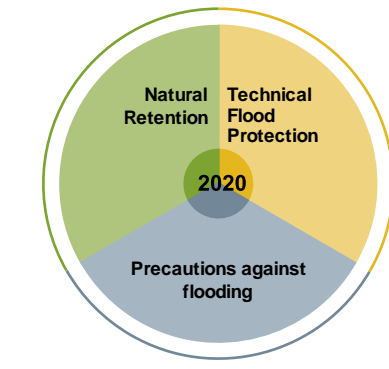


# Flood Protection and Climate Change – The Bavarian Adaptation Strategy



## Flood Protection - Action Programme 2020 – Flood Action Plan- Main – Taking Climate Change into Account

The necessity for intensified action in the field of flood mitigation was demonstrated painfully by the impact of the major flood events in 1999 and 2005 in southern Bavaria and 2003 in northern Bavaria. Climate change will exacerbate existing conditions significantly. The Federal State of Bavaria has already enhanced its flood protection strategy by launching the Flood Protection - Action Programme, which will run until the year 2020. Central elements of this approach are natural water retention, technical flood protection and precautions against flooding. Sustainable flood protection can be ensured by combining appropriate measures from the key areas of action. Whilst rivers and streams are given more space, thus storing water and delaying the propagation of flood waves, technical flood protection leads to further attenuation of flood peaks and settlements are protected by dykes and floodwalls. In addition, the local community is to be informed in good time of the dangers and given the necessary support for individual precautions.



Flood Protection - Action Programme 2020: the three sectors of integrated flood risk management

The flood protection strategy for the Bavarian part of the Main river basin, which covers about 23.000 km<sup>2</sup>, is specified in the Flood Action Plan – Main. This plan describes necessary local and state activities, with the aim of reducing damage risk and flood water levels, whilst raising awareness and improving the dissemination of relevant information. Initially, climate change was not taken into account. For this reason, the emphasis of the first part of the Bavarian contribution to ESPACE



The climate change factor is added onto the one-hundred year flood discharge, resulting in a design flood on which protection measures are based, thereby taking climate change into account.

was placed on the assessment of the impacts of climate change on the water budget of the Main river basin. This supplied the necessary information on which to base adaptation measures in the field of water management. In a second phase, a general methodological approach was developed, describing how flood protection planning could be modified to incorporate adaptation to climate change. The pilot project for the catchment of the Main tributary

Fränkische Saale was conducted for this purpose. In Bavaria, the design of flood protection constructions is based on the one-hundred-year flood. Statistically this is the discharge which is equalled or exceeded on average once every 100 years. Flood protection measures therefore offer protection up to this point. As climate change is leading to an increase in flood discharge, the difference between the discharge corresponding to a one-hundred-year flood at present and in the future was assessed, and found to be about 15%. Consequently, this is the percentage by which the design flood for protection constructions should be increased, known as the Climate Change Factor. Its inclusion in the planning process for flood protection measures in the Main river basin means the impact of climate change is being taken into account, which is, in general terms, in accordance with the future EU Floods Directive.

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## ESPACE

ESPACE (European Spatial Planning: Adapting to Climate Events) is a European cooperation project which aims to communicate the necessity of adapting to climate change. An equally important objective is the formulation of recommendations for the integration of adaptation to climate change into spatial planning mechanisms at local, regional, national and European levels. Special emphasis has been placed on the field of water management.



The ESPACE partners carried out numerous case studies, on the basis of which recommendations were formulated jointly for the adaptation of spatial planning to the consequences of climate change. The three most important conclusions can be summarised as follows:

- Adaptation to climate change should be a central objective for all fields of spatial planning.
- Planning should be flexible in order to keep options for adaptation open, even in the distant future.
- Successful integration of climate change adaptation into the planning process is only possible if risk management is combined with changes to governance and management.

Further information about the results of the Interreg-III-B-Project ESPACE is available in the internet:

About the Pilot Project Fränkische Saale:  
[www.klimawandel-hochwasser.bayern.de](http://www.klimawandel-hochwasser.bayern.de)

About the European Project ESPACE:  
[www.klimaprojekt-espace.bayern.de](http://www.klimaprojekt-espace.bayern.de)  
[www.espace-project.org](http://www.espace-project.org)



Bayerisches Landesamt für Umwelt



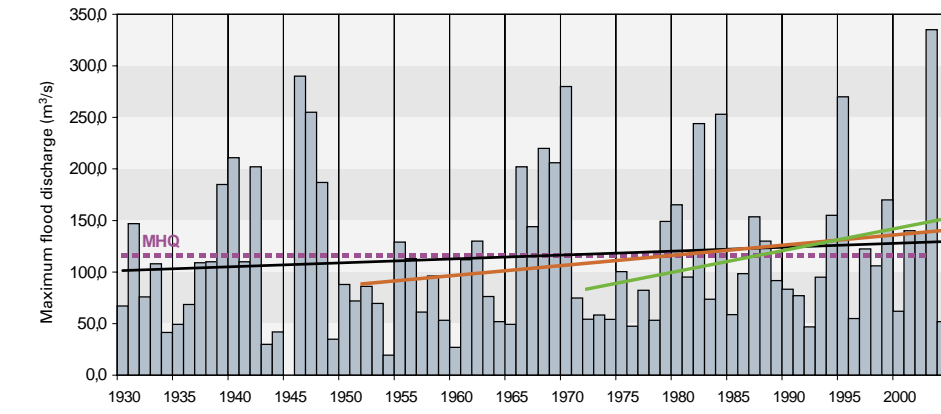
Wasserwirtschaftsamt Bad Kissingen



# Climate Change and River Catchment Planning – the Bavarian Project in ESPACE

## ESPACE – a European Cooperation Project

Climate change is already having a palpable impact on our daily lives. In addition to a global commitment to intensive climate protection, we need to address the consequent negative developments locally, with appropriate adaptation measures. This is above all a challenge for professionals in all fields related to spatial planning; in the past there was a lack of suitable methodological instruments. In 2003 the European cooperation project ESPACE, with its ten European partners from Belgium, Germany, the United Kingdom and the Netherlands, was launched to address this deficit. The Bavarian Environment Agency (Bayerisches Landesamt für Umwelt) is the German partner. In its contribution to ESPACE, the impact of climate change on the water budget of the river basin of the Main, the second largest tributary to the Rhine, was assessed. For the catchment area of the Main tributary Fränkische Saale, this work was advanced further to deliver specific recommendations for the adaptation of flood protection measures. Findings resulting from the ESPACE activities form the basis for recommendations for actions that support appropriate climate change adaptation measures in spatial planning.



Trend analysis for the average yearly maximum discharge [m<sup>3</sup>/s] (1931 – 2000) for the river Fränkische Saale at the gauge Bad Kissingen

## Climate change in the Main River Basin

### Knowing the past:

Long series of climate data-sets show that there have been definite changes in the river Main basin. In recent decades the average winter temperatures have risen by about 1 °C. Significant changes to precipitation also occurred principally in the winter half-year. Another noticeable change in the winter half-year is the increase in extreme events; the incidence of extreme precipitation has risen by up to 30%. It is evident that the climate has already begun to change and that this is having a noticeable impact on the discharge regime of the Main river basin. For example, the frequency of floods has increased.

### Estimating the future:

Changes to the climate in the future for the Main river basin were assessed by down-scaling the results of global climate models. The calculations for this area show a continuation of the trends observed in the past: In winter the average temperature increases by about 2 °C, in summer by about 1,3 °C. The changes to precipitation are even more evident, with a decrease in summer by up to 20%, increasing the risk of drought. Precipitation in winter could increase by up to 35% with a growing frequency of extreme precipitation, leading to a significant rise in the danger of flooding.

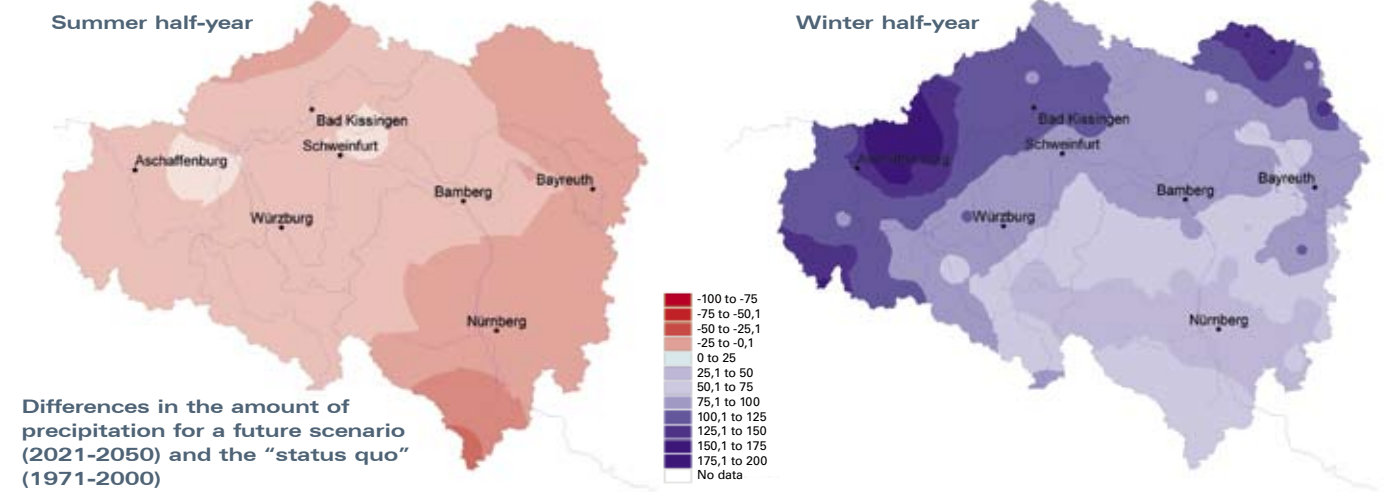


# Climate Change and River Catchment Planning

## Flood Protection Planning for the River Fränkische Saale: A European Pilot Project



The Bavarian Contribution to the EU-Project ESPACE  
(European Spatial Planning: Adapting to Climate Events)



Differences in the amount of precipitation for a future scenario (2021-2050) and the "status quo" (1971-2000)



# Flood Protection for the River Fränkische Saale

## Incorporating Climate Change into Flood Protection Planning

Most of the 2.765 km<sup>2</sup> catchment area of the Fränkische Saale lies in the low mountain range of the Rhön. The average discharge of the Fränkische Saale measured at the gauge Wolfsmünster, close to the confluence of the Fränkische Saale with the river Main, is 17 m<sup>3</sup>/s. The one-hundred-year flood has a discharge of 440 m<sup>3</sup>/s at this gauge. Some parts of the catchment area are characterised by steep gradients, which means that flood peaks can form very quickly. In particular the major winter floods repeatedly cause considerable damage.

Most recently the winter flood of 2003 showed that in many cases the existing flood protection was insufficient. For this reason the Water Management Agency of Bad Kissingen (Wasserwirtschaftsamt Bad Kissingen) launched a comprehensive assessment of the technical possibilities for optimising flood protection for settlements along the Fränkische Saale. The planning options available divide into three categories:

- Local protection using measures such as dykes and flood walls
- Regional protection using flood retention basins
- Combination of local and regional protection measures

The local protection measures for Bad Kissingen were completed recently. For several other towns such as Aura, Euerdorf, Diebach, Moreslau and Westheim appropriate protection is still needed.

The pilot project Fränkische Saale, as part of ESPACE, initiated and integrated the inclusion of climate change into the planning process. To exemplify how this can be done, a methodological procedure was developed, showing how the existing planning process can be adapted. The complexity of this task requires a step by step

**Flood protection planning – holistic consideration of physical, economic, ecological and social impact for an entire river basin.**

A climate change induced increase in the danger of flooding, demands that the following socially relevant questions be considered:

- Which areas and functions (buildings, business, industry, infrastructure) are affected and exposed to additional risk? (physical impact)
- What is the extent of the damage to humans, property, cultural heritage and the environment? (economic, social and ecological impact)
- How is the additional danger perceived and translated into action? (raising awareness, changing behaviour)

This integrative approach is a central element of the EU project ESPACE. It is of fundamental value for the sustainable integration of adaptation to climate change into river basin management.

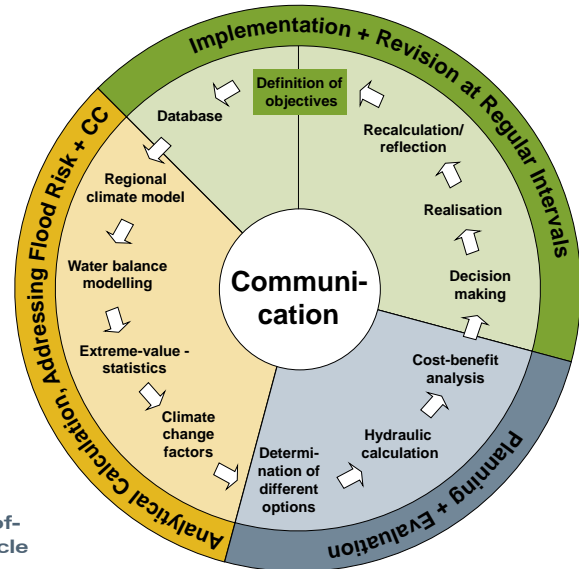
approach, which is illustrated in the "Climate-Proof-Planning-Circle":

- Definition of the objectives for flood protection planning, preparation of basic data and design bases, calculation of the relevant Climate Change Factors for the dimensioning of technical protection measures
- Conception of possible planning options, determination of flood

plains and project assessment with cost-benefit-analysis

- Communication of the planning process, involvement of decision makers, stakeholders and the general public, decision making and realisation.

Due to the dynamic nature of climate change, the protection strategy has to be revised at regular intervals to ensure its continuing effectiveness.



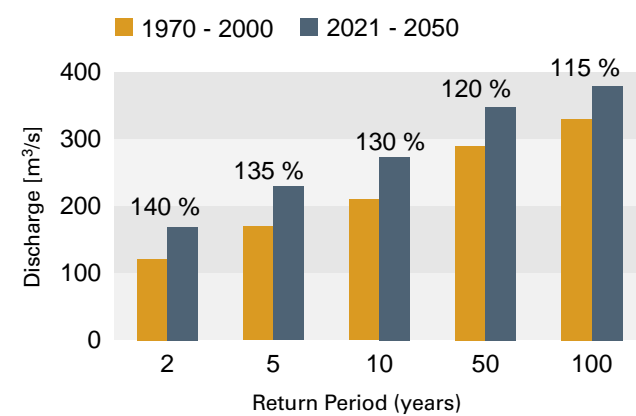
Climate change is already in progress, leading to increased danger of flooding. Consequently, existing tools and planning processes have to be revised and adapted.

# Affected Areas and Functions

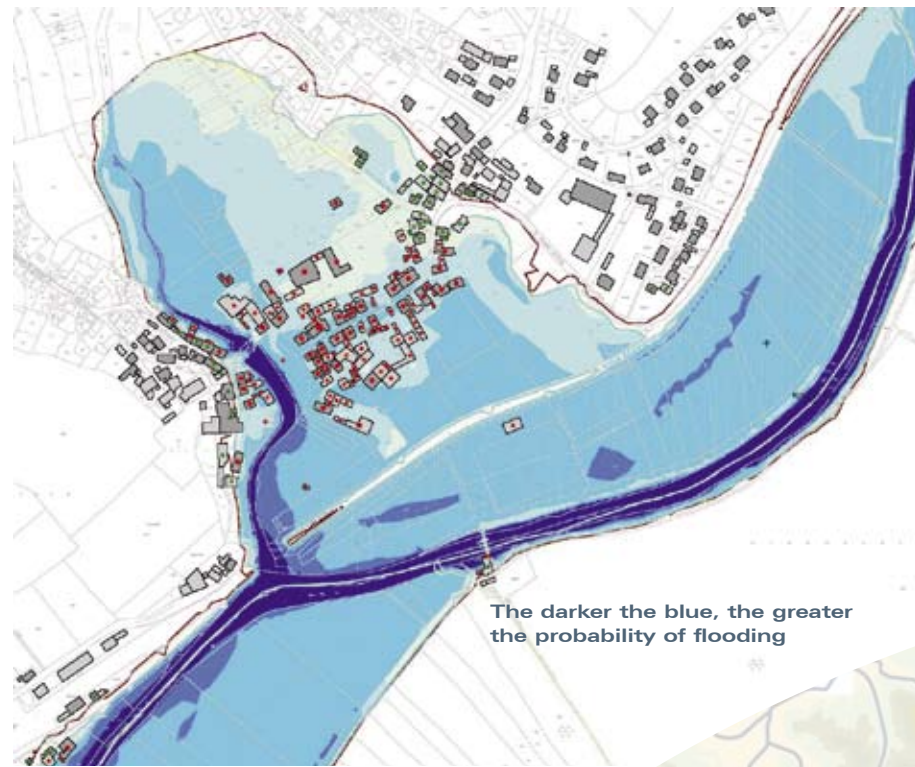
## Changes to Discharge

The basis for assessing additional impacts induced by climate change is the determination of expected flood discharges with as much precision as possible. The starting point is a global climate model that supplies the input for a water budget model. These allow the calculation of any significant changes to the natural water cycle. The flood discharge values derived from extreme value statistics are used as a basis for hydraulic calculations, which supply information relevant for the assessment of possible impacts such as flood water levels.

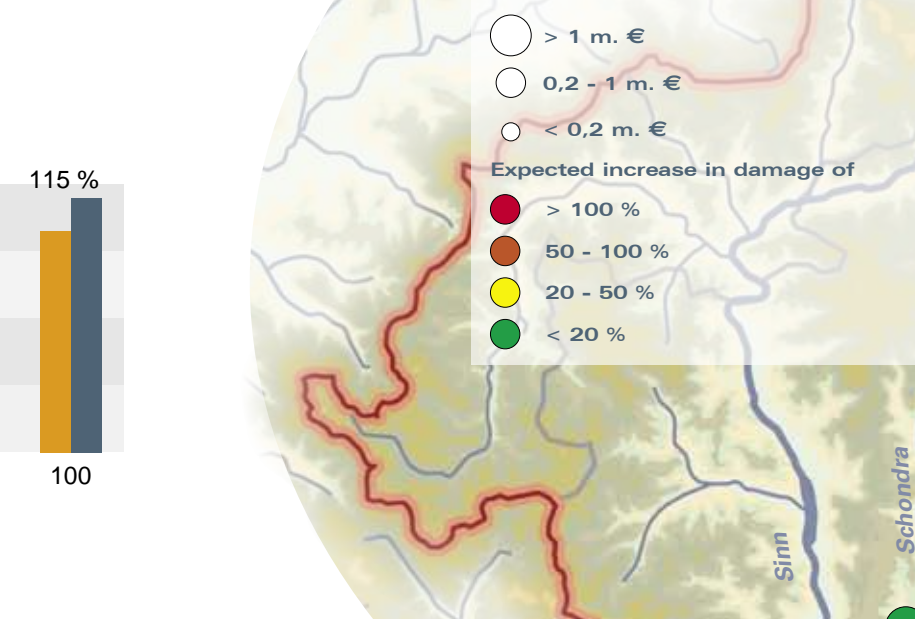
For the town of Hammelburg by the river Fränkische Saale, for example, the calculated climate change induced by a 15% rise in flood discharge for a one-hundred-year flood by the year 2050 would lead to a rise in the flood water level of approximately 30 cm. However, the increase in discharge for smaller flood events is considerably higher. For the specific assessment of the physical impact, the corresponding flood plains were derived for the calculated floodwater levels. These show which properties and settlements would be inundated by a particular flood event. A total of 274 flood



Changes in the discharge for flood events with different return periods due to climate change for the town of Bad Kissingen



plain maps were created, showing clearly which areas would be at risk of flooding for events with different return periods. These maps can be accessed at [www.klimaprojekt-espace.bayern.de/hochwassergefahr](http://www.klimaprojekt-espace.bayern.de/hochwassergefahr).



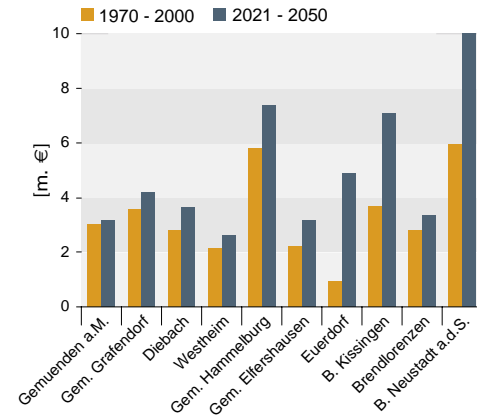
The discharge of a one-hundred-year flood is expected to increase by 15% by the year 2050. In some settlements this can lead to an increase in flood depth of up to 30 cm.

# Economic, Ecological and Social Impact

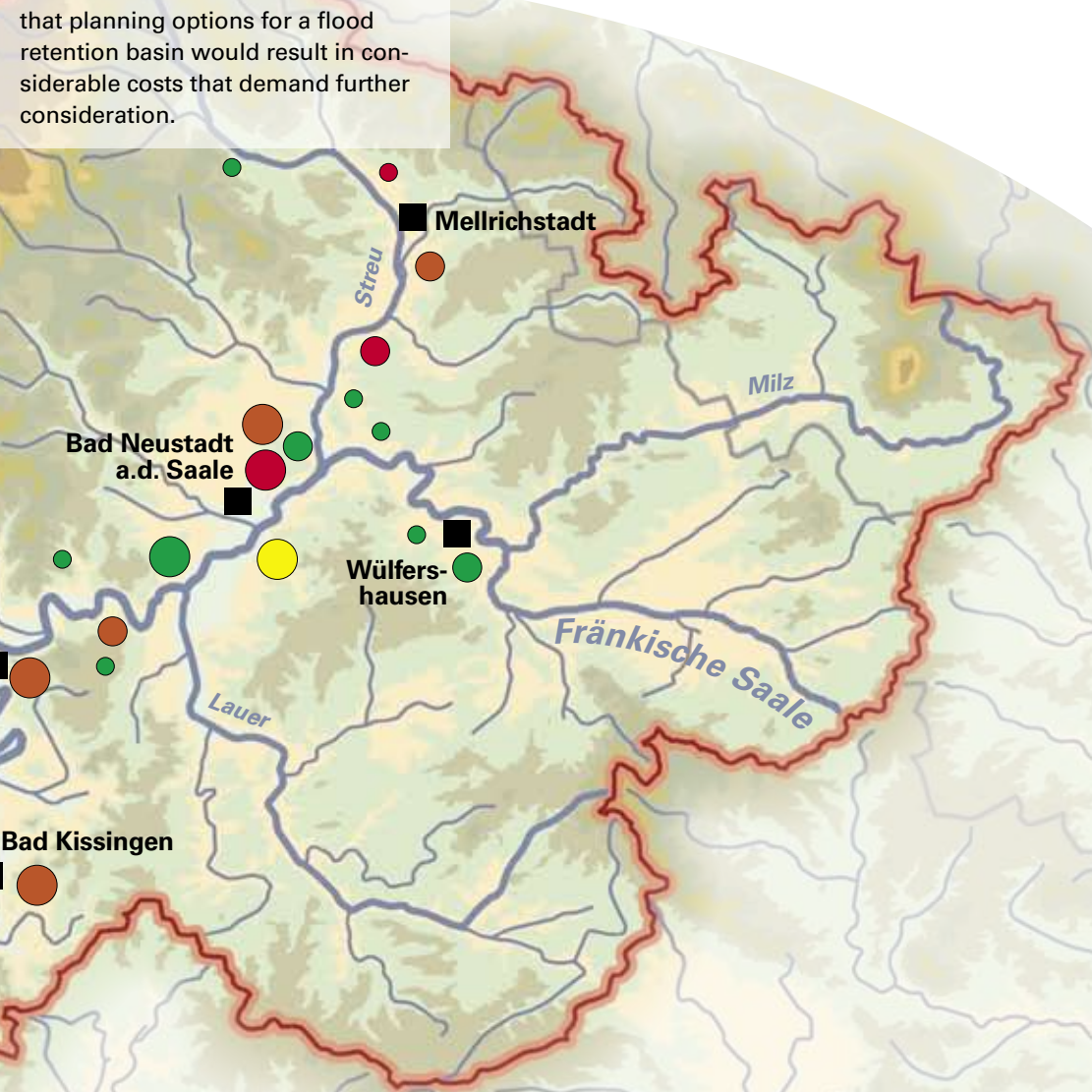
## Damage Extent and Adaptation Options

Based on the flood plains and the vulnerability of the land use type, different damage potentials were calculated for floods with different return periods, both with and without climate change. It was demonstrated in the pilot project for the river Fränkische Saale that the damage potential calculations were more realistic when they were calibrated based on local conditions. This involves both site inspections and questioning those affected. It was established that in frequently inundated and consequently more experienced areas in terms of flooding, far more damage-reducing precautions are taken than in areas where the rarity of flood events has led to an underdeveloped sense of risk. It also became evident that in many places the damage potential increased disproportionately when the one-hundred-year flood is exceeded. Without adaptation measures the increase in discharge induced by climate change would lead to an even greater rise in damage. The research carried out in ESPACE has delivered significant findings in this context.

The extent of flood damage can be limited by appropriate and optimised flood protection measures. In contrast, there is the cost of construction and maintenance for such measures. Cost-benefit-analysis can be used to establish whether the reduction in damage is high enough to justify the costs. This type of assessment provides the elementary foundation on which to base decision-making, thereby making a valuable contribution to the well-founded evaluations of different planning options, whilst taking the basic need for protection into account. Preliminary estimates for the river Fränkische Saale have shown that planning options for a flood retention basin would result in considerable costs that demand further consideration.



As a result of climate change, the damage in towns and communities caused by a one-hundred-year flood in the future could far exceed present levels.



The increase in flood discharge induced by climate change can sometimes lead to a disproportionate rise in damage. More frequent small flood events can make a change in agricultural land use unavoidable.

# Residual Risk, Raising Awareness, Behaviour Change

## Flood Protection and Residual Risk

Technical flood mitigation measures can only offer limited protection. The design flood can be exceeded by extremely rare major flood events. Therefore people and property in areas prone to flooding will always be exposed to a certain amount of danger, which is more or less appropriately described as the "residual risk". It is clear that the danger will continue to increase as climate change continues. Consequently, those affected must sustain a high level of awareness to ensure that additional protection is provided through private individual measures. A key factor in this context is access to information about potential flood plains as well as a risk dialogue with public administration. In ESPACE the relevant information was disseminated through various media outlets and published on the internet: [www.klimaprojekt-espace.bayern.de/hochwassergefahr](http://www.klimaprojekt-espace.bayern.de/hochwassergefahr).



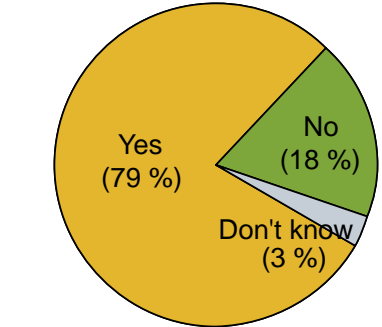
Raising Awareness

A survey was carried out as part of the pilot project Fränkische Saale, to establish how aware the general public is of issues concerning flood protection and climate change. The results show that the population in areas frequently exposed to flooding is very willing to invest in precautionary measures and recognises the potential additional risk resulting from climate change. There is, however, a lot of uncertainty and 95% of those questioned would like more information on the subject, preferably through individual consultation or information meetings with experts.



Behaviour Change

Awareness of the true extent of highly destructive floods tends to be erased from collective memory comparatively quickly as a result of their extreme rarity. Additionally, climate change is a steadily growing danger, hence the need to increase flood awareness, thus supporting enduring and appropriate precautionary behaviour. A Communication Strategy was developed in ESPACE to facilitate the dialogue between experts, decision makers and stakeholders. Especially in the context of a changing climate, the importance of this dialogue as a part of integrated flood protection will continue to grow, not least because of the increasing significance of private precautionary measures.



Survey in the town of Hammelburg: Do you expect an increase in flood danger as a consequence of climate change?

Limited state protection: Private precautionary measures are an indispensable part of integrated flood risk management. Information and risk dialogue encourage awareness and counteract the collective tendency to forget.



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