebiete im Einzugsgebiet der Mosel* (www.gefahrenatlas-mosel.de).

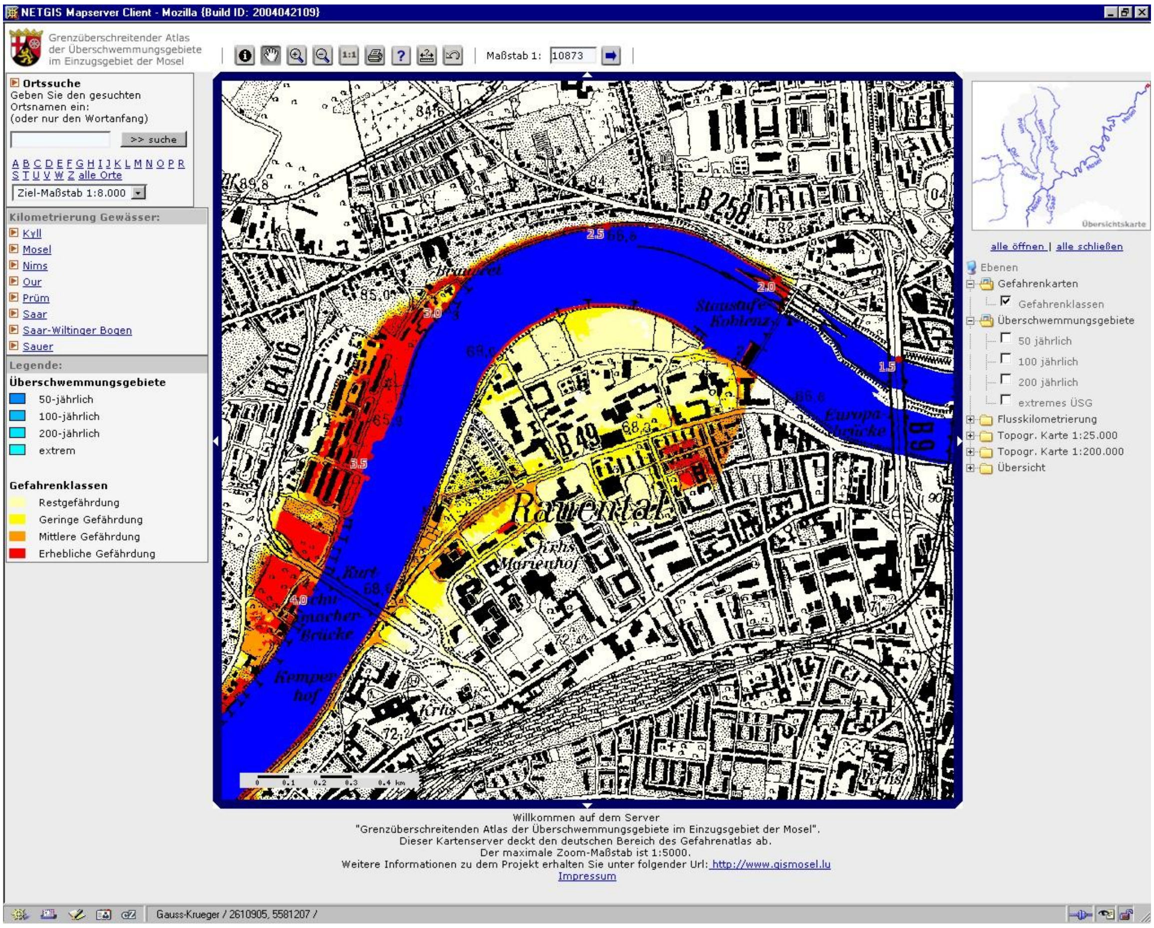


Figure 6: Web-based flood hazard zone map for the Moselle River in Rhineland-Palatinate (http://www.gefahrenatlas-mosel.de/)

Translation:

| | |
|---|---|
| Grenzüberschreitender Atlas der Überschwemmungsgebiete im Einzugsgebiet der Mosel | Interregional atlas of flood areas in the Moselle River basin |
| Legende | Legend |
| Überschwemmungsgebiete<br>50-jährlich<br>100-jahrlich<br>200-jährlich<br>extrem | Inundated area<br>50 year<br>100 year<br>200 year<br>extreme flooding |

| Gefahrenklassen | Flood hazard categories |
|---|---|
| Restgefährdung | Residual hazard |
| Geringe Gefährdung | Low hazard |
| Mittlere Gefährdung | Medium hazard |
| Erhebliche Gefährdung | Severe hazard |

It is anticipated to extend these maps under Interreg III B TIMIS and to make them available online to the public (Worreschk 2005).

The atlas shows the following: (a) areas with flooding return periods of 50, 100, and 200 years; (b) areas that are subject to severe flooding; and (c) hazard zones. The latter are identified on the basis of a hazard matrix, which shows the interplay between (a) the probability of flooding described above; and (b) the (arithmetic) product of water depth and velocity. The hazard categories are severe, medium, low, and residual flood risk.

## 5.5 Overview of map features

The table below provides a comparative overview of the variables that are shown on flood hazard maps produced by the Bundesländer of North Rhine-Westphalia, Baden-Württemberg, Saxony, and Rhineland-Palatinate.

Table 4: Flood hazard map features

| **Bundesland** | **Hazard zones?** | **Water depth?** | **Water velocity?** | **Return periods** |
|---|---|---|---|---|
| North Rhine-Westphalia | No | yes | yes | 10-50, 100, years; extreme flooding |
| Baden-Württemberg | No | yes | no | 10, 50, 100; extreme flooding |
| Saxony | No | yes | no/partially specific flow (discharge) | 20, 50, 100, 200 years; extreme flooding |
| Rhineland-Palatinate | Simplified | partially | no/partially | 50, 100, 200; extreme flooding |

Rhineland-Palatinate is the only one of the four aforementioned Bundesländer whose flood hazard maps show all flood hazard zones. Water depth is classified in various ways on the maps, but only the North Rhine-Westphalia and Rhineland-Palatinate maps show water velocity. All four of the Bundesländer maps mentioned above show statistical return periods of 100 years or less frequent. Extreme flood events are defined in all of the maps as the statistical recurrence of flood events less frequent than once every 200 years. Flooding at more frequent intervals (recurrence of 10-50 years) is shown on the maps of all four Bundesländer. North Rhine-Westphalia's maps establish a correlation between the statistical probability of flooding and the beginning of damage-inducing inundation.

The publication of flood hazard maps is required by law in Saxony and Baden-Württemberg. Both the latter Bundesland and Rhineland-Palatinate produce both web-based and printed maps. Baden-Württemberg's flood hazard maps are legally binding in that the mapped areas with a return period of 100 years constitute officially defined flood areas merely by virtue of the maps having been published. Rhineland-Palatinate's online maps neither show water velocity nor water depth.

# 6 Requirements and parameters

## 6.1 Prerequisites for flood hazard map production

In order for flood hazard maps to be successfully produced, certain technical and organizational criteria must be met. Technical criteria are about developing and compiling of data that forms the basis for elaboration of maps, i.e. primarily hydrology and watercourse hydraulics calculations, as well as topography. The organizational criteria are relevant to project and resource management.

### 6.1.1 Hydrology

The purpose of gathering hydrological data for flood hazard maps is to (a) define the flood hazards that should be mapped and the flood discharge that should be calculated for each watercourse; and (b) determine the relation between these parameters and the probability of flooding. Discharges can be determined based on the available water depth and water velocity data, or on specific regional data. Thanks to the greater availability in recent years of basic hydrological data in digital format, rainfall-runoff-models are coming into increasing use for flood discharge calculations. In this approach, discrete flood events and precipitation scenarios can be simulated on the basis of the available data and models, or long-term simulations with subsequent statistical analyses.

The following factors should be used as a basis for determining which probabilities are to be shown: (a) the discharge scenario that results in the first significant flooding; and (b) the valid or usual design flood for the area in question, which in most cases means flood events with a statistical return period of 100 years (although local conditions must also be taken into consideration). If necessary, an additional extreme discharge that exceeds the design flood level should be defined.

### 6.1.2 Watercourse hydraulics

Hydraulic models are used to calculate water levels and flooding for discharges that are determined on the basis of hydrological calculations, as well as various possible models, depending on topography and watercourse type. One of the key model selection criteria is constituted by so called valley characteristics, i.e. the valley width and slope that are used to categorize the watercourse. In this regard, a basic distinction can be made between the following: (a) watercourses in high mountains, low mountains, and plains; (b) tidal estuaries; and (c) whether the watercourse is an open system without any flood control structures or a closed system with a flood control structure.

The flooding models that are used for hydraulic simulations can be differentiated according to whether they are one dimensional/multidimensional; or steady/unsteady. All other distinguishing characteristics of these models are of secondary importance and will not be discussed here.

Flood hazard in open systems is largely determined by the watercourse level in situations where voluminous flood waves occur in relatively narrow valleys. Water velocity is also a factor, depending on watercourse descent and topographical slope. Conditions such as these mainly occur in high and low mountain regions, for which steady one-dimensional models are more suitable. In scenarios characterized by wider valleys and less steeply inclined slopes, as well as for the estuaries of larger watercourses, it must be determined whether (in view of the more complex flow characteristics involved such as meandering, and extensive embankments with substantial water velocity variation) a steady or unsteady model will yield more useful results.

### 6.1.3 Project management

The compilation of flood hazard maps for multiple river basins or an entire Bundesland requires an efficient and professional project management team, which should be defined before the project gets underway and should assume responsibility for all project management and quality assurance processes. The project management team should consist, among other things, of a representative of the project agency and a consultant. It is recommended that flood hazard map projects be structured and implemented as described in the sections that follow.

#### 6.1.3.1 Phase 1: Project definition; data inventory and requirements analysis

- Define responsibilities in the water catchments
- Plan public information measures, as well as ways to involve the public
- Examine and evaluate existing maps and other documentation
- Available data concerning watercourse networks, watercourse cross-sections, river basin studies (rainfall-runoff models), and water surface profiles should be used, their quality and currency permitting
- Define the relevant reaches of watercourses
- The reaches of each watercourse for which flood hazard maps are to be produced should be clearly defined. Flood hazard maps for the source areas of rivers are of little practical use since flood hazards are the main criteria for producing such maps. The farthest upstream point of the watercourse, or a minimum catchment area (e.g. 10 square kilometres), should be defined.
- Identify data gaps
- Determine the extent of the required data collection activities
- Estimate cost and efforts for data collection
- Draw up a description of project tasks, which should then be integrated into the RFP performance specifications for the subsequent project phases.

#### 6.1.3.2 Phase 2: Definition of the relevant topography

- Surveying
- The hydraulic engineer and surveyor jointly define the amount and location of cross-sections required for the hydraulic simulations
- Survey the watercourse, i.e. the watercourse cross-sections and banks, excluding embankment
- Survey engineering structures in and on the watercourse
- Submit the surveying data to the hydraulic engineer
- Create terrain models on the basis of photogrammetric analyses of aerial photographs, or using laser scanning terrain data.

#### 6.1.3.3 Phase 3: Hydrology and hydraulics

- Coordinate and validate surveying data

- Append embankments from the digital terrain models to the watercourse cross-sections
- Incorporate the available documentation
- Carry out hydrological calculations as needed (see section 6.1.1)
- Carry out hydraulic calculations as needed (see section 6.1.2)
- If one-dimensional hydraulic models are used, intersect water profiles with terrain model
- Determine water levels

#### 6.1.3.4 Phase 4: Map production

- Produce flood hazard maps according to the layout specifications (see section 7)
- Incorporate map data into the official geographic coordinate system of the respective Bundesland

#### 6.1.3.5 Phase 5: Public information measures

- Publish and distribute the maps using the measures defined jointly with the client (e.g. workshops and training for map use).

## 6.2 Quality assurance

Some map project work may have to be outsourced to specialized providers (depending on the scope of the catchment area covered by the maps). The project management team's responsibility also includes quality management, so as to ensure that the project is brought to a successful conclusion and that the maps meet the required quality standard.

### 6.2.1 Quality management

The quality management team is to implement quality assurance measures aimed at defining and enforcing standardized working methods that are suitable for a specific region and are consistent with the characteristics of the relevant water bodies. These measures are to be based on rigorous standards which are reflected in performance specifications in documents regarding:

- Surveying
- Digital terrain models
- Hydrology
- Hydraulics
- Flood hazard map layouts

The performance specifications are to be incorporated into the description of deliverables in the RFP documentation.

### 6.2.2 Information management

It is indispensable for the success of flood hazard map projects that their results are passed smoothly and efficiently from one set of project phase to the next. This involves the following:

- The surveyor and hydraulic engineer should jointly define modalities such as data formats for one-dimensional hydraulic models.
- Format specifications should be defined for the water surface profiles.

Project stakeholders should also define suitable data formats for processing flood hazard maps in geographical information systems (GIS), with attributes such as

- water course code
- water course station
- reference system for position and elevation
- water levels.

Cross-sections, engineering structures and other project data (suitably attributed) must be provided in a format that allows for integration into the relevant Bundesland's official geographic coordinate system. This again underscores the multifunctional nature of flood hazard map projects.

### 6.2.3 Timeline management

The project management team has to (a) coordinate all performance deadlines for the RFP process, as well as for the outsourcing and completion of sub-projects; (b) ensure that all results are passed from the stakeholders of one project phase to the next in a timely manner; and (c) work closely with the interdisciplinary working groups (formed in phase 3) to draw up flood hazard map priority lists that define the order in which the maps are to be produced on the basis of the following criteria:

- production capacity
- budgetary and financial situation
- data situation
- potential flood hazards.

### 6.2.4 Finances

The project management team has to oversee the entire project's financial status, including (a) consolidation of the project's public and private funding; (b) elaborate a financial plan based on the estimated data and work requirements; and (c) elaborate of annual plans indicating the project's funding requirements.

## 7 Map design and format guidelines

The following guidelines are intended to promote standardized designs and formats for all flood hazard maps and flood hazard zone maps produced in Germany.

### 7.1 Data processing and map structure

Geographical Information Systems (GIS) should be used to collect, customize and update basic flood hazard map data, as well as to produce the maps. These systems allow for the storage of vector, grid and other data, as well as joint management of spatial data and attributes. This data is to be archived without map sheet divisions or administrative boundaries, and insofar as possible is to be described in terms of the relevant meta-data, namely source, accuracy, scale, and date of last update.

In the interest of producing printed flood hazard maps easy to handle, DIN A0 should be the largest format used. Each map should meet basic cartographic standards and integrate the following elements:

- Map title indicating the map content and its geographic region, preferably at the upper left
- A legend in the upper right hand corner with the scale and scale bar beneath it
- A map overview beneath the scale, if possible
- Beneath the overview, the following publication information: publisher, publication date, date of last update, author(s), copyright, map sources, and map approval.

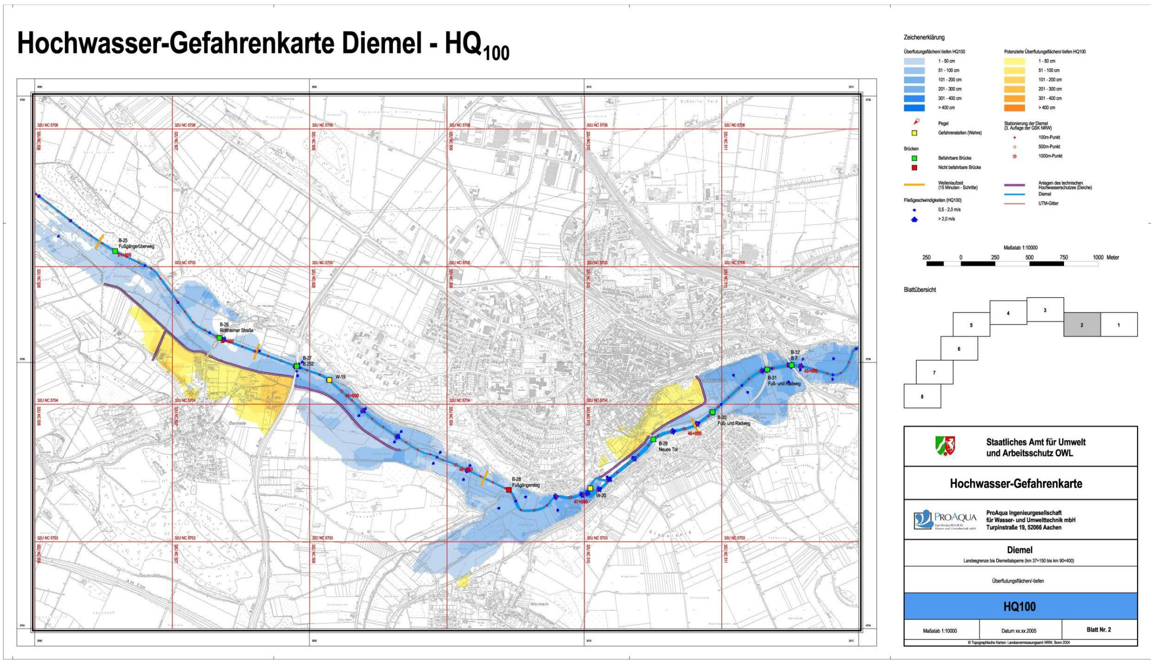


Figure 7: Recommended map structure (shown here: flood hazard map for Diemel, North Rhine-Westphalia)

Translation:

| | |
|---|---|
| Hochwasser-Gefahrenkarte Diemel $HQ_{100}$ | Diemel 100 year flood map |
| Zeichenerklärung | Legend |
| Überflutungsflächen/-tiefen $HQ_{100}$ | 100 year flood areas and depths |
| Potentielle Überflutungsflächen/-tiefen $HQ_{100}$ | Potential 100 year flood areas and depths |
| Pegel | Gauging station |
| Gefahrenstellen | Hot spots |

| | |
|---|---|
| Brücken<br>Befahrbare Brücke<br>Nicht befahrbare Brücke | Bridges<br>Passable bridge<br>Non-passable bridge |
| Wellenlaufzeit | Flood wave propagation time |
| Fließgeschwindigkeiten | Water velocity |
| Stationierung der Diemel | Diemel kilometre marking |
| Anlagen des technischen Hochwasserschutzes (Deiche) | Flood protection facilities (dikes) |
| Blattübersicht | Overview of map sheets |
| Maßstab | Scale |
| Datum | Date |
| Blatt | Map no. |

Maps in web-based cartographic information systems should be designed and realized without map sheet divisions of any kind, and should support continuous panning and zooming as well as displaying and hiding specific types of information, including specific scales. A maximum zoom-in percentage should be defined so as to avoid a false implication of accuracy. The basic information shown on the map's background should be to scale, and the map's publication information and legend should be in separate boxes.

## 7.2 Content design

### 7.2.1 Flood hazard maps

It is recommended that water depth be represented using the five-tone colour scale shown in figure 8, with variable colour tone and brightness. This scale allows for clear differentiation, both on paper and on screen, between the various depth categories, as well as between map and legend elements. Flooding depth in open systems should be depicted in blue tones, while yellow and red should be used for closed systems. In order to standardize the colour schemes in all maps, the colour values for various colour systems are provided in Annex 2.

| **Water levels** | 0 1 2 4 m |
|---|---|
| **Examples** | |
| Rheinatlas of IKSR (IKSR 2000) | |
| North Rhine-Westphalia flood hazard maps (flooding with a return period of 100 years) | |
| Cologne flood hazard maps (open systems) | |
| Cologne flood hazard maps (closed systems) | |
| **LAWA guidelines** | |
| **Open Systems** | |
| **Closed systems** | |

Figure 8: Water level categories and coloration for flood hazard maps

The definition of category thresholds is based on technical factors. The 0, 0.5, 1, 2, and 4 meter thresholds should be used to categorize water levels. If steep slopes, dense concentrations of buildings, or high water velocities greatly limit the accuracy of water level calculations, less precisely defined categories can be used. Conversely, more precisely defined categories should be applied to smaller watercourses.

If a map shows various flood areas with differing flood probability levels (see figure 9), each probability should have a different colour, but the brightness of these various colours should be uniform. The blue to green range should be used for frequent flooding, whereas the red and violet range should be used for extremely infrequent flooding. In order to standardize the colour schemes in all maps, the colour values for various colour systems are provided in Annex 2.

| | |
|---|---|
| **LAWA guidelines for zone mapping** | frequent ... infrequent events |

Figure 9: Colour scheme for a single map containing a series of flood areas with different flood probability levels (zoning).

Water velocity can also be shown in flood hazard maps. The North Rhine-Westphalia flood hazard map guidelines recommend that water velocities ranging from 0.5 to 2 m/s and >2 m/s be shown, and that this be done using various sized arrows and types of hatching for, respectively, data derived from one-dimensional and two-dimensional hydrodynamic calculations (MUNLV 2003). This allows flooding depth and water velocity to be shown in the same map. North Rhine-Westphalia's recommendations in this regard are suggested.

### 7.2.2 Flood hazard zone maps

All flood hazard zone maps show four hazard categories using the colours shown in figure 2 (yellow, blue and red), with residual hazard shown as hatching. The relevant colour values are listed in Annex 2.

| **Flood hazard categories** | Rest | Geringe | Mittlere | Erhebliche |
|---|---|---|---|---|
| Example from the flood hazard maps published by Switzerland's flood control agency BWW | | | | |
| **LAWA recommendation** | | | | |

Figure 10: Flood hazard categories and colours for flood hazard zone maps (residual, low, medium, high)

### 7.2.3 Map scales

Flood hazard maps and flood hazard zone maps, which are realized with a scale of 1:5,000 up to 1:10,000, constitute a primary information source that can be used as a basis for the compilation of other maps, providing that other technical information is available for support purposes. The table below shows the most common scales.

Table 5: Map scales used for flood hazard maps

| **Users** | **Scale** | **Basic information on map background** | **Map type** |
|---|---|---|---|
| Regional planners | 1:50,000 up to 1:100,000 | Topographical maps with a scale of 1:25,000 up to 1:50,000 | Regional plans |
| Local planners | 1:1,000 up to 1:25,000 | Topographical maps with a scale of 1:25,000<br>ATKIS DLM 25<br>Cadastral maps | Urban development land use plans<br>Development plans |
| Water management agencies | 1:5,000 up to 1:10,000 | Topographical maps<br>[German topographical maps with a 1:5,000 scale]; topographical maps with a 1:5,000 or 1:10,000 scale | |
| Emergency planning agencies | 1:1,000 up to 1:25,000 | Topographical maps with a scale of 1:25,000<br>ATKIS DLM 25<br>Cadastral maps | Emergency alert and emergency action plan maps |
| Insurance sector | 1:10,000 | Topographical maps with a scale of 1:10,000 | Zoning maps |

If maps are reduced to a scale of 1:25,000 or less, a generalization process must be carried out. Cadastral maps with a scale of 1:100,000 or less are impractical.

## 8 Public information measures

Flood hazard maps can be distributed via portals such as that used by Rheinatlas (http://rheinatlas.de) and the interregional atlas of the Mosella river basin (http://www.gefahrenatlas-mosel.de). Viewing these maps requires a fast internet connection and a modern computer. However, some private users do not own or have access to such equipment, and some population groups have no internet access at all. Hence other distribution channels are needed.

The public information strategies and realizations by cities such as Cologne in the internet (http://www.hochwasserinfo-koeln.de [available in German only])), and the information brochures about flood prone areas are successful (LAWA 2004). Any interested person or group can join associations and can be integrated into the flood management process. A flood safety prize was inaugurated in 2005 with a view to arousing the interest of children and adolescents in flood related issues.

It is also recommended that flood hazard information be disseminated through programs such as an annual flood safety day or flood safety festival (also see LAWA 2003). However, classic information dissemination modalities such as posting flood hazard maps in public buildings or in places that are frequented by the public should be applied as well.

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# Annexes

## Annex 1: RFP checklists

The checklists below enumerate key factors which must be taken into consideration and defined for the RFP process in accordance with the phases described in section 6.1.3.1, in addition to the other flood hazard map recommendations in this report.

### 1.1 Checklist for phase 1: Project definition; data inventory and requirements analysis

Relatively large cartographic areas should be broken down into smaller areas and the relevant scales should be defined. The purpose of the project should be described as well.

<u>Recommendation for a RFP text for this purpose</u>:

The project aims at defining all existing data and current data requirements for the compilation of flood hazard maps for the area. In accordance with this, an inventory and requirement analysis involving the gathering, examination and evaluation of the following data is to be realized:

- Digital watercourse data
- Digital terrain models (insofar as not already provided by the Bundesland)
- Watercourse cross-section data
- Survey and other data on engineering structures in and on watercourses (retention basins, dams, dikes, weirs, barriers, bridges, flood canals etc.)
- Hydrological flood probability estimates based on regionalization, time-series analyses, and rainfall-runoff models
- Hydraulics models (water surface profile calculations)
- Floodplains.

In addition to identifying the available data, it must be determined as to whether the data is useable and sufficiently accurate, and as to whether it will cause any significant costs.

**The following additional preparatory tasks are to be realized:**

- Define the relevant watercourse network
- Extend the digital terrain model
- Estimate the expense and/or efforts of gathering watercourse profiles
- Estimate the expense and/or efforts of gathering data about engineering structures
- Carry out baseline assessment of the available hydrological data.

The following is to be determined with regard to reaches that are affected by retention measures:

- Have rainfall-runoff-models been set up for these reaches?

- If so, when, by whom and for what purpose were these models set up? Have existing flood control reservoirs been integrated into the current operating rules in models, and are the models consistent with the current status of the areas of interest and the watercourses in them?

- Do the rainfall-runoff-models provide any calculation results for floods with a statistical return period of 10, 20, 50 100 and (if applicable) more than 100 years?

- Can it still be assumed that flood control reservoirs will be effective during extreme flooding (less than once every 200 years)?

## 1.2 Checklist for phase 2: Surveying

### 1.2.1 Surveying of watercourse cross-sections

<u>Recommendation for a RFP text for this item:</u>

Cross-sections are to be documented in accordance with the surveying specifications (see section 6.2.1). The location and number of the cross-sections to be surveyed are to be defined on site in collaboration with the client's hydraulic engineer. Normally only the watercourse bed and up to 5-10 meters of the adjoining zone are to be surveyed. The hydraulic engineer has to integrate the embankment of the cross-section, using the data from the digital terrain model.

The following elements should be surveyed:

______Cross-sections (up to 5 meters of watercourse width; average distance between sections: 100-150 meters)

______Cross-sections (5-50 meters of watercourse width; average distance between sections: 100-150 meters)

______Cross-sections (more than 50 meters of watercourse width; average distance between sections: 100-150 meters)

The cross-section figures indicated here are meant as suggested values. The surveyor is to be charged only for cross-sections that are actually measured in accordance with the hydraulic engineer's specifications and the quoted unit price.

The data format, visualization modality and data transfer methods are to be described in the surveying specifications.

At least one photograph is to be taken of each cross-section from the vantage point of its flow direction. If the view of the cross-section is obscured in any way, a series of shots should be taken. All further details are to be defined in the surveying specifications.

### 1.2.2 Measurement data for engineering structures

<u>Recommendation for a RFP text for this item:</u>

Engineering structure data is to be gathered in accordance with the surveying specifications. The location and number of the engineering structures to be surveyed are to be defined on site in collaboration with the client's hydraulic engineer.

The following elements should be surveyed:

______Bridges/underpasses (up to 5 meters of clearance)

______Bridges (5-50 meters of clearance)

______Bridges (greater than 50 meters of clearance)

______Culverts (from 10 meters in length)

______Dikes and other flood control structures

______Weirs/ drop structures (up to 5 meters of clearance)

______Weirs/ drop structures (5-20 meters of clearance)

______Weirs/ drop structures (more than 20 meters of clearance)

The figures indicated here are meant as suggested values. The surveyor is to charge only for structures that are actually measured in accordance with the hydraulic engineer's specifications and the quoted unit price.

The data format, visualization modality and data transfer methods are to be described in the surveying specifications. In addition, at least one photograph of each structure is to be taken from the vantage point of its flow direction and the reverse. If the view of the structure is obscured in any way, a series of shots should be taken. All further details are to be defined in the surveying specifications.

## 1.3 Checklist for phase 3: Hydrology and hydraulics

### 1.3.1 Coordination of surveying work

<u>Recommendation for a RFP text for this item:</u>

The surveying work is to be coordinated in accordance with the work order that is issued for the surveyor, with whom the locations of the cross-sections and engineering structures to be surveyed are to be jointly defined in accordance with the surveying specifications. Normally only the channel and up to 5-10 meters of the adjoining zone are to be surveyed. Following this, the embankments are to be added for the cross-section from digital terrain data.

The scope of the reaches that are to be surveyed should be defined on the basis of inventory and requirements analyses.

### 1.3.2 Validation of the surveying results

The hydraulic engineer has to check the completeness and practicality of the data submitted by the surveyor.

### 1.3.3 Additional surveying data

As a rule, when surveying cross-sections, the surveyor only surveys the watercourse bed and 5-10 meters of the adjoining zone. In order to carry out the hydraulic calculations, the embankments from the digital terrain model are to be integrated with the cross-section. If, as is sometimes the case, the digital terrain model is provided long after the surveying has been completed, this is to be taken into account for cost calculations.

The cross-sections are to be documented on the basis of layout plans, which are to show the following: all pre-existing and newly surveyed cross-sections with their locations and kilometre mileage; orientation of the watercourse axis; and length of the cross-section. Longitudinal sections of the watercourse are to be set up as well.

The cross-sections are to be documented on the basis of cross-section views, which have to include the items specified in the data gathering specifications. Cross-sections are to be documented from the vantage point of the watercourse flow direction. Elevations are to be indicated as heights above sea level or using the relevant official elevation system such as DHHN92: NHN. The cross-section polygon coordinates are to be shown in a local coordinate system comprising distance and height, and the coordinates in the relevant official reference system are to be indicated as well.

### 1.3.4 Exporting surveying data into a Bundesland geo-database

Following validation of the surveying data, its cross-section and engineering structure data sets are to be exported to and tested in, respectively, the Bundesland cross-section database and the relevant government agencies' cadastral survey databases. The data transfer formats for these processes are to be described in the data export specifications.

### 1.3.5 Hydrological computations

The discharges for flooding with statistical return periods of 10, 20, 50, and 100 years, as well as for extreme flooding, are to be determined for the watercourse reaches that were identified by the data inventory and requirements analysis. The discharge at top-of-bank level is to be calculated as well.

### 1.3.6 Hydraulic (water surface profiles) calculations

<u>Recommendation for a RFP text for this item:</u>

The water surface profiles for flooding with return periods of 10, 20, 50, and 100 years, as well as for extreme flooding, are to be determined, in accordance with the water surface profile specifications, for the watercourse reaches that were identified by the data inventory and requirements analysis. The water table is to be calculated for discharge at top-of-bank level as well. As a rule, water surface profile calculations are to be realized as one-dimensional computations divided into constituent sections (left-hand embankment, main channels, and right-hand embankment). Calibration results are to be documented (wherever possible) along with the roughness assumptions that were made. If the hydraulic engineer thinks that a two-dimensional calculation is required, this is to be clarified with the competent government agency.

### 1.3.7 Hydraulic calculations (identification of flood plains and inundation areas)

<u>Recommendation for a RFP text for this item:</u>

New and old water surface profiles for the flood plains and inundation areas is to be integrated into flood hazard maps on the basis of the digital terrain model. The engineering structure data compiled by the project, as well as existing watercourse structures, are to be integrated appropriately into the digital terrain model, its resolution permitting. A trapezoidal or rectangular cross-section can be used to carry out approximate calculations for the channels.

The envisaged method for the integration of water surface profiles into the digital terrain models is to be described, along with the consequent methodological advantages and disadvantages.

### 1.3.8 Realization of flood hazard maps

Uniform and updatable flood hazard maps can be obtained if they are produced by the competent Bundesland government agencies, which have access to the results of all previous map production phases (via their proprietary databases). Moreover, these agencies have good local knowledge of potential floodplains by virtue of the involvement of administrative personnel. However, sufficient human resources and appropriate technical equipment must also be available in order to produce flood hazard maps. If this is not the case, specialized providers should be called in, although this necessitates tight coordination of the map production process by the government agency in question.

Recommendation for a RFP text for this item:

In the final work step, flood hazard maps are to be produced in the specified GIS format on the basis of the available geo-data and hydraulic scenarios and in accordance with the standardized layout specifications. The project database and directory system are to be structured as indicated in the data gathering specifications. All data needed for the attribution of GIS elements is to be included in this system.

Printed flood control maps are to be produced in a suitable DIN format such as DIN A1, and in accordance with the layout and colour schemes described in section 7 of this document. The printing templates for these maps are to be presented in a digital Format such as jpg, tif or pdf and in a sufficiently high resolution such as 300 dpi.

## Annex 2: Colour values for the realization of standardized designs of flood hazard and flood hazard zone maps

| {RGB and CMYK colour values | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Figure no.** | **Map element** | **Colour intensity** | **RGB colours** | | | **CMYK colours** | | | |
| | | | **R** | **G** | **B** | **C** | **M** | **Y** | **K** |
| Figures 2 and 10: Hazard categories based on the interplay between probability and intensity | Hazard category diagram | weak | 255 | 211 | 81 | 1 | 17 | 81 | 0 |
| | | medium | 127 | 158 | 210 | 51 | 19 | 3 | 0 |
| | | strong | 241 | 92 | 67 | 0 | 80 | 84 | 0 |
| Figure 8: Depth categories and coloration | Recommendations for open systems | 0-0.5 m | 228 | 254 | 252 | 13 | 1 | 8 | 0 |
| | | 0.5-1 m | 180 | 242 | 252 | 31 | 1 | 13 | 0 |
| | | 1-2 m | 132 | 206 | 252 | 42 | 2 | 4 | 0 |
| | | 2-4 m | 52 | 154 | 252 | 88 | 17 | 0 | 0 |
| | | > 4 m | 132 | 26 | 252 | 96 | 93 | 0 | 0 |
| | Recommendations for closed systems | 0-0.5 m | 252 | 254 | 180 | 3 | 2 | 35 | 0 |
| | | 0.5-1 m | 252 | 226 | 140 | 2 | 10 | 52 | 0 |
| | | 1-2 m | 252 | 178 | 100 | 1 | 32 | 72 | 0 |
| | | 2-4 m | 252 | 102 | 52 | 0 | 78 | 92 | 0 |
| | | > 4 m | 252 | 0 | 1 | 1 | 99 | 95 | 0 |
| Figure 9: Colour scheme for a single map containing a series of flood areas with differing flood probability levels (zoning) | | blue | 95 | 171 | 221 | 59 | 8 | 5 | 0 |
| | | green | 151 | 204 | 99 | 34 | 2 | 80 | 0 |
| | | yellow | 245 | 203 | 81 | 3 | 18 | 81 | 0 |
| | | red | 227 | 96 | 85 | 2 | 75 | 68 | 0 |
| | | violet | 170 | 103 | 159 | 27 | 65 | 4 | 0 |

**Annex 3: Glossary**

This glossary lists the key terms that are used in connection with flood hazard mapping, for which the basis terminology can be found in the relevant statutory standards such as DIN 2425 parts 5 and 6.

Sensitivity: Refers to the vulnerability of a specific structure to a destructive event. Sensitivity can be expressed in terms of relative damage functions or other parameters (Merz et al. 2005)

Bundesland: A regional state in Germany

Bundesländer: Plural form of Bundesland

Exposure: Number or monetary value of specific structures affected by destructive events (Merz et al. 2005)

Hazard: The interplay between probability and intensity; or probability alone (Merz et al. 2005)

Danger: The possibility that damage might occur, but without data concerning probability (Plate et al. 2001)

Closed system: Refers to a protective structure such as a dike, fixed/mobile protective wall, or an element that is downstream a floodwater retention basin

Flood hazard potential map: An overview map that is elaborated using empirical methods. This type of map contains information on flood hazards that are known and localized, but which have not been exhaustively analyzed and assessed (BUWAL 1997)

Intensity: A qualitative metric that is used to describe various physical attributes of a destructive event. For flooding, these attributes are classified according to relevance as follows: water depth, water velocity, the arithmetic product of water level and velocity, duration, rate of rise, transport of sediment and pollutants (Merz and Gocht 2003).

Incorporation of intensity data into regional plans allows for the communication of relevant phenomena-related information to water resource and water law planners (among others), if necessitated by the coordination of competing land use requirements (see § 7(3) of the Regional Planning Act (ROG)). The mapping of elements such as floodplains (*Überschwemmungsgebiete*) within the meaning of the Federal Water Act (WHG) and Bundesland water statutes generally has no legal implications that exceed the scope of statutory development standards (e.g. floodplain specific restrictions).

Open system: An area prone to flooding that is not protected by flood control structures (LAWA 2004).

Potential floodplain: In land use parlance, an area that can potentially be flooded owing to the failure of dikes and other flood control structures (MKRO 2000). Has the same meaning as a LAWA's definition of a closed system (LAWA 2004).

RFP: Request for Proposal

Risk: The interplay between hazard and vulnerability (Merz et al. 2005); also means the risk of damage (IKSR 2001).

Risk map: A map that shows the possible consequences of flooding for a specific geographical area. Risk maps amalgamate hazard and vulnerability data, show the spatial distribution of risk, and are based on quantified risk such as the risk to human life or the anticipated value of flood damage (in Euros per year). Risk maps contain general information concerning modelled (probabilistic) events (Merz et al. 2005).

Floodplain: Pursuant to § 31b(2) of the Federal Water Act (WHG), an area where flooding can occur with a statistical return period of 100 years.

Area prone to flooding: An area that is prone to flooding owing to the failure of dikes and other public-sector flood control structures, pursuant to (§ 31c(1) of the Federal Water Act (WHG)).

Priority Areas are area categories that are used in regional planning and that form the basis for the definition of usage priorities for specific areas. Pursuant to § 7(4) and § 4(1) of the Regional Planning Act (ROG), priority areas constitute "regional planning objectives" and thus are no longer subject to assessment. Buildings or facilities in flood control or disaster protection priority areas are prohibited by law, insofar as such facilities could sustain flood damage or impair flood control measures.

Reserve areas: Pursuant to § 7(4) and § 4(1) of the Regional Planning Act (ROG), Reserve Area is a regional-planning category that defines assessable requirements for future assessment or discretionary decisions made by government agencies in connection with land use planning and the attendant measures. In contrast to Priority Areas, in Reserve Areas land use measures can be implemented insofar as the attendant planning processes take flood control structures into account.

Vulnerability: The interplay between exposure and sensitivity (Merz et al. 2005)

Probability: A metric for the uncertainty of future events. In the field of water resource management, recurrence forms the basis for probability calculations, which measure the relative frequency of an event based on a range of factors and scenarios.

## Annex 4: Terminological differences in describing the spatial dimension of flood hazards

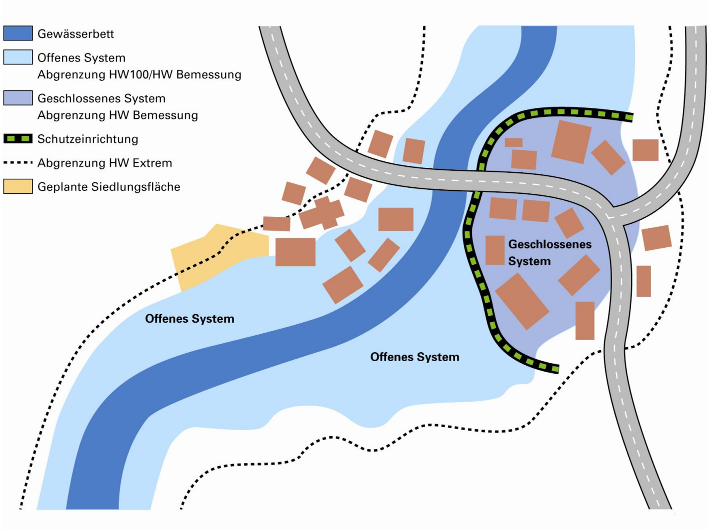


Figure 11: Land use terminology pertaining to the implementation of flood control measures in regional plans (adapted from Heiland 2002)

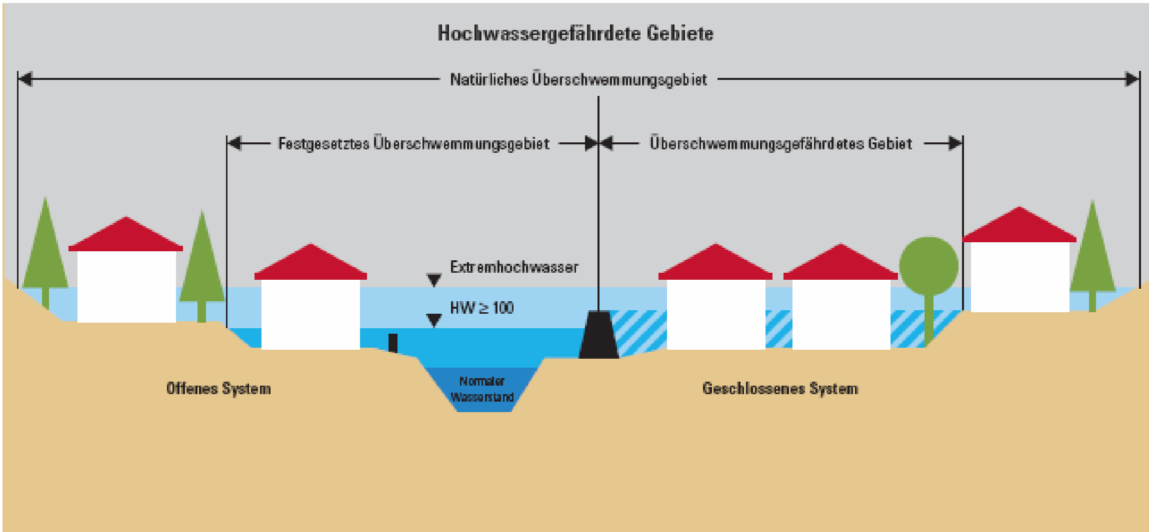


Figure 12: LAWA terminology (LAWA 2004). The Federal Water Act (WHG) states that areas with a statistical recurrence of flooding exceeding 100 years also count as flood prone areas

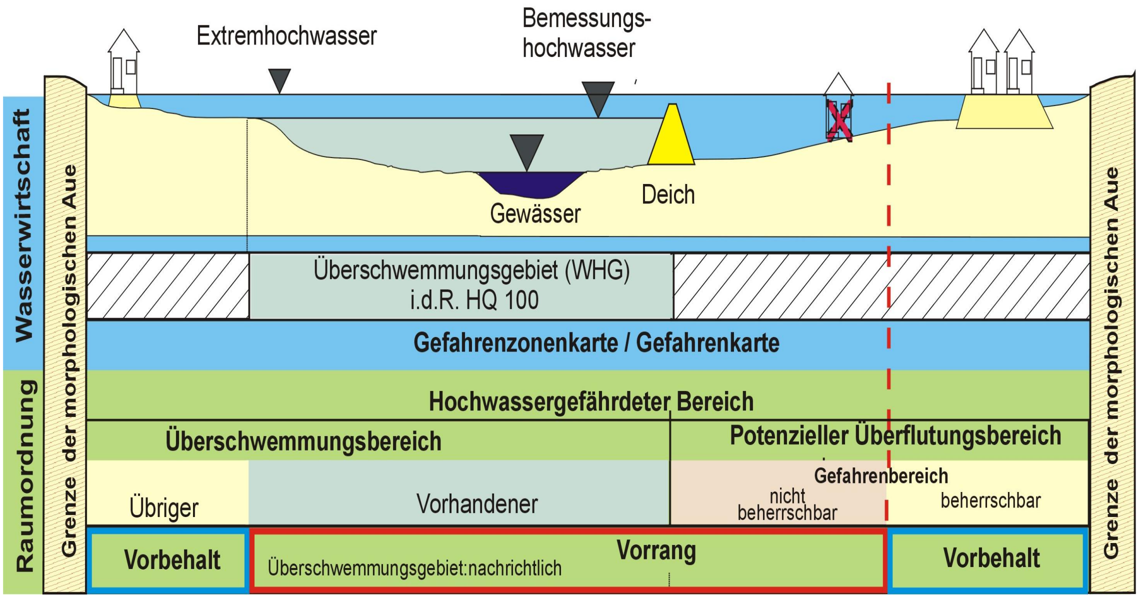


Figure 13: Land use terminology pertaining to the implementation of flood control measures in regional plans (adapted from Heiland 2002)

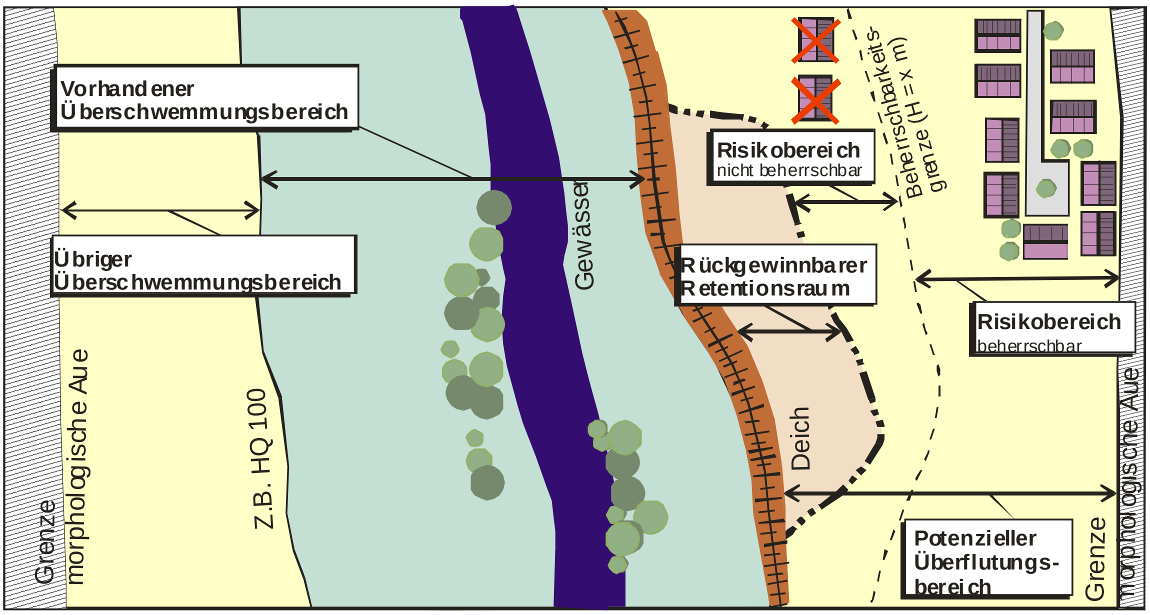


Figure 14: Terminology from MKRO 2000