Bavarian State Ministry of the
Environment and Consumer Protection

Bavaria, Land of Water

Sustainable Water Management in Bavaria

Seventh updated edition

www.wasser.bayern.de

District government seat
Urban areas
National border
State border

Main watershed divide
Watershed divide

River
Channel
Lake

0 25 50 km

0 100 200 300 450 600 900 1,300 1,900 2,700 3,600 m

Elevation levels

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Preface

Dear Reader,

'Water is life.' This sentence is more relevant than ever. In Bavaria, we assume that we can enjoy the luxury of having access to water in the desired quantity at any time. Record high temperatures, the absence of rain, and the occurrence of drought on the one hand, and torrential rain, flooding and capricious weather on the other, plainly show us, however, that climate change has now also greatly altered the water balance in Bavaria. This has a direct impact on our lives. We will have to rethink our relationship with our resource, water, which is becoming more precious every day. To have water in sufficient quantities, and of the best quality, is something which cannot be taken for granted nowadays.

Protecting Bavaria, its residents and their property, as well as towns and infrastructures, from flooding has always been one of the core responsibilities of our water management. With its Flood Protection Action Programme 2020plus, the Free State is investing approximately 3.4 billion euros in the protection of the population. Additional components have been added to the Bavarian Waters Action Programme 2030, which follows. Apart from the need for flood protection, our waters and meadows are now coming more into focus as habitats for animals and plants and as relaxation zones for Bavarians.

Back in 1970, the Bavarian State Parliament approved the construction of a system connecting the water-rich south to the north, where water is scarcer. Although some droughts were able to be successfully tackled with this far-sighted system, climate change calls for other adaptation measures for dryness and water management to be tested and adopted.

The preservation of natural stream and river courses, as well as the near-natural restructuring of our bodies of water, remain important social responsibilities, as does the cleaning thereof and the maintenance of water quality through a well-functioning sewage system and riparian strips. Groundwater protection, soil de-sealing and conservation are further topics that can only be addressed with the support of the local authorities and of yourselves, the readers of this brochure. Only if we all continue to do our best to keep our bodies of water and groundwater sources clean and ecologically-valuable, and align our behaviour accordingly, can we pass on the treasure of water to the following generations in both the quantity and quality that we have come to know and expect.

This brochure is your introduction to the various areas of expertise of the Bavarian Water Administration, Using a number of examples, we would like to show you how we will meet the challenges of the future.

Yours,

Thorsten Glauber, MdL
State Minister

Contents

Water is life –

a molecule shapes our world

How misleading! Why is this planet called ‘Earth’? The name deceives us about its real nature, since seven-tenths of the Earth's surface is covered in water. Without water, Earth would be as hostile as Venus, for it is water that determines and enables life.

‘The principle behind everything is water;
everything comes from water and everything returns to it.’
Thales von Milet (Greek philosopher, 624–546 B.C.)

Water is the beginning

Life on our planet started over three billion years ago – in water. Here, the first single-celled organisms developed and the evolution of life began. Even up to, and including today, water has remained the most important nutrient for plants and animals. This also applies to humans, and in the truest sense of the word: In our early years, water makes up almost 70 percent of our bodies – a testimony to our origins.

Likewise, water shapes our landscape: When frozen into ice, it can erode cliffs; as a raging river, it carves deep canyons. Over a timespan of millions of years, it can level entire mountains, grinding stone down to gravel and sand to clay, then depositing these at distant locations. During the Ice Age, glaciers formed the Alpine foothills and Upper Bavarian lakes.

Water knows no boundaries and forms a network around our planet. Through countless surface and subterranean arteries, our villages are linked with cities, forests with fields, mountains with oceans, ultimately linking – by way of ocean currents and the atmosphere – the continents together.

Flowing water can develop an enormous force. As a raging torrent, such as here in the Breitachklamm gorge near Oberstdorf (in the Allgäu region), it cuts deep chasms into the rock and thus shapes the topography.

Water is civilisation

Since time immemorial, water has led to a fight for survival for us as humans: Fighting for water, so that we can live and feed ourselves; fighting with water, taming it and harnessing its power for our purposes; yet also fighting against water, to protect ourselves from its destructive force.

From time to time, rainstorms, floods, blizzards and torrents remind us that our protective measures – even in the high-tech, industrialised society in which we live today – are not always sufficient.

Water is sacred to us. Many religions include the practice of ritual washing to cleanse the soul. For example, Christians are admitted into the Christian fellowship through the rite of baptism.

The cradles of civilisation were all situated close to major rivers, like the Tigris and the Euphrates, the Nile and the Tiber. Man went where there was water – initially for drinking or irrigating their crops. In time, humans founded settlements along the riverbanks, conducted trade and gradually established civilisations.

In Bavaria, humans settled first in the particularly fertile areas of the Danube river basin. Later, they settled in pile dwellings on the edges of the lakes in the Alpine foothills.

Lakes and rivers offered drinking-water and food, and also served for the disposal of waste. A waterside location often offered strategic advantages, such as protection against wild animals and enemies, and the control of important trade routes.

Water is fun! No-one knows that better than children frolicking in a lake or swimming pool. Adults have also been enjoying the pleasures of bathing for thousands of years – the ancient Romans enjoyed their bathhouses, just as we enjoy the adventure pool complexes of today.

The first records of the moated Castle Burgsinn by the River Sinn in Lower Franconia date from 1001. The moat is fed by an underground spring.

The inviting Bavarian lakes are the locations for a wide variety of leisure activities.

Water is special

Behind this life-giving and sustaining elixir, there is an astonishingly simple formula known to almost every child: two atoms of hydrogen and one atom of oxygen combine to form the molecule H_2O. The element water – a colourless, seemingly unremarkable liquid that is really quite exceptional – is derived from two chemical elements.

Nowhere in the world will you find pure water – because H_2O is the best natural solvent. It dissolves salts and other solids from the soil and rocks and transports them into the sea. Above all, when it moves towards the Earth's interior, it is enriched with dissolved substances and gases, such as carbon dioxide, and it then refreshes our body and spirit as mineral or even curative water.

Even rainwater is not pure. When a drop of rain weighing 0.05 grammes strikes the ground after falling from an altitude of one kilometre, it has already washed and purified over 16 litres of air – clearly perceptible after warm summer rain.

Despite, or perhaps because of, its simple structure, water possesses a number of unusual characteristics which deviate from many general rules and distinguish it from other natural substances. Every child learns at school, for instance, that substances are typically denser in their solid state than in their liquid state. Water, however, is densest at +4 degrees Celsius. That is why ice floats on water. If this were not the case, lakes and rivers would freeze from bottom to top and no aquatic life would survive a winter.

Water also has a very high specific heat capacity, meaning that it stores a large amount of energy. This physical property affects our climate; without it, we in Central Europe would otherwise be living in an ice house. This is because ocean currents store solar energy at tropical latitudes and transport it toward the polar regions, thereby continuously warming the ambient air. In this way, the ocean currents ensure moderate temperatures for our planet. The Gulf Stream alone delivers roughly a billion megawatts of heat. That is the equivalent of a million nuclear power plants. It is only thanks to this warm-water heating system that Central Europe remains largely ice-free, even in winter.

Water in all its states: water vapour in the form of clouds (photo, top), liquid in the form of raindrops (photo, middle), and solid in the form of ice (photo, bottom). Ice demonstrates water's special property: Water is densest, and therefore heaviest, at +4 °C, which means that solid ice floats on liquid water.

Life cycles

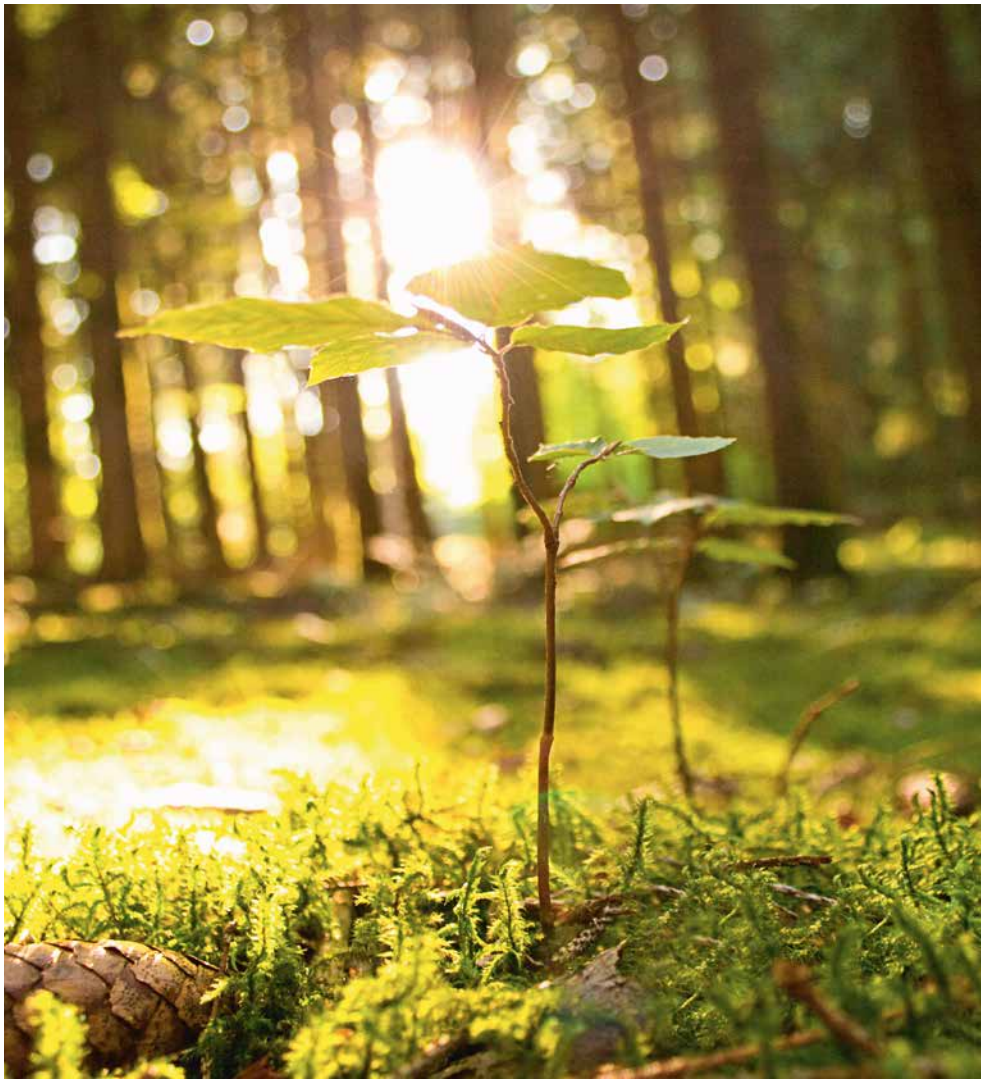
It is an ongoing cycle to which we owe our lives, the water cycle. Precipitation, after falling to earth, seeps into the ground, is taken up by plants and feeds the rivers and streams, which flow into the sea. Enormous amounts of water evaporate each day from the world's oceans to form clouds. These, in turn, are blown ashore by the wind, where new precipitation falls. Water is not lost, but is instead part of a perpetual cycle.

Plants are an important part of this cycle, too, as they also release water vapour into the air by means of transpiration. This can be observed in any garden, especially when the plants need watering to get them through a dry summer. A potato plant, for example, transpires between 0.4 and 1 litre of water per day under average weather conditions.

The water consumption of plants benefits all of us because, in simple terms, plants transform water and carbon dioxide into sugar with the help of solar energy. This process, photosynthesis, also produces essential oxygen, which we all – humans, animals and plants – inhale again and use to metabolise carbohydrates. This, in turn, produces carbon dioxide and water, i.e. another water cycle, but this time a biological one. Life would be unimaginable without it.

Every person absorbs water for their body's metabolic processes, which is excreted when the process is completed. Just like any other living creature, a human-being is part of the water cycle – the life-giving sustenance system that connects everything and ensures our survival.

Every plant needs water in order to convert the sun's energy into sugar. Oxygen is a by-product of this. Water is therefore fundamental to all life processes.



An abundance of water?

The view from outer space clearly reveals that some two-thirds of the Earth is blue, as it is covered with water. The sheer amount is almost unimaginable: 1.4 billion cubic kilometres of this treasure. If you were to pour this volume into a hollow column with a diameter as wide as Germany (about 670 kilometres), it would have to be roughly 3,900 kilometres tall. However, this apparent abundance is deceptive, as water is not always readily usable.

The lion's share of this is ocean salt water. Just some 2.6 percent of the Earth's water is actually fresh water. Of this amount, more than two-thirds is frozen as ice or snow. The most easily available source of drinking-water is the surface water in lakes and rivers, but this only makes up about 0.02 percent of the overall volume. The more significant water resource is groundwater. Similarly, of this pure source, only a proportion is useful for humans. Altogether, of the Earth's enormous water treasure, only the comparatively tiny proportion of 0.3 percent is available as drinking-water. In other words: if all of the Earth's water were to fit into a five-litre jug, only the equivalent of a teaspoonful of this would be available as drinking-water.

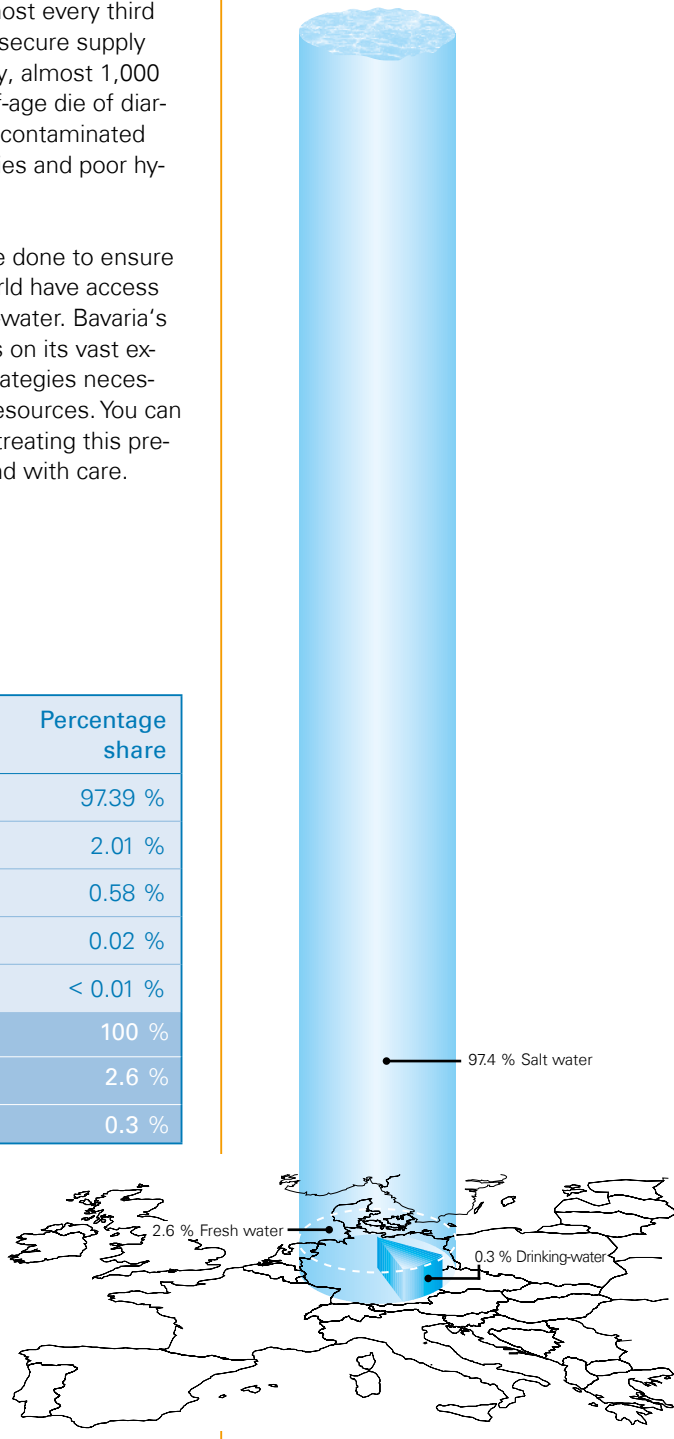
In Bavaria, we obtain 90 percent of our drinking-water from groundwater reservoirs. This is, therefore, our most important source of drinking-water. Herein lie the foundations of great wealth, because in many countries the constant availability of an adequate supply of good-quality water out of the tap is by no means guaranteed. Although access to clean drinking-water and sanitation was declared a basic human right in 2010, some 844 million people worldwide still do not have a drinking-water supply. In other words, almost every third person has no access to a secure supply of drinking-water. Every day, almost 1,000 children under five-years-of-age die of diarrhoeal diseases caused by contaminated water, a lack of toilet facilities and poor hygiene (status as of 2015).

So, there is still much to be done to ensure that people all over the world have access to sufficient clean drinking-water. Bavaria's water administration draws on its vast experience to develop the strategies necessary to protect our water resources. You can help to contribute, too, by treating this precious asset consciously, and with care.

For further information

www.unesco.de
www.unicef.de

The Water Masses of the Earth	Volume in cubic kilometres	Percentage share
Oceans	1,348,000,000 km³	97.39 %
Polar ice, sea ice, glaciers	27,820,000 km³	2.01 %
Groundwater, soil moisture	8,062,000 km³	0.58 %
Lakes and rivers	225,000 km³	0.02 %
Atmosphere	13,000 km³	< 0.01 %
Total	1,384,120,000 km³	100 %
Fresh water proportion		2.6 %
Drinking-water proportion		0.3 %



All of the Earth's water – fresh water and salt water – would together form an approximately 3,900 km-high column over Germany. The fresh water proportion only amounts to 2.6 percent. Moreover, only 0.3 percent is usable as drinking-water.

Our precious resource –

using and protecting water

We not only need water to wash and drink – substantially greater amounts are also required to produce food and consumer goods. At the same time, there are many competing demands on our water resources. Ships transporting goods, power-plants that need cooling water, and crops which need irrigation. This makes water protection an especially important task that does not end at national borders.

'Water is the best of all things'.
Pindar (Greek philosopher, 5th century B.C.)

How do we use water?

Water is absolutely vital – for humans, animals and plants. Everyone uses it on a daily basis. It arrives in our homes as tap-water and is ready to drink. We primarily obtain it from groundwater.

In addition to groundwater sources, we also make intensive use of streams, rivers and lakes. These are crucial for agriculture, recreation and tourism, as cooling water for power-plants, for hydroelectric power generation, and for shipping – in addition, surface waters receive our wastewater once it has been treated. To enable these different forms of water use, we have heavily altered many bodies of water, both in their structure and in their character.

As we have a seemingly unlimited supply of water, we are wasteful with it. We are not aware of how much water we directly use, or how much is necessary to produce our food and consumer goods.

Usage of groundwater

Our tap-water – in Bavaria roughly 865 million cubic metres per year – is obtained primarily from groundwater. Usually, the quality of our groundwater is so good, that it can be directly fed into our supply network without complex prior treatment.

In Bavaria, there is sufficient precipitation to constantly replenish these groundwater reservoirs. Water shortages are therefore fortunately not typically a problem here in Bavaria. In Southern Europe, however, and even more so in many emerging economies and developing countries, the situation is completely different. At this point, it is also important to keep in mind the possible effects of climate change on water supply.

Water serves as a transport route, as a source of recreation, and it provides energy. These are just a few examples of the many services water provides.

In order for field crops to grow, they need rainfall and, to some extent, irrigation water. That is why virtual water is hidden in the foods we consume every day.

Water consumption – also via consumer goods

In Germany, tap-water of drinking-water quality is taken for granted – and it is not the only type of water that we use each day.

On average, every resident of Bavaria uses 131 litres of drinking-water per day. Half of this is needed for flushing toilets, washing clothes and doing the dishes; about a third is used for personal hygiene. We only consume the smallest proportion (about five litres) of this perfectly hygienic water as drinking-water – although tap-water fulfils higher quality standards than bottled mineral water.

The water consumed for drinking, cooking, washing, bathing or gardening is visible and measurable, because it is accounted for by water-metres in private households. However, in addition to this direct consumption, shouldn't the water consumed or contaminated by producing food and consumer goods also be measured?

After all, hardly anything can be produced without water. The amount of water used in the production process is referred to as 'virtual water', and the volumes required are significant!

Roughly 132 litres of water are needed to produce a cup of coffee; for a kilogram of paper, an average of 2,000 litres are consumed; and one kilogram of beef requires up to 15,400 litres. In the case of beef, the calculation includes the water used to produce fodder, the drinking-water consumed by the cattle, and the water used for cleaning the stalls and in the slaughtering process.

The goods we use in our daily lives are often produced abroad, the smartphone being an example. In manufacturing one of these products, approximately 910 litres of water is consumed. That means that we import virtual water. Germany is among the top 10 importer countries of virtual water. If you take all this into account, the daily water consumption of each German is 3,900 litres!

To produce one cup of coffee, some 132 litres of water are needed.

For further information.

Brochure entitled 'Virtuelles Wasser – Verstecktes Wasser auf Reisen':
www.bestellen.bayern.de

Water consumption of different products, in litres

1 sheet of DIN-A4 paper	10	1 smartphone	910
Tomato, 70 g	15	Hamburger, 150 g	2,400
Cola, 200 ml	67	Cheese, 1 kg	3,200
Cup of coffee, 125 ml	132	1 PC	from approx. 15,000
Strawberries, 1 kg	347	Beef, 1 kg	15,400
Paprika, 1 kg	379	Cocoa, 1 kg	15,600
Banana, 1 kg	790	1 car	up to 400,000

Utilisation of rivers and lakes

The utilisation of water masses and watercourses has a tradition that is as long as the history of mankind. Over a very long period, this exploitation took place in harmony with nature, due to the limited technical possibilities. This changed rapidly with the Industrial Revolution and the resultant sharp increase in the population.

On the one hand, huge quantities of wastewater containing new substances were generated as a result of industrial production methods, particularly in cities. This, in turn, led to enormous water pollution.

On the other hand, due to the use of machinery, humans became far more capable of structuring and re-engineering bodies of water to suit their needs. Rivers were canalised and exploited to utilise hydropower. Moreover, due to the increased demand for food, large areas of floodplains were drained and turned into farmland. Harbours and protective floodwalls were built along river banks and lake shores to protect the properties on the waterfront. Consequently, in many places, the water-body structure, i.e. the composition of the shorelines and lake and river-beds, the connectedness with the natural surroundings and the watercourses, was changed.

Despite the variety of water usage, water quality has improved considerably in recent decades due to numerous protective measures. In many places, a more natural water-body structure is being restored. As a result, Bavarian rivers and lakes have regained their appeal as recreation and sports locations, are attractive tourist destinations and offer, with their fish, a valuable, healthy source of nutrition.

Wealth obliges – it is also true for water

The fact is that water cannot actually be consumed, for it does not vanish when it is used, but is always preserved in the water cycle in some form. By using it, however, we change its quality and turn it into wastewater. It is therefore our responsibility to limit the negative consequences of water usage to the greatest extent possible.

Balancing the pros and cons of the various forms of usage, while keeping water ecology in mind, is one of the most important aims of Bavaria's water administration.

Our water usage changes the structure and the quality of our bodies of waters.

Naturally free-flowing rivers, such as the Isar in its upper reaches, have become quite rare.

Taking preventative measures to protect water quality

Our guiding principle is sustainable and ecologically-compatible water usage in harmony with nature.

The variety of water usage calls for a range of measures to protect ground and surface water. The common goal of all protective measures is to supply both citizens and industry with high-quality water and to sustain an ecologically intact environment. That is not a contradiction, as the best water comes from the streams and springs which are untouched by humans. In densely-populated and highly-industrialised countries, hardly any natural bodies of water remain. However, we aim to make the water environment as natural as possible with regard to water quality, water volume and water-body structure. This way we can ensure that our water is clean and our lakes and rivers are full of life – today and in the future.

Keeping water clean

In Germany, the times when rivers and streams were used as sewage canals for untreated wastewater are fortunately long gone, billowing mounds of foam floating on the water are a thing of the past. The killing of fish caused by wastewater has also been significantly reduced.

Today, Germany has one of the best networks of sewage systems and wastewater treatment plants worldwide. Nearly 97 percent of the 12.8 million residents of Bavaria are connected to the public wastewater disposal system, and the remaining approximately 3 percent are connected to a private small treatment plant.

The treatment of residential, commercial and industrial wastewater has helped to ensure that, once again, sensitive flora and fauna can now again be found in most of our surface waters. To achieve this, since 1946, over 35 billion euros has been invested in Bavarian construction projects to build or expand the public sewage systems and wastewater treatment plants.

Improving water quality at the source

Despite all the progress, nutrients and some pollutants today still undermine the self-purifying capacity of lakes and rivers, or endanger the groundwater. However, fewer of these substances originate from single, identifiable discharge sources: they also originate from industrial air emissions, agriculture or road traffic, often affecting large areas – which is why they are referred to as diffuse inputs. The best way to deal with these pollutants is either to contain them at their source, or to adapt production processes, introducing methods which are less environmentally harmful. Substances that could have detrimental effects on water quality, but which are indispensable – such as fertilisers and pesticides – should be applied properly and only in the necessary amounts (according to best professional practice). Here, water management and agriculture work closely together.

With hose dispensers, liquid manure fertiliser can be applied in stripes near the plant root. The purpose is not only to reduce the offensive odours, but also to lower harmful nitrate losses.

Hose dispensers enable farmers to apply just the necessary amounts of liquid manure fertiliser in a precise manner. This not only reduces the offensive odours, but also prevents excess concentrations of nitrates in the soil.

Modern wastewater treatment plants, such as this one in Kempten on the River Iller, ensure clean water in rivers and streams.

A danger to reproduction?

Anthropogenic trace substances are chemicals which can be toxic to the environment, even in the smallest concentrations. In aquatic environments, these can include pharmaceuticals that have been excreted by humans, or improperly disposed of in the toilet. Many of these pharmaceuticals, or other chemicals, are not completely removed in wastewater treatment plants. A few of these substances can, for example, have a similar effect on some aquatic organisms as the natural female sex hormone, estradiol. These include:

- Synthetic oestrogens (e.g. active ingredients of the contraceptive pill)
- Phthalate plasticisers, which are used in many synthetic materials, e.g. PVC
- Transformation products of non-ionic detergents from cleaning agents (alkylphenols), such as those contained in imported textiles
- Bisphenol A, a building block of epoxy resins and polycarbonates, which are frequently found in packaging materials for foodstuffs
- UV-filter substances in sunscreens and other cosmetics

Furthermore, it has been proven that some pesticides (vinclozolin, diuron, linuron) can have an antagonistic effect on the male sex hormone, testosterone. Other such substances, like tributyltin, which has been used in the past in anti-mould paints for ships, have been known to have a hormone-like effect, leading to masculinisation. According to current knowledge, however, the concentrations detected in Bavarian surface waters do not appear to show any harmful effects.

The additional application of modern techniques in wastewater treatment can minimise the contamination of bodies of water with numerous hormone-like environmental chemicals.

Improving structures

In recent years, there has been a greater focus on the nature-orientated development of surface waters, alongside the treatment and prevention of contamination. Previously concrete-encased, straightened or channelised streams, rivers and lakes are now being transformed back into functional aquatic landscapes that are valuable to humans and nature. The more they resemble natural models, the better they are able to retain floodwaters and compensate for low water levels. In addition, lakes and rivers with near-natural properties offer a habitat to a much greater variety of animal and plant species and are able to remove diffuse pollution deriving from industry, agriculture and road traffic more effectively.

A complete return to the original state, without any human influence, is, however, impossible and is also not the goal. Renaturing objectives are therefore carefully chosen to take into account what is actually also feasible and possible, with the main aim being the restoration of rivers and streams to continuous networked systems that are sustained by their own dynamics. The development objectives are orientated to the particular local conditions, as a wide variety of river types can be found among Bavaria's aquatic landscapes.

Why the international protection of bodies of water?

The sources of important tributaries of large European rivers can be found within Bavaria; the River Main originates in the Fichtelgebirge and flows into the Rhine, while the Rivers Saale and Eger are tributaries of the River Elbe. The Danube, in turn, connects 10 countries on its way from Germany to the Black Sea.

Neither wastewater contamination, nor floodwaters stop at national borders. A river must, therefore, be considered in its entirety, including all of its tributaries and the landscapes through which it flows, from its source to its mouth. Consequently, for many years, Bavaria has been collaborating with its neighbours on water management and protection. Not only does nature benefit from the transnational protection of bodies of water, man does, too, with the guarantee of a secure supply of high-quality ground and surface water and a reduction in exposure to floods and water scarcity.

European directives have been adopted with the aim of permanently improving the quality of rivers, lakes and groundwater, as well as increasing flood protection in an internationally co-ordinated way. This provides the basis for the highest possible level of sustainable water use in a united Europe.

Water does not stop at borders. Water protection therefore requires an internationally co-ordinated approach.

The River Wörnitz, near Weiltingen, winds its way through the landscape along its natural river course.

Balancing water use and protection – the EC Water Framework Directive

'Water is not a commercial product like any other, but rather, a heritage which must be protected, defended and treated as such.'
(Preamble 1 of the EC Water Framework Directive)

With the European Water Framework Directive (WFD), the member states of the European Union laid the cornerstone of a modern European water policy and created the framework for harmonised water protection at a high level. A nearly-natural state for bodies of water should be attained and preserved across all EU borders. It is only by adopting a sustainable approach to water issues that we can continue to benefit from important eco-system services, and thus also available water, as in an adequate supply of good-quality drinking-water.

This approach specifically considers bodies of water within their natural catchment areas, which calls for cross-border collaboration in international commissions.

Specific environmental goals

The goal of the Water Framework Directive is to protect European bodies of water on a consistently high level.

The WFD sets specific environmental goals. By 2015, or 2027 at the latest, all surface waters, i.e. all rivers, lakes and coastal waters, should demonstrate a 'good ecological status' and have achieved at least a 'good chemical status'. By then, groundwater everywhere should have a chemically and quantitatively 'good status'. In addition, a no-deterioration clause applies to all bodies of water.

The condition of a body of water is tested, based on various criteria. For instance, the populations of fish, benthic invertebrates, plants and algae, in particular, are examined to assess the ecological status. Where a body of water fails to meet the environmental objectives, the respective EU member state(s) must carry out suitable measures to improve its status.

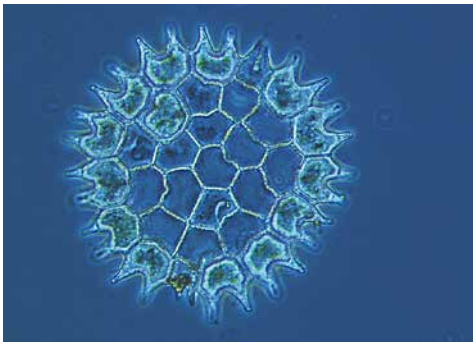
Under certain circumstances, exceptions can be made, for example, in the form of a deadline extension for achieving an environmental objective. Possible reasons for such a measure include natural conditions. For example, once intrinsically dynamic developments have been successfully initiated in a body of water, it still takes a certain amount of time until near-natural water-body morphology is reestablished. In such cases, the status improvement would often not be able to be completed by 2027. In addition, adapted environmental targets could also apply to inland waters that have had their structure substantially modified for certain specified uses, such as flood protection systems.

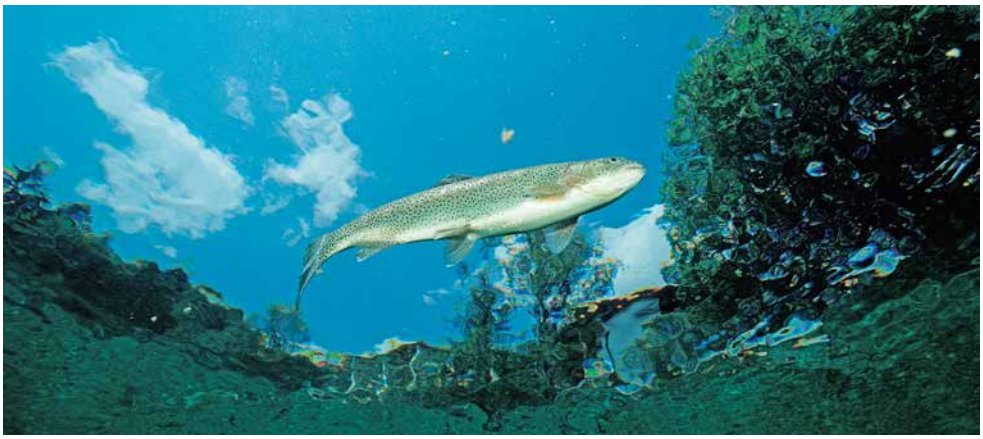
Achieving 'good status' step-by-step

The WFD specifies a clear time schedule and work plan. For each river basin, this includes the development of a management plan which describes the pressures impacting upon a body of water, its status, and a summary of the measures needed to achieve the objectives. These are described in detail in the accompanying action programme. Economic factors are also taken into account in the management planning, so that the measures selected are as cost-effective as possible.

The first management plans and action programmes were published in December 2009 and implemented by the end of 2015. The second river basin management period runs from 2015 until the end of 2021, and the third from 2021 until the end of 2027. The management plans and action programmes are updated in a six-year management cycle.

What is the status of a body of water? Not only chemical and physical values, but also, in particular, organisms that live in the water, provide information: small invertebrates (photo, left), aquatic plants (photo, centre), algae (photo, right; microscopic image) and fish (photo, opposite).





Riverbed morphology and river continuity can be assessed particularly well on the basis of occurring fish species.

Actively participating

The protection, preservation and improvement of our water environment is a collective responsibility that can only be successfully accomplished as a collaboration between water users, local authorities, governmental and non-governmental organisations. In a water management context, this includes open discussion about opposing user interests and the search for joint solutions, in order to achieve the environmental objectives for all inland waters, as stipulated either in the Water Framework Directive or the water laws.

Informing and involving the public are therefore key to implementing the Water Framework Directive. In Bavaria, the provision of information and exchanges of views had already started in 2002, with the founding of the Bavarian Water Forum (Wasserforum Bayern), which meets once or twice-a-year. Furthermore, in recent years, the district governments have hosted regional water forums, workshops and round-table discussions on various topics. Such events, tailored to the target groups and task-orientated, will continue to be offered in the future.

A legally-required formal consultation of the public on the development of the river basin management plans was carried out during the respective six-month consultations on the work programmes and time schedules, on the significant water management issues and, finally, on the drafts of the river management plans and action programmes, including their strategic environmental assessments.

European water-related directives

The EC Water Framework Directive (WFD) came into force in 2000. It supplements and consolidates a large portion of the existing European regulations on water protection. Two additional directives are connected to the WFD. The Groundwater Directive (GWD), which came into force in 2007, is intended to protect groundwater from contamination and deterioration. The Directive on Environmental Quality Standards (EQS), which came into force in 2009, defines threshold values for substances in the aquatic environment.

In 2007, the EU countries, after several catastrophic flood events in Europe, adopted a directive which aims to harmonise flood risk management, the EU Floods Directive (EFD). In order to protect the marine environment, the Marine Strategy Framework Directive, 2008/56/EC, has been in effect since 15th July 2008.

Finally, the European nature conservation project entitled 'NATURA 2000' is intended to protect species and habitats within the EU by means of a transboundary network of biotopes. The objective is to permanently preserve biological diversity. This applies to a broad spectrum of flora and fauna, both in and near the water. The legal basis for NATURA 2000 is the Wild Birds Directive of 1979, 79/409/EEC, which provides for the protection of all bird species living in the wild; and the Habitats Directive of 1992 (FFH), which aims to preserve habitats, as well as animal and plant species deemed to be particularly worthy of protection from a European perspective.

For further information

WFD implementation, maps and brochures:
www.wrrl.bayern.de

Liquid riches –

Bavaria is a land of water

We live in a region where water is plentiful. Not everywhere in the world will you find clean drinking-water, inviting bathing lakes or an abundance of hydro-electric power. So, where does this wealth come from that makes Bavaria a land of water? Furthermore, will it stay with us in future?

'The soul of man resembles water: from heaven it comes, to heaven it ascends, and to Earth it must return again, eternally changing.'
Johann Wolfgang von Goethe (German poet, 1749–1832)

The water cycle

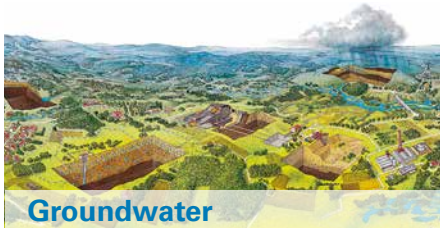
The hydrological balance is the prerequisite for healthy, unspoiled nature, as the quantity, distribution and composition of water determine the living conditions of humans, animals and plants.

Water moves in an eternal cycle consisting of evaporation, rainfall, seepage and runoff. In this cycle, it changes its form; it can occur as a gas, as a liquid or in frozen form. It passes through an enormous range of altitudes, from the Earth's atmosphere to rocky subterranean depths, and travels great distances – in clouds, driven by the wind, or in streams, rivers and ocean currents.

You will find out just how water is distributed in the water cycle throughout Bavaria, what the challenges are, and what is being done to protect water in the chapters entitled *Precipitation* (Page 32), *Groundwater* (Page 42), *Streams and Rivers* (Page 62) and *Lakes* (Page 88).

Precipitation

Water reaches us from the atmosphere in the form of rain, snow, frost, sleet, hail, fog and dew.

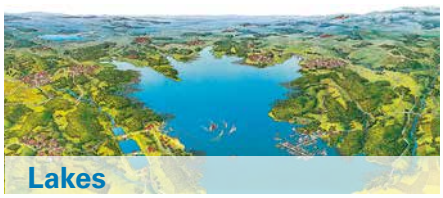


Groundwater

If precipitation or surface water percolates through rock into the earth, an unseen treasure is produced: groundwater, which is the source of most of our drinking-water.

Streams and rivers

Streams and rivers traverse the land and form a natural network, fulfilling crucial functions within the ecosystem, while also serving humans in many different ways.



Lakes

Lakes have always attracted people. They are also sensitive ecosystems that need special protection.

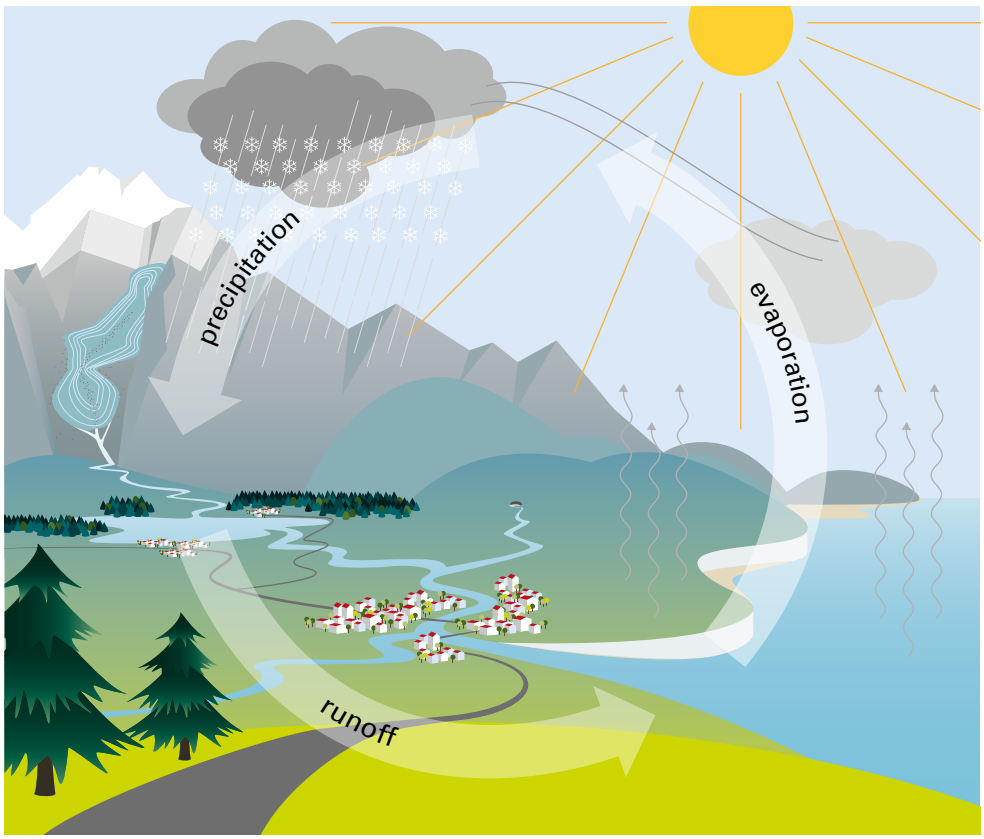
Water is not only found in rivers and lakes, but also in the air, in the form of fog or clouds.

The journey of a water drop

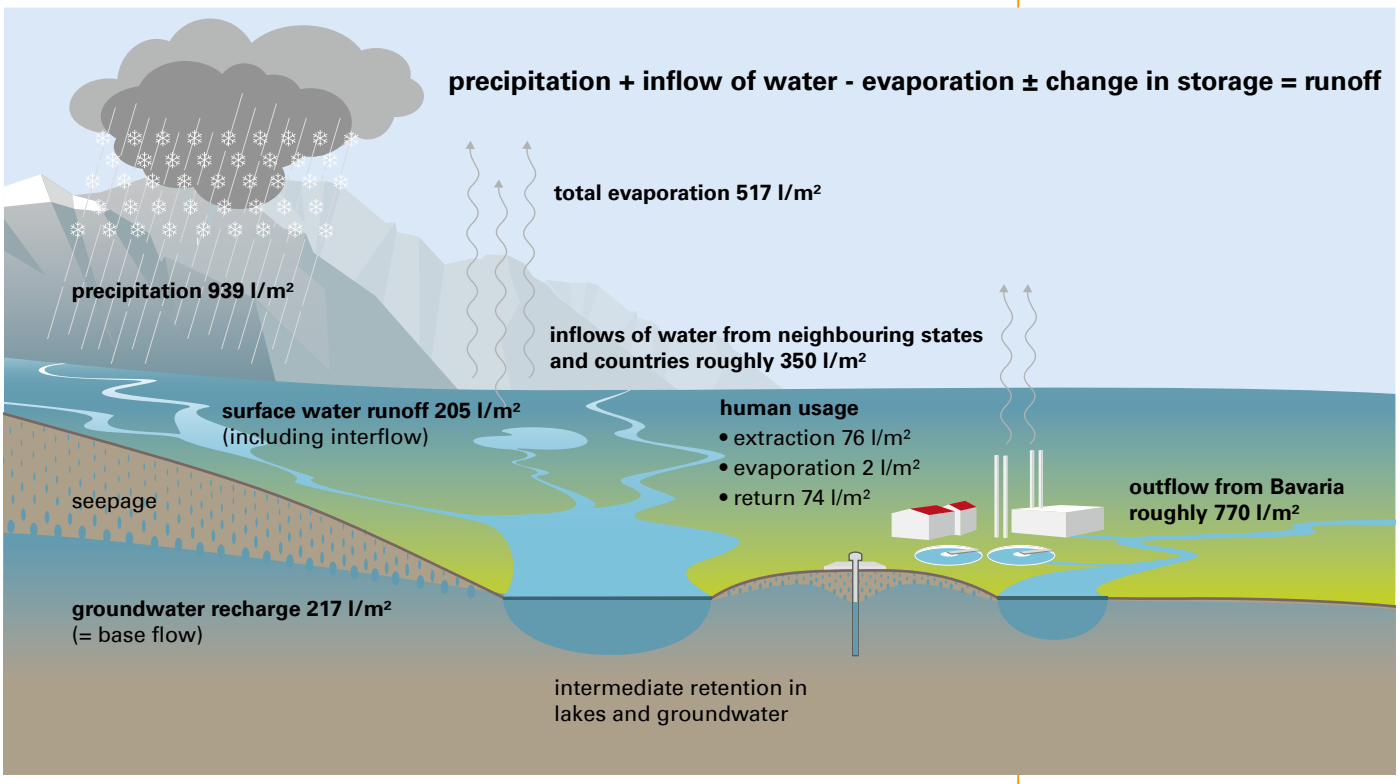
High above our heads, a substance that gives life is accumulating in the clouds. When it rains, billions of water drops fall to Earth. They replenish streams and rivers, lakes and seas, and seep into the earth; the drops penetrate through rock or evaporate once again.

The water which has seeped into the ground flows under the earth as groundwater until it re-emerges somewhere above ground as a spring, or joins a stream, river or lake – that is, if it has not already been drawn to the surface from wells. We then use it as high-quality drinking-water – and contaminate it in the process. Subsequently, it flows as wastewater through the sewage system into the treatment plants. There it is treated and purified before it returns to streams, rivers and lakes.

So, following this path, each drop of water – if it does not evaporate first – ends up in the ocean, some in just a few days, others in a few thousand years. Once in the ocean, the warming power of the sun will cause it to evaporate and rise to the sky. This completes the cycle – and then it begins all over again.



Each water drop moves in an eternal cycle consisting of evaporation, precipitation, and runoff.



In the water balance, the 'inputs' (the precipitation and the inflow of water), and the 'outputs' (the outflow and the evaporated water), are balanced against each other.

Bavaria´s water balance

Bavaria's natural water budget can be described in terms of a water balance calculation. A balance sheet has inputs and outputs. In Bavaria's water balance, the 'inputs' are the precipitation that falls on Bavaria and the inflows of water from the neighbouring states and countries. The 'outputs' are evaporation and outflowing water. The water is intermediately retained – in groundwater, for example, or in lakes. Even the water extracted and used by humans is considered as being in temporary storage, because – after a certain usage period – it returns to the water cycle.

On average, throughout Bavaria, 939 millimetres – or, alternatively, 939 litres per square metre – of precipitation fall per year. Overall, this amounts to 66 billion cubic metres each year. Some 25 billion cubic metres of water flow into Bavaria from neighbouring states, primarily via the Danube and its tributaries. This water, cascading onwards, leaves Bavaria as surface water and groundwater in the direction of its downstream neighbours.

Runoff forms in Bavaria itself: on average, roughly 55 percent of the precipitation evaporates from plants, the soil and surface areas. The water that remains – 45 percent of the precipitation – runs off below or above ground. This volume of water is also referred to as the 'available water resources' because it is available for water administration purposes, for example, the drinking-water supply. Each year, this amounts to almost 30 billion cubic metres, which is equivalent to 422 litres per square metre. In addition to using groundwater, mankind also exploits the water in rivers – for cooling water for power plants, for example.

The proportion of precipitation, which seeps into the groundwater via the soil and continues flowing underground, enters streams and rivers through springs or by seeping through the riverbanks. If the inflow of water from neighbouring states and countries is added, the outflow from Bavaria amounts to a total of 54 billion cubic metres per year. This corresponds to 770 litres per square metre.

'Available water resources' means the proportion of water from total annual precipitation which does not evaporate and is therefore available for human utilisation.

The climate change challenge

Fossil fuels, such as coal or oil, are consumed to produce electricity and goods, and are used for mobility and heating. Carbon dioxide is formed from the burning of these fuels and accumulates in the atmosphere. Together with other gases, it is responsible for human-induced climate change.

Since the advent of the Industrial Revolution, mankind has generated massive carbon dioxide (CO_2) emissions – especially from fossil fuels. The resulting increase of CO_2 emissions has caused, in combination with other greenhouse gases, a global temperature rise of around 1.0 °C. In Bavaria, it has become warmer, too. Since 1931, the average annual temperature has increased by 1.3 °C.

What does that mean for us? If you look at the regional climate in different parts of Bavaria, the potential effects of a temperature increase become clearer. The difference between the long-term average annual temperatures in relatively cold cities – such as Hof or Garmisch-Partenkirchen – and that of the warm wine-growing centre of Würzburg is about 2.5 °C. Just those few degrees difference have a decisive effect on the living environment and the potential for agricultural usage.

The impact of extreme weather events is more intense than the effect of gradually rising temperatures. Unusually hot days, lengthy dry spells and heavy precipitation events are becoming more frequent. Especially the prolonged heat waves, river floods or localised flash flooding in residential areas could potentially cause a high level of damage. Thus, these extremes necessitate a host of preventative and adaptive measures for many sectors of our society.

The climate changes observed thus far affect us with varying intensity in the course of the year. This is particularly true of precipitation. In the hydrological summer half-year (from May to October), there has been no recognisable trend in measured values since 1931. However, in the hydrological winter half-year (from November to April), the mean precipitation has increased by 15 percent in Bavaria. Changes such as these have, in turn, very different regional effects: Especially in Northern Bavaria, the increased winter rainfall is leading to a greater danger of flooding.

Similarly, there have been marked changes with regard to heavy precipitation events, when an exceptionally high amount of precipitation falls within just a few hours or days. In Northern Bavaria, the maximum daily precipitation in the winter half-year increased by up to 30 percent between 1931 and 2015.

Long-term measurements show that, in Bavaria, the temperature has already increased, and the precipitation patterns have noticeably changed

Temperature and precipitation changes in Bavaria	Change in the period 1931–2010	Mean value in the period 1971–2000
Average annual temperature	+1.3 °C	7.8 °C
Winter precipitation in Northern Bavaria	+17 %	350 mm
Winter precipitation in Southern Bavaria	+13 %	430 mm
Summer precipitation in Northern Bavaria	–2 %	415 mm
Summer precipitation in Southern Bavaria	–2 %	630 mm

The climate of the future

Climate models are the tool used to give an insight into future changes. The starting point for these are scenarios which are a gauge of future additional warming. These are used in the calculation of global climate models. From the models, we know that the global mean temperature could increase by up to 5.4 °C by 2100, in comparison with the pre-industrial era. At present, it is still possible for us to prevent a probably fatal transformation of the Earth's climate by quickly making the transition to clean and resource-saving technologies. Based on the large-scale findings of the global climate models, various methods are used to derive climate projections for smaller regions like Bavaria. The result is a spectrum of future potential climate changes.

Based on these climate simulations, a rise in the mean temperature of 1.5 to 3 °C can be expected in Bavaria by 2050. By the end-of-the-century, the temperature could increase by up to 5 °C. Hot days, on which the mercury climbs to over 30 °C, currently only occur, on average, about five times per year. It is assumed that this number will triple in some of Bavaria's regions in the future.

In winter, the number of ice days with sub-zero temperatures will decline. Although these have occurred some 30 times per year in the past, there may only be half as many such days in the future.

The precipitation changes are particularly decisive for Bavaria's groundwater, rivers and lakes. For the winter half-year, the computed changes through to 2100 vary quite a bit, depending on which climate model you look at. The majority of the models estimate that the changes will amount to less than 10 percent, which does not deviate substantially from the precipitation variance to date. Only for the end-of-the-century projections do most of the models indicate a larger increase in the precipitation levels of up to 20 percent. As an increase in winter half-year precipitation has already been detected in the past, a further future increase seems entirely plausible.

The precipitation changes for the summer half-year show an increasingly drier climate. Up to the end-of-the-century, decreases in precipitation quantities will continue, reaching a maximum of 20 percent by 2100; most projected decreases will remain below 10 percent. In combination with rising evaporation rates due to temperature increases, this will lead to an increase in periods of drought.

It will get much warmer in Bavaria by the end of the century. Climate change will probably also lead to wetter winters and drier summers.

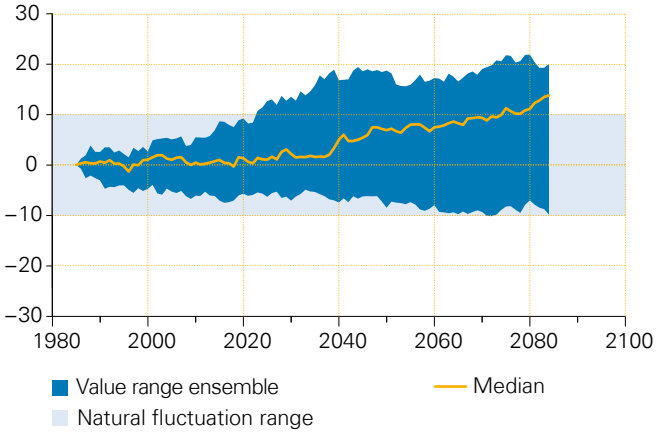
For further information

Klimawandel in Bayern:
www.kliwa.de

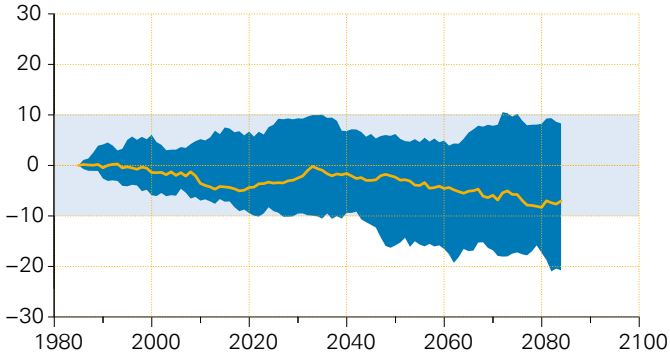
Brochure entitled 'Klima-Report Bayern 2015':
www.bestellen.bayern.de

In the future, winters are more likely to be wetter (graph, left) while the summers are more likely to be drier (graph, right). Despite the wide range of results, which are based on 10 climate projections, they are mostly unanimous with regard to the future changes in precipitation in comparison with the 1971 to 2000 period. Only changes of more than 10 percent are greater than the variability of precipitation in the past, and are thus considered to be significant.

Change in precipitation in Bavaria in the winter half-year (percent)



Change in precipitation in Bavaria in the summer half-year (percent)



Due to climate change, droughts could occur more often in the future. This will be spurred on by increased temperatures leading to more intense evaporation. Furthermore, if there is no precipitation for weeks on end, the rivers are not replenished, such as the River Iller in Kempten, seen here in December 2011.

For further information

Low-Water Information Service
www.nid.bayern.de

Effects of climate change on runoff:
www.kliwa.de > Hydrologie

Brochure entitled 'Niedrigwasser in Bayern – Grundlagen, Veränderung und Auswirkungen':
www.bestellen.bayern.de

Climate change signals in the water

Only those who are aware of the effects of climate change can react with appropriate measures. To assess the situation, values are monitored and data is regularly evaluated to gain a picture of long-term trends. Moreover, areas that are largely unaffected by humans are regularly investigated to determine what aquatic life can be found there. If changes are found in such uncontaminated waters, these can also be attributed to climatic causes.

Possible future changes are also being researched. With the temperature and precipitation data from the regional climate projections, hydrological models are generated. These describe the future water cycle of an individual catchment area with all its processes, such as evaporation, infiltration and runoff in rivers and streams.
Such a tool, which provides a window into the future of our bodies of water, helps Bavaria's Water Administration to prepare for climate change and implement adaptation measures.

It is already clear that we can expect more frequent dry spells, especially in summer. Between 1971 and 2000, longer dry periods, when no rain occurred for more than seven days, were seen about four times per year on average. There could be many more such droughts in Bavaria up to 2050. As a result, low-water periods in Bavaria, like we saw in 2018, could become more frequent in the future.

This could have disastrous consequences on agriculture, and increase the need for irrigation. Moreover, these changes would severely affect shipping on inland waterways and businesses along river courses that depend on cooling water, as well as hydroelectric power generation. For this reason, a Low-Water Information Service (Niedrigwasser-Informationsdienst; NID), modelled on the Flood Warning Service (Hochwassernachrichtendienst, HND), has been established in Bavaria. It provides information on current low-water levels, water temperatures, groundwater levels and the water levels in lakes and reservoirs.

Due to the rising temperatures, less snow will remain in the Alps in the future. Not only will this affect winter tourism, it will also impact upon the seasonal water supply for the southern Danube tributaries which, in the spring and summer, are greatly affected by melting snow.

How climate change will affect flood occurrence in Bavaria is also being researched. The measurements at gauging stations show that the flood discharge volumes have increased since 1931, especially in the winter months. By introducing the so-called climate change factor into its calculations, Bavaria's Water Administration has already made preparations in advance. For new hydraulic engineering protective systems, such as dykes, a safety margin is taken into account in order to ensure sufficient safety and protection, even in case of more intensive flooding.

Will climate change affect our drinking-water?

According to present knowledge, from 2021 to 2050 only minor changes in the mean annual groundwater replenishment are expected in Bavaria. However, changes in the seasonal distribution of precipitation could indeed locally affect the aquifers. With increasingly dry summers, shortages are possible in areas with shallow groundwater reservoirs or low-yielding groundwater sources, in combination with increased water demand. The regional effects of climate change on the available water sources have been investigated in several case studies. The results have been fed into the water supply balance sheets that are published by the district governments. Long-distance water supply schemes, or network system solutions, will become even more important than in the past in order to ensure a secure and flexible drinking-water supply.

In addition, climatic changes could also lead to the localised temporary impairment of drinking-water quality. These potential effects are also a subject of research.

How will aquatic habitats change?

The effects of climate change also influence organisms that live in our rivers and lakes. The rising water temperatures will make survival more difficult for fish and small organisms as, with rising temperatures, less oxygen is available in the water. Not only the cool and oxygen-rich water surfaces are affected, but also the larger rivers that are warm in summer, as well the lakes. Living conditions will worsen for hitherto widespread, but sensitive fish, like brown trout, grayling and whitefish, and even rarer insect types, like stoneflies. At the same time, living conditions will change for algae and water plants. A number of species, which are sensitive to temperature and nutrients, will be reduced in favour of more hardy creatures.

Marine ecologists have identified a negative trend that they expect will strengthen, also due to altered runoff patterns: on the one hand, it is expected that lower precipitation levels in the summer half-year will result in reduced water levels in rivers, lakes and streams, while, on the other, increasingly heavy rainfall events will feed more chemical substances into the water. The environmental conditions as a whole will deteriorate.

For further information

Effects of climate change on the biology of rivers and streams:

www.kliwa.de > Gewässerökologie

Effects of climate change on groundwater:

www.kliwa.de > Grundwasser

Climate change will especially affect the rivers and lakes. Just how shoreline vegetation will change, for example, is being examined in research projects.

Three invasive species newly present in Bavarian waters are the Asian clam (photo, upper-left), the Danube opossum shrimp (photo, upper-right) and the killer shrimp (photo, bottom). Invasive animal species are known as neozoa, while invasive plants are called neophytes.

Alien species: 'New residents' in domestic waters

Alien species are animal and plant species that have migrated, or have been introduced from their original native areas and have propagated in new areas. Most of these 'migrants' become integrated into the native animal and plant world without causing problems. Some, however, have no natural competition or enemies in their new habitats, or they are more competitive than the native species. They can displace the native species as predators, or as competitors for space, light or food. Often, they do not fulfil their function within a given ecosystem – as a food plant, for instance – to the same extent as comparable native species.

Today, animals and plants from overseas, often from Asia or Eastern Europe, are introduced in a multitude of ways; for example, via sailing and motor boats, or yachts that cruise on various lakes and rivers, or even as stowaways in the bilge water of container ships. Moreover, alien species are introduced in aquaristics, aquacultures and fisheries, and enter our bodies of waters either intentionally (release/stocking) or unintentionally (escape).

Due to the warming of our climate, and particularly our milder winters, it is to be expected that many of these more warmth-loving species will continue to find suitable living conditions here in the future.

For further information

www.kliwa.de > Gewässerökologie > Flora und Fauna

What does climate change mean for Bavaria?

In order to counter climate change, there are two strategies which must complement each other; reducing greenhouse gas emissions (climate protection) and adapting to the inevitable climate change. Limiting global warming to well below 2 °C (ideally to 1.5 °C) is the goal of international climate policy, to which the global community committed itself in the Paris Agreement, that was concluded in 2015 at the 21st UN Climate Change Conference. Warming above this level can lead to almost incalculable changes in the Earth's climate system. In order to reach the 2 °C goal, by 2050, worldwide emissions must fall by more than 50 percent from the 1990 levels. As the major polluters, the industrialised nations will have to undertake the greatest reduction efforts. To this end, the international community adopted a rulebook in Katowice in December 2018 which enables the implementation of the Paris Climate Agreement.

Germany's goal is to cut CO_2 emissions by 55 percent (from the 1990 levels) by 2030. By 2050, reductions of between 80 to 95 percent will be necessary, according to the European Union framework. The measures required to achieve this, such as promoting renewable energies, are intended to prevent the occurrence of catastrophic and irreversible changes to our climate system.

This also means, however, that everyone must play their part in order to reach this goal, for example, by driving a vehicle with low fuel consumption or refurbishing buildings to make them as energy-efficient as possible. After all, every German currently produces an average of 9.6 metric tons of carbon dioxide per year. For comparison: each American produces nearly 17 metric tons per year; in contrast, the average amount in India is 1.5 metric tons.

However, in addition to the measures to reduce greenhouse gas emissions, we must now prepare ourselves for the consequences of climate change. Just one example is the increased danger of flooding due to more frequent heavy rainfall events. On the other hand, the probability of lengthy dry spells will grow, resulting in a variety of negative effects, for instance on the regional water availability for public supply, water quality and waterway navigation, as well as on vegetation and, consequently, on agriculture and forestry. In urban areas, excessively hot days could result in health problems, particularly among the elderly. This is why adaptation strategies are already being developed today.

That climate change can also have some positive aspects is reflected in the prospect of extended growing seasons, with the corresponding beneficial effects for agriculture. However, farmers have to take into account that late frosts and stormy weather, for example, could cause significantly greater damage than in the past.

Climate change remains a challenge which everyone has to face and which will affect many areas of our lives. Bavaria's rivers and lakes will naturally also experience the negative effects of climate change. Timely implementation of adaptation measures will, however, help to master the challenges.

Flooding, such as here at Eining on the Danube in 2005, occurs time and time again. In all likelihood, there will be a clear shift in precipitation patterns as the climate changes. Climate modelling and hydrological modelling help assess as to what extent river flood volumes will be affected.

For further information

Brochure entitled 'Bayerische Klima-anpassungsstrategie 2016':

www.bestellen.bayern.de

Brochure entitled 'Klima-Report Bayern 2015':

www.bestellen.bayern.de

Brochure entitled 'Pilotstudie Niedrigwasser Naab und Sächsische Saale – Bericht aus der Kooperation KLIWA (Klimawandel und Auswirkungen auf die Wasserwirtschaft)':

www.bestellen.bayern.de

Bavarian energy atlas:

www.energieatlas.bayern.de

Dried-up lake-bed of Schloßweiher castle pond, Burgwalden

Drought year 2018 – climate change scenario?

2018 was the hottest year (as of January 2019) since records began in 1881, and the previous 10 dry months (February to November 2018) had been unique in terms of the absence of rain up to that point. Looking back over the last 50 years, 2018 was the fourth-driest year in North Bavaria and the sixth-driest in South Bavaria. Even if we know whether to attribute this drought to natural weather fluctuations, or to recognisable climate change, it changes nothing in its effects on the environment.

The watercourses showed low, and often very low, runoff over long periods in 2018, with the negative ecological and economic consequences. This is why, for example, boat trips were reduced, field irrigation was sharply increased, and the condition of our water resources deteriorated. Such periods, when water is scarce, temperatures are higher and oxygen reserves in watercourses are lower, cause physiological stress, particularly for species which prefer cooler climates.

The lakes in Bavaria also frequently exhibited low, sometimes very low, water levels. Dried-up shorelines spoiled the scenery and impeded riverbank activities. As reed beds were cut off from the water surface, lakeshores were rendered inaccessible, and therefore unable to fulfil their functions as habitats for plants and invertebrates and as spawning locations and refuges for juvenile fish. Unusually high and long solar radiation, lower inflows and higher temperatures in the lakes promote the growth of algae, which can lead to a lack of oxygen at greater water depths – a critical factor for aquatic organisms.

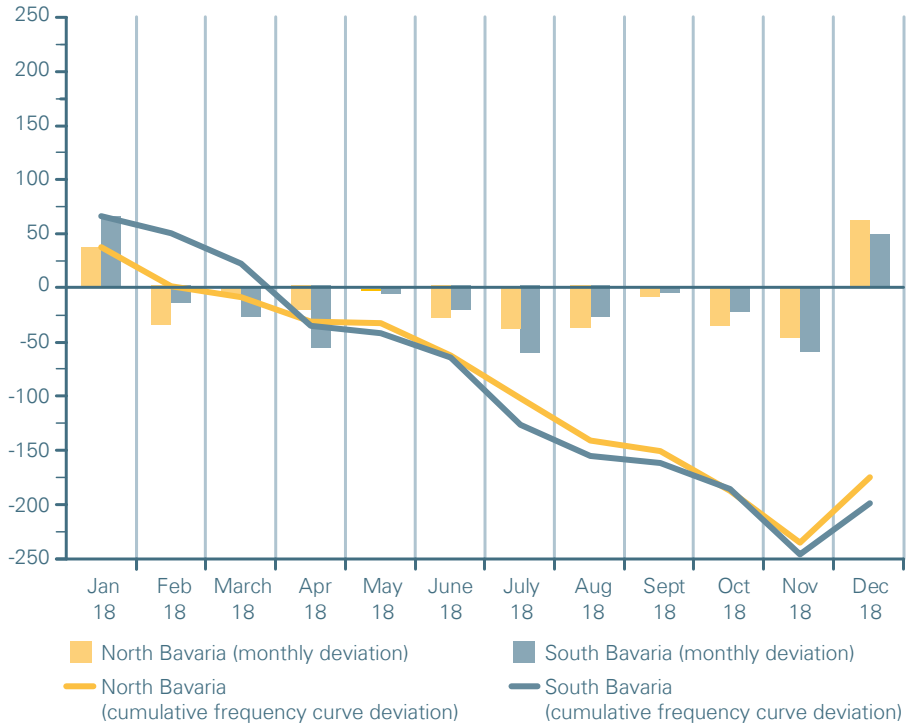
The groundwater levels near the surface fell in the 2018 drought year to low, or very low, levels and spring discharges were mostly significantly weaker. In numerous cases, record low levels were noted. Certain restrictions were imposed on water supply facilities, primarily those that were fed from springs.

In order to manage periods of drought, the Bavarian Water Management Administration develops strategies and measures to reduce the negative effects. One measure is the replenishment of water levels using the state-run reservoir. In 2018, a targeted release of storage water took place; 11 dams with a total operating capacity of 180 million cubic metres were used for this purpose. A further activity is the assessment of the groundwater availability and the management of the available groundwater resources.

Key data for 2018

- Average temperature for the year: 9.9 °C (mean 1971–2000: 7.8 °C)
- Hottest year in the 138-year record
- Annual precipitation: North Bavaria 624 mm (mean 1971–2000: 800 mm)
  South Bavaria 904 mm (mean 1971–2000: 1,107 mm)
- 12-month precipitation deficit: approx. 200 mm
- 10 consecutive too dry months
- 9 consecutive too warm months
- Extremely dry summer half-year: North Bavaria 279 mm (new minimum)
  South Bavaria 510 mm (only 1972 was drier)
- In the last 50 years, only the following years were drier (annual precipitation): 2003, 1972, 1971, 2015, 1976
- Fewer hot days than in 2003

Deviations from the average precipitation and emergence of the precipitation deficit between 1971 and 2000 (in mm).



The Förmitz Dam with dry river-banks in September 2018

Too warm and too cold months in Bavaria compared with the long-term average air temperature between 1971 and 2000 (deviations in °C).

Liebensteinspeicher flood control reservoir under pressure: 70 percent of the capacity was used to replenish low water levels in Tischenreut's River Waldnaab.

Precipitation –

rain, snow and sleet

When precipitation and water falls to the Earth's surface, it not only comes in the form of rain or snow. Sleet, hail, frost and dew are other forms water adopts when it falls from the atmosphere onto vegetation and the ground. This continuous replenishment supplies our groundwater, rivers and lakes. However, precipitation also poses certain dangers.

'Endless rain is pouring down, from the hills the springs are gushing, and the streams, the rivers are swelling.'

Friedrich von Schiller (German poet, 1759–1805)

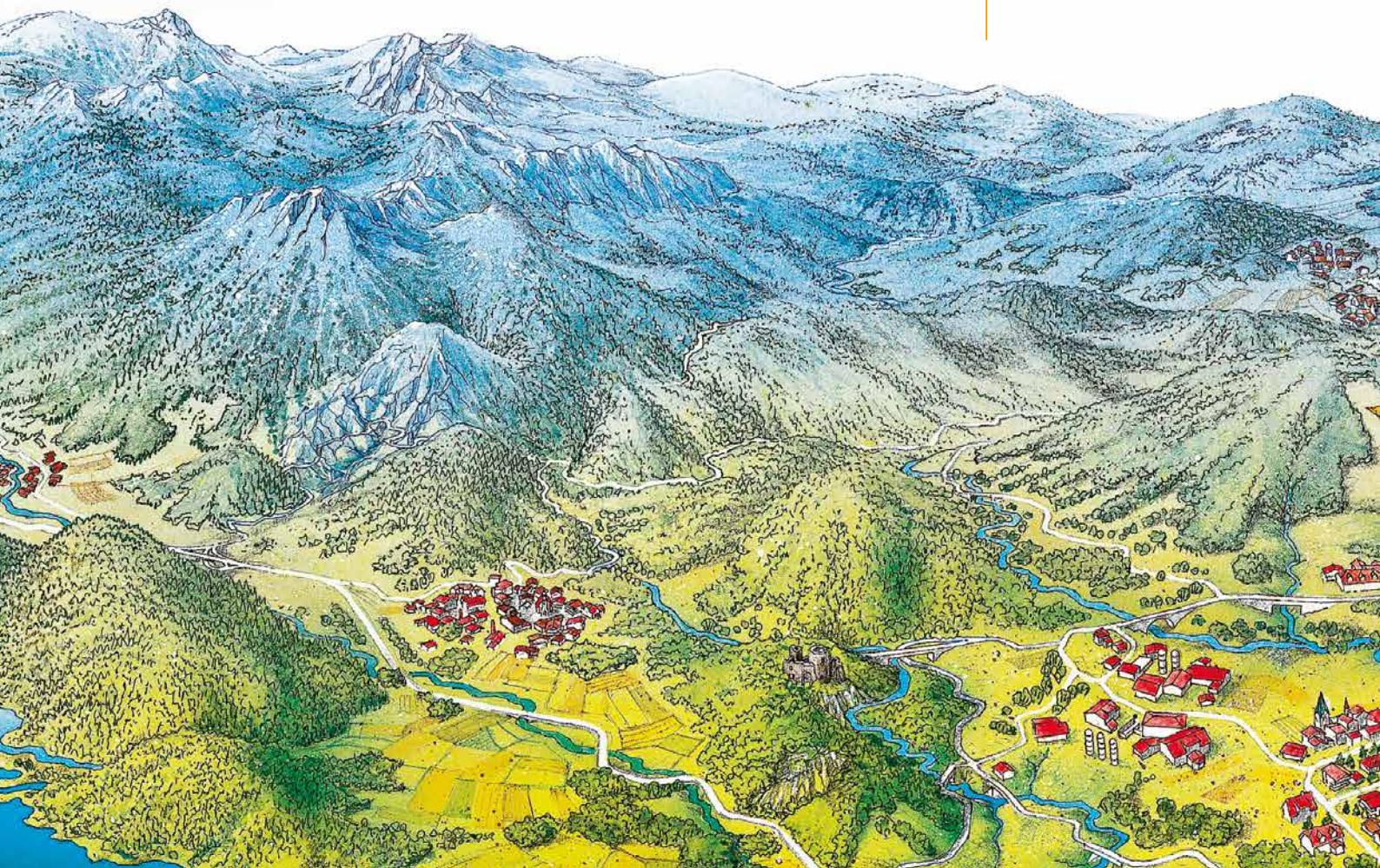
1 *Most precipitation falls in the south of Bavaria; over 2,000 millimetres can fall in the Alps per year, whereas parts of Northern Bavaria only experience 650 millimetres per year.*

2 *Mountain streams often display sharp fluctuations in runoff; even just a brief, heavy rain shower can lead to tumultuous flooding, and the torrent will often sweep large amounts of rubble and wood with it.*

3 *A healthy mountain forest retains water and holds snow masses back, providing protection against avalanches and mudslides. Sections of mountain forest that have been damaged are attended to, and trees are replanted.*

4 *Large quantities of snow in the mountains in winter lead to the threat of avalanches – the Bavarian Avalanche Warning Service (Lawinenwarndienst) measures, advises and issues warnings.*

5 *Particularly avalanche-prone slopes over inhabited areas and roads have to be secured with technical avalanche protection, i.e. defence structures.*



Replenishing the land of water

Precipitation usually occurs in liquid form – as rain or, if frozen, as snow.

Everyone is familiar with the fresh, clear air that comes after heavy summer rain, and most people look forward to a thick, white blanket of snow over the Christmas holiday season; and even though rainy autumn days are not everyone's cup of tea, precipitation is an essential part of the water cycle. It replenishes rivers and lakes, as well as the groundwater. Vegetation, in particular, depends on water from the atmosphere to flourish.

Depending on whether precipitation is fluid or frozen, the terms 'rain' and 'snow' are used respectively. There is another form of solid precipitation which, in contrast to the fine ice crystals of snowflakes, consists of compact clumps of ice. Chunks with a diameter of 0.5 centimetres and above are referred to as hailstones; small grains are called sleet. When water reaches the Earth's surface in a gaseous form and condenses there directly on surfaces such as leaves, it is referred to as dew. A variant of this is produced when the condensation freezes immediately as it settles; this is referred to as frost.

Rain purifies the air

Cloud water, naturally distilled during its ascent from the ground, is actually the purest water there is.

This changes, however, when it returns to the Earth's surface as precipitation, as, on its way back to Earth, it purifies the air of many airborne substances. Just one litre of rain can purify over 300,000 litres of air.

In the process, it also absorbs pollutants discharged into the atmosphere by humans. As a result of the burning of fossil fuels – such as coal, oil and natural gas – nitrogen oxides and carbon monoxide, as well as other pollutants, are added to the air. More than half of these are generated solely by the combustion engines of motor vehicles. These and other exhaust gases cause an enormous amount of air pollution.

However, there was a positive development in the 1980s with the desulphurisation of industrial exhaust gases. Sulphur dioxide concentrations in Germany have been significantly reduced since then thanks to the consistent application of this process. The acidification of soils and water bodies caused by so-called 'acid rain' is therefore no longer such a problem today.

Similarly, all other air pollutants must increasingly be stopped at source. If not, once they have entered the ground and the water via rain and snow, removing them is extremely difficult, if not impossible.

Rainwater is one of nature's greatest treasures. However, on its way to the ground, it also picks up air pollutants.

Bavaria, Land of Water

Quantity matters

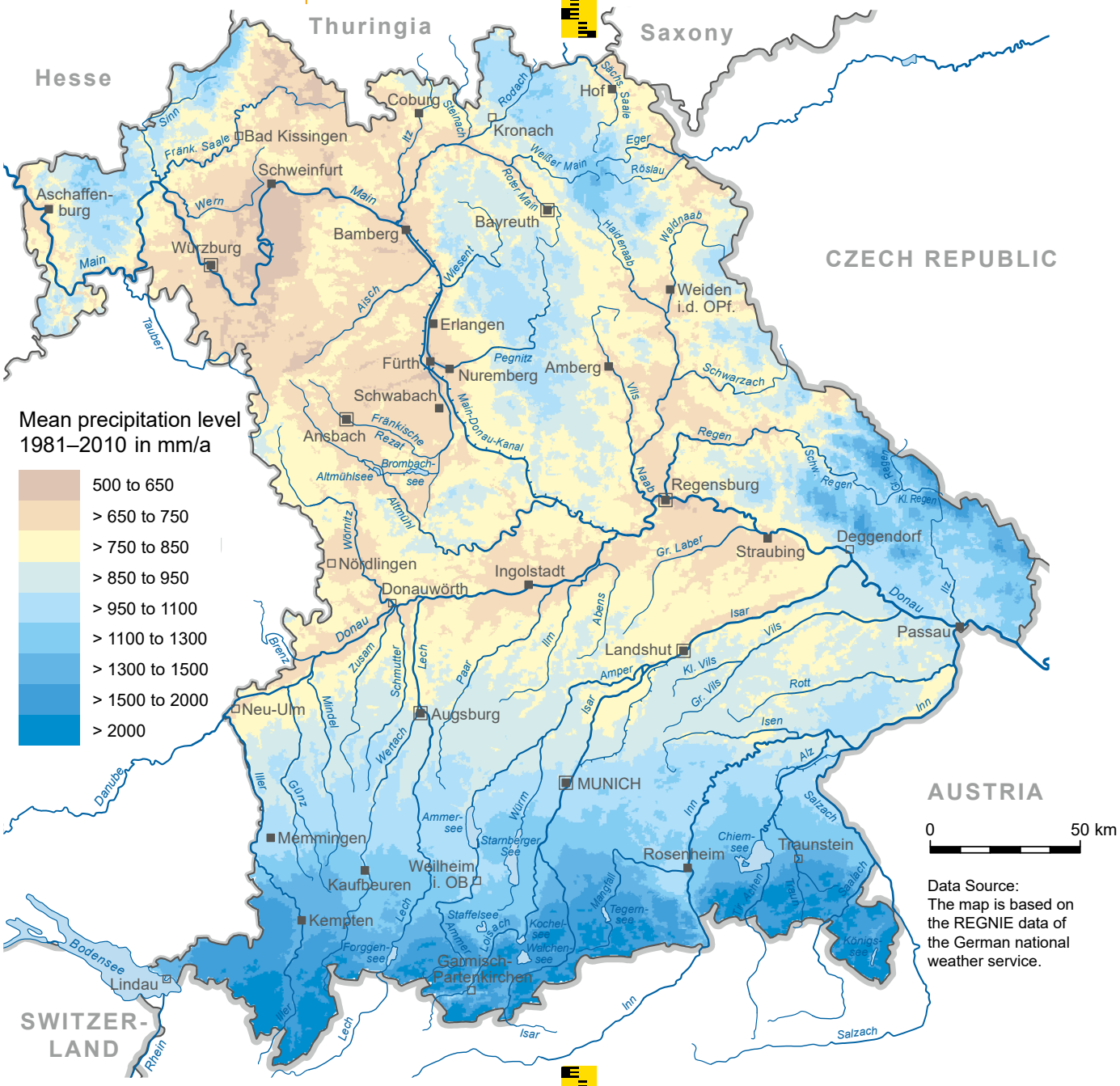
On average, 939 millimetres of precipitation falls in Bavaria every year. However, there are major regional differences in the precipitation amounts.

In particular, the regions south of the Danube experience – with an average of 1,110 millimetres per year – very high levels of precipitation, and therefore an abundance of water. In the Alps, the annual precipitation amount can rise to over 2,000 millimetres. There is another reason why water is so plentiful in southern Bavaria; in the Alpine foothills, the subterranean rock often consists of very water-permeable and porous gravel. There, large amounts of water can seep into and fill the aquifers.

By contrast, many areas of Franconia and the Upper Palatinate only receive an average 650 millimetres of precipitation per year. Furthermore, the subsurface strata there often consist of solid rock, such as granite, sandstone or Jurassic limestone. As a result, there is considerably less groundwater replenishment which, in turn, has a negative effect on the water balance. Under Würzburg, only approximately 125 millimetres is collected per year, whereas under Munich the amount is 315 millimetres. In addition to the regional differences between Northern Bavaria and Southern Bavaria, there are also fluctuations in the amounts of precipitation from year to year. In the especially wet year of 2002, 1,200 millimetres fell on Bavaria. This was followed by an extremely dry year, as 2003 saw only 690 millimetres of annual precipitation. Up to a certain point, such fluctuations are just part of the climate's natural variability, but they can have far-reaching consequences.

If there is no precipitation for a lengthy period of time, and if the dry spell is accompanied by a heat wave, low water levels and drought periods occur. Low water levels especially affect water quality, water supply, shipping, agriculture and electric power generation. The exceptionally dry years of 2003, 2015 and 2018, which brought widespread restrictions on water usage, gave an indication of the potential future effects and dangers.

Precipitation can lead to flooding. The difference between low and high water levels can be clearly recognised in these images of the River Rezat in Franconia (Lichtenau).



Data Source:
The map is based on the REGNIE data of the German national weather service.

Mean annual precipitation in Bavaria amounts to 962 mm. There is significantly less rain and snowfall in the north, than in the south, as can be seen on the map. This shows the mean annual precipitation from 1981 to 2010.

The precipitation amount varies so greatly in Bavaria according to region: In Franconia, there is just enough to get wet feet; by contrast, the water rises over the heads of Upper Bavarians.

Water on its way to the north

In order to ensure comparable living conditions, water management in Bavaria strives to maintain a balance between the drier north and the water-rich south.

Thus, in the early 1970s, the Bavarian state parliament adopted a resolution that initiated the construction of Germany's biggest state-run water engineering project: a system for diverting water from the Rivers Altmühl and Danube into the Regnitz-Main region. To this end, the water had to overcome the main European watershed. South of it, all the rivers flow towards the Black Sea; north of it, all the rivers flow towards the North Sea.

On average, the Rivers Regnitz and Main receive some 150 million cubic metres of additional water each year to increase their discharge volume. Two different routes are used to direct this water volume from the Danube region to the Main region.

Firstly, since 1994, an average 125 million cubic metres of water has been taken per year from the Danube and Altmühl rivers, pumped over the main watershed divide via the Main-Danube Canal and is intermediately stored in Lake Rothsee; from there, it is supplied as needed to the Main region. Secondly, since 1993, floodwaters of the River Altmühl have been retained in Lake Altmühlsee and diverted via the Altmühl Canal to the Großer Brombachsee reservoir. Since the full dam was built in 1999, the water has been released into the watercourses as needed (on average 25 million cubic metres per year). Lakes Altmühlsee and Brombachsee are connected by the Altmühl Canal, which passes beneath the main Donau/Main watershed as an undergroundwater gallery.

Today, the project's successes are clearly visible. Not only has the water management project improved the infrastructure for business in Northern Bavaria, but the water quality of the Regnitz and Main rivers has also stabilised due to the increased water volume and upgraded wastewater treatment plants.

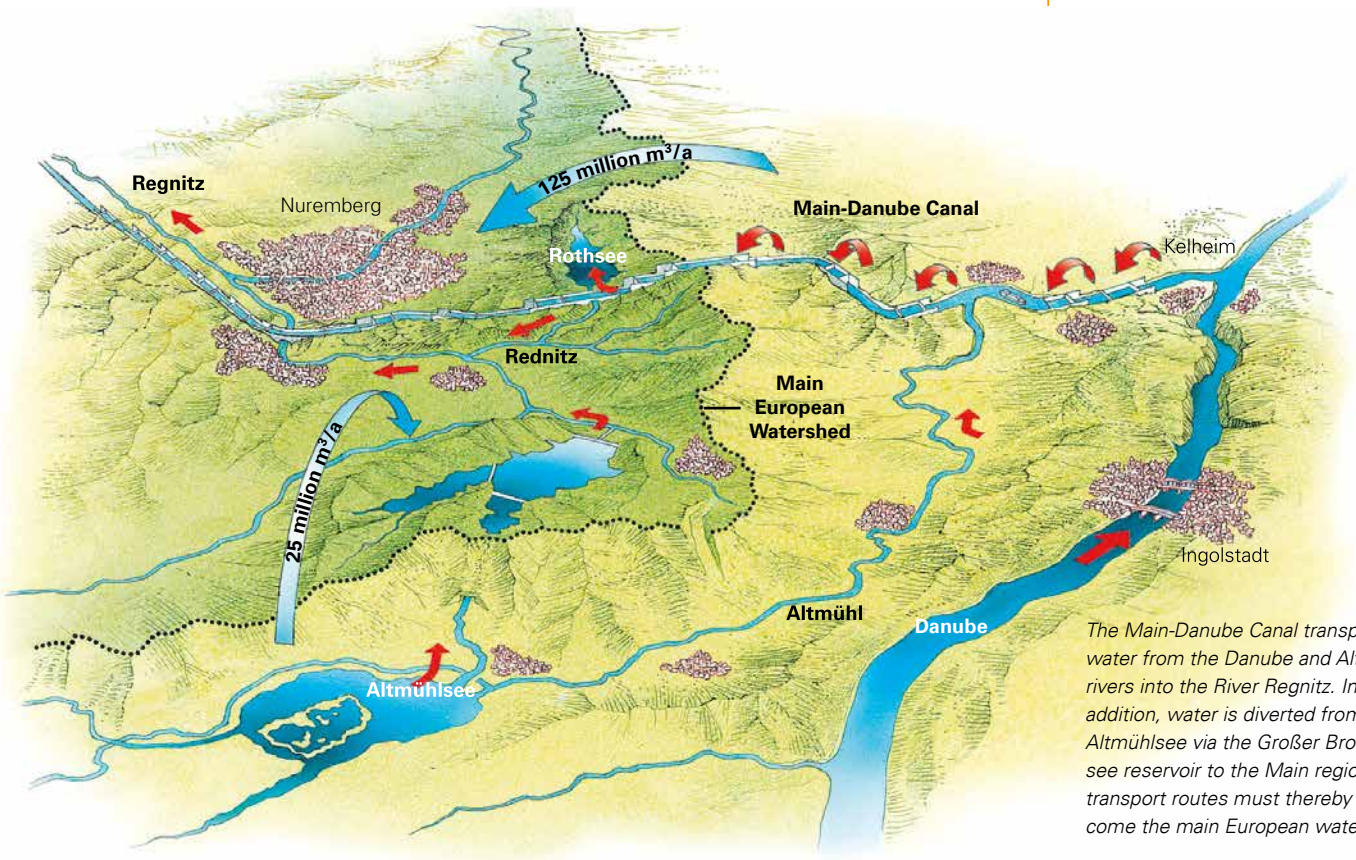
The significance of this water transfer for water management has been highlighted in recent summers. It contributed substantially to ensuring that the general water scarcity did not turn into an ecological crisis in the Northern Bavarian rivers.

In addition to the water management benefits of this construction project, the newly-created Franconian Lake District which resulted from the water transfer has become a very popular recreation area and tourist attraction, providing economic stimulus to the entire region.

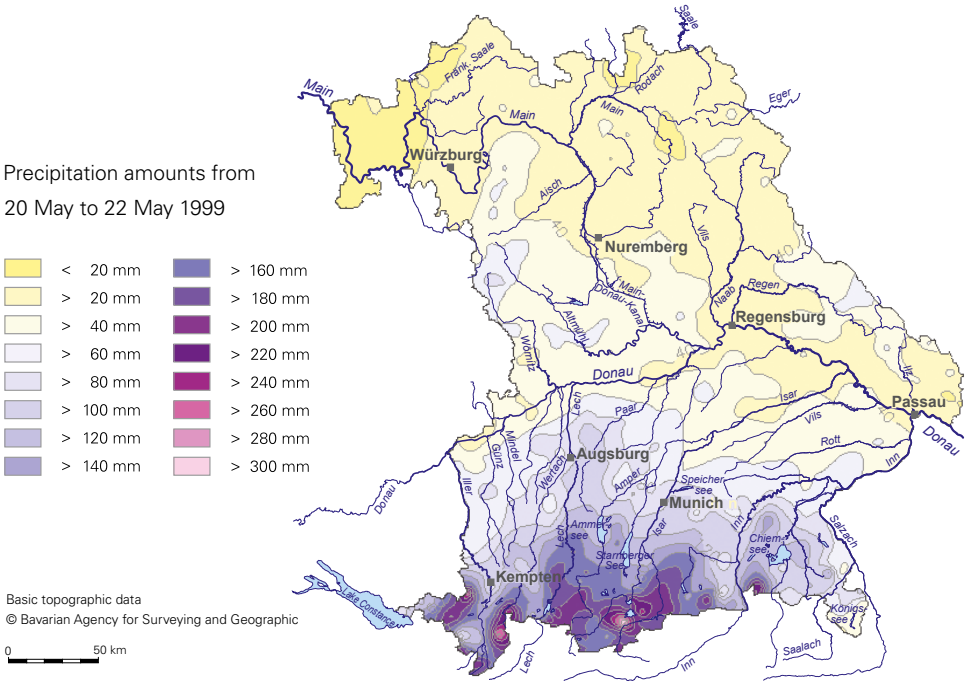
Ensuring a balance between the water-rich south and the drier north is one task of the water management authorities in Bavaria.

For further information

Franconian Lake District:
www.wwa-an.bayern.de > Überleitung Donau – Main > System > Fränkisches Seenland – Überleitung Donau-Main



The Main-Danube Canal transports water from the Danube and Altmühl rivers into the River Regnitz. In addition, water is diverted from Lake Altmühlsee via the Großer Brombachsee reservoir to the Main region. Both transport routes must thereby overcome the main European watershed.



If there is more than 300 millimetres of rain within 48 hours, the volume is equivalent to several months of normal precipitation. Severe rainstorms, such as these at Whitsun in 1999, led to extreme flood damage in the Werdenfelser Land region.

Floodwaters come from above

Ceaseless rain, extending over many days and many kilometres, or brief, intense thundershowers, can cause bodies of water to swell and thus lead to flooding. In the case of large rivers, continuous rainfall is usually responsible, whereas localised thundershowers cause flash flooding of streams with small catchment areas.

Exceptionally high daily precipitation occurs above all in Bavaria's mid-range mountains and in the Alps. With the appropriate weather conditions, the clouds remain in place and release their rain.

Melting snow in spring can also lead to flooding. The larger the winter snow masses and the faster they melt, the greater the volume of meltwater that runs off into rivers. You will find more information on the effects of precipitation on flood occurrence and on the necessary protective measures in the chapter entitled *Streams and Rivers*.

Letting rainwater seep in

Precipitation which naturally enters the ground enables the replenishment of groundwater. The more rainwater that infiltrates the ground or evaporates, the less rainwater flows into streams and rivers. This prevents floodwaters from rising to even higher levels.

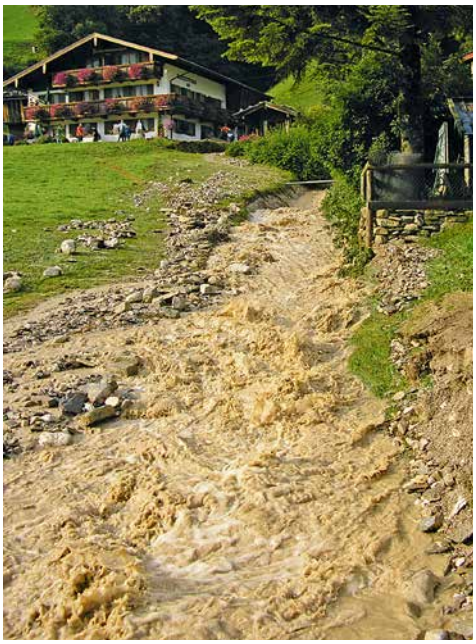
Rapid drainage of rainwater also impairs groundwater replenishment. The aim must therefore be to interfere as little as possible in the natural water balance, especially in new housing development areas, and to manage rainwater in a nature-orientated way.

In the future, efforts towards nature-oriented rainwater management will be further continued and intensified.

For further information

Brochure entitled 'Praxisratgeber für den Grundstückseigentümer. Regenwasserversickerung – Gestaltung von Wegen und Plätzen':
www.bestellen.bayern.de

Rainwater often runs off into the drainage system. It is desirable that as much uncontaminated water as possible is left to seep into the ground.



A small mountain stream, such as the Freidinggraben in the Berchtesgaden area, can swell and sweep rubble, wood and mud into the valley in a short time after heavy downpours.

Alpine nature hazards

Heavy rains in the Alps turn small mountain torrents into raging masses of water. In addition, landslides can occur on slopes and boulders come crashing down. Heavy snowfalls can, in turn, lead to avalanches. Over many centuries, mankind has learned to cope with the dangers that can be unleashed by the forces of nature, and to avoid the most risky areas.

In recent decades, however, the Alps have seen increasing development – of travel routes, housing developments and, last but not least, recreation and leisure facilities. With greater pressure for residential development, building activities have gradually extended into areas threatened by torrents, rockfall, mudflows or avalanches.

Accordingly, the risk of damage from Alpine natural hazards has risen significantly. The costs of protecting housing developments and Alpine travel routes as effectively as possible have risen correspondingly.

Where mountain rivers rush

When it rains heavily in the Alps and the mid-range mountains, very little water can seep into the ground due to the steep gradient of the mountain slopes and their frequently craggy substrate. Hence, most of the water runs off the surface. Consequently, within minutes, mountain streams can turn into torrents which sweep up everything that has accumulated along their banks, such as mud, rubble and entire tree trunks. Due to the potentially serious danger, the development and maintenance of mountain streams is a government duty.

High precipitation in the mountains also increases the danger of mudflows. The term ‘mudflow’ (more precisely ‘debris flow’) is used if water contains more than 30 percent solid material – especially coarse and fine debris, mud and wood – and surges downward at speeds of up to 50 kilometres per hour. These flows can cause devastating damage.

Mountains in motion

Rockfall, falling boulders, landslides and sinkholes are the natural consequences of the weathering of rocks. Especially in high and mid-mountain ranges, these are usually gradual, but sometimes very rapid, occurrences which reshape the landscape. They are often triggered by heavy precipitation, frost and weathering – and sometimes by humans.

Not only sudden, quick events, such as rockslides, entail risks; slowly unfolding ground movements can also be a frequent cause of damage to buildings, roads and supply lines.

Rapidly surging torrents and avalanches can become a grave danger to people living in the populated areas of the Alps.

For further information

Brochure entitled ‘Wildbachbericht Bayern‘:
www.bestellen.bayern.de

Geological risks, such as landslides on mountain slopes, can endanger residential areas.

It is not very pretty, but technical measures, like the mudslide barrier here on the Faltenbach stream near Oberstdorf in the Oberallgäu rural district, protect residents from the dangers of an alpine torrent.

'The white danger'

In winter, precipitation falls mostly as snow in the mountains. The avalanche threat quickly increases with very heavy snowfalls, snowdrifts, a sudden warming, or when rain falls on snow cover. Once snow is in motion, as a 'powdery avalanche', it can reach speeds of up to 300 km/h and, as a 'wet-snow avalanche', it can develop enormous destructive pressure.

The importance of a mountain forest

A healthy mountain forest provides a form of natural defence against avalanches, mudslides and rockslides. It also prevents soil erosion, stores precipitation, promotes the replenishment of groundwater and stabilises entire slopes. The situation becomes hazardous if an over-mature mountain forest dies off because rejuvenation is hindered by air pollution and wildlife browsing. High surface runoff, erosion and repeated landslides are the consequences – as well as an increased risk for local residents. This is why no effort is spared in regenerating mountain forests.

How can protection be achieved?

Wherever built-up areas are endangered and the protection offered by mountain forests is insufficient, additional measures must be taken. Technical measures, such as concrete barriers, massive stream and riverbank fortifications, and integrated protection concepts against dangers from torrents, are imperative. To counter the risks from avalanches and rockfalls, for example, devices to support the snow cover, protective nets or diversion dams are constructed.

In addition, supplementary measures – such as an early-warning system or plans for an effective disaster response – can help to reduce risk and damage. As a matter of principle, new construction activity in endangered areas should be avoided.

Yet, in spite of all the technical and planning efforts, it has to be recognised that there can never be 100 percent effective protection against natural hazards in the Alps.

An avalanche develops destructive forces. Touring and off-piste skiers are particularly in danger from avalanches, the more so because they often trigger them themselves. In addition, exposed transport routes, and occasionally also residential areas, are also threatened by avalanches.

Information and warnings

The section entitled Natural Dangers of the Bavarian Environmental Atlas (UmweltAtlas Bayern) and the Information Service for Flooding-Prone Areas offers information so that endangered areas can be kept clear of building activity or, in case of minor risk, appropriate protective building measures can be used. Instructive historical documentation of harmful events and information on known endangered areas that are susceptible to geological risks, avalanches and flooding are accessible online. These have been determined by analysing historical events and applying mathematically-based model calculations.

The warning services alert users to current hazardous situations as a basis for deciding on immediate action, such as evacuations. Due to the spontaneous nature of the occurrences, or the usually brief time frames in which such events occur, providing an immediate alert on geological risks and flooding for smaller mountain torrents is scarcely possible. However, up-to-date storm warnings and the Flood Information Service can provide reference points.

The current avalanche threat is derived from observations of weather and snow cover developments made over a period of time, which are assessed by the Bavarian Avalanche Warning Service. Since 1967, it has been warning local residents and tourists, especially ski mountaineers, of avalanche threats. In addition, it supports public authorities and private organisations that are responsible for security measures.

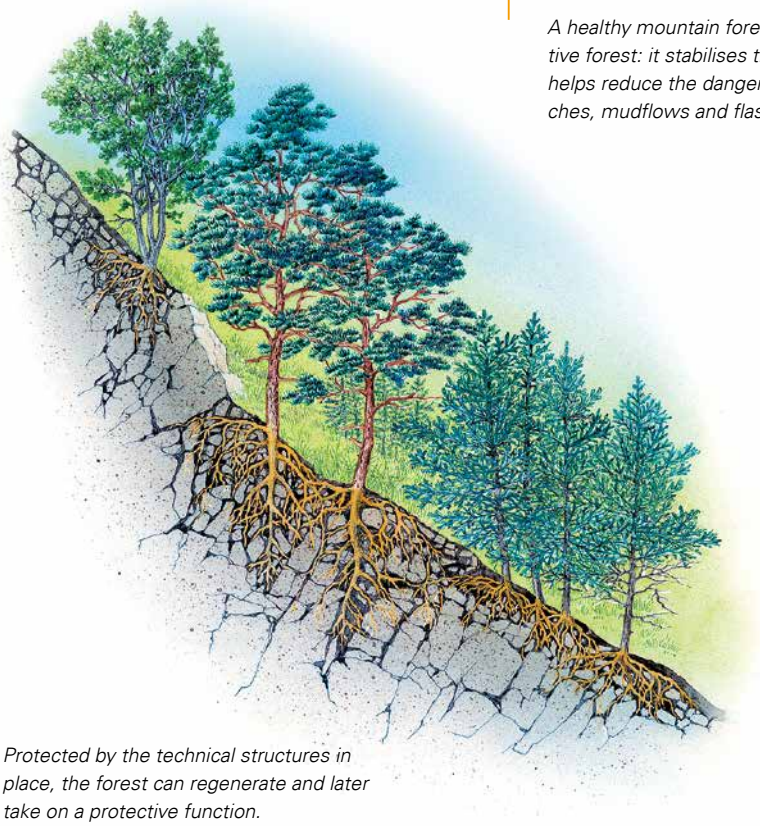
In winter months, the avalanche warning centre issues a daily status report.

The avalanche status report for the Bavarian Alpine region is available via:

Tel.:	+ 49 (0)89 9214-1510
Teletext:	BR3 – Tafel 646
Internet:	www.lawinenwarndienst.bayern.de
Email:	Newsletter after online registration
Social media:	https://www.facebook.com/lawinenwarndienst.bayern
Messenger:	Kanal@lawinenlagebayern on the Telegram messenger service (only during the winter months)

For further information

www.naturgefahren.bayern.de



A healthy mountain forest is a protective forest: it stabilises the slopes and helps reduce the danger of avalanches, mudflows and flash floods.

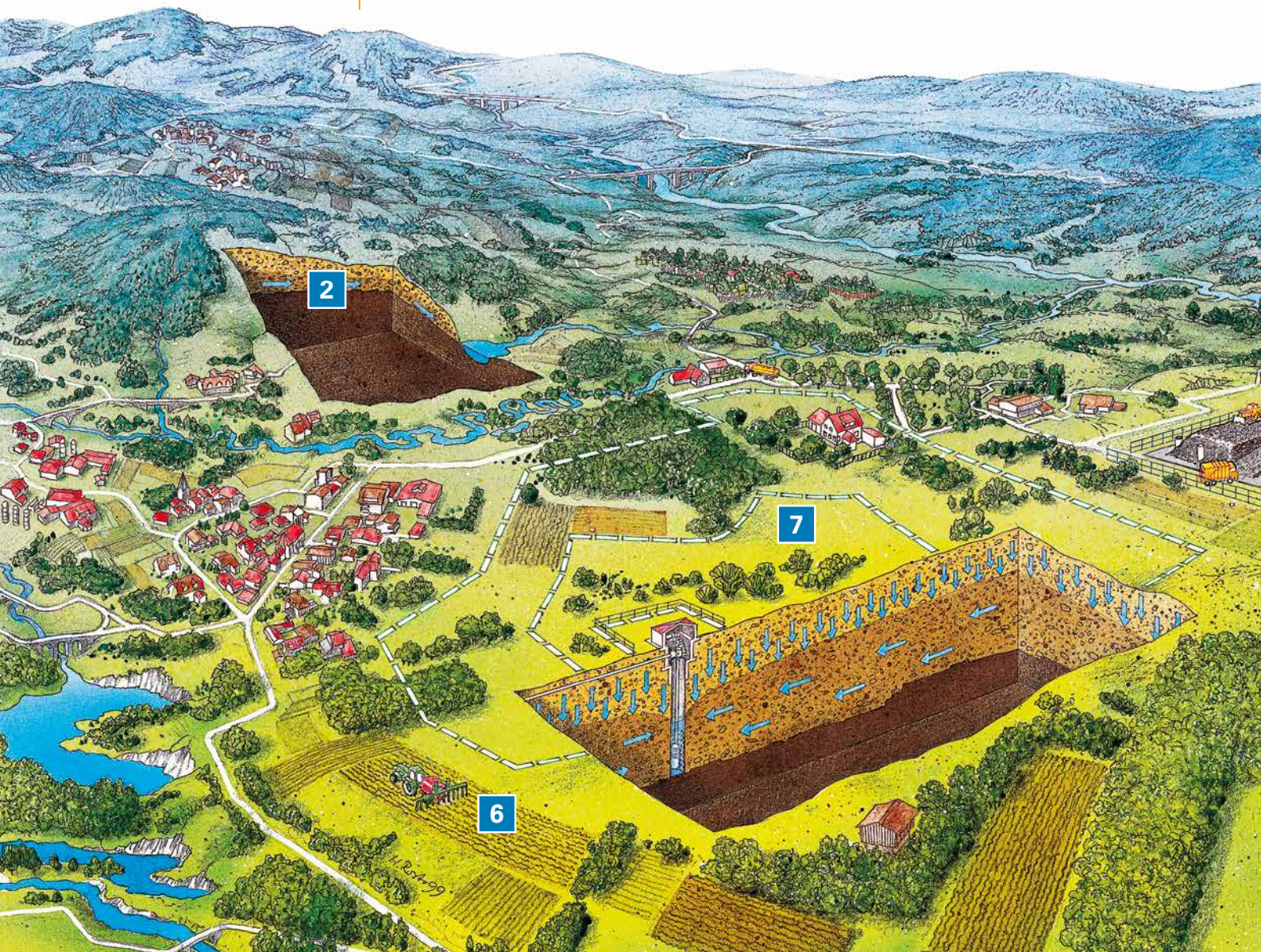
Protected by the technical structures in place, the forest can regenerate and later take on a protective function.

Groundwater –

the invisible treasure

Our most important and best drinking-water reserve, groundwater, is found in the rocky pores and fissures. The filtering effect of the soil and highly specialised micro-organisms purify it on its way from the Earth's surface to the subsurface strata. This self-purifying ability is limited, however, and it would be dangerous to act according to the old saying: 'Out of sight, out of mind'!

'Nature has laid down the death penalty for the pollution of groundwater.'
Max von Pettenkofer (pioneer of scientific hygiene, 1818–1901)



1 *In our moderate climatic zone, most groundwater comes from rain that has seeped into the ground.*

2 *Groundwater flows at several levels: often there are several aquifers – porous gravel deposits, for example – which are separated from each other by virtually impermeable layers of clay, for instance.*

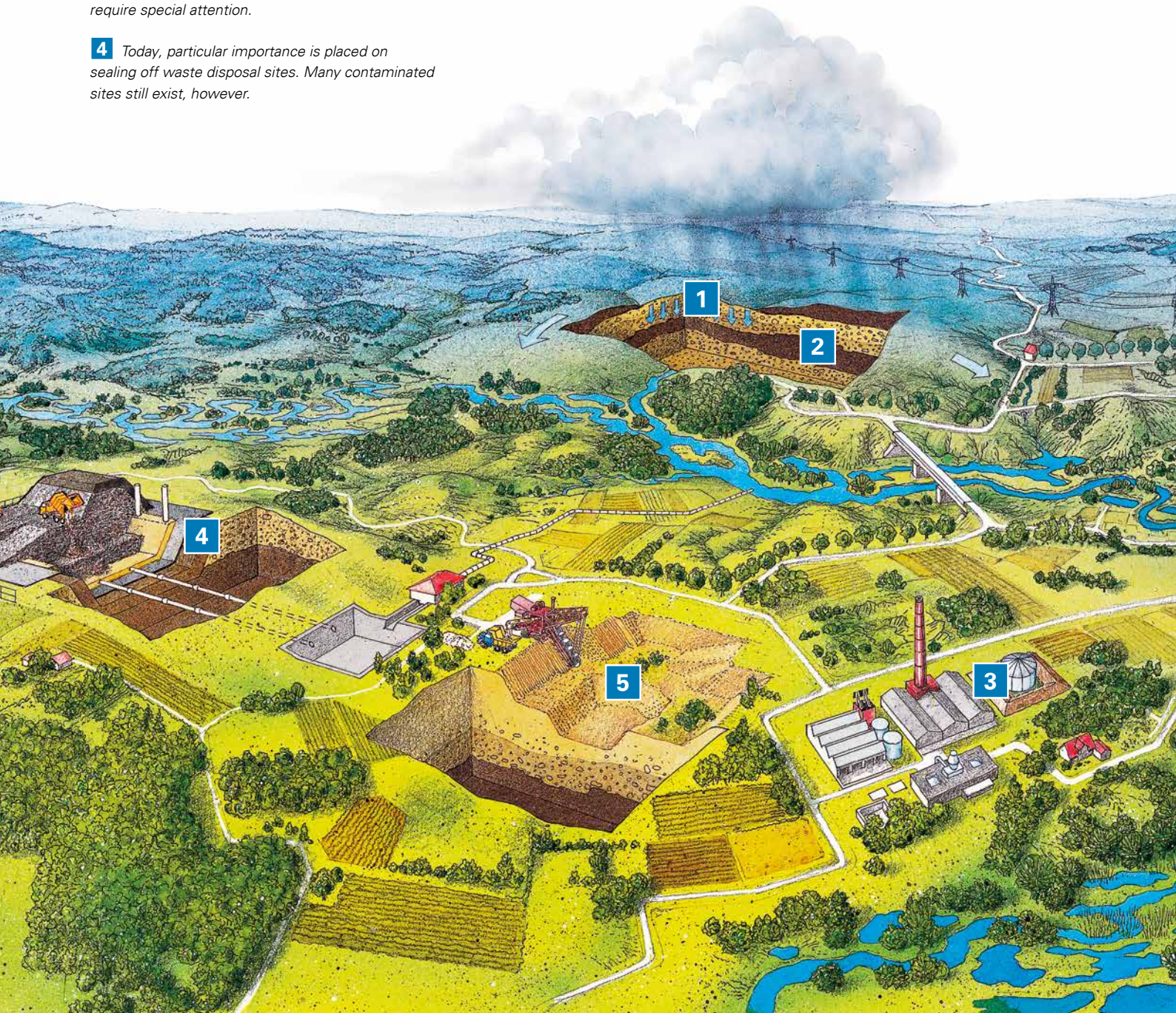
3 *Some substances that can be used in industry and commerce can endanger groundwater, and thus require special attention.*

4 *Today, particular importance is placed on sealing off waste disposal sites. Many contaminated sites still exist, however.*

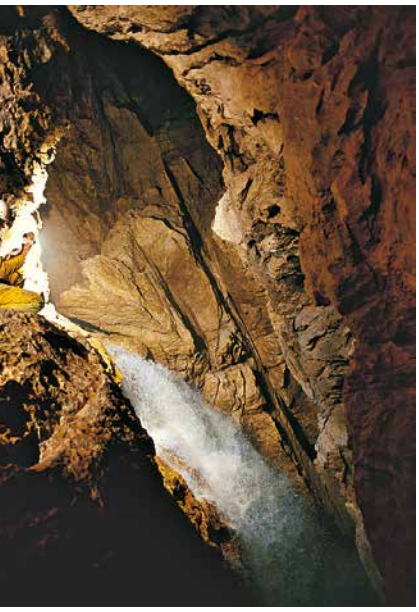
5 *During the mining of raw materials, the protective top layers are often removed and the groundwater table can be affected.*

6 *If used excessively, fertiliser and pesticides can endanger the purity of groundwater.*

7 *Water protection areas comprise three zones: the area immediately surrounding the well, the inner protected zone and the outer protected zone.*



Stored underground



Groundwater usually remains hidden from human view. It is visible only in some caves.

In the 17th century, Heaven and Earth were strictly separated – at least as far as water was concerned. Back then, it was unimaginable that seeping rain or thawing snow could become groundwater. Groundwater, and even springs and rivers, were believed to be fed by underground pathways flowing directly from the sea to the mainland. Seawater was supposed to be absorbed by the Earth, and its salt filtered out before travelling further to the Earth's surface.

We now know that just the opposite is true. After precipitation seeps into the ground, and is thereby filtered, it collects above less permeable layers of rock. There, it forms groundwater. It is continually renewed. It can also even flow down into far greater depths, where it can remain for thousands of years. After a certain flow time, sometimes longer, sometimes shorter, the groundwater re-emerges somewhere as a spring, or in streams, rivers or lakes. The streams and rivers, in turn, flow into the sea, from where the water evaporates and returns to land again in the form of clouds.

In our moderate climatic zone, not every raindrop seeps in. More than half of the precipitation already evaporates in the atmosphere. One-fifth of it flows on the Earth's surface into streams and rivers. A further fifth of the precipitation makes its way into Bavaria's underground aquifers and forms our groundwater.

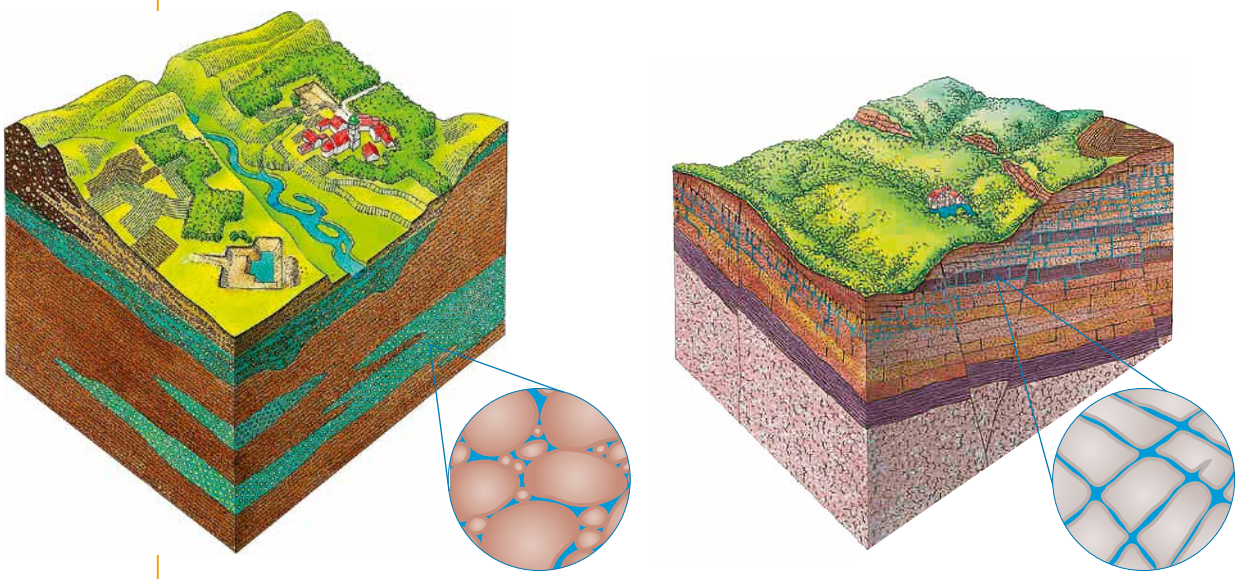
Through pores, fissures and caves

Groundwater flows unseen, in smaller or larger cavities, sometimes slower, sometimes faster. Although groundwater can be found everywhere, its amount and quality depend on the type and structure of the rocks in which it is retained.

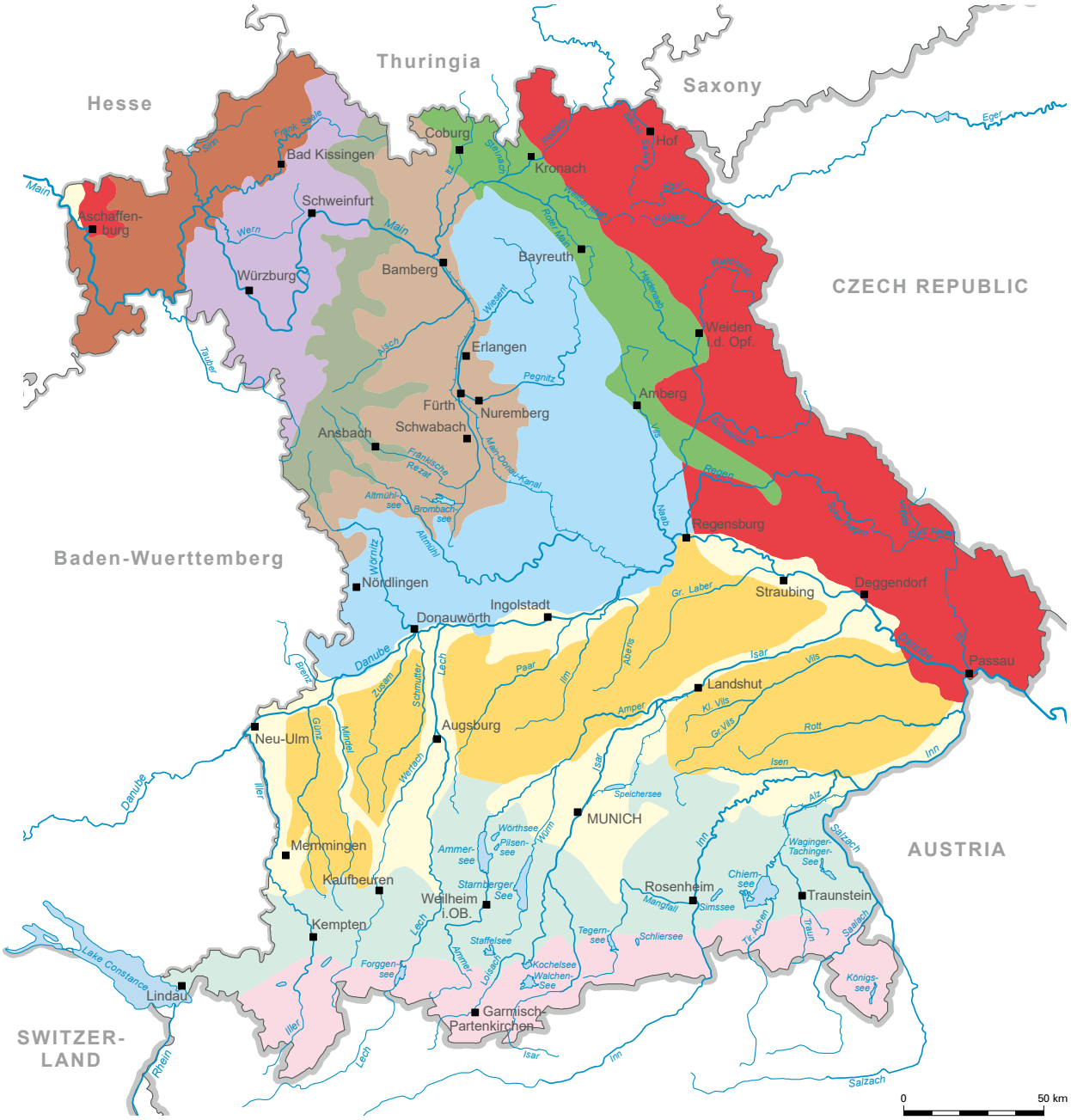
Groundwater that has collected in sand and gravel fills the cavities – usually fine and extremely fine pores – like in a sponge. This is frequently the case along the large rivers or the gravel plains in the Alpine foothill region.

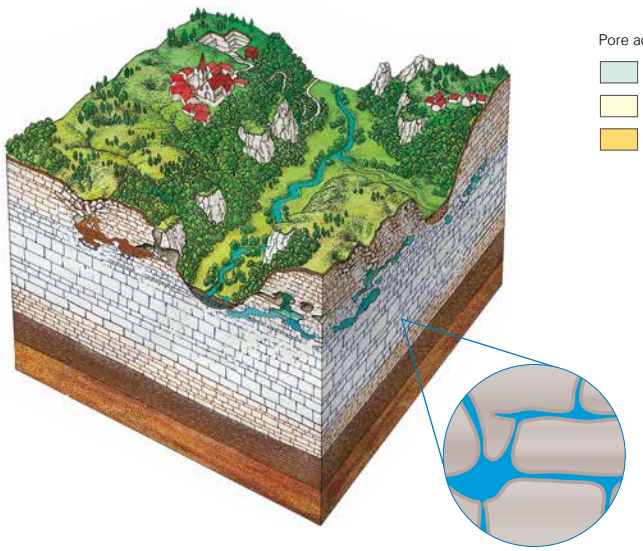
In contrast to this, the solid rock (sandstone or granite, for example) of the mid-range and high mountains serves as a so-called joint aquifer. The groundwater flows much more quickly here, in a three-dimensional network made of joints and fissures, than is the case in porous rock.

One special type of fissure are the karst cavities in limestone or gypsum, as found in the Swabian Alb or Franconian Alb. They originate when water is strongly enriched with carbon dioxide from the air and soil, and the carbonic acid that forms attacks the calcium-rich stone. Thus, over thousands to millions of years, subterranean water courses are created – from small gaps to enormous corridors, caverns and cave systems.



Groundwater can be stored in a wide variety of different rocks. There, it fills the pores in sand and gravel (pore aquifer; left), the fissures and fractures in solid rock (joint aquifer; centre), and the large cavities in karst rock (karst aquifer; right).





Pore aquifers
- Alpine foothills moraine belt
- Gravel plains and river valley fillings
- Tertiary hill country

Joint aquifers
- Lower Triassic sandstone in Spessart, Odenwald, Rhön
- Franconian Keuper gypsum
- Franconian Keuper sandstone
- East-Bavarian Triassic-Cretaceous landscape
- Basement

Karst aquifers
- Main-Franconian Muschelkalk
- Jurassic of Franconia and Swabia
- Alpine region

The geological map shows that Bavaria is made up of a variety of different rock types. The soil and underlying rock of a region also determines its water balance.

Forest areas provide good protection for groundwater.

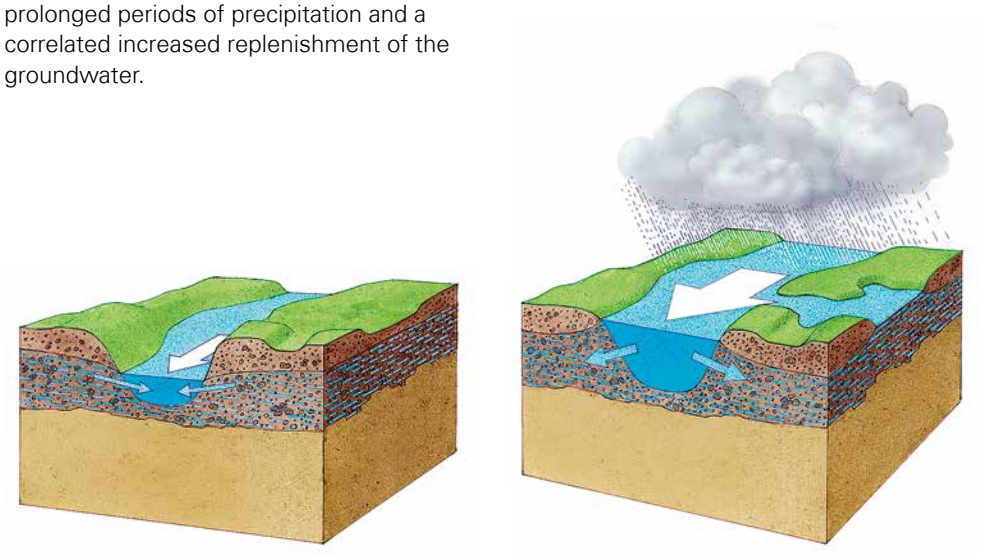
High groundwater levels

High groundwater levels (where the groundwater is three metres higher than the land) are widespread throughout Bavaria and occur at irregular intervals. In most of these cases, the causes are natural, such as the spread of near-surface aquifers, or prolonged periods of precipitation and a correlated increased replenishment of the groundwater.

When buying land or a house, you should definitely enquire about the groundwater situation underneath your property (builder's/client responsibility). You can find information from your municipality or the responsible Local State Water Management Office (WWA).

For further information

Current groundwater levels:
www.lfu.bayern.de > Wasser > Grundwasser > Messnetze/ Daten > Grundwasserstand



Illustration, left: Groundwater often flows towards the nearest streams and rivers. The groundwater table rises and falls with the water level of the rivers.

Illustration, right: During a flood, floodwaters also flow back into the groundwater. This does not only happen in the riverbed itself. In the flooded wetlands, the groundwater level also rises.

Groundwater – our biggest drinking-water reservoir

Bavaria's drinking-water comes from primarily beneath the earth: 90 percent of our most essential source of sustenance is obtained from groundwater, as we live in a region with an abundance of water. Altogether, some 15 billion cubic metres of groundwater are formed each year in Bavaria.

With the condition that the ecosystem must be preserved and financial costs kept at an acceptable level, an estimated 1.6 billion cubic metres could, theoretically, be extracted each year.

Presently, more than 800 million cubic metres of groundwater are extracted annually for drinking-water. This is the equivalent of half of the volume of Lake Chiemsee. In Bavaria, water is accessed through some 8,400 public wells and springs, as well as some 30,000 domestic wells. Not least due to this decentralised supply structure, groundwater must be protected throughout the entire state. 'Comprehensive groundwater protection' is therefore the crucial foundation for the water supply system. This pays off, because more than half of the required groundwater is so pure that it can be used as drinking-water without any further treatment. Most of the rest is treated using natural processes, due to technical reasons. Iron, manganese or carbon dioxide are removed, for example, because they can lead to corrosion in the supply pipes. A part of the obtained water is filtered and disinfected for preventative healthcare purposes.

Bavaria's high-quality drinking-water is the result of decades of careful water management by the state and the municipalities. Especially important are the intensive consultations between municipalities and the regional State Offices for Water Management.

In order to ensure the water supply for the long-term, Bavaria's water management administration has, since 1974, explored 127 significant groundwater reservoirs. In 78 areas, a precious water resource of around 166 million cubic metres per year is secured for the future.

A gratifying development against this backdrop: Since the 1990s, water consumption in Bavaria has dropped, despite a slight increase in population up until 2007 – since then, it has stagnated. Among other things, this is attributable to the average daily water consumption per person (households and small businesses) having been reduced from 144 litres in 1991, to just 129 litres today.

Industry also requires water, and it uses river water in addition to groundwater. In addition, water is increasingly being reused in the various production processes. Thanks to improved conservation technologies, industry's water consumption has, over the last 30 years, dropped to below one billion cubic metres per year, despite a growing economy. The proportion of withdrawals from groundwater has dropped to 253 million cubic metres per year. Moreover, the possibilities for further water savings have by no means been exhausted.

The drinking-water in Bavaria is obtained, for the most part, from groundwater.

Drinking-water is the most important source of sustenance. Nothing can replace it.

In the groundwater collection tunnels of Munich City Utilities (Stadtwerke München) in the Mangfall region, water flows in from the surrounding rock layers. It is then collected and directed to Munich.

What is drinking-water?

Water that is used as drinking-water should; under no circumstances; be detrimental to health, even if consumed over a lifetime. That is why it is the most closely monitored foodstuff, and is regularly tested in accordance with the German Drinking-Water Ordinance.

Drinking-water:

- Must meet at least the health requirements of the German Drinking-Water Ordinance
- It should be obtained as locally as possible, in order to maintain the immediate relationship between consumers and their drinking-water
- In Bavaria, it should be available as naturally pure as possible, without being treated
- Is primarily to be obtained from protected natural groundwater
- It should be made available under the supervision of responsible experts and at an affordable cost

Micro-organisms in the ground ensure that our groundwater is purified.

The invisible purification

The quality of the groundwater is decisively influenced by the chemical, physical and biological characteristics of the soil and rocks through which the water must flow. Micro-organisms perform valuable purification during this process.

In addition, the groundwater is mechanically filtered when it seeps through the rocks. The finer the rock pores, and the longer the underground route over which the water must flow, the more thoroughly the groundwater is filtered. Thus, by its nature, groundwater is better protected against human influence than the water in rivers, streams and lakes.

Purified on its way through the layers of rock, groundwater usually emerges at a spring in drinking-water quality.

Threats to groundwater

The purifying power of ground and rock has its limits, however. If these limits are exceeded because of severe contamination, pollutants can enter the groundwater.

Comprehensive prevention is therefore the best protection in order to preserve groundwater from contamination in the long run. This means that groundwater should be protected throughout Bavaria, regardless of whether or not drinking-water is actually obtained at a certain location. Where there is already groundwater pollution, extensive remediation measures are often necessary.

Local and diffuse sources of pollutants

Pollutants that contaminate water can have various origins. Usually these originate in residential areas, industrial and service trade sites, or waste disposal areas. These are referred to as point-sources of pollution.

Pollutants also enter the groundwater through intensive agricultural utilisation and the exhaust gases emitted by road traffic, industry and private households. As, unlike point-source pollution, the exact origin of pollutants that leach from the land surface cannot be exactly localised, these are referred to as diffuse sources of pollution. Consequently, the emitters should ensure that as few as possible of these substances end up in the environment.

Especially problematic are those substances which – because of their good solubility, poor degradability or greater mobility – can cause far-reaching and long-lasting contamination of the groundwater. Examples of this are the per- and polyfluorinated chemicals (PFC), dioxane and trifluoroacetate (TFA), which were previously released as additives in firefighting foams or in chemical production processes. 1.4-dioxane originates, inter alia, from the solvents used in, or deriving from, various production processes. In addition to industrial dischargers, wastewater treatment plants and agriculture, TFA input pathways into groundwater can also include atmospherically formed TFA from precipitation (after photochemical degradation of certain propellants and refrigerants).

Discharge of pollutants due to improper operation, careless handling and accidents

Many substances used in industry, service trades, agriculture and in private households endanger the water. Included among such substances are fuels and oils, varnish and solvents, detergents and cleaning agents, effluents from agricultural tanks, fermentation substrates from biogas plants and pesticides. There is potentially great danger from the improper operation and careless handling of these substances and accidents that occur as a result. A well-known example is tetrachloroethene ('Per') used in dry-cleaners, which has led to numerous cases of groundwater damage in the past.

A further ongoing issue is that of the many thousands of oil tanks – from large industrial tank depots, with individual tanks, which can hold up to 150,000 cubic metres, to the small residential tanks that are often not properly maintained. Particularly during filling operations and while being carried by road, accidents often occur in which oil ends up in the groundwater.

In many areas, it has been possible, by means of statutory requirements, to persuade the users of substances hazardous to water to reduce the amounts used, to switch to less hazardous substances, or to improve their preventative safety measures. Nevertheless, the remediation of contaminated sites will still take decades.

Pollutants from contaminated sites

Contaminated sites pose hazards for humans and the environment – in particular for the groundwater.

Today, there are 17,500 sites in the Bavarian contaminated site register that have either been proven to be contaminated or are suspected of it. There are some 5,700 former industrial and service trade sites, and roughly 10,600 old deposits, many of them former municipal waste dumps.

Contaminated sites which endanger drinking-water and the environment are prioritised for remediation under the supervision of the technical authorities.

Substances that contaminate the groundwater come from many sources, such as residential areas, industrial sites and agriculture.

For further information

Handling of substances hazardous to water in Bavaria:

www.lfu.bayern.de > Wasser > Grundwasser > Gefährdung und Schutz > Umgang mit wassergefährdenden Stoffen

Contaminated sites in Bavaria:

www.lfu.bayern.de > Altlasten > Altlasten und altlastenverdächtige Flächen > Altlastenkataster

Brochure entitled 'Alte Lasten – Neue Chancen':

www.bestellen.bayern.de

Per- and polyfluorinated chemicals – PFCs:

www.lfu.bayern.de > Analytik/Stoffe > Analytik organischer Stoff > Per- und polyfluorierte Chemikalien

Legacies of our society endanger groundwater and thus our drinking-water supply.

When groundwater is exposed during raw material extraction, it is subjected to possible contamination without protection.

Danger from the mining of raw materials

When raw materials, such as gravel, are mined, protective surface layers are partially or entirely removed, sometimes leaving the groundwater exposed. Both during the mining process and subsequently, this could have a negative impact on the groundwater, or at least significantly increase the threat to it.

The refilling of mining pits, quarries and open cast mines is only possible with uncontaminated, or mildly contaminated, material. Pits and open cuts are often left exposed so that biotopes can develop. In mines in which the groundwater is exposed, refilling is generally prohibited and should only be carried out in exceptional cases and with uncontaminated ground material. Since mineral resources are finite, and drinking-water supplies in many areas depend on groundwater reserves in water-storing rocks such as gravel, the recycling of building materials is a fundamental contribution to sustainable groundwater and drinking-water protection.

For further information

UmweltWissen leaflets entitled 'Oberflächennahe Geothermie and Erdwärme – die Energiequelle aus der Tiefe':

www.lfu.bayern.de > Bürger > Klima/Energie > Ökoenergien > Geothermie – oberflächennahe Geothermie

www.lfu.bayern.de > Bürger > Klima/Energie > Ökoenergien > Geothermie – Erdwärme aus der Tiefe

Could geothermal energy endanger the groundwater?

Geothermal energy is a regenerative energy source that takes advantage of the heat-storage capabilities of the water and ground to generate electricity and heat. This thermal usage of groundwater and substrata helps to reduce the use of fossil fuels, such as coal and oil, thus reducing CO_2 emissions. Domestic facilities utilise the heat of the surface layers of the Earth. The selection of the heat source (subterranean, groundwater) and the technology utilised (geothermal collector, geothermal probe, groundwater heat pump) depends on the local underground conditions, the requirements for groundwater and drinking-water protection, the space available and the needs of consumers.

Geothermal energy plants can pose a threat to the groundwater if poorly planned and executed, leading to pathways being created underground which could allow pollutants from the surface to enter the groundwater. It is also possible that the frequently-used glycol-based heat transfer medium could pollute the groundwater if there is a leak in the plant.

Geothermal energy from deep underground is particularly exploited in the Southern Bavaria region and is used for both the district heating supply and to generate electricity. A high level of technical expertise is required of the operators before setting up, and sustainably using, this heat potential.

Pollutants from the land and air

Today, bodies of water are decreasingly being polluted by clearly identifiable discharge sources. What is still problematic is the widespread impact stemming from agriculture, road traffic, residential areas and industry. The contaminants end up in bodies of water either directly, or through the atmosphere, with subsequent deposition on the bodies of water or the soil, thus entering the groundwater. It is often difficult, if not impossible, to identify the offending sources. This diffuse pollution, with its unforeseeable consequences, cannot be decontaminated with the technical means we have today. The discharge of pollutants must therefore be reduced or stopped at the emitting source, e.g. industry, agriculture and consumers.

Among other things, nitrogen compounds pose a problem in this context: nitrogen oxides from power-plants and in particular from motor vehicles, are emitted into the atmosphere. This is also the case with ammonia, which originates primarily from animal husbandry. In agriculture, large amounts of nitrogen are spread as fertiliser. Excess nitrogen not absorbed by the plants can be transformed by soil bacteria into nitrate, which is easily dissolved and transported by seepage water into the groundwater, thus causing pollution. In the human body, nitrate can be transformed to nitrite, which is especially harmful to babies. Nitrite also facilitates the formation of nitrosamines, which are suspected to have carcinogenic and mutagenic effects.

The long-range transport of substances released into the atmosphere can also have a negative impact on the ecosystem. For instance, emissions from coal-fired power-plants and volcanic eruptions can lead to excessively high levels of mercury in fish.

The discharge of sulphur dioxide from the air has declined greatly in recent years and is now no longer significant as a pollutant. However, those forests of Bavaria's Fichtelgebirge, Spessart and Bavarian Forest, still suffer today from the severe damage incurred by 'acid rain' in past decades. The soil, streams, rivers and the groundwater there are still very acidic, making life difficult for fish and micro-organisms.

Diffusely distributed pollutants from agriculture, road traffic, residential areas and industry can lead to widespread contamination.

Agriculture cannot do without fertiliser. The key is to use the right quantity at the right time.

The groundwater needs our protection

Groundwater is given precautionary and comprehensive protection in Bavaria.

If you pass this sign, you are in a water protection area. Any accidents could have severe consequences for the groundwater.

Ensuring the supply of pure drinking-water – today and in the future – is one of the most important goals of a sustainable water management policy.

The comprehensive, preventative protection of the groundwater is therefore anchored in various laws and regulations, essentially stipulating that areas used for agriculture and other purposes must not cause any damage to the groundwater. The public water supply has priority over all other uses.

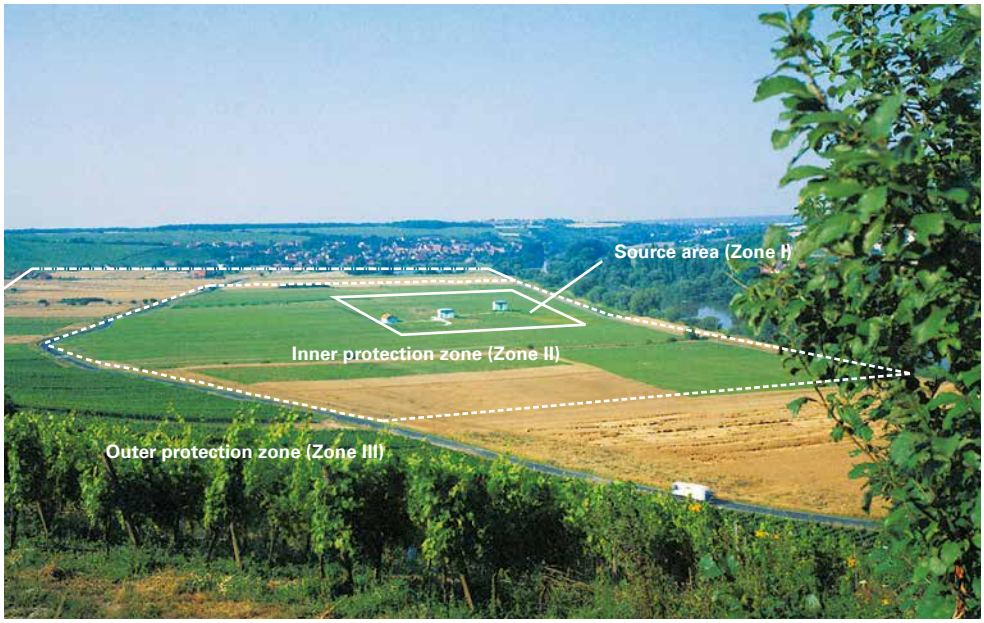
Drinking-water catchment areas, and all the facilities involved in obtaining and providing water are, in addition to comprehensive groundwater protection, especially protected. The most important regulatory mandatory instrument is that which classifies water protection areas as so-called highly vulnerable and close proximity areas. Additionally, zoning conflicts can be prevented if priority or reserved areas are designated in regional planning. The fundamental basis for this is determining the catchment areas and their sensitive parts, and making them known.

Protective zones for drinking-water.

Water protection areas consist of three protected zones which encompass the wells:

- Zone I – the source area – protects the spring/groundwater extraction system and its immediate vicinity from contamination; entry into the zone is prohibited.
- Zone II – the inner protection zone – extends from Zone I up to a line from where the groundwater takes about 50 days to reach the collection facility. In this time period, health-threatening micro-organisms are removed. A ban on organic fertiliser protects against pathogens from mixed manure, liquid manure or dung from entering into the groundwater. Construction, earthmoving or drainage ditches are also prohibited here.
- Zone III – the outer protection zone – protects the groundwater against extensive impairment, especially from chemical substances with little or no degradability. The handling of substances hazardous to water is restricted to a minimum.

Currently, water protection areas make up 4.9 percent of the state's ground area. This proportion, relatively low in comparison to the rest of Germany, is only acceptable if the 'precautionary, comprehensive protection of the groundwater' is consistently implemented in the remaining parts of the catchment areas.



The three zones of a water protection area encompass the area from which drinking-water is extracted. Different protective measures and regulations apply within their boundaries.

Sustainably protecting groundwater

The EC Water Framework Directive (WFD), which took effect in 2000, as well as the Groundwater Directive (GWD) adopted in 2007, have the main long-term objectives to protect groundwater from danger or – in the event of existing contamination – to restore it to a good status, and to ensure preservation of this. Various criteria must be fulfilled for this 'good condition'. For example, specified threshold values for certain groundwater pollutants may not be exceeded. In addition, the amount of extracted groundwater may not exceed the rate at which groundwater is replenished. To assess the status, the quality and quantity of extracted amounts of the groundwater are monitored.

What can agriculture do?

Plants need nutrients, such as nitrogen, phosphorous and potassium compounds. Nitrate in particular is washed out of the soil and ends up in the groundwater. This cannot be entirely prevented, but agriculture can, of course, greatly influence the scope of the contamination by correctly applying fertiliser.

Less is good – even less is better still

Although it has been possible to reduce contamination of the groundwater with nitrate and pesticides to some extent since the peak at the end of the 1980s, the levels are currently stagnating.

The substance discharge can be reduced,

- if all farmers tend to their fields in accordance with so-called 'good agricultural practice', which includes fertilising at the right time, with the right amount, and using the right method
- if the use of pesticides is cut to the absolute minimum necessary level.

Collaboration between farmers and water suppliers, more intense consultation, promotion of ecologically orientated agriculture and measures taken to implement the EC Water Framework Directive can contribute to reducing contamination of the groundwater.

Organic farming protects water

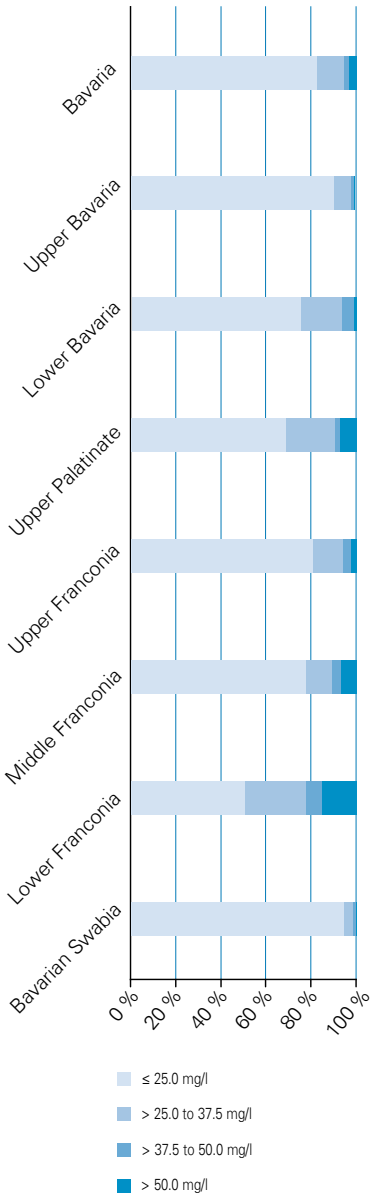
Ecologically orientated farmers abstain from using chemical pesticides and mineral-based nitrogen fertilisers. Furthermore, only livestock quantity that is adapted to suit the operating area is permitted. Thus, compared with conventional farms, they produce far less excess soil nutrients. Studies on nitrogen leaching confirm that the groundwater is less contaminated with nitrate when organic farming methods are used.

Organic farming is carried out in accordance with specific rules. Since 1991, an EU directive has governed the production, labelling and monitoring of organic food. Some agricultural organisations for organic foods have even stricter rules. In 2017, approximately 1.37 million hectares were cultivated by 29,395 farms in Germany in accordance with EU regulations. This corresponds to roughly 8.2 percent of the agricultural land in use. In Bavaria, around 10.5 percent was cultivated organically over the same time period.

Meanwhile, an increasing number of waterworks have recognised the advantages of ecologically orientated farming for water pollution control. For instance, the Munich and Augsburg municipal water utilities promote the transition to this form of agriculture in their water protection areas.

Each one of us can also make his or her own contribution to protecting everybody's water by buying organic food.

After all, anyone who buys organic food from local sources is also helping to protect the water, because ecologically orientated agriculture protects groundwater through low-pollution cultivation.



Nitrate in raw water – the groundwater extracted for the drinking-water supply. The graph shows the regional distribution of nitrate contamination in 2017. In the water-rich south, contamination is significantly lower, than in the drier north. The percentages relate to the extracted amounts of water.

For further information

Report entitled 'Entwicklung der PSM-Belastung in bayerischen Gewässern – Bilanz nach 30 Jahren PSM-Monitoring und Ausblick':

www.bestellen.bayern.de

Nitrate

Nitrate is primarily leached in winter, when the plants are not consuming it and a particularly large quantity of precipitation seeps away. Between 80 to 90 percent of the nitrate in groundwater comes from agriculture. The EC Water Framework Directive (WFD) and Groundwater Directive (GWD) placed special emphasis on protecting groundwater from nitrate contamination in the river basin management plans and action programmes which were published at the end of 2009 and/or at the end of 2015. Fertilisation should be carried out in such a manner that the nitrates contained in the soil before winter are used up as much as possible.

Mineral fertiliser consumption has dropped since the 1980s and is currently around 100 kilos of nitrogen per agricultural hectare per year. Nevertheless, the levels of nitrates in the groundwater are still too high, which is reflected in the 2015 chemical condition analysis of the bodies of water, in accordance with the Water Framework Directive.

The highest nitrate contamination level is still found in Lower Franconia, which receives low precipitation. This leads to problems in the drinking-water supply in particular: the threshold value of the German Drinking-Water Ordinance only permits a maximum of 50 milligrams of nitrate per litre. In Bavaria, this value is exceeded in approximately 3 percent of the groundwater obtained for drinking-water purposes. At facilities with nitrate-contaminated raw water, the water supplier must ensure that the drinking-water supplied to consumers does not exceed the threshold limit for nitrates – it does this by mixing water from various water extraction plants, or by means of complex treatment processes. In addition, measures must be taken in the affected water catchment areas to ensure that nitrate levels in the groundwater fall again.

Pesticides – a big problem, even in small quantities

Groundwater condition is also assessed for pesticides in accordance with the WFD and GWD standards. In 2017, a total of 818 pesticides (1,581 trade names) with 277 different active ingredients were approved for use in Germany. Residues and degradation products from the pesticides' active ingredients are also found in the groundwater.

In nearly one-third of the 480 groundwater measurement points examined within the scope of the WFD in 2017/2018, the presence of the pesticides' active ingredients, or their degradation products, were established. In about 8 percent of these, concentrations of over 0.1 micro-grammes per litre – the threshold limit of the German Groundwater Ordinance – were found. Most of the proven pesticides with concentrations above this threshold have not been in use for many years (e.g. Atrazine). This shows that groundwater has a 'long memory' for pollutants.

Aquifers covered by shallow and highly permeable soils, such as the fissured karst of the Swabian and Franconian Alb regions, are particularly endangered due to the poor purifying effect of the soil.

Prevention is the best protection

Once the groundwater is contaminated, the consequences for humans and nature are hardly calculable. A restoration, i.e. the removal of the pollutants from the groundwater is only possible, if at all, at enormous expense. Bavaria's water management administration therefore actively undertakes a series of preventative measures, such as:

- Continuous checks of the groundwater at 620 measurement points, as well as at the wells and sources of the water suppliers.
- Measurement of the groundwater levels at around 2,000 measurement points, in order to monitor the water resources.
- Special multiple safety systems for facilities to handle and monitor substances hazardous to water.
- Focused surface area management within the scope of regional and building planning. Area usage is managed so as to ensure that there are as few conflicts as possible.
- Preservation of the protective surface layers of the ground.
- Preservation of the soil as a rainwater reservoir.
- Connecting as many properties as possible to the wastewater treatment plants.
- Protection of the groundwater from alien, slowly degrading and toxic substances.
- Advising the water suppliers.
- Collaboration with agriculture to reduce the contamination of groundwater by fertilisers and pesticides.
- Informing the general public so that everyone can treat 'their' groundwater responsibly.

Only if groundwater is less contaminated in the future, can we preserve our most important and precious source of sustenance for the future.

At groundwater measurement points, water resources are continually monitored and the composition of the groundwater is tested.

From groundwater to the tap

Our drinking-water has travelled a hidden path before it runs from our taps. Raw water is drawn from wells, springs or drinking-water reservoirs – usually far away from the city – and, if necessary, treated. The drinking-water is stored in elevated reservoirs before passing through pipes and plumbing fittings and ultimately arriving in individual households.

From deep wells and fresh springs

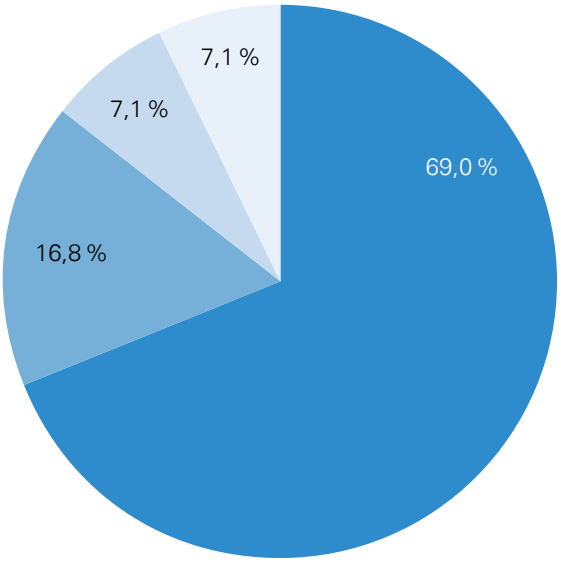
Most of our drinking-water comes from over 4,300 wells. They vary in depth from a few metres to more than 100 metres. They are carefully monitored by examining the technical equipment, by means of microbiological and chemical-physical analyses of the groundwater, and by checking the water levels.

If water seeping in the soil flows on an impermeable rock layer to a slope, it reaches the surface as a spring. Even today, springs provide – with almost 17 percent of the water volume obtained in Bavaria – a large part of the drinking-water supply.

Usually, groundwater is relatively 'young', i.e. it has only spent a few months or years underground. At some locations in Bavaria though, water that is 1,000 or even 5,000 years old is being pumped to provide drinking-water. This should remain an exception, however, in order to conserve the sensitive deeper groundwater.

The water derived from springs and wells is protected by water protection areas that are regularly monitored by water suppliers in order to safeguard against local contamination. In many areas, the quality and volume of the groundwater is even tested in the wider surroundings of the facilities. The water supplier can then react promptly to any changes, before the water reaches the facilities.

Natural springs, such as here by the Blaue Gumpe on the southern shore of the Großer Ostersee lake, are places where groundwater rises to the surface.



Water extraction by water source, measured in terms of water volume. The majority of Bavaria's drinking-water supplied to the public comes from groundwater and spring water.

- Groundwater from wells: 69 % (630.4 million m³)
- Groundwater from springs: 16.8 % (153.3 million m³)
- Bank filtrate and enriched groundwater: 7.1 % (64.7 million m³)
- Surface water: 7.1 % (64.6 million m³)

(Water catchment 2016: 913.1 million m³ = 100 %)

Data source: Bavarian Environmental Statistics (Umweltstatistik Bayern) 2016

From surface water and bank filtrate

Not everywhere in Bavaria is there sufficient groundwater and spring water available for the water supply. Thus, drinking-water reservoirs have been built in parts of Upper Franconia and in the Bavarian Forest to ensure adequate provision to the water supply system. The city of Lindau obtains its water from Lake Constance. In some regions, people resort to bank filtrate. Near rivers or lakes, water is extracted, some of which seeps to the well from the bodies of water through the subsoil. The quality of the shore filtrate depends on the purification capacity of the subsoil and the nature of the rivers and lakes. Contamination from the discharge of fertilisers and pollutants must be prevented if at all possible, and the quality must be regularly monitored.

In Bavaria, groundwater from wells and springs makes up most of the drinking-water supplied to the public. Only about 14 percent is obtained from surface waters or from shore filtrate and enriched groundwater (river or lake water deliberately seeped near a well).

Distant water supply systems ensure that residents of all of Bavaria's regions are equally and dependably supplied with drinking-water.

Groundwater from well-protected wells supplies most of the drinking-water in Bavaria.

Distant water supply systems ensure that residents of all of Bavaria's regions are equally and dependably supplied with drinking-water.

From a distance

Some regions in Bavaria, particularly Northern and Eastern Bavaria, are considered groundwater shortage areas due to their prevailing climatic or hydrological conditions. In order to cover local requirements for drinking-water, distant water supply systems have been built. Drinking-water, which is obtained in water-rich areas, is transported via pipelines to the areas lacking in water. The Northern Bavarian balancing and grid system, a pipeline grid consisting of six Franconian and Swabian distant water supply companies, compensates for Franconia's deficit with drinking-water from the Danube region.

Our drinking-water is stored in elevated tanks, such as the drinking-water elevated tank at Am Steinbuckel. From there, it is fed into the water supply system.

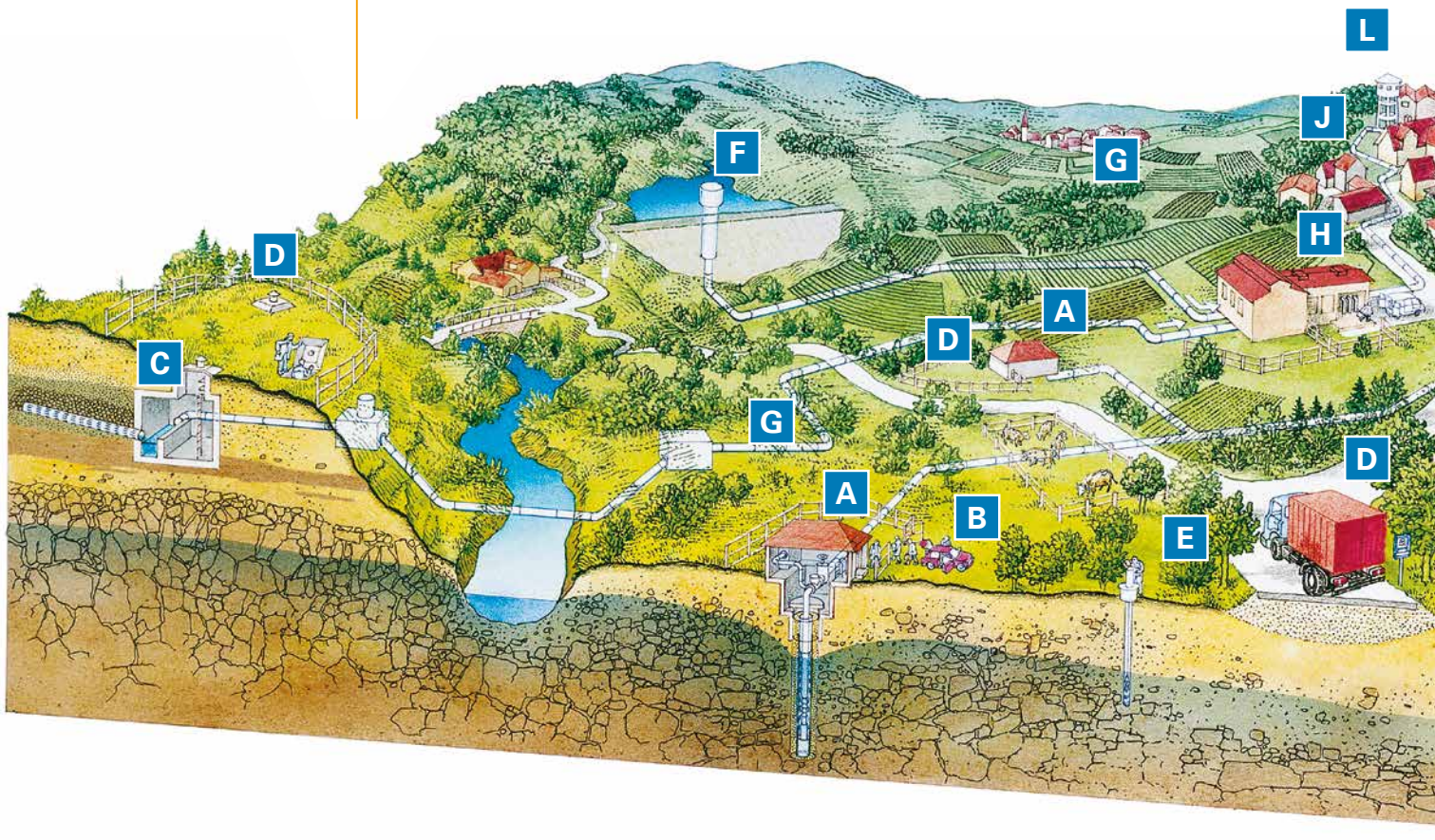
From raw water to drinking-water

The water obtained from springs and wells, referred to as raw water, is pumped to the waterworks. The raw water is often pure enough to be distributed directly to the consumers as drinking-water. Thanks to the natural filtration underground, and the protection provided by the water protection areas, this water fulfils the strict requirements of the German Drinking-Water Ordinance without any additional treatment.

While travelling through the soil layers, the groundwater absorbs minerals. Large amounts of certain substances are undesirable in drinking-water. Higher concentrations of iron and manganese, for example, cause an unappealing brown discolouration of the water. Hence, they must be removed. This is one of the tasks of the waterworks, i.e. ensuring the biological, chemical and physical quality of the drinking-water.

From the waterworks to the tap

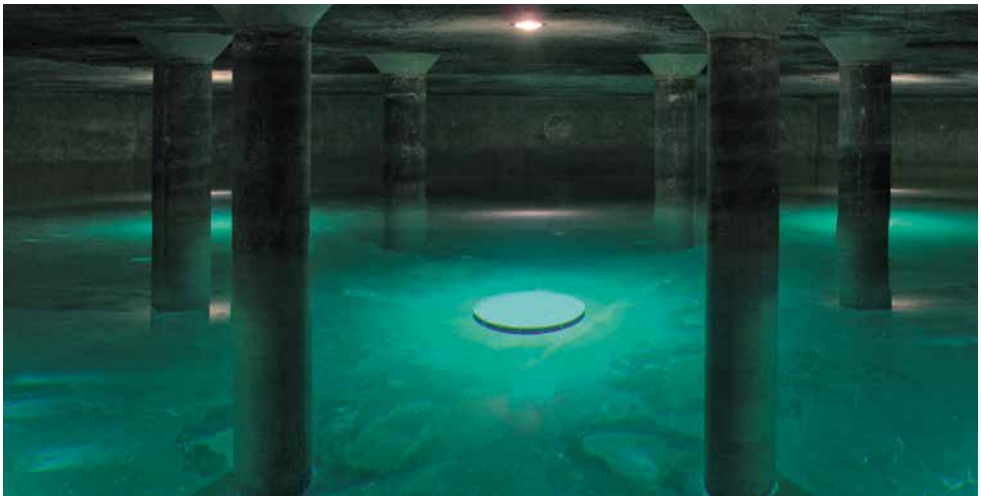
Subsequently, drinking-water has to be transported to consumers. Sometimes, the natural landscape gradient between the waterworks and the consumer is so high that the water can simply flow into the households by itself. However, usually pumps are required – especially if drinking-water is being intermediately stored in elevated tanks or water towers. The water flows via a branched network of undergroundwater supply pipelines until it reaches the connection points of individual households.



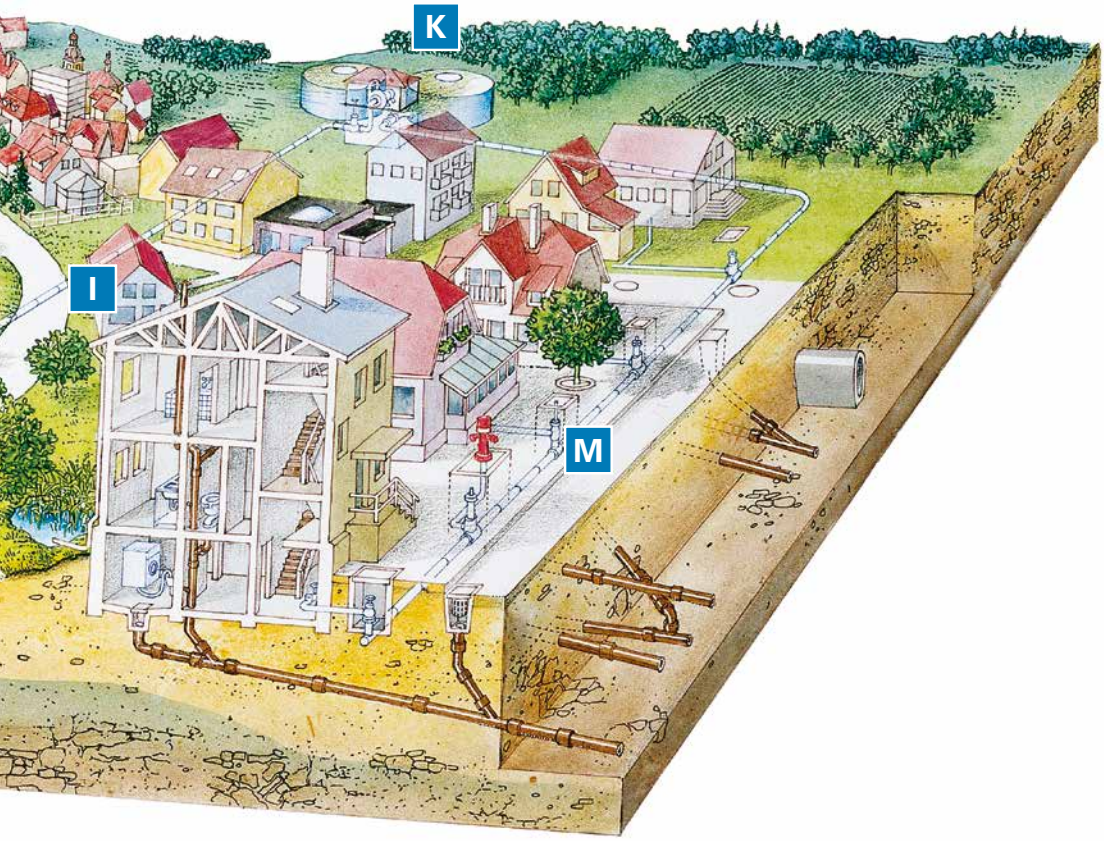
Water supply and water consumption

It seems so simple and routine; we turn on the tap and pure drinking-water flows out – at any time and in any quantity we desire. In Bavaria, over 1.4 million litres of water flow each minute from water pipes – that adds up to 2.1 billion litres per day. Reliably providing this amount of top quality water is an enormous undertaking.

We can scarcely imagine that this stream could run dry, even for a short period of time – and we also cannot afford it. Not only residential households need drinking-water. Industry, skilled trades and agriculture dependent on water of drinking-water quality would also have to stop operations abruptly if they did not have these large volumes of water available.



Our drinking-water is stored in elevated reservoirs by public utility companies. From there, it is fed into the water supply network.



On its way from groundwater to the tap, drinking-water passes through a whole series of stations. (The illustration continues in the chapter entitled 'Streams and rivers', pages 72/73).

- **A** *Wells*
- **B** *Analysis of the groundwater*
- **C** *Spring*
- **D** *Water protection area*
- **E** *Observation well*
- **F** *Drinking-water reservoir*
- **G** *Raw water pipe*
- **H** *Waterworks*
- **I** *Raw water pipe*
- **J** *Drinking-water pipe to the elevated reservoir or water tower*
- **K** *Elevated reservoir*
- **L** *Water tower*
- **M** *Water supply pipe to consumers*

Bathing, showering, personal hygiene: 36 % (47 l)

Toilet flushing: 27 % (35 l)

Washing clothes: 12 % (16 l)

Dishwashing: 6 % (8 l)

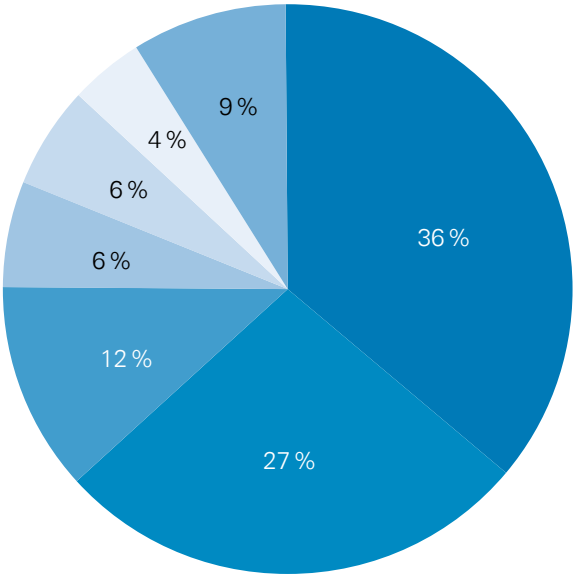
Facility maintenance, vehicle cleaning, gardens: 6 % (8 l)

Eating and drinking: 4 % (5 l)

Proportion used by small businesses: 9 % (12 l)

Bavarian total: 131 l per resident and day (100 %)

Data source: Bavarian Environmental Statistics (Umweltstatistik Bayern) 2016/BDEW 2011



On average, 131 litres of water per day are used, per person, by every resident of Bavaria. Only a very small proportion of this is used for drinking and cooking.

Bavaria's water supply is locally organised. This means that our water is primarily derived from nearby sources.

Who does what in the water supply system?

In Bavaria, the municipalities are obliged to provide residents with clean water. It is obtained and distributed by 2,232 water suppliers – usually operated directly by the municipalities – which also monitor the quantity and quality of the raw water and the water protection areas.

The water management administration, represented locally through 17 regional State Offices for Water Management, is responsible for protecting the groundwater and surface waters in all of Bavaria, and ensures that these waters are used responsibly. This includes providing advice and support, but also monitoring the extraction of water.

Health authorities verify whether the threshold limits of the German Drinking-Water Ordinance are being adhered to, and whether the water supply facilities meet the hygiene requirements. The water suppliers, the Bavarian water management administration and the county offices, including the health administration, work hand-in-hand to provide us with drinking-water reliably, and at the least possible cost.

One unique aspect in Bavaria is its decentralised water supply system. This means that local water suppliers provide water from nearly 8,400 wells and springs.

The well-established decentralised structure offers decisive advantages:

- Bavaria's groundwater is comprehensively protected.
- The groundwater reservoirs are utilised sustainably.
- Thanks to short travel distances, the drinking-water is delivered fresh to consumers.
- The sources of the water are traceable.
- A sense of responsibility for one's own drinking-water is strengthened.

Additionally, the proximity to municipal water suppliers ensures close contact with consumers. Municipal enterprises are not – in contrast to private companies – geared towards short-term profit. Based on these considerations alone, there is a convincing case for keeping the water supply system in municipal hands.

Regardless of the form of organisation, water suppliers must operate economically in order to keep the fees and charges as low as possible for residents. To do this, today more than ever, it is necessary that economic efficiency is monitored and that the water suppliers co-operate and work together even more closely than before.

Project work for water suppliers

To increase the economic viability, particularly through the optimisation of company-internal processes, the benchmark project entitled 'Efficiency and quality study of the municipal water supply in Bavaria' was launched in 2000. In this project, the water suppliers were compared with one another based on technical and economic key performance indicators. The process optimisation measures derived from these contribute to improving the competitiveness of the municipal water supply systems. In addition, benchmarking enables water suppliers to show their production costs transparently.

Good water comes at a price

It is a long way from a water catchment to the tap. Construction and maintenance of the facilities, as well as the expenditure for compensating farmers in water protection areas, have an impact on the price of water. As the Free State of Bavaria also partially financially supports the municipalities in constructing the facilities, an affordable price can still be ensured in many places. In Bavaria, the average price of a cubic metre of water is 1.69 euros (volume-dependent fee plus basic charge; as in 2016, data from LfStaD, evaluated by the LfU).

At 80 percent, the fixed costs of the water supply system are relatively high. Consequently, the water price cannot be substantially reduced, even if consumption is frugal. Nevertheless, every litre of water that is saved means less energy consumption and less water pollution, hence lower fees for wastewater treatment. This benefits the environment – and your bank balance!

The largest portion of our drinking-water is used for washing, flushing toilets and other such purposes. However, as the name suggests, drinking-water is our most closely monitored foodstuff and is also intended for drinking! Whether 'carbonated' or direct from the tap, drinking-water tastes great and is healthy! Furthermore, it is the most inexpensive beverage! Five litres of drinking-water generally cost less than one cent.

Drinking-water in Bavaria – the best quality at a low price

Streams and rivers –

lifelines in the landscape

Streams and rivers, together with their wetlands, form a natural network which interconnects habitats over great distances. To keep these waters clean, wastewater has been purified for over 100 years. Our bodies of running water should be both clean and able to flow naturally This is why, at many locations where we have straightened and constricted them, they are to be given back some of their natural ability to seek a course.

'Panta rhei' ('Everything flows')

Heraklit (Greek philosopher, about 520–460 B.C.)

1 *Many streams and rivers have been straightened in the last 200 years, for purposes of hydroelectric power and land reclamation, or to protect against flooding, for example.*

2 *Today, attempts are being made – wherever possible – to let rivers flow freely again and to restore their natural dynamics.*

3 *Backwaters and river wetlands are valuable biotopes which have a compensatory effect on the water balance. They hold back floodwaters and increase the drainage during dry periods.*

4 *Wherever residential areas or important infrastructures are endangered by flooding, technical flood protection systems are required.*

5 *In Bavaria, hydroelectric power is the most important regenerative energy source. However, its utilisation also affects ecosystems in and around rivers.*

6 *By-pass waterways or fish passes ensure that weirs are not insurmountable obstacles for fish and other life forms.*

7 *Today, in order to prevent damage, wastewater treatment plants purify nearly all residential and industrial wastewater before it is released into rivers.*

Our natural network

For further information

Brochure entitled 'Spektrum-Wasser 4 Flüsse und Bäche – Lebensadern Bayerns':
www.bestellen.bayern.de

On the one hand, streams and rivers form our landscapes. On the other, they themselves are also influenced by the catchment areas, i.e. those regions from which they receive their water, and through which they also flow. Many factors have an influence: the amount of precipitation, the underground rock composition and calcium content, the landscape gradient, vegetation and how the area is utilised. The running waters are just as varied as the regions they flow through.

Rivers span continents, unaware of national borders. For us humans, this means that, today, whoever lives along a river must also take into consideration the interests of other riverside residents downstream – just as he or she would expect from those who live upstream, whether the issue concerns protection against flood damage, or the usage of rivers. This recognition that rivers and streams must be seen as a link between countries, and that they should be jointly managed and protected, has been codified in the two most important EU Water Directives: the EC Water Framework Directive and the EU Floods Directive.

Humans have always taken advantage of the benefits offered by water. Rivers provide us with water for sustenance, foodstuffs and energy; they allow for relaxation and many recreational activities, serve as transport routes and absorb our treated wastewater. Many of these 'ecosystem services' can only function optimally if the waters are intact. The self-purifying ability of rivers is a good example of this.

Efforts to determine a monetary assessment of the benefits provided by ecosystem services are still at an early stage.

However, the value of diverse and nearly natural habitats, and their inhabitants, in and around running waters is recognised by politicians. Thus, improving the ecological penetrability of weirs is anchored in Bavaria's biodiversity strategy as one of its central goals.

Habitats for plants and animals

In Central Europe, nearly natural rivers and their wetlands are the ecosystems which have the greatest variety of animals and plants because they consist of many different habitats. Within just a few metres, gravel banks alternate with deep pools. Shorelines constitute a complex mosaic of wet and dry sections, which are swamped time and again with floodwaters. Steep breaches in the shoreline adjoin flat silted zones. Various biotopes are thus naturally interconnected with one another.

On its way from its source to its mouth, a river changes fundamentally; the water volume increases, while the current velocity decreases. The underground geology can also change along the course of the river. This leads to a variety of very different habitats with their typical characteristics. The narrow, lively flowing mountain stream is thus transformed into a broad, sluggish waterway within an extensive wetlands landscape. As diverse as natural waters and wetlands are, the habitats they form, and the species that settle there, are just as diverse. Streams and rivers are therefore crucial lifelines of biodiversity. As 'blue lifelines', the new Bavarian Aquatic Action Programme (BAP2030) aims to strengthen and expand this function.

Even today, in the event of flooding, the Isar river changes its course in the Pupplinger Au area.

How are the rivers and streams doing?

Our lives, actions and economic activities are not without consequences. The denser the settlement, the more intensive the agricultural and industrial usage, the more we drastically change and reconstitute our environment. Consequently, there are very few natural stretches of water left in Bavaria today. We humans have – especially in the last 200 years – substantially changed most of the bodies of flowing water. The protection and continuous monitoring of the bodies of water is therefore all the more necessary in order to detect harmful changes early on, or to identify potential dangers.

Today, the quality of the streams and rivers in Bavaria is far better than just a few decades ago. This is attributable to the enormous progress made in wastewater treatment. Wastewater treatment plants have been built and continuously improved, and more and more communities have been connected to the sewer system. This is due to the collaboration between the Free State of Bavaria, the municipalities and industry, which quickly ensured, in a timely manner, that wastewater could be purified, thereby significantly reducing the discharge of pollutants.

Nowadays, however, the remaining negative impact on the running waters – which had earlier been long concealed by the previously high wastewater and pollutant contamination of past decades – has now become apparent. The negative impact was recognised insofar as – despite the often very good water quality – the life forms which had earlier inhabited the waters, and could now be expected again, had not yet returned.

One reason for this is the often excessive contamination with plant nutrients. Especially in slow-flowing or dammed waters, this unintentional fertilisation results in unnaturally strong plant growth. Although modern wastewater treatment plants have already led to a significant reduction of the concentrations in rivers, there is still a considerable need for action.

In addition, the banks of many rivers were built up and straightened in the past. These measures particularly served to aid flood protection, hydroelectric power generation, agricultural land reclamation and improving waterway navigation. In many areas, however, this resulted in the destruction of ecologically valuable habitats in and around the rivers. Fish and small invertebrate animals especially provide evidence of these changes. Today, however, many streams and rivers reflect the successes achieved through the modern management of bodies of water close to nature. Altogether, the results of the assessment of streams and rivers show that, by 2020, almost 20 percent of the bodies of running water are expected to attain the required – and also legally stipulated – good ecological status. The quality of the remaining water bodies is to be improved through appropriate measures by 2027.

Nature-orientated management, and the protection of waters from substance pollution, are the most crucial steps towards reaching a good status.

A lesser volume of pollutants and a heightened awareness of wastewater treatment have contributed significantly to improving the condition of Bavaria's waters.

However, there is still a lot to do before bodies of running water can once again have an almost natural stream or river bed.

Types of rivers and streams in Bavaria

No two rivers are alike. Nevertheless, bodies of water can be classified into certain types according to characteristics, such as size, structure, geology and biological community.

The Rivers Danube and Main belong to the river type referred to as very large gravel-dominated rivers. South of the Danube, there are Alpine-characterised types. These include, going from south to north, the streams of the Calcareous Alps, the streams of the Alpine foothills and the young moraines of the Alpine foothills. These are all characterised by gravel and rocks. North of the Danube, there are primarily rock regions, such as the Bavarian Forest and the Fichtelgebirge with gravel-characterised streams and rivers of the siliceous Central German Highlands. In the Franconian Alb, the streams flow through calcareous areas characterised by loess, gravel, rock and karst streams. In addition, some types of flowing waters are independent of the natural environment through which they flow. These include the organic substrate-dominated streams and rivers characterised by lake outflows.

For further information

Map service for the management of rivers and lakes:
www.umweltatlas.bayern.de > Gewässerbewirtschaftung

Maps of river basin management plans:
www.lfu.bayern.de > Wasser > Wasserrahmenrichtlinie > Bewirtschaftungspläne 2010–2015 > Karten 2010–2015

How is the river status assessed?

The European-wide harmonisation of water pollution control through the EC Water Framework Directive has, since 2000, also achieved the adaptation and advancement of methods for the assessment of rivers. Today, this is done in comparison to unaffected reference conditions, i.e. the variance from a natural, optimum state is described. Altogether, 14 of the 25 types of flowing waters occurring in Germany can be found in Bavaria. They vary with regard to the geology of the underground composition, the river size, the flow velocity and many other factors. Thus, individual reference conditions are described for each individual type of flowing water.

To assess the status of a river – in comparison with the reference conditions – biological and physico-chemical measurements are taken at representative locations, and the water flow and river features (hydromorphology) are recorded.

The biological investigation of the bodies of water

The species composition and abundance of typical aquatic organisms are examined:

- Free-swimming algae (phytoplankton)
- Higher-level water plants (macrophytes), stationary algae and mosses (phytobenthos)
- Tiny organisms on lake and river beds (macrozoobenthos)
- Fish

For one thing, these groups include species that indicate certain water conditions – both positive and negative. Accordingly, some stonefly larva can only be found in clean and oxygen-rich waters, unlike tubifex worms, which can also tolerate extreme oxygen depletion. However, the lack of typical species makes it possible to draw conclusions regarding deficits in waters. Numerous fish species, for example, need different river sections over the course of their lives: the headwaters to spawn, flat, warm places to grow and develop, and deep areas of the river as their wintering grounds. If such migratory fish – the Danube salmon, for instance – are lacking in a particular river section, this could be an indication that they are unable to overcome a weir.

The major advantage of a biological assessment of waters is that living things give evidence on the water quality over a longer period of time, because they can only exist if they have had sufficiently good conditions throughout their entire lifespan. This is as true for short-lived algae or insect larva, as it is for fish or the fresh water pearl mussel, which can live to be over 100 years old.

Animal and plant species indicate the status of a river through their presence – or lack thereof.

What are all the things that swim and grow in the water? In a biological investigation of a stream, everything is collected, counted and analysed.

The physico-chemical investigation of bodies of water

In contrast to a biological evaluation, physico-chemical analyses make it possible to precisely determine the chemical composition of the water at the time of the examination. To do this, pollutant and nutrient concentrations are ascertained, in addition to parameters, such as water temperature, pH value and oxygen saturation. The nutrients, nitrogen and phosphorous, stimulate the growth of algae and plants and thus have a major influence on the biological status.

The list of the pollutants analysed ranges from heavy metals, to pesticides, to pharmaceuticals. For particularly hazardous pollutants – the 'priority substances' – there are uniform threshold limits throughout Europe (environmental quality standards).

Examining the water body structure

The variety of forms at the riverbed and the adjacent wetlands, shaped by the runoff conditions, is referred to as the structure of the body of water (hydromorphology) by experts. The criteria include whether rocks, gravel, sand and deadwood occur in a stream, whether the width and depth of the body of water vary, or whether it flows in a uniformly-shaped channel. Also recorded is whether a river regularly swamps the floodplain forest, whether there are dead river branches, and whether a body of water can change its course, or is instead forced to flow within a rigid channel formed of dykes.

The ecological and chemical status

The ecological status is derived from the results of the biological assessment, taking into account the structure of the body of water and physico-chemical parameters. Evaluations are made based on a scale with the grades high, good, moderate, poor and bad. A 'good' ecological status is strived for; if it is 'moderate' or worse, then improvement measures must be carried out. Furthermore, there may be no deterioration. The good chemical state can only be achieved if the threshold values for all 'priority substances' have not been exceeded.

Surface bodies of water which are used, e.g. for waterway navigation, water retention or flow regulation, can be classified as being 'heavily-modified' or 'artificial'. They must meet a modified ecological environmental objective, i.e. the so-called 'good ecological potential'. The 'good' chemical status must also be achieved here, though.

The River Inn, north-west from Mühldorf am Inn. A canal is characterised, inter alia, by an absence of a connection from the body of water to the floodplain or foothills, and limited variation in flow behaviour.

Rivers in reference conditions – the way it should be everywhere

In order to assess the status, reference conditions – which describe the surface waters in the most natural state possible – are established for each type of flowing water. They form the 'yardstick' that can be used to ascertain the status on the affected river sections. Optimum reference conditions are often found in the headwaters of the rivers, in the mid-range mountains, or the Alpine region. Here, there are waters with almost unimpaired catchment areas. Experts make a distinction with these as to whether the rivers flow over calcium-rich (calciferous/carbonatic) or calcium-poor (siliceous) rocks. Examples of rivers in reference condition in Bavaria, unique in their naturalness, include the upper reaches of the River Isar, as an Alpine river; the Großer Regen as a representative of the siliceous highland rivers; and the Forellenbach stream in the southern Franconian Alb as a small calcareous/carbonatic highland river.

However, also for the other types of flowing water, such as the rivers of the Alpine foothills, as well as for the Rivers Danube and Main, reference conditions must be specified. As these rivers have been vastly over-impacted upon by humans, the conditions that are established as a reference are specified for selected measurement points at places where the water conditions are as natural as possible.

The River Isar near Mittenwald – reference for an Alpine river

The upper Isar is regarded as one of the most valuable river landscapes in Germany. As one of the Alp's nearly-natural rivers, it is shaped by constant change. During the snow-melt in early summer, or after a thundershower, it becomes a torrential mountain river that digs new paths into the gravelly valley floor, often completely shifting the riverbed. In contrast, low runoffs are common in winter.

The animals and plants that live here are optimally adapted to these inconsistent and relatively uncommon living conditions. That is why numerous endangered and protected animal and plant species are located here. The small invertebrate animal species, such as insects and their larva, are especially diverse. Fish, such as Danube salmon and bullhead, can be found here. On the gravel plains, which can only be inhabited by plants for a few short years due to shifts of the river caused by flooding, the German tamarisk – which is threatened with extinction – grows. To protect this species, the upper reaches of the River Isar have been placed under protection within the scope of the Habitats Directive.

Characteristic of the clean and oxygen-rich water of the Isar are stonefly larva, such as the banded brown stoneflies (Taeniopteryx sp., photo, left), and fish, such as the Danube salmon (photo, centre) and bullhead (photo, right).

As a near-natural river in the Alps, the Upper Isar provides optimum living conditions for many endangered animal and plant species.

The willow moss, Fontinalis antipyretica, is only native to clean and nutrient-poor rivers, such as the Großer Regen.

The River Großer Regen in the Bavarian Forest – reference for siliceous/low calcareous highland rivers

Large boulders and blocks of granite or gneiss shape the River Großer Regen and other streams in siliceous regions, such as the Bavarian Forest, the Fichtelgebirge and the Franconian Forest. They resist the flow of the water, and the current varies strongly due to these obstructions. Turbulent flow alternates with more sedate areas where there are sand deposits. Between the stones of the streambed, there is a widely-branched and streamed-through gap system, providing habitat and protection to many organisms. Here, for example, water bugs or stonefly larva can be found. The species occurring there are very sensitive and thus an indicator of good water quality.

Higher water levels are more likely to occur on the Großer Regen as a result of precipitation in the winter half-year. In summer, small highland rivers usually show low runoffs.

The upstream areas of the River Regen are inhabited by protected species, such as Danube salmon, bullhead and asp, as well as fish otters and fresh water pearl mussel. On the Großer Regen, special areas of conservation serve to protect these species and their habitats.

In the Bavarian Forest, the river pearl mussel (picture, above), which is threatened with extinction, is found in the upper reaches of the Regen (picture, left).

The Balkan Golden Ring dragonfly, shown here, both as a larva (photo, top) and as a mature dragonfly (photo, bottom), is on the red list of dragonfly species threatened with extinction. They find ideal living conditions in the Forellenbach.

The Stream Forellenbach in the valley of River Altmühl – reference for small calcareous highland rivers

The Forellenbach is a brook in the southern part of the Franconian Alb that flows into the Main-Danube Canal north of the town of Beilngries. In this karst landscape, the underground composition is made of limestone which is partially dissolved by water containing carbon dioxide that seeps into the ground. This leads to an underground drainage system containing fissures and caves.

The stream originates from a natural seepage spring area, trickles over moss-covered limestone cliffs and gradually grows to become a small spring-fed brook. It is often the case in summer that the Forellenbach in part transports very little water because its water seeps into the ground. At other locations, however, the karst water re-emerges from the underground; hence, the flow of the stream's water is relatively stable in the lower reaches.

The streambed is comprised of many different substrates – from fine sand to blocks of stone. The flows, widths and depths of the stream vary greatly. Trees, bushes and shrubs typical of the locality form a thick border of shoreline vegetation, shading the stream. The roots often jut out into the water, forming small coves and niches that serve as habitats for fish and small organisms.

Among the small organisms, the most common species are those which react sensitively to a reduction in the structural diversity and to contamination of the water. Rare species, such as the Balkan Golden Ring dragonfly, a type of dragonfly included in the red list of the most highly endangered species, can be found here.

The Forellenbach forms part of the 'Mittleres Altmühltal' fauna-flora-habitat protected area. Determinant for this are populations of bullhead and stream mussels. Beavers are also native to the area, damming the upstream areas in particular.

Typical of the Forellenbach are the lush shoreline vegetation and often meagre runoffs.

Purifying wastewater, avoiding contaminants

Bavarian wastewater management has been a success story for more than 100 years.

According to water management precepts, water pollution control is regarded as comprising all the measures necessary to ensure the best possible surface water and groundwater quality. In conjunction with water usage and wastewater disposal, the following are especially important:

- Production-integrated measures which provide for optimised water utilisation and ensure that water-relevant contaminants can only be used in the amounts that are absolutely necessary and are kept out of wastewater.
- Treatment of the municipal, commercial and industrial wastewater, which is usually discharged into waters at defined locations, i.e. so-called point sources.
- Measures that reduce substance discharges into the atmosphere or ground surface. As the origins of these contaminants cannot be precisely determined, they are referred to as diffuse contaminant sources.

Sewer systems instead of cholera

Surface waters fulfil an important function for society of which many are not aware – they must absorb wastewater. The self-purification ability of waters may not be overloaded, however, since other water uses – such as fishing, recreation, drinking and service water production – would then need to be restricted. Furthermore, biodiversity, that is the variety of aquatic habitats and organisms, is also negatively impacted upon by wastewater discharge. We therefore may only allow those wastewater inputs which have been cleaned by technical means according to the current state-of-the-art.

It was scarcely 170 years ago that, in the large Bavarian cities, many people died because inadequate hygiene led to the outbreak of cholera epidemics. Only in the aftermath of these catastrophes, and in light of improved knowledge about diseases, were plans made for a systematic sewer system. These initially served to drain off rainwater and wash basin wastewater. Excrement was still collected in toilet pits. These had to be regularly emptied and transported away. The faecal matter was then used to fertilise the fields. It was only towards the end of the 19th century that hydraulic sewer systems become firmly established in the cities. Gradually, outhouse toilets were replaced by flush toilets and this wastewater was routed through the sewer system, together with the rainwater and wash basin wastewater, into rivers or streams. This combined sewer system thus contained residential wastewater and rainwater. There was not yet any purification treatment of the wastewater, however.

The bodies of water were not up to handling the ever-increasing volumes of wastewater – the hygienic and ecological conditions in the streams and rivers deteriorated. The riverside swimming areas, which had been common earlier, were shut down and massive fish kills occurred repeatedly.

This was the starting point for a second period of focus on wastewater disposal. Although, with the introduction of hydraulic sewer systems, the epidemics were a thing of the past, the river water could often no longer be used. In 1907, 'Wastewater Management' was included in the Bavarian Water Act and, in 1911, the first wastewater treatment plant was put into operation in Hohenschwangau. Particularly the comprehensive construction of wastewater treatment plants after World War II ensured that the quality of the bodies of water improved impressively, despite an expanding population. In order to achieve all this, nearly 34 billion euros has had to be invested by cities and municipalities since 1946. For this purpose, they received some 9 billion euros in subsidies from the Free State of Bavaria.

Wastewater treatment is a success story in water pollution control. In some respects, this will continue to be improved in the years ahead; such as by connecting smaller districts to the municipal wastewater treatment plants. However, some 380,000 residents cannot be connected to municipal wastewater treatment plants at reasonable expense. In Bavaria, there are around 100,000 decentralised wastewater disposal systems, of which about 16,000 are drainless pits, and about 84,000 are small wastewater treatment plants. Most of these are currently being retrofitted with biological treatment stages. Thus, wastewater treatment will remain an ongoing task – in order to maintain and increase the high level of quality.

For further information

Brochure entitled 'Abwasserentsorgung in Bayern – Schutz von Fließgewässern und Seen':
www.bestellen.bayern.de

Micro-organisms – only fractions of a millimetre large, such as the mobile ciliate here, are the biological 'cleaners' active in the wastewater treatment plant. Thanks to modern technology, humans are providing it with an optimum 'working environment'.

Wastewater treatment plants – wastewater is turned into river water

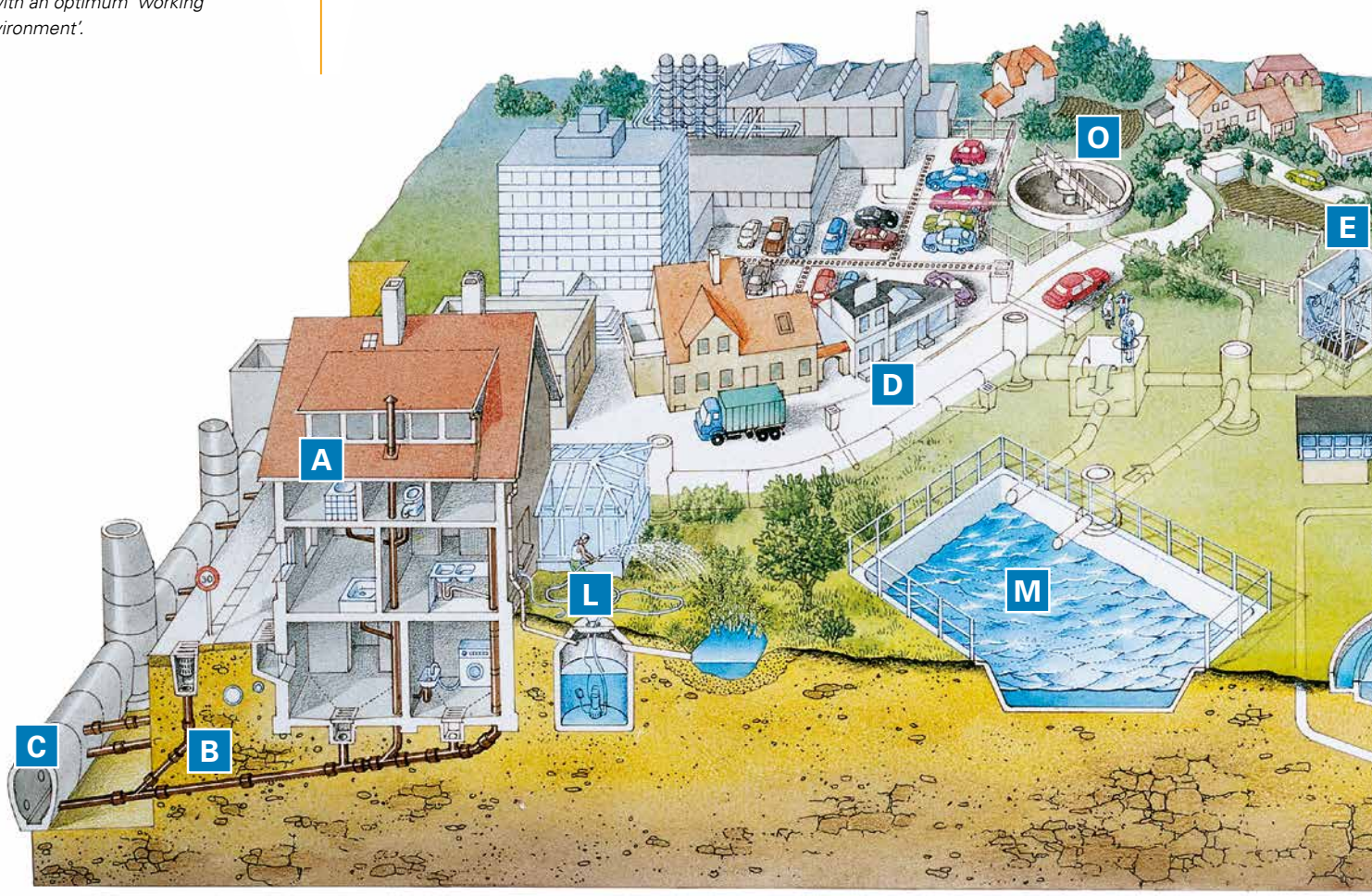
The wastewater is transported from the outlet pipes of individual homes to the public sewer system. Untreated water from residential areas, businesses and industrial parks frequently flows together with rainwater through the local sewer system to a main collector – a large sewer pipe – that ends in a wastewater treatment plant. At a typical, larger wastewater treatment plant, the wastewater goes through the following stations.

First, the wastewater is mechanically filtered: screens remove coarse materials and, in a grit chamber, those solids which are heavier than water sink to the bottom. In the primary settlement tank, the flow rate of the wastewater is so slow that fine, suspended particles can settle on the bottom.

Subsequently, many organic substances are reduced in the biological phase of the wastewater treatment plant. Certain micro-organisms greedily devour these substances if they are provided with a sufficient amount of oxygen. Aeration tanks, where wastewater is intensively aerated, work according to this principle. The mix of micro-organisms ('activated sludge') and purified wastewater is then separated by sedimentation in a secondary settlement tank.

Part of the activated sludge is routed back into the aeration tank; the rest is treated together with sludge from the preliminary clarification tank in the digestion tower. A by-product that develops in this decomposition process is a gas that can be used for producing energy.

Presently, some 12 percent of the decomposed sewage sludge is still used as agricultural fertiliser, and about 19 percent is used in landscaping, for example, for the land re-cultivation of former brown coal open cast mines. For the future, Bavaria plans to stop the agricultural and landscaping usage and to apply thermal treatment (incineration) instead. This is aimed at preventing the distribution of a multitude of contaminants along with plant nutrients, such as phosphorous. This objective is also being pursued by the new Sewage Sludge Ordinance of September 2017. This stipulates that, after a transitional period, large sewage treatment plants will no longer recycle their sewage sludge in relation to the soil, but will instead carry out phosphorus recovery.



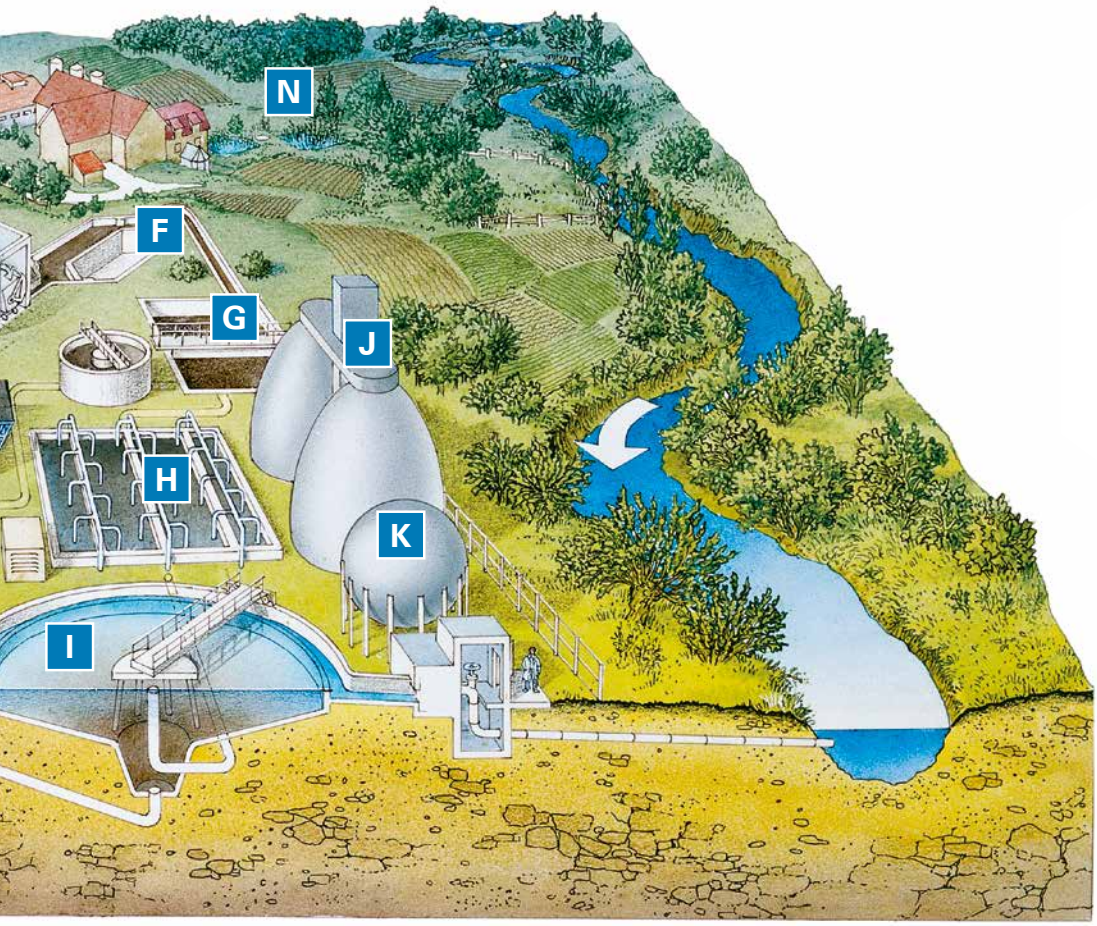
Bavarian wastewater management in figures

- Public sewer systems: roughly 100,000 kilometres, approx. 64 percent of which consists of combined wastewater sewer systems
- Connection rate to municipal wastewater treatment plants: approx. 97 percent of Bavaria's residents. The remaining residents treat their wastewater in small biological wastewater treatment plants, whose purifying performance is comparable with that of centralised wastewater treatment plants.
- Municipal wastewater treatment plants: 2,486
- Mixed water treatment plants: around 9,000
- Small scale wastewater treatment plants: around 84,000 in the long-term
- Municipal wastewater volume to be treated annually: roughly 1.9 billion cubic metres
- Directly and indirectly discharging facilities with industrial/commercial wastewater treatment plants: around 2,600

System for removing trace substances at the wastewater treatment plant in Weissenburg

In the meantime, all the larger wastewater treatment plants have facilities for removing the plant nutrients, nitrogen and phosphorous. An additional purification stage also reduces trace substances in the wastewater. To test the use of this new technology, a large-scale pilot plant was built at the Weissenburg sewage treatment plant.

One goal of Bavarian wastewater management is to thoroughly inspect all the public sewer systems – if not already done – by means of cameras or walk-around inspection. Any damage ascertained is to be rectified, in order to prevent contamination of the groundwater and soil, as well as preventing the ingress of extraneous water.



In various facilities, the wastewater is purified step-by-step (continuation of the illustration from the chapter entitled 'Groundwater', pages 58–59).

- **A** *Household*
- **B** *House connection*
- **C** *Local sewer*
- **D** *Main collector*
- **E** *Screen*
- **F** *Grit chamber*
- **G** *Primary settlement tank*
- **H** *Aeration tank*
- **I** *Secondary settlement tank*
- **J** *Digestion tank*
- **K** *Energy generation based on the gas developing from the decomposition process*
- **L** *Cistern*
- **M** *Storm-water basin*
- **N** *Small-scale wastewater treatment plant*
- **O** *Pre-treatment of industrial wastewater*

Precipitation water does not always have to be routed into the sewer system. Permeable structural elements enable seepage.

Rainwater does not need to become wastewater

Precipitation water which is collected as runoff from stationary structures, such as roofs or roads, becomes wastewater. Virtually uncontaminated rainwater should, however, be allowed to remain in the natural water cycle through seepage and retention. In this way, the replenishment of groundwater and evaporation are aided, the surface runoff is kept low and unnecessary overloading of the sewer systems and wastewater treatment plants is avoided. Many municipalities also grant financial incentives to private property owners. There, no wastewater treatment fee is charged for rainwater if it can seep into the ground on private property. Household usage, e.g. for watering yards and gardens, for flushing toilets or washing cars, is also sensible. Rainwater can also be used purposefully for commercial uses or to water public property.

If rainwater is routed separately from residential and commercial wastewater, this is referred to as a separate sewer system. Unless there is something to the contrary, this type of drainage should be preferred in new housing developments.

If necessary, the precipitation water – from heavily travelled roads, for example – is to be treated and intermediately retained, before it is routed into the groundwater or surface waters.

In the combined sewer system, widely employed in Bavaria, residential and commercial wastewater is mixed together with rainwater. Thus, large volumes of mixed water are drained when it rains. Depending on how strong the rain is, this can be more than a wastewater treatment plant is able to process. Larger amounts are therefore intermediately retained in storm-water basins. They are designed to only pass along as much mixed water as the wastewater treatment plant is capable of handling. If the basin is full, a part of the mixed water flows directly into the river. Such measures do not present any danger to the river, however, if the dimensioning is correct, because contaminants settle in the storm-water basin and the discharged wastewater is greatly diluted.

In the future, the possibilities for nature-orientated rainwater management should be more thoroughly used by cities and other municipalities, as well as by property owners.

Wastewater is water that is collected from various sources and rerouted. It contains dissolved substances, minute particles, and also some solids. Distinctions can be made based on the origin of the wastewater:

Residential wastewater consists, above all, of water from flush toilets, bathwater, cleaning and rinsing water. This water primarily contains organic substances and can thus be relatively easily degraded by micro-organisms.

Industrial and commercial wastewater occurs during production processes. It can be much more heavily organically contaminated than residential wastewater and can also contain substances that are difficult, or impossible, to bio-degrade.

Precipitation water from rooftops or the streets is especially contaminated with sand, dust, dirt, oil and abraded tyre particles at the beginning of the rainfall. De-icing salts are also present in winter. Additionally, there is also ground contamination from air pollution.

Extraneous water consists of groundwater or precipitation water that ingress through leaky sewer pipes, and of forbidden inputs from residential drainage. Extraneous water dilutes the wastewater, which then requires large sewer pipes and leads to a reduction of the wastewater treatment plant's purifying capability.

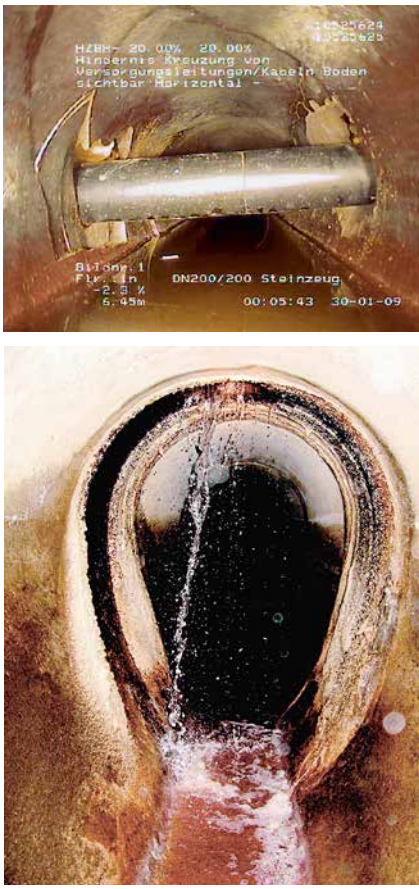
Responsibility and supervision

The purifying capability of wastewater treatment plants must be regularly verified. The facilities are inspected, the output quality of the water is measured, and the results are documented. The verification measures are primarily performed directly by the operator, i.e. particularly the municipalities or industrial proprietors. The state monitors them by performing random samples to see whether the wastewater quality meets requirements, and if the proprietors are fulfilling their duties. Increasingly, private authorised experts are used for this. In addition, those waters in which the purified water output from the wastewater treatment plants is discharged are also examined. This is done by the Local State Water Management Offices in accordance with the provisions of the EC Water Framework Directive, and makes it possible to detect deficits and implement focused measures for improvement.

It is also important to check the sewer pipes for leakage. Damage that requires repair can be ascertained through direct inspection, or by operating special cameras. Only in this way, can contamination of the groundwater and soil, or the ingress of extraneous water in the sewer system, be prevented.

Responsibility for this is borne by the municipalities for the public network of sewer systems, and the property owners for private wastewater pipelines. The regular inspections and necessary refurbishment also serve to maintain the value of the municipal networks of sewer systems, as these are often among the largest assets in which cities and municipalities invest. Unfortunately, there is a lot of catching-up to do with regard to the inspection and refurbishment of the networks of sewer systems.

Not all environmentally-relevant pollutants can be removed by the existing municipal wastewater treatment plants. Hence, pre-treatment of the wastewater is necessary for some facilities. Residential wastewater can also contain undesirable substances, such as pharmaceutical active ingredients or biocides. Measures that target the elimination of such substances are therefore of great significance. In addition to the legal regulations, self-commitment by industry, and conscientious consumer behaviour can also contribute to a reduction of the contaminants.



Sewer system damage: a sewer pipe wall is severely damaged by a supply pipeline (upper photo) crossing directly through it; groundwater ingress due to a leaky sewer (lower photo).

The condition of wastewater collectors with a transverse section is checked by means of a walk-through inspection.

The cultural landscape along the Danube near Hermannsdorf. Water pollution, due to agricultural areas, can be reduced through the sparing and correct use of fertilisers and pesticides.

The offices of the Bavarian State Ministry for Food, Agriculture and Forestry advise farmers as to how they can reduce the widespread contamination of the streams and rivers.

For further information

Microplastics in the environment:

www.lfu.bayern.de > Analytik/ Stoffe > Chemikalien in der Umwelt > Stoffbewertung > Mikroplastik in der Umwelt

Water pollution control on fields and meadows

Contaminants in streams that originate from surface runoff, groundwater or the atmosphere, rather than wastewater, are referred to as diffuse inputs. The waters suffer especially from the plant nutrients, nitrogen and phosphorous, pesticides and, after rainfall, washed-in soil. For a long time, these diffuse inputs only played a minor role in comparison to the direct discharges from wastewater. Due to the successes achieved through wastewater treatment, however, in many areas they are now mainly responsible for the nutrient contamination and sedimentation of the riverbeds.

Nutrient and pesticide surpluses can easily be minimised if agriculture uses fertilisers and pesticides sparingly and correctly. Conservation-orientated cultivation of agricultural lands, and ground-cover planting throughout the entire year if possible, would help to reduce erosion – so that the soil stays on the fields and does not end up in the surface waters.

The Offices of the Bavarian State Ministry for Food, Agriculture and Forestry advise farmers on this subject and have, with the state-wide erosion atlas, developed an important aid for identifying sensitive areas.

Sewage sludge, which has, up to now, been used in part as agricultural fertiliser, also contains pollutants and contributes to diffuse contamination. In Bavaria, the objective is to only process sewage sludge thermally in the future.

Successes in reducing the diffuse contaminants of waters are evident, for instance, in measures to keep the air clean. Thus, sulphur emissions from coal-fired power-plants that cause 'acid rain' have dropped significantly after desulphurisation facilities were installed in the power-plants. Consequently, many formerly severely-acidified waters have been able to recover. The acidification is dropping and the biodiversity in the waters is slowly growing.

The topic of 'microplastics' is currently the subject of intensive research, also in Bavaria. Microplastics are plastic particles smaller than five millimetres. Studies show that microplastics can also be detected in rivers and lakes in Bavaria. Research projects are now to bring clarity about the possible dangers for the environment and the health of humans and animals.

Water protection efforts in the countryside must be given even greater emphasis in the future. In particular, measures in conjunction with the EC Water Framework Directive must be consistently implemented, in collaboration with agriculture, in order to improve the quality of the running waters.

Let the rivers follow their own course

Rivers and streams are constantly changing – insomuch as we let them. The power of flowing water shapes the course of the flow and determines the form or shape, depth and width. Rivers take a twisting course and, especially where the land is flat, they wind their way through the landscape – they meander. Sometimes the riverbed is deep and narrow, sometimes wide and flat. Hence, the flow velocity is never the same, and the riverbed alternates between fine silt and coarser sand and gravel. The riverbank is rocky or overgrown; sometimes it rises steeply and elsewhere it merges smoothly with the floodplains.

Water management experts follow this basic principle with regard to planning for near-natural rivers. Once they have been liberated from their narrow concrete or stone constraints, rivers reveal their potential to shape their own riverbed again.

The concept of a near-natural development of a river is to give it more space for its own dynamic development. Only where necessary, for example, to protect housing areas and infrastructure, are the natural dynamics guided or restricted.

This return to more dynamism and naturalness offers many advantages to humans and nature:

- Animals and plants benefit from the diverse habitats that evolve in dynamic streams. A great biodiversity of fish and invertebrate animals, such as insects, crustaceans and snails develops.
- Along the riverbanks and in the floodplains, typical plants begin to grow again.
- In broader wetlands, floods can overflow without causing any damage. Wetlands also subdue floods, helping to protect residential areas further downstream.
- Near-natural banks protect a river against inputs of nutrients and contaminants from the intensively cultivated countryside.
- Near-natural running waters are also more appealing as areas for leisure and enjoyment than straightened channels.

In order to promote a river morphology that is as near-natural as possible, first riverbank reinforcements are removed, the riverbed is widened and the riverbanks flattened out.

The river is returned to its natural, irregular course. Indigenous trees and shrubs are planted along the riverbanks.

If you allow a river that has been ecologically restored to further develop naturally, numerous animal and plant species readily adapt to it: the so-called succession begins. A near-natural habitat evolves.

The flowing water continually reshapes the rivers and streams and, with it, our landscape, such as here along the River Main near Ebersbach.

Why are wetlands so valuable and important?

Wetlands are the natural floodplains along rivers, in which a frequent fluctuation between floods and low water is the norm. In nearly natural wetlands, floodwaters can spread out without causing damage. Thus, they contribute to the flood protection of residential areas and infrastructure. For the natural ecosystem, they are a very valuable, yet increasingly rare and endangered habitat with many facets:

- In separated river loops, dead river branches and flood channels develop in which the water hardly flows any more. Here, amphibian larva and water insects grow.
- Gravel and sand banks are swept away by the currents and re-deposited elsewhere. Annual plants prevail at these short-lived localities, and complete their life cycles at a rapid pace.
- Pioneering plants, which cannot flourish in the shade of higher trees and shrubs, take root along the riverbanks.
- In the frequently swamped zone of the riparian soft-woods, flood-resistant trees and shrubs, such as alder and willow, grow.
- The species of hardwood, such as oak and ash, settle in areas that are only swamped during extreme flooding.

Many of the numerous animal and plant species of the river wetlands are included in the red list of threatened, or most highly endangered, species. For life-forms of the running waters, the wetlands also offer safe sanctuary if the enormous force of floodwaters leaves no stone unturned.

Bottomland forest along the Franconian Saale

Near-natural future

A complete return to a primal state, without any human influence, is impossible for the ecological river restoration. It is also not the goal. Instead, the water management must be orientated to the fundamentals of sustainability. The guiding principle of Bavaria's waterbody management and development concept is – with regard to the water volume, morphology, water quality and species composition – to attain a state of the bodies of water that is as nearly natural as possible while, at the same time, balancing environmental, societal and business interests.

Since the beginning of the 1980s, the Bavarian Water Administration has steadily improved the ecological quality and natural habitats of rivers and streams, inter alia, by means of the following measures:

- Restoring channelled sections of rivers to their natural state, where possible.
- Securing of natural floodplain areas.
- Restoring the continuity of larger sections of rivers for migrating organisms, as well as for gravel and sand – referred to as debris.
- Acquiring riverside properties and creating bank structures typical for the rivers;
- Promoting the natural evolution of the rivers.
- Establishing new biotopes, and
- Enabling leisure and recreation areas in river wetlands close to cities.

Principally, Bavaria's natural river and wetlands landscape should be maintained or restored for both humans and nature. For this, river development and restoration concepts have been worked out for all the larger Bavarian rivers which allow for solutions that have been custom-made for the river in question. Implementation concepts constitute a bridge between the Water Framework Directive's programmes of measures for the specific implementation at the rivers.

Numerous development and restoration concepts, as well as implementation concepts for the bodies of water have already been successfully implemented. At many locations, bank reinforcements have been removed, riverbeds widened, and fish passes or by-passing streams built at weirs to improve biological continuity.

Particularly with regard to the larger rivers – the Inn, Isar and Salzach – there is still much to be done. Due to the straightening of the rivers and the resultant shortening of their length, the water flows more quickly and develops much greater force. The riverbed becomes unstable – and the river digs more deeply into the ground. This deepening then dries out the surrounding land much more intensely, which not only harms the wetlands vegetation, but can also sink the water tables of land even further away. Previously, this problem was solved with weirs, i.e. structures that hinder the flow of water, but which also interrupted the migration of fish. Today, threatened, ecologically valuable river sections such as these are stabilised in a nearly natural manner; with flat riverbed ramps made of boulders, for example.

Between 2001 and the end of 2018, some 2,700 kilometres of rivers, and around 2,600 hectares of floodplain areas, have been restored to their natural state throughout Bavaria. Dykes were removed on about 71 kilometres of land, thus creating habitats that can be swamped by the river during floods. Almost 26 million cubic metres of retention space have been obtained in this way.

Our rivers and streams should be kept in, or restored to, their essential state in such a way that they can regenerate themselves and have sustainable ecological functionality as 'blue lifelines'.

Nature-orientated by design – the river development and restoration concept

To restore a developed river and its wetlands to a natural state, with as few interfering measures as possible, a specialised ecological landscape and water management plan is being drafted: the watercourse development concept. Here, the most important objectives are restoration of the ecological viability, increasing the natural resilience and the recreational and leisure value.

Head for higher ground? Concepts to counter flood damage

Floods are important for the natural ecosystem – but a risk to humans at the same time.

We remember several major river floods and cases of heavy rainfall events from the last 30 years. These caused considerable economic damage: 657 million euros throughout Bavaria during the Whitsun flood of 1999, 1.3 billion euros during the June flood of 2013 on the Danube, and over 1.25 billion euros during the heavy rainfall events of May/June 2016 in the administrative district of Lower Bavaria. Much more serious than material damage, however, are the fatalities suffered in the catastrophic events of 1999 and 2016.

Flooding is a natural phenomenon that has quite beneficial effects along unspoilt rivers, as the floodwaters transport more debris, nutrients and minerals than the usual flow of running water does. In this way, the riverbed is cleaned and it keeps its natural dynamics and biodiversity. The transported materials are deposited elsewhere in wetlands and backwaters. Thus, when rivers burst their banks, it furthers the connectivity with the surrounding land area.

In nature, there is no such thing as flood damage – only changes. A flood only becomes a catastrophe when humans are massively affected by it. The more intensively flood-prone areas are used by residential and industrial areas, or traffic infrastructure, and the less the construction has taken into account the flood risk, the greater the potential for damage. Meanwhile, many river valleys are heavily populated and are thus risk zones.

The development of a flood is, primarily, determined by the weather and the circumstances in the catchment area of a river. Prolonged, widespread and intensive precipitation is responsible for the flooding of large rivers. Alongside smaller streams, localised heavy rains can trigger a flash flood. In general, rain that can seep into the ground or that is held back by natural retention space, such as soil reservoirs or depressions and basins, rarely causes flooding. Conversely, the less permeable the ground, and the less vegetation and greater the incline of the terrain, the more precipitation flows immediately and directly into the water bodies without obstruction. In addition, many rivers have been developed, straightened and hemmed in by dykes, so that water can runoff more quickly and worsen the flood situation downstream.

For further information

Naturgefahren in Bayern – Informationsportal:
www.naturgefahren.bayern.de > Hochwasser

Brochures:
'Hochwasser im Spiegel der Zeit – Leben mit dem Fluss':
www.bestellen.bayern.de

Water management report entitled 'Das Junihochwasser 2013 in Bayern':
www.bestellen.bayern.de

Water management report entitled 'Sturzfluten- und Hochwasserereignisse Mai/Juni 2016':
www.bestellen.bayern.de

The 2013 flood caused immense damage in Deggendorf-Fischerdorf after a dyke failure.

In the 2016 flood, huge masses of water flowed down the Innstrasse in Simbach am Inn and swept away several cars.

The regulation of rivers was never a purpose in itself, but always served the interests of society. From the middle of the 19th century, until the end of the 1950s, economic goals predominated. Land was to be cultivated for agriculture; settlements, industrial plants and commercial facilities made possible along rivers; large rivers made navigable for ships, and water power exploited.

Nowadays, great efforts are being made to restore wetland areas wherever possible. Holistic strategies, which take into account the river basin as a whole, are required. Isolated protection concepts are outdated, as they only shift the problem downstream.

Protecting against flooding and managing risks

The natural phenomenon of flooding as part of the natural water cycle cannot be avoided. We can make great efforts, however, to prevent disasters and keep flood damage as low as possible.

The key is focused flood risk management which primarily aims, through methodical action, to reduce the damage caused by floods, and to promote an appropriate level of risk awareness.

Following the 1999 Whitsun floods, the Bavarian State Government decided, in May 2001, to consolidate and further promote the prevailing efforts in flood protection by means of the Flood Protection Action Programme 2020 (AP2020). Then, after the flood of 2013, the AP2020 was expanded, becoming the Action Programme 2020plus (AP2020plus). Measures in the areas of follow-up care, prevention, protection and preparedness are intended to improve flood protection and reduce the flood risk for future flood events. Essential new technical-strategic cornerstones of AP2020plus are the increase in the resilience of the flood protection facilities against overload, and in-depth considerations of the remaining risk. The financial resources were increased from 2.3 to 3.4 billion euros. From 2021, AP2020plus is to continue as a pillar of the future Bavarian Water Action Programme 2030 (BAP 2030).

With its integrative approach, AP2020plus lays a solid foundation for a unified strategy for flood risk management throughout Germany and Europe. It comprises defined planning processes for catchment-orientated flood risk management. Flood risk management plans describe objectives and measures for minimising flood risk for rivers at risk. In addition to flood protection, more emphasis will be given to preventing and coping with flood events and providing subsequent assistance.

Flood risk management consists of measures from the four areas of activity: risk avoidance, protection, prevention and recovery. In addition to technical flood protection and natural retention, further measures of preparedness, subsequent assistance and coping measures are promoted.

For further information

Brochure
'Hochwasserschutz Aktionsprogramm 2020plus – Bayerns Schutzstrategie':
www.bestellen.bayern.de

For further information

Umsetzung des Hochwasserrisikomanagements in Bayern:
www.lfu.bayern.de > Wasser > Hochwasser > Umsetzung des Hochwasserrisikomanagements in Bayern

For further information

Leaflet entitled ‚Hochwassergefahren erkennen, Risiken bewerten, gemeinsam handeln - Hochwasserrisikomanagement‘:
www.bestellen.bayern.de

www.lfu.bayern.de > Wasser > Umsetzung des Hochwasserrisikomanagements in Bayern

The Flood Risk Management Directive

The flood risk in Europe has increased due to strong settlement pressure and climate change. Consequently, the EU decided that the identification of flood risks, the development of strategies against flooding and the transnational co-operation in river basins were to be given more emphasis.

As regards the EU Flood Risk Management Directive from 2007, the name says it all. The focus of the regulations, incorporated into German and Bavarian water legislation in 2010, is on the reduction of the flood risk for:

- Human health
- The environment
- The cultural heritage
- Economic activity and valuable property

Since local and regional circumstances are distinctly different, the EU refrained from stipulating definitive objectives for individual river basins, but did specify a strict time schedule and a transnational, interdisciplinary work methodology. The assessment and management of flood risks is carried out in regular and recurring cycles, each containing three stages:

1st stage: Preliminary flood risk assessment.
Identification of areas with a potentially significant flood risk.
Initially until 22nd December 2011 – Updated until 22nd December 2018, and then every six years thereafter.

2nd stage: Flood hazard maps and flood risk maps.
Visualisation of flood hazards and risks in the identified areas.
Initially until 22nd December 2013 – Updated until 22nd December 2019, and then every six years thereafter.

3rd stage: Flood risk management plans.
Setting of goals and measures to reduce the negative effects of flooding on the ‘objects under protection’.
Initially until 22nd December 2015 – Updated until 22nd December 2021, and then every six years thereafter.

Wetlands, like here on the Danube, are the natural floodplains of rivers. If floodwater can escape into these natural retention areas, the flood risk in downstream settlements decreases during smaller flood events.

As natural as possible

Near-natural watercourses and wetland landscapes, in which floodwaters can spread without causing great damage, are especially important for natural retention. The relocation of dykes and the restoration of rivers and its wetlands is, wherever possible, the most environmentally compatible form of flood protection, especially where there are frequent, small flood events. Here, flood protection and aquatic ecology complement each other, which is also why rivers in Bavaria have been comprehensively ecologically restored for decades. The ‘Bavarian Wetlands Programme’ was launched to protect the wetlands that are still intact, and to foster the development of new wetlands. It is interdisciplinary and combines aspects of water management and nature conservation in wetlands, in agreement with users; it is co-ordinated by the Bavarian Environment Agency.

The natural retention of floodwaters is possible not only in the immediate vicinity of the rivers, but also in the catchment areas. The Bavarian flood protection strategy thus provides for retaining as much water as possible, and letting it seep in where it falls. In built-up areas, as much rainwater as possible should seep into the groundwater instead of flowing into the rivers via the sewer system. By means of adapted land use and careful cultivation, agriculture and forestry can also contribute to extensive water retention.

Retaining water in the landscape by natural means has several advantages. It prevents or delays, when there is light precipitation, the occurrence of floods, reduces the soil erosion of cultivated fields and promotes the replenishment of groundwater.

However, the natural retention in a catchment area reaches its limits during prolonged precipitation. If the ground is saturated with water (waterlogged), or frozen, water can no longer seep away and be retained. During major flood events, the natural retention areas in wetlands can already be filled before the highest water level is reached and can thus no longer contribute to reducing the flood peak.

As much technology as necessary

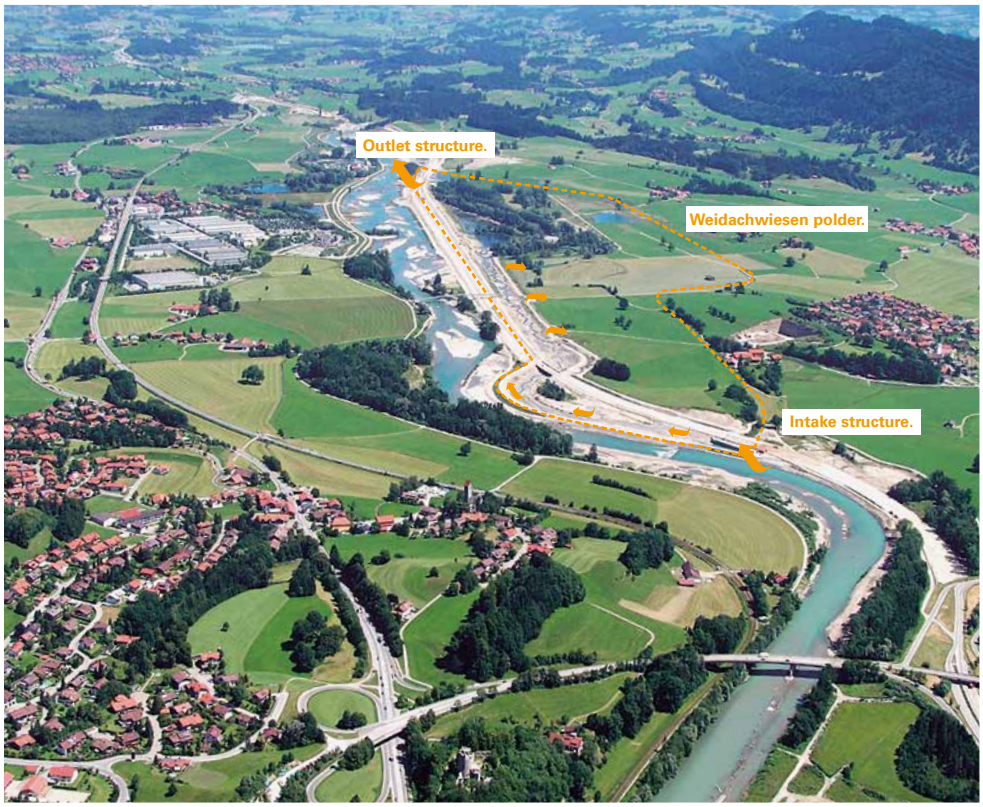
As sensible as the ideas of extensive water retention and the restoration of wetlands to their natural state might be, the protective effect of these measures is limited in the event of heavy flooding. The best flood protection is, therefore, to avoid building settlements in flood-prone areas. However, if vulnerable usage is already present in these areas, technical flood protection measures, such as dykes, flood walls, flood channels (artificial second riverbeds), flood control reservoirs or flood polders are necessary.

As a principle, only settled areas and traffic infrastructures of supra-regional significance should be protected against flooding by means of technical measures. The basis for this is the rule that a flood event is only expected to occur once in a hundred years, using a long-term average.

As a mean value, this runoff can also occur several times within a hundred-year period. When planning flood protection measures, possible changes in the return period of flood events as a result of climate change are taken into account by the so-called climate change factor. In doing so, today's standard for the level of protection can also be ensured in the future.

Since 2000, around 330 kilometres of dykes and flood protection walls have been refurbished and rebuilt, and around 182 kilometres of dykes and 71 kilometres of flood protection walls, as well as the major part of the mobile flood protection systems, have been newly constructed. Along the large rivers, controlled flood polders shall reinforce the basic protection if it becomes overwhelmed, by reducing extremely high water levels to protect downstream residents.

On a large scale, the drainage of major rivers can be influenced by dams and flood polders. In Bavaria alone, there are now roughly 200 million cubic metres of retention space for floodwaters provided by supra-regional dams and the Weidachwiesen flood polder. In addition, there are hundreds of smaller water retention basins for local flood protection that are mainly operated by municipalities or interest groups.



Flood polders, such as the Weidachwiesen polder on the Iller (Oberallgäu district), are dyked depressions or floodplains that are deliberately flooded during major flood events to lower the peak discharges in the river.

Flood protection is also achieved through specific construction measures.

For further information

Technical flood protection:
www.lfu.bayern.de > Wasser > Hochwasser > Hochwasserschutzstrategie Aktionsprogramm 2020plus > Technischer Hochwasserschutz

Be well-prepared

Despite all the natural retention and technical protection measures against flooding, a residual risk always remains. There is no absolute protection against flooding, which is why preparedness is crucial, and everyone is called upon to act – the state, the municipalities and the affected citizens.

The most effective way to prepare against flood damage is to avoid construction in endangered areas. These flood-prone areas are important for flood risk management and can be legally designated as flooding areas and kept in their undeveloped condition. New construction sites in flood-prone areas are generally forbidden.

Important information on the endangered areas is provided by the flood hazard maps and flood risk maps that are drafted for rivers and lakes with a significant flood risk. Based on events and computer-assisted simulations, they visualise how water spreads during frequent, medium and extreme flooding events. They also show the water depths that can be expected. Particular emphasis is also placed on the residential and business areas, cultural heritage assets and facilities that could cause environmental pollution in case of a flood. The maps provide information on the individual flood risk and the management plans derived from it, which contain objectives and measures for reducing flood damage.

Flood risk management is not solely the duty of the water administration office, as many areas – from urban development planning, to agriculture, environmental protection and civil protection – are affected. Thus, cities and municipalities play an active role in drafting flood risk management plans, and private individuals are encouraged to secure their own belongings by taking out natural hazard insurance, for example.

In areas where adequate flood protection is not possible due to urban planning or economic reasons, precautionary safeguards in existing buildings or the adapted usage of the basement and ground floor ensure that a flood can only cause minor damage. Flood-adapted construction methods, for example, with water-insensitive materials or tight, raised light wells and building openings, avoid major damage. Furthermore, everyone should be aware in advance of how to most quickly rescue him or herself and any family members in the event of a flood. Timely and reliable flood warnings also help the residents of affected areas, especially near large rivers, to effectively prepare for the floodwaters and prevent damage. Here, the timing of the advance warning is decisive.

Early warnings in case of flooding

The regional State Offices for Water Management issue warnings for each county during pending and ongoing floods. These are published on the internet (see below) and transferred directly to the communities via the county administration offices. The forecasts by the experts of the Flood Information Service (Hochwassernachrichtendienst; HND) are being continually improved, thanks to state-of-the-art equipment and support by the German national weather service (DWD). Using computer models tailored to the individual river basins, hydrologists calculate the water levels for the next 6, 12, 24 or even 48 hours. The larger the river, the longer the forecast timeframe.

In the event of warnings by the water administration offices, flood status reports are produced and sent to all central government offices, radio and television stations, and press agencies. The local State Offices for Water Management inform the county offices, which warn municipalities and facilities proprietors. Decision-makers are thus provided with the basis for a timely response.

For further information

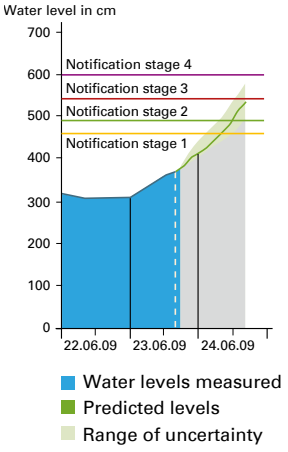
Interactive map service, 'Informationsdienst Überschwemmungsgefährdete Gebiete':

www.lfu.bayern.de > Wasser > Hochwasser > Informations- und Warndienste > Informationsdienst Überschwemmungsgefährdete Gebiete

Environmental Atlas of Bavaria with flood information:

www.Umweltatlas.bayern.de > Naturgefahren

Gauging station at Kelheim/Danube



Example of a water-level hydrograph, with warning levels and forecast range

The Flood Warning Service provides information under:

Tel.:	+ 49 (0)821 9071-5959 status report + 49 (0)821 9071-5976
Teletext:	Bayerisches Fernsehen (Bavarian television), screen 647 (status report) Screens 648 and 649 (water levels)
Internet:	www.hnd.bayern.de

When all the dykes fail, limiting the damage

Even a flood protection system can reach its limits during an extreme event. A residual risk always remains – as history has shown time and again.

Finally, comprehensive and cross-border planning is necessary for larger river basins to limit damage in case of a catastrophe: for instance, by defining spillways and technical safety mechanisms along dykes in order to prevent a sudden failure, or by targeted relief in controlled flood polders. Through such measures, catchment-based co-operation on flood management is being intensified at the European level.

The flood hazard maps and flood risk maps serve as a good basis for discussions on the necessary objectives and measures for catchment areas within the scope of developing flood risk management plans. This should also contribute to fostering each individual's sense of responsibility.

Despite all the protective measures, there is always a risk, as the August floods of 2005 on the Stillach River showed.

Flooding due to heavy rain can affect anyone

Floods and inundations caused by heavy rainfall also occur far from bodies of water and in hilly areas. Exceptionally intense precipitation leads to rapidly flowing water on the land surface, and to overloading of the sewage system in towns and cities. The water follows the terrain, flows and collects in low-lying areas, and can cause damage even before it reaches a body of water. The flowing water develops great forces that result in severe soil erosion and can carry away heavy objects, such as silo bales, stored wood and cars. Those affected are often taken by surprise and underestimate the danger to their lives caused by high flow velocities and in enclosed spaces with no means of escape. The fact that this occurs suddenly, and in a specific, small area makes timely warning almost impossible. Targeted municipal risk management and precautionary measures by each individual, therefore, take on even greater importance in connection with heavy rain.

For further information

Personal precautions against flood hazards:
www.hochwasserinfo.bayern.de
> Aktiv werden

Free-flowing water causes considerable soil erosion on a field.

Utilising the power of water

Hydroelectric power is a form of regenerative energy and thus contributes to climate protection.

For further information

Bavarian energy atlas:
www.energieatlas.bayern.de

With a share of 33 percent, hydroelectric power is the most important regenerative energy source for producing electricity in Bavaria. Its share of electricity consumption is currently about 13 percent. Some 12.5 billion kilowatt hours are generated annually in approximately 4,200 hydroelectric power-plants (excluding pumped storage power-plants). Over 90 percent of the electric power comes from around 230 large plants with a capacity of over 1,000 kilowatts.

Contribution towards the energy transition

Hydroelectric power is an energy source that is renewable, domestic, decentralised and carbon-free. By 2025, 70 percent of our energy consumption should be covered by regenerative sources (Bavarian Energy Programme 2015). It is expected that hydroelectric power will contribute its share by further exploiting the existing potential through an ecologically compatible expansion.

Utilisation of hydroelectric power is frequently at odds with the ecology of watercourses. Migratory fish and small organisms, for instance, would not be able to – or only to a limited degree – surmount the obstacles presented by hydroelectric power-plants without fish passes. To achieve the objectives set forth by the EC Water Framework Directive and Habitats Directive, natural habitats need to be preserved or restored and interconnected so that indigenous species can live and propagate there. Essential elements of this are an adequate minimum water supply, the possibility to travel freely in the river (biological penetrability) and a conveyance of solids that is as nature-orientated as possible.

To implement the transition to renewable energy, hydropower use is to be expanded in an environmentally compatible manner (10-point roadmap for ecological and nature-compatible hydropower use, 2012). The greatest potential lies in the modernising and retrofitting of larger plants that already exist. In addition, the transverse structures that have not yet been used for energy purposes were identified, where there is potential for electricity generation with an expansion capacity of more than 100 kilowatts. Hydroelectric power utilisation should also be integrated in an environmentally compatible manner, within the scope of necessary river restoration measures. Building new obstructing features just to generate power on river-sections that have flowed freely up to now, contradicts the objectives of the ecological transition to renewable energy sources.

The research and usage of innovative hydroelectric plants or plant concepts, such as fish friendly turbines, should be expanded in the future. These hydroelectric concepts also take ecological aspects of the river into consideration. The debris and suspended particle transport should be considerably less hindered, or not at all. In addition, thanks to technical measures, harm to fish caused by turbine passages should be reduced to a minimum.

The Walchensee power-plant generates approximately 293 gigawatt hours of regenerative electric power each year. This amount of electricity is calculated to supply 70,000 households.

Migratory paths for fish

Dam structures interrupt the free flow of almost all larger rivers. Consequently, studies pertaining to the Water Framework Directive show that the continuity for fish in particular is often restricted.

Several options provide assistance for fish travelling upstream, despite obstructing features. Near-natural riverbed structures can often assume the function of existing transverse structures; like natural rapids, they are passable for almost all aquatic organisms, sand and gravel. At weirs, technical fish ladders or near-natural bypasses can help. The water administration office wants to use such measures to improve the ability of fish to migrate in Bavarian rivers.

However, downstream fish migration is also impeded by transverse structures. The screens and turbines of hydropower plants also pose a threat to them.

The Technical University of Munich is therefore conducting research on behalf of the Bavarian State Office for the Environment into how hydropower plants can be made more compatible with fish. Researchers are investigating the effects on fish, plants and smaller animals in the river at various innovative types of hydropower plants.

There is also a need for further research and development on the topic of downstream fish passages and fish protection.

Minimum water levels are a must

Over two-thirds of the plants in Bavaria are diversion hydroelectric power-plants, whereby water is diverted from the natural water flow to a weir and then flows into a (power) canal until it reaches the actual power-plant. The water then returns to the river. The natural riverbed between the diversion and return, the diverted stretch, can be up to several kilometres long.

The habitat of flowing waters is significantly shaped by flow velocity, water depth and solids transport, which are directly dependent on discharge. The minimum flow is the discharge volume that must remain in the diversion stretch in order to ensure good living conditions there for all aquatic organisms. It must be released into the diversion stretch at the weir and cannot be used for power generation.

Even today, many diversion stretches often have too low discharge rates over long periods of time. In the meantime, however, higher minimum water discharges are generally set – an important step towards the 'good ecological status' required by the Water Framework Directive for all Bavarian water bodies by 2027.

Environmentally friendly usage of hydroelectric power enables migratory paths for fish and a sufficient minimum amount of water in rivers and streams.

For further information

Together with the Bavarian fisheries association (Landesfischereiverband), a practical manual entitled 'Fischaufstiegsanlagen in Bayern – Hinweise und Empfehlungen zu Planung, Bau und Betrieb' (Fish passes in Bavaria – Information and recommendations for planning, construction and operation) has been published.

www.bestellen.bayern.de

www.lfu.bayern.de > Natur > Fische, Muscheln, Krebse > Fische

Fish passes, such as the 'pool passage' shown here, make it possible for migratory fish to surmount dam-like structures.

Lakes –

oases in nature and the outdoors

What would Bavaria be without its lakes? Not only are they unique habitats for many animals and plants, they also offer people wonderful swimming and leisure facilities. However, the more the lakes are used, the more they are put under pressure. Furthermore, lakes – like the seas – are often the final stop for all kinds of substances and, as sensitive ecosystems, are therefore particularly endangered.

'The lake is smiling, inviting us to bathe.'
Friedrich von Schiller (German poet, 1759–1805)

1 *Perimeter wastewater treatment systems protect Bavarian lakes against the untreated wastewater of surrounding communities.*

2 *Lake shores need our special attention because, as a highly endangered buffer area between water and land, they have a high degree of ecological diversity.*

3 *Lake ecosystems react especially sensitively to nutrients because, in contrast to rivers, they remain still for a long time. Fertiliser runoff in the catchment areas must be prevented so that the feared 'tipping point' is not reached.*

4 *Most Bavarian lakes are rated as having bathing water quality, and thus improve our quality-of-life.*

A world of its own

Bavarian lakes form the scenery and act as important recreation areas, as well as protection from floods.

Bavaria is rich in lakes. The scenery in Southern Bavaria is characterised by deep, natural lakes that originated during the Ice Age. Large artificial lakes (from river dams) can be found both in the south and north of Bavaria. They have a high recreational value and they also protect against floods, provide drinking-water and compensate for low water levels in downstream rivers. Many smaller, artificial lakes – as well as artificial ponds and quarry ponds – are scattered throughout the countryside. They are important to the local economy, providing building materials and high-quality foodstuffs. Shallow, natural bodies of water that are suffused with light are regarded as ponds and can be found in numerous landscapes in Bavaria.

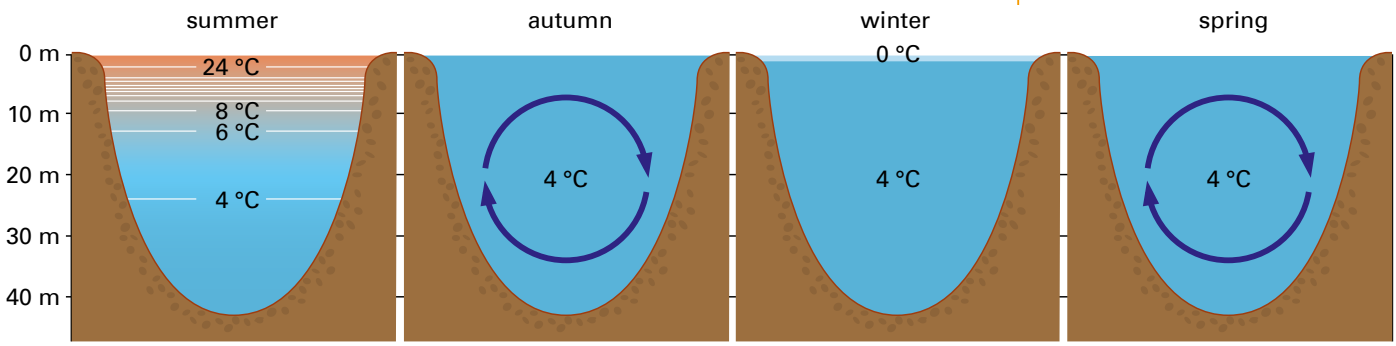
The major difference between rivers and lakes lies in the length of stay of the water. Whereas in rivers, the water is constantly streaming by and renewed, the water in some lakes needs a great deal of time before it is completely replaced. In the Starnberger See (Lake Starnberg), this takes nearly 21 years.

Particularly plant nutrients, such as phosphorous and nitrogen, remain longer in lakes. Thus, lakes react much more sensitively to increased inputs than rivers. If fewer nutrients are discharged, e.g. due to a wastewater treatment plant being built, the existing quantity in rivers is quickly swept away. In contrast, nutrients in lakes – especially shallow ones – repeatedly influence the growth cycle of aquatic plants. An excessive amount of nutrients leads to more intense plant growth. The decomposition of dead plants by microorganisms can lead to inordinate oxygen consumption, triggering decay processes in the ecosystem.

The nutrient content therefore directly determines the so-called trophic state – the vegetative productivity of a body of water. It is decisive for the water quality of lakes.

Classification of standing bodies of water	Shallow	Deep
Natural origin	Pond/small lake	Lake
Artificially-made	Artificial pond	Dammed river

Bavaria's lakes, such as the Tegernsee here, are habitats for plants and animals, as well as recreational space for us humans.



The water in the lake remains in stratified layers in summer and winter. In autumn and spring, it circulates when all the water has a temperature of 4 °C.

Temperature levels in lakes

The animals and plants in a lake need oxygen to survive. This oxygen is primarily introduced into the water through the interaction with the air on the surface of the lake, but is only then transported to the depths of the lake during the transitional seasons of autumn and spring.

The reasons for this are attributable to the seasonal temperature differences and special characteristics of the water. Water reaches its greatest density at 4 °C and thus sinks to the lakebed, where it forms a colder layer. If the surface water warms up in summer, the density is reduced – the water becomes lighter and floats on top of the colder layer. Both layers are kept separate by the so-called discontinuity layer, within which the temperature declines rapidly. This phase is also referred to as the summer stratification, because the condition remains stable for a longer time period.

The oxygen-rich surface water cannot reach the depths during this period. Only in autumn, when the temperature differences are equalised by the cooling of the surface, does the water get circulated thoroughly down to the depths with the aid of strong winds. In winter, the layering is reversed: the water at depth is 4 °C and thus warmer than the surface water, which even freezes at sub-zero temperatures and, although the top layer is colder than the lower one, it floats on top – due to the density anomaly of water. A renewed turnover can take place again in spring, when the water's temperature differences are reduced by the warming of air.

In some deep Bavarian lakes, such as the Königssee, the surface water needs much more time to warm up or cool down due to the enormous volume of water involved. Mixing up of the water usually only takes place once-a-year between January and March.

For further information

Lakes in Bavaria:
www.lfu.bayern.de > Wasser > Flüsse und Seen > Seen

Bavaria's ten largest lakes have widely varying characteristics with regard to their depth or circumference, for example. The term 'renewal cycle' refers to the time required for a lake's tributaries to refill it, if it were empty.

The ten largest lakes in Bavaria	Surface area [km²]	Max. depth [m]	Volume [Million. m³]	Renewal cycle [years]	Circumference [km]	Catchment area [km²]
Chiemsee	80	73	2,048	1.3	64	1,399
Starnberger See	56	128	2,999	21.0	49	315
Ammersee	47	81	1,750	2.7	43	993
Walchensee	16	190	1,300	1.3	27	783
Tegernsee	9	73	323	1.3	21	211
Staffelsee	8	39	75	1.3	19	81
Waginger See	7	27	90	1.0	16	124
Simssee	6	23	87	1.4	14	60
Kochelsee	6	66	185	0.1	15	684
Königssee	5	190	512	2.4	20	136

How warm will our lakes be in the future?

A new challenge for the quality of our bodies of water is posed by the changes in environmental conditions that accompany climate change. According to the climate models, winters will not be as cold in the future. Chances are that the upper water layers of deeper lakes will no longer cool off as much. If the surface water remains warmer than the deep water throughout the year, the temperature layers of the lake could remain in place, resulting in no complete turnover of a lake's waters. The necessary refreshing of the lake's oxygen supply would cease – with a multitude of consequences: fish eggs would no longer be able to develop on the bed of the body of water, and nutrients, that are chemically bound in the sediment, would be released again if there were a lack of oxygen; the danger of the lake's ecology 'tipping' would therefore increase.

To minimise the effects of the rising temperatures as much as possible, the Bavarian Water Administration is examining what effects a water temperature increase could have on lake ecosystems, how these changes can be measured, and – in case of negative changes – which measures are possible and can be planned.

Artificially-constructed reservoir lakes supply Bavarian regions with drinking-water, protect against flooding, enable low water elevation and are popular travel and recreation destinations.

For further information

State water reservoirs in Bavaria:
www.lfu.bayern.de > Wasser > Flüsse und Seen > Gewässerentwicklung und Wasserbau > staatliche Wasserspeicher

View over the Sylvensteinsee dam

State water reservoirs

Bavaria has 26 state-owned water reservoirs (river dams, flood retention basins, flood polders) with a total storage capacity of over 500 million cubic metres and a lake surface area of 35.4 square kilometres in normal flood conditions – 54 square kilometres in flood conditions.

The water reservoirs regularly fulfil several tasks at the same time. They protect against floods and supply water to rivers and streams during periods of drought.
In some groundwater deficient areas, they secure the drinking-water supply. As far as water management regulations and necessities allow, some reservoirs also contribute to energy production. In addition to valuable, ecologically designed areas for animals and plants, many reservoirs also offer attractive recreational opportunities, such as swimming and sailing.

Through the controlled operation of flood retention basins and dams, the available flood retention space can focus on reducing flood peaks and extending the duration of flood waves. This reduces the maximum flood level for the benefit of downstream riparians and gains time for measures to reduce the damage potential.

Controlling the reservoirs requires a high degree of operational experience, as well as extensive knowledge of the hydrology of the catchment area and the water body systems upstream and downstream of the dam.

Prolonged dry periods lead to low discharges in bodies of water. As a result of climate change, an increase in low flow periods is likely, so low flow management is gaining in importance. Dams with an operating area for low water augmentation, store the water flowing in during periods of high precipitation on a pro-rata basis. If the water discharge in bodies of water falls below certain minimum values for low water discharge, additional water is released to stabilise the discharge in the bodies of water downstream of the water reservoirs. This supports the function of the body of water as a diverse habitat and, if necessary, compensates for adverse effects resulting from the existing uses thereof.

In the case of a drinking-water reservoir, the increased inflow is stored in the service area from autumn until spring. During the course of the year, the water is released from the service area to the raw water treatment plants of the water suppliers. The Frauenau drinking-water reservoir ensures the water supply for large sections of the Bavarian Forest, whilst the Mauthaus river dam in the Franconian Forest supplies Upper Franconia with drinking-water. The two drinking-water reservoirs are located in areas with very little or no agricultural use, and where bathing is not possible.

Ponds lined up in a row in Aischgrund create a large water surface, which creates structures in the landscape and further ecological habitats.

Artificial ponds

Ponds are artificial, shallow waters that have been used for aquaculture, as a fire-fighting water source or for aesthetic purposes since medieval times. Many regions of the Upper Palatinate and the Aischgrund, located between Nuremberg and Bamberg, are suitable for artificial ponds. The hilly countryside, criss-crossed by streams, and with an impermeable ground structure that holds back water, makes it easy for people to create ponds by means of simple dams. There, carp were raised as a high-quality food.

Today, in the Upper Palatinate, there are 26,000 artificial ponds with a total area of 6,900 hectares. In the Aischgrund, there are 4,000 artificial ponds with a total area of 3,500 hectares. The ponds are generally operated as a side-line business.

The large number of artificial ponds, and their various forms of use, allow diverse habitats to evolve. In less intensively cultivated ponds with highly structured shoreline zones, and in ponds that are gradually silting up, there are stoneworts and pondweeds, as well as rare plants such as bladderworts, and also amphibians, reptiles and small fish. Important Bavarian populations of the moor frog can be found, for instance, in the pond areas of the Upper Palatinate and the Aischgrund. For many bird species, the ponds serve as breeding grounds or transit stations. Large areas of the regions are therefore environmentally protected and classified as protected natural habitats.

Ponds also have a compensating effect on the water balance. During the spring, the water supply from streams is used to fill the ponds. When the ponds are drained in autumn, they raise the frequently low water flow of the streams and rivers. However, during the draining of the water and catching of the fish, large amounts of silt also often end up in the streams. With a cautious approach to the draining, and by setting up fish-catching basins filled with stones or cement, even better protection for the downstream rivers could be achieved.

The moor frog – during the spawning season, the male has a remarkable blue colour – is native to many ponds in the Upper Palatinate and the Aischgrund.

Nutrient-poor lakes with their clear water are habitats for numerous animals and plant species (photo, left). The murky water of nutrient-rich lakes is attributable to the prolific growth of algae (photo, right).
If it gets out of hand, oxygen depletion can occur in the lake, asphyxiating plants and animals.

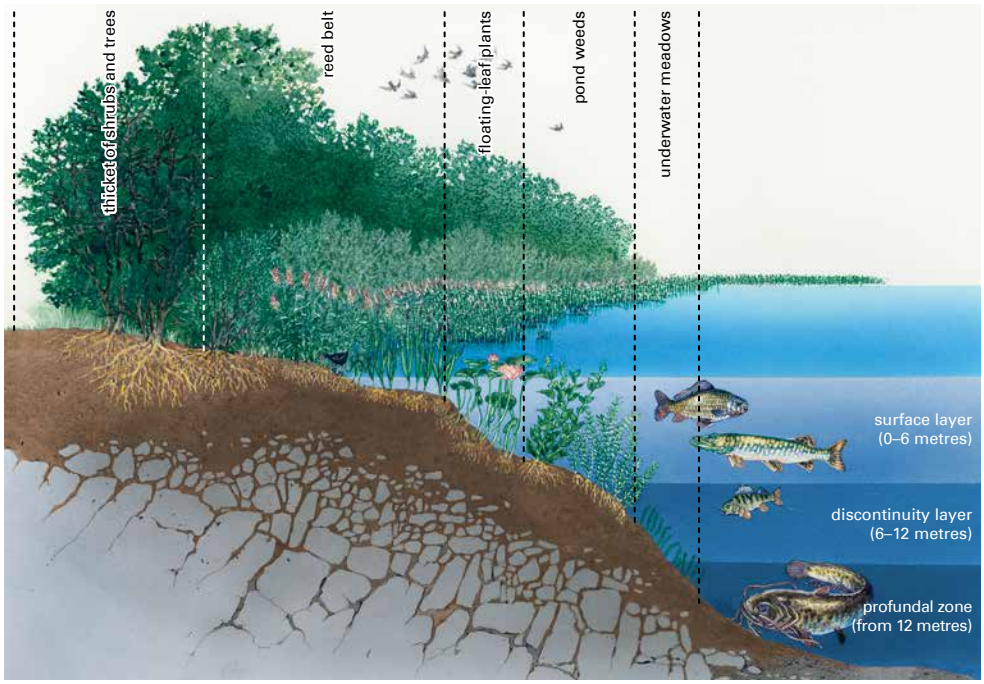
Lake life

Despite the many uses by humans, a lake is, above all, the home of numerous plants and animals. Very diverse biotopes can be identified if examined closely.

What we can all experience is the shoreline zone, which begins with a thicket of shrubs and trees on natural lakes and gradually changes to a reed belt. In nutrient-poor lakes, typical plant associations group together, such as water lilies and other floating-leaf plants in shallow areas; higher-growing plants, such as pondweeds in somewhat deeper waters; and stoneworts – which often form dense 'underwater meadows'. The water in the shoreline zone warms up over the course of the summer; the plants offer protection and nutrition for many life forms. Thus, the shoreline is used by many animals for procreation and raising their young.

The open water that is suffused with light is the biotope, in which the microscopically-small planktonic algae form the basis of the food chain. They are fed upon by water fleas, which are in turn eaten by fish, such as whitefish. Although these biotopes seem very homogeneous because here there is only water with similar temperatures and a similar chemical composition, the diversity of species is surprisingly broad.

The creatures on the lakebed feed on the dead algae and animals that settle on the bottom. It is inhabited, for example, by worms, snails, mussels and crustaceans.



Lake shores are sensitive border zones with high ecological biodiversity, and many functions. They therefore need our special protection.

Types of lakes in Bavaria

No lake is identical to any other. Their sizes, volumes, depths, and thus the proportions of the three biotopes – shore, open water and deep zones – are always unique. Nevertheless, natural lakes can be categorised in groups with similar structures. Of great importance in this regard are the size and attributes of the catchment area, as these factors have an influence on the nutrient content of a lake.

There are four types of natural lakes (with a more than 50 hectares surface area) in Bavaria: 'Deep Alpine lakes with an Alpine catchment area', such as the Königssee and Chiemsee; 'Deep Alpine foothill lakes with a small, non-Alpine catchment area', such as the Staffelsee; 'Deep Alpine foothill lakes with a large catchment area', such as the Pilsensee; and 'Unstratified Alpine foothill lakes', such as Lake Hofstätter.

This categorisation plays an important role in evaluating the ecological condition of the natural lakes as, for example, those lakes only fed by Alpine streams – such as the Königssee – have less nutrients than shallow Alpine foothill lakes which naturally receive more nutrients by way of their inflows. Thus, different lake types must also be evaluated based on different approaches.

Diverse habitats

In Bavaria, there are many different lakes: nutrient-poor Alpine lakes and nutrient-richer Alpine foothill lakes, silted-up moor lakes, various reservoir lakes and numerous artificial ponds and quarry ponds. In addition, most lakes are linked through their inflows and outflows to the 100,000-kilometre-long network of streams and rivers. Together with these other links, the lakes are a crucial pillar of biodiversity in Bavaria because they unite the species diversity and ecosystem diversity, and thus the diversity of various habitats.

If the conditions in an ecosystem change, its species composition also changes – because many species cannot survive any longer under these altered conditions. If this not only occurs in one lake, but in several, then these species no longer have a habitat and they become extinct. Particularly those few, nutrient-poor lakes that still exist in Bavaria are threatened and, along with them, all of the plant and animal species that have become specialised in clear and clean lake water.

Furthermore, plants and animals, which have no natural enemies here, have been introduced over recent years – also to lakes – and are becoming an increasing threat to indigenous species. They can multiply into a widespread presence and consequently eliminate the basis of existence for indigenous flora and fauna.

This is also true for lakes, as it is only through the diversity of habitats, that a diversity of species can thrive.

Different lakes in Bavaria: The Ammersee and the mouth of the River Ammer, a moor lake near the Kochelsee, and residual lakes formed by mining in the Upper Palatinate (photos, left-to-right).

Bavaria's lakes progressing to a 'good' status

When taking samples from a lake, a boat is usually indispensable. The mapping of water plants is best done by specially-trained scientific divers.

On the lakes, periodic biological and physico-chemical samples are taken and analysed in accordance with the stipulations of the Water Framework Directive. Here, the evaluation of the algae and plant species that occur is most significant. These make it possible to draw conclusions regarding the contamination with plant nutrients that are very important for the water quality of a lake. Fish or invertebrate animals can also be indicative of deficiencies in a lake. If harmful substances are present, is it still possible for fish to reach their spawning grounds in the discharging rivers, or what impact does embankment shoring have?

The results of the studies form the basis for the management plans and the implementation of measures. The same applies to lakes, whereby the good ecological and chemical status is to be achieved by 2027 at the latest. Furthermore, the status of the lakes may not deteriorate. Somewhat less stringent objectives apply to artificial river dams and reservoir lakes.

All lakes with a surface area larger than 50 hectares must be evaluated using the EC Water Framework Directive methodology. There are 55 of these in Bavaria, of which 31 are natural lakes and 24 are heavily modified or artificial lakes. About half of these 55 lakes have a good or even excellent status. For the other half, measures are planned to achieve the 'good' status.

In addition to the evaluation in accordance with the EC Water Framework Directive, the bathing water quality of lakes is also assessed. Accordingly, many smaller lakes – 375 bathing locations altogether – are examined, with the focus on the hygienic quality. The results show that most Bavarian lakes are of an excellent bathing water quality.

Even if the situation of the lakes is generally better than that of the running waters, they still face similar challenges. Firstly, contamination from plant nutrients in particular is still often too high. These nutrients frequently come from nutrient-rich inflow sources, or diffuse contamination stemming from agriculture, road traffic and industry. Secondly, there has also been a negative impact on the shoreline structure. Those shorelines that are still intact must therefore be preserved. In addition, attempts are being made to restore shoreline sections to their natural state.

When is something in a lake 'rotten'?

Without plant nutrients there cannot be any life in a lake, but, if there are too many of them, the inhabitants will virtually asphyxiate. The nutrient content is key for the so-called trophic status – the productivity of the algae and plants – and therefore decisive for the water quality of the lakes. An excessive nutrient input is referred to as eutrophication.

Wastewater pipes and fertiliser runoff in particular, with their high phosphorous and nitrogen content, cause the nutrient levels in lakes to rise. This triggers a chain-reaction. First, the algae begin to grow. Soon, they multiply so much that water fleas and other organisms cannot eat enough of them. The algae die and, as they rot, use up huge amounts of oxygen from the lake. The water becomes putrid and murky – in the worst case causing a massive fish kill.

Clear water due to fewer nutrients

In natural lakes, the plant nutrients, phosphorous and nitrogen, are only present in minor quantities. This limits the growth of plants. The water is relatively clear in summer and, in shallow water, algae and higher-level plants grow in amounts relative to this natural supply of nutrients. Due to the use of phosphates in detergents, and the discharge of untreated wastewater and intensive agricultural cultivation, the concentrations of nutrients in many lakes increased rapidly in the post-World War II years. This resulted in massive plant growth, particularly of algae.

The problem of lake eutrophication had already been recognised in Bavaria over 50 years ago, and a solution was found for it. Bavaria's larger lakes started receiving perimeter sewer systems in 1957. With these, all the wastewater from the vicinity of the lake is collected in pipelines, which either surround the lake or pass through it, and itis then purified in a multi-stage wastewater treatment plant.

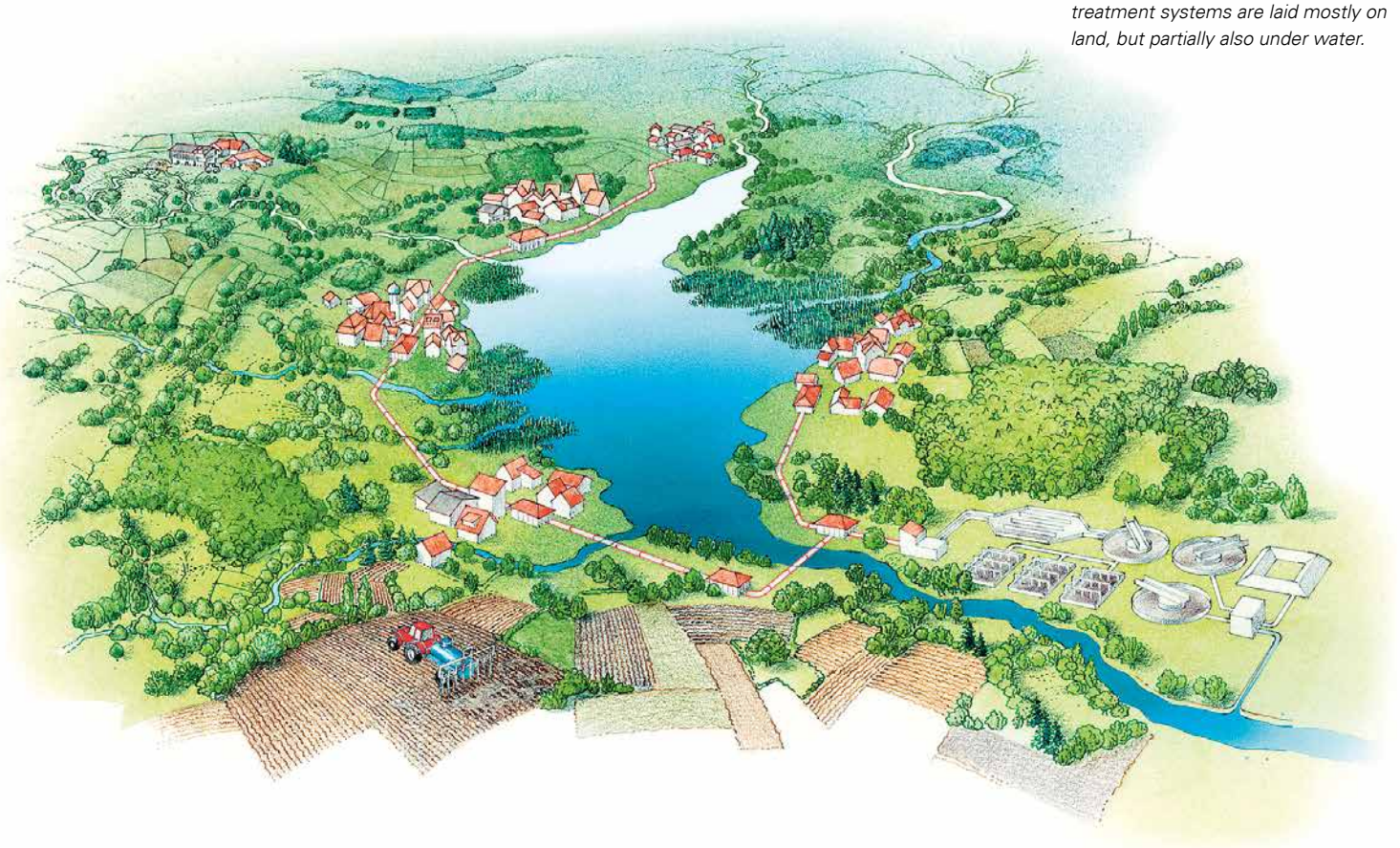
Consequently, the phosphorous content of the lakes Ammersee, Kochelsee, Chiemsee and Tegernsee was able to be substantially reduced after wastewater treatment plants were built. Today, we know that a perimeter wastewater treatment system is the best solution to protect lakes. These have since been implemented at many Bavarian lakes.

Today, the technical possibilities for treating wastewater to secure and improve water quality have been implemented for the most part. However, there are still lakes which are regarded as eutrophic, i.e. nutrient-rich, despite wastewater remediation. These lakes can only be expected to improve if the diffuse nutrient input from a widespread area, primarily from agriculture, can be reduced.

Within the scope of the programme of measures to implement the EC Water Framework Directive, methods are being developed to promote the best regional-specific and water friendly cultivation of the land in the catchment areas of lakes and their tributaries. The goal is to apply fertiliser more efficiently, so that the distributed nutrients are taken up by the plants and do not end up in the water.

The first perimeter wastewater treatment system was built between 1957 and 1965 around the Tegernsee.

Temporary storage of the ready-to-lay pipes for the Chiemsee perimeter sewer system. Perimeter wastewater treatment systems are laid mostly on land, but partially also under water.



On many lakes, such as here on the Staffelsee, reed belts are the natural transitional zone between land and lake (photo, right).
Rare birds, such as the bittern, can be found here (lower photo).

Creating near-natural shorelines

The motion of the waves continuously deposits sediments on lake shores – such as stones, gravel and sand – and redistributes them. A variety of plant species grow on the shorelines, some of which are only found in Alpine lakes and those of the Alpine foothills. Preserving and protecting the remaining nearly natural shoreline sections is therefore especially important.

Many areas – particularly those sites exposed to strong winds – have had to be reinforced, often with walls or rock buttresses, in order to secure the shoreline or for building harbour facilities. Today, we know that these construction measures negatively impact upon the shoreline zone as a habitat and that the lakebed erodes as a result, because waves are effectively reflected and intensified by the walls. Where possible, a natural dynamic development should be allowed to take place on the shoreline, such as through the corresponding removal of shoreline walls.

Just as for rivers, the Bavarian Water Administration is working towards protecting lake ecosystems against any negative impacts, safeguarding ecologically valuable shoreline areas, and providing guidance for the usage of lakes to be more compatible with nature. In this way, certain shoreline areas can be specified for recreational purposes and others as protected conservation areas.

The Lake Constance forget-me-not is unique globally. It can only be found along Lake Constance and the Starnberger See, and needs unspoiled, gravelly shorelines on nutrient-poor lakes that are regularly swamped.

Lakes as meeting places

Water has always held a great appeal for people and, accordingly, Bavaria's lakes are valued by residents and tourists as a major recreation and leisure attraction. Popular destinations are, in particular, the lakes of southern Bavaria, such as the Ammersee and the Starnberger See. In northern Bavaria, it is more the artificial lakes, such as the Brombachsee or Altmühlsee, that attract many visitors.

Although tourism and local recreation are vitally important to the economic development of these areas, they also contribute to the negative impact on the lakes and environs. For instance, people bathing in non-permitted areas can have a very detrimental effect on the vegetation and destroy animal habitats. By establishing protected zones that prohibit motorised boats, swimmers, surfers, sailors and fishermen, lake inhabitants have refuges where they can retreat to intact vegetation. With a network of roads and paths which is well signposted, recreational visitors can be guided, and sensitive shoreline vegetation protected from harm.

A common goal for everyone should also be to minimise hygienically detrimental contamination at the designated bathing areas as much as possible. In line with this, rubbish – such as packaging materials or barbecue remains – should not be left behind on sensitive lakeshores. Broken glass in and around the water poses the danger of injury to all lake visitors and must be prevented.

Unfortunately, the well-intended feeding of water birds is also harmful. The birds become accustomed to being fed and thus lose their natural foraging and feeding instincts. Furthermore, the unsuitable nourishment leads to growth impairment in young birds. Food that is not consumed, together with the excrement of the numerous birds, sinks to the bottom of the lake. Putrid sludge and gases develop there, leading to increased oxygen consumption and a negative impact on the lake's water quality. Thus, there are many reasons to not feed the birds.

Everyone can help to preserve lakes as an ecological treasure and attractive recreational destination. These efforts are richly rewarded: beautiful, unspoiled lakeshores, water in which you can swim without any hazards to your health, and delicious fish from a lake that is free of pollutants.

Everyone can play an important part! With responsible behaviour, the lake habitat will remain an intact ecosystem.

For further information

Bathing water quality in Bavaria:

www.lgl.bayern.de > Gesundheit > Badegewässer

Lakes have an irresistible appeal, particularly in mid-summer.

Think globally, act locally –

a model of sustainability

"In short, each and every one of us needs to realise that he or she – no matter how insignificant or helpless they may feel – is in a position to change the world, but we all have to start with ourselves. If we wait for someone else, none of us will ever see any change."

Václav Havel (Czech author and politician,1936–2011)

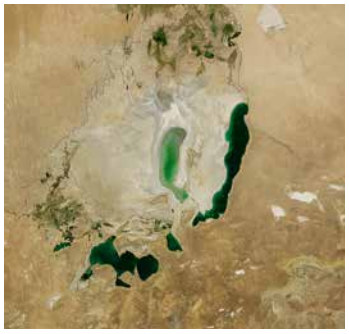
The global challenge

Water is a precious and scarce resource – even though we are blessed with an abundance of it in Bavaria. Looking at the global situation, the UN recognises a water crisis: Too much water is being consumed from rivers, lakes and groundwater sources. Too little wastewater is sufficiently purified to permit it to be safely channelled back into the water circulation system. This has far-reaching consequences for the drinking-water and food supply, the local hygiene conditions and, therefore, human health.

An example of the unchecked consumption of water resources and its consequences is the situation with the Aral Sea in Kazakhstan and Uzbekistan. Sixty years ago, this sea, with an area of approximately 68,000 square kilometres (almost the size of Bavaria), was the fourth-largest on Earth. Only a small fraction of this enormous water mass survives today. Intensive irrigation in the catchment area enables, above all, the cultivation of cotton and has caused the sea to dry up. The exposed seabed becomes sand and dust and is blown away in the wind. People and animals breathe in this dust, which is partly contaminated with pesticides and other poisonous elements, and can therefore cause serious illness.

Water crises, such as that in the Aral Sea, cause suffering to entire regions, but these are not the only challenges to preoccupy us in the 21st century. From a global perspective, human civilisation, according to the Institute for Earth System Preservation (IESP), is threatened by three further Earth crises: climate change, loss of biodiversity and social injustice. Water plays a key role in these crises: More frequent flooding and drought are symptoms of climate change. Biodiversity is also declining rapidly in aquatic habitats. Furthermore, how can we possibly justify a situation where, on the one hand, people have too little water to flush away their excrement whilst, on the other, golf courses are being watered in desert regions?

The cause of these Earth crises is the exploitation of resources through the lifestyles of industrialised nations, a lifestyle that can also increasingly be found in countries with emerging economies.



The Aral Sea, which is located in both Kazakhstan and Uzbekistan, is gradually disappearing due to the overuse of water supplies. The photo at the top was taken in 1985; the photo below in 2011.

The solution: sustainable living

"Sustainability does not mean limitation and self-denial, but rather responsibility and rationality. Humanity, human life, indeed every life, can only flourish on this Earth when acting in harmony with nature, not against it. Otherwise, it will destroy itself. Therefore, in the long-term, that which is sensible for the economy is only that which makes sense ecologically, too."

(Federal President, Joachim Gauck, 2012)

The problems are neither new, nor unknown. Even back in 1992, they were the theme of the UN conference on Environment and Development which took place in Rio de Janeiro. At that time, 179 countries signed Agenda 21, thereby agreeing to strive towards sustainable and future-orientated development on our planet. Since then, there have been many positive developments; a reduction in CO_2 emissions through the extension of renewable energies, an increase in energy-efficiency and the negotiation of the International Convention on Biological Diversity. These positive attempts have been undermined by continual population growth and the growing industrialisation of the developing countries.

Since then, the global situation has unfortunately not improved: Climate change, lack of food and water, social injustice and loss of biodiversity – the problems have grown more severe.

The solution can only come from life and work that is based on sustainability. It is precisely here that the industrial nations must set a good example, for they have profited from the uncontrolled exploitation of resources and, in the process, they have generated, for example, the majority of the greenhouse gases which are active today.

None of us, however, may wait for a global solution. Although, in the meantime, a human right to safe, clean, accessible and affordable drinking-water has been adopted by the United Nations General Assembly, this UN resolution is, however, non-binding. Everyone should, therefore, make their own contribution to the practice of sustainability at a local and regional level, as each individual's consumption behaviour and attitude to the environment is decisive. Consequently, companies – from small enterprises to global players – will also become involved in this process.

What is the definition of sustainability?

The term, 'sustainability', stems originally from forestry, and refers to the way a forest is managed so that only as much wood is harvested as can grow back. This approach can be adopted on a much greater scale. For the unlimited use of our resources comes at the expense of the basic things we need for our livelihoods. This is why maintaining a sensible balance between economic progress, protection of the natural environment and advancement of social issues also means retaining a habitable environment for our children. All of these ideas are contained in the term 'sustainability' as we use it in this brochure.

Sustainable management – not only of water – will be the cornerstone of future-looking global development. It will depend on being able to reconcile the three pillars of sustainability.

- Economic sustainability, which contributes to an enduring solid foundation for commerce and prosperity, and protects economic resources from exploitation.
- Ecological sustainability to protect and preserve a liveable environment, for climate protection and preservation of biodiversity.
- Social sustainability, which targets improvements in health, education, the housing situation, security, equality and population trends.

It is not easy to co-ordinate these three areas in order to produce the best result. All too often, commercial and personal interests stand in the way of doing the right thing. This is particularly true for our common resource, water. Unfortunately, the massive use of water often generates additional profits. This is true both for water extraction and water contamination, for building in areas prone to flooding and for rainforest clearance, and it is also true for the careless polluting of the world's oceans.

Sustainable water management

In view of global population growth, it is absolutely necessary to use our resources economically. The effects of climate change on the water cycle and the resultant water crises will pose greater challenges for us than the rising temperatures.

Sustainable water use can be described in a few sentences:

- Never use more than can be replenished.
- Take precautions to ensure that sufficient water of good quality is available.
- Minimise the possibility of contamination when using water.
- Inform the public and let them take part in decision-making.

In Bavaria, the sustainability concept has a long tradition. For decades, the Bavarian water administration has been committed to three principles.

- Precautionary principle: Sustainable water management to secure a long-term water supply provides the basis for human life and the natural environment.
- Polluter-pays principle: Anyone who uses water and produces wastewater, or otherwise interferes with the water balance, must take protective and precautionary measures and bear the related costs.
- Collaboration principle: Where water is concerned, responsible behaviour is the duty of us all. Government environment policy and legislation alone cannot solve the existing problems. The pressures on our water courses today mainly stem from the extensive infiltration of micro-organisms. Dispersed over the land, they enter the water through the air and the earth. We are all – producers and consumers – sources of this pollution. Farmers, car drivers, holidaymakers, business people and athletes – in fact, everyone plays a part. Only if we act together can we ensure that our bodies of water are protected.

In Bavaria, the environmental report presents the status of environmental sustainability every four years, including graphics displaying environmental indicators.

www.lfu.bayern.de > Daten > Indikatoren

Prevention, co-operation and demanding accountability from those who cause emissions – Bavaria has a tradition of protecting its water.

What can we do?

For further information

Brochure entitled 'Virtuelles Wasser – Verstecktes Wasser auf Reisen':
www.bestellen.bayern.de > Virtuelles Wasser

UmweltWissen – compact, sound information on climate protection and energy:
www.lfu.bayern.de > Bürger > Klima und Energie

How our consumer behaviour influences water consumption in distant countries:
www.waterfootprint.org

The Free State of Bavaria, the local authorities, businesses and the general public must work constructively together to reach the sustainability goals. In order to achieve this, the concept of sustainability has to take root. Through its laws and governmental agencies, the state aims to ensure the preservation and development of our common resource, water. At the local authority level, water disposal, water supply and development of water resources should all be performed responsibly. Water management activities are also undertaken by the business world when it is conscientious in planning, building, maintaining its facilities and in its communications. Furthermore, the residents of Bavaria, this land of water, can make conscious sustainable choices as consumers with regard to water.

The concept of sustainability must become second nature to everyone who uses water. This holds true for industries that use or consume water, and for citizens of Bavaria, the land of water, who, as residents and consumers, can consciously decide to act sustainably with regard to water.

Every single person

Our high consumption of virtual water makes us aware of how much water we directly and indirectly require for the production and transport of foodstuffs and other consumer goods. Additionally, it is possible to make a 'balance of accounts' of water consumption in the producing countries. This makes it clear that, for example, vegetable cultivation in Spain, or cotton-growing in India, Uzbekistan or Pakistan comes at the cost of the water reserves. This leads to the complete exploitation of groundwater, as well as the rivers and lakes. As consumers, we can give preference to regionally and seasonally-grown organic foodstuffs – with the positive side-effect that this also secures local jobs. When buying clothes, we can check for a seal of approval that provides information on the ecological and health aspects of production. In our own gardens, we can use rainwater for watering plants, and there are many more good ideas for conserving resources.

Virtual water covers the whole world.

The private sector

Many entrepreneurs, whether in agriculture, or in the industrial or service sectors, take their social responsibility very seriously. They operate in Germany and abroad in an environmentally and socially responsible manner.

Today, for most German companies, especially those that have implemented an environmental management system, e.g. following the EMAS regulation or DIN EN ISO 14001, environmental protection is standard daily practice. The measures extend from environmentally conscious procurement and environmentally compatible production processes to ecological product development and the training and motivation of employees to behave in an environmentally conscious manner.

Organic farming has also expanded continually in recent years. Agriculture is, for example, an important partner in the campaign for the protection of groundwater.

The interaction between an environmental orientation in product development, an ecological orientation in agriculture and in the service sector, as well as a sustainability orientation in our consumer needs form the basis for the preservation of our environment. A rethink and a new way of acting will be enough to preserve our environment, step-by-step. The economy also reacts to the needs and demands of consumers. Consumers are increasingly not just looking at the price when considering both large and small purchases, but also at the social and environmental standards in accordance with which the products were manufactured. This gives companies incentives to not only do business as cheaply as possible, but also sustainably.

Administration

The effects on our bodies of water must be classified and monitored. This is a duty of the public authorities and is carried out based on the applicable water protection legislation.

The Bavarian State Ministry of the Environment and Consumer Protection, the Bavarian Environment Agency, the 17 state offices for water management, the seven district governments, 96 county administration offices and over 2,000 local authorities actively work together to not only protect the water itself, but also to protect from the hazards water can pose, and to regulate usage of the bodies of water in Bavaria. An important role with regard to statewide water conservation measures is also played by the Bavarian state agricultural authority. The local authorities assume one of the most important duties of all in water management, i.e. supplying residents with drinking-water.

For further information

Groundwater protection campaign:
www.grundwasserschutz.bayern.de

The Information Centre for Environmental Economics provides practical information and management tips on the topics of water and environmental management.

www.umweltpakt.bayern.de > IZU

The Bavarian Resource Efficiency Centre – for an efficient use of materials and resources throughout the product cycle.

www.umweltpakt.bayern.de > REZ

The Eibsee lake which lays beneath the Zugspitze in the Wetterstein mountain range.

Bavaria's team for water –

public authorities and citizens' involvement

Ensuring our waters are safe for tomorrow is the primary goal of the Bavarian Water Administration. The most important guiding principle for fulfilling this task is sustainable management. This means that our most important and precious source of sustenance may not be exploited; it must remain in the cycle of nature and be secured for coming generations. We can do without many things, but not without clean water.

'Citizens of a town can demand that fountains run and that there is enough water available. Where it comes from, however, is up to the man who lays the pipe.'
Johann Wolfgang von Goethe (German poet, 1749–1832)

Managing the water

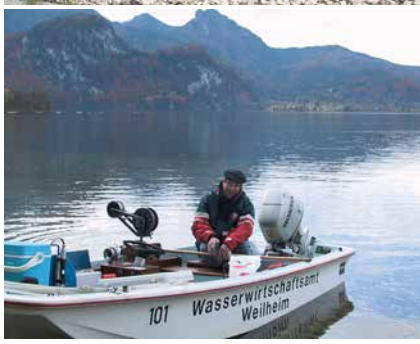
In Bavaria, water management planning and operations have a 200-year-old tradition. Today, the Bavarian Water Administration comprises expert employees in the public water management offices, from the Bavarian State Ministry of the Environment to the county offices. Our standard of living is directly dependent upon water being available. In conjunction with a functional infrastructure, the Bavarian Water Administration therefore secures the long-term basis for our quality-of-life. After all, water is absolutely essential as drinking-water and for the production of many economic goods.

The central goals of the water administration are:

- To protect water as an element of the ecosystem and as an animal and plant habitat.
- To enable humans to use water responsibly.
- To protect against the hazards posed by water.

Each individual, each municipality and every company has different water use demands and these expectations cannot always be reconciled with environmental protection. It is the duty of the Bavarian Water Administration to regulate and control the utilisation of the resources, so that the general public and each one of us is served, without harming nature and the water balance.

The increasing complexity of the multifaceted usage of water, and the management thereof, not only requires the involvement of the state; it also places demands on the citizens' sense of responsibility and willingness to take part, especially with regard to conserving and protecting water, so that water reserves can be ensured for future generations.



Water management is not only practised in modern office buildings, such as the Bavarian Environment Agency in Augsburg (upper photo), but also outdoors in inclement weather, such as at the Kochelsee (centre photo). One goal is to improve the water-body structure for humans and for nature, as was done when the Isar in Munich was restored to its natural state (lower photo).

Sustainable use and protection

To ensure that our bodies of water also remain sustainably usable in the future, the following objectives and principles are effective in Bavaria:

- The water cycle is to be observed, so that negative changes can be prevented or countered in a timely manner.
- The self-purifying ability of the bodies of water must be preserved and improved.
- Water should be used sparingly and with care.
- Substance discharges are to be avoided or at least reduced – up to complete abstinence from hazardous substance use.
- Groundwater throughout Bavaria is to be kept in the most natural state possible.
- Service water should be obtained primarily from bodies of surface water.
- Surface waters, wetlands and valleys must be kept and developed as near-to-naturally as possible.
- Natural drainage outflows are to be maintained and extreme low and high water occurrences compensated.
- The retention and storage capabilities of the landscape should be aided.
- Flood protection must be improved through natural retention, technical protective measures and more comprehensive preparedness.
- Water management objectives must be taken into account vis-à-vis competing uses, especially in drinking-water catchment areas and flood-prone areas.

The Bavarian Water Administration

The bodies responsible for the legal and technical enforcement of the water statutes in Bavaria are:

- The Department for Water Management of the Bavarian State Ministry of the Environment and Consumer Protection (StMUV, the highest-level public water authority)
- The Bavarian Environment Agency (LfU, the central public technical authority)
- The specialist departments for water management and environment-related legal matters of the seven Bavarian District Governments (upper public water authority)
- The 17 water administration offices (WWA, lower public technical authority)
- The specialist departments for water-related legal matters and water management at the county offices (at 71 counties and 25 autonomous cities, lower public water authorities)
- The specialist offices for water management of the county offices (fkS, specialised offices for certain water management issues concerning construction-related legal matters)

The governments and county offices are executive authorities which, for example, issue official notices to citizens. The main duty of the highest-level public water authority is to control water management in Bavaria, especially by overseeing the performance, technical and legal supervision of subordinate public authorities in the field of water management administration. The governments carry out the co-ordination and consolidation work, as well as the performance and technical supervision activities within the administrative districts. The county administration offices are responsible for water management at the county and autonomous city level.

The LfU and the WWA provide advisory support. The LfU handles water management issues as the specialised public authority for scientific and technical matters. It advises the StMUV and acts as a service provider for public authorities and water management institutions. As the specialised public authority for technical matters, the WWA provides support and advice to the government and county administrative authorities with regard to water management duties; for example, as an official expert or as part of their role as the technical water supervision authority. In addition, they are responsible for the development and maintenance of state-managed bodies of water, torrents and water infrastructure facilities. Furthermore, official experts in the field of water management are tasked with handling certain duties, particularly on behalf of the technical water supervision authority.

In the service of Bavaria's water resources

The history of the Bavarian Water Administration dates back to the 18th century. The general directorate for road, bridge and water engineering was established as early as 1767. Back then, water engineering primarily served to secure the raft transport and lumber trade, and to protect the population – who were pushing ever more into the river valleys – from flooding.

Today, many different professions work together to keep water management sustainable: technical personnel, such as master river specialists; biological and chemical laboratory technicians; engineers; scientists; administrative personnel and legal staff.

Hydrological service

The hydrological service regularly observes and examines the situation regarding surface waters and groundwater for their water level, volume and quality. Only with the information obtained in this manner, is it possible to ensure the governmental provision of public services and sustainable development of the waters.

Throughout Bavaria, data is collected at:

- 125 precipitation measurement points.
- 20 automatic measuring stations for the Avalanche Warning Service.
- 620 groundwater measurement points for the water level (basic network).
- 220 compaction network measurement points for groundwater level.
- 95 spring discharge measurement points.
- 595 measurement points for the general and operational monitoring of groundwater attributes.
- 3 measuring sites for the monitoring of measures pertaining to seepage water.
- Approximately 1,030 state special network measurement points for groundwater levels.
- 579 water level measurements of surface waters.
- 38 surveillance monitoring sites and 25 measuring points in the state measuring network for the quality of rivers and streams.
- 24 reference measurement points for the quality of rivers and streams.
- Approximately 1,000 measurement points for the operational monitoring of rivers and streams.
- 180 general measurement points for the quality of lakes.
- 54 reference measurement points for the quality of lakes.
- 195 measurement points for the operational monitoring of lakes.
- 92 measurement points for checking the prohibition of deterioration.
- 42 suspended particle measurement points.
- 129 water temperature measurement points of surface waters.
- 6 automatic quality measurement stations for the continuous monitoring of rivers and streams.
- 24 measuring stations in the acidification of surface waters measuring network.
- 3 measuring stations for integrated hydrological monitoring: monitoring of the precipitation, seepage water, groundwater and streams in small catchment areas.

In addition, data is collected from monitoring programmes to verify compliance with the objectives of the EC Water Framework Directive and Habitats Directive. Furthermore, at many locations, measurements are made, or samples taken, on an as-needed basis.

In this way, every year, millions of measurement values are compiled and stored as data for detailed evaluation. Most of these are available on the internet.

The water-resources service collects data at over 3,500 measurement points.

The Spielmannsau water gauge at the Traufbach stream (county of Oberallgäu)

For further information

www.lfu.bayern.de > Wasser > Wasserrahmenrichtlinie > Gewässerüberwachung

www.umweltatlas.bayern.de > Gewässerbewirtschaftung

For further information

Bavarian State Office for the Environment with the topics of analytics and water:

www.lfu.bayern.de > Analytik/Stoffe

www.lfu.bayern.de > Wasser

Flood Information Service Bavaria:

www.hnd.bayern.de

Low Tide Information Service Bavaria:

www.nid.bayern.de

Water monitoring and control service

The Water monitoring and control service checks on a random sample basis:

- Approximately 8,400 water intakes of the public water supply system
- Some 3,100 officially established drinking-water protection areas
- 2,486 discharges from municipal wastewater treatment plants
- Some 1,700 industrial and service trade sites that discharge wastewater into the sewer system (indirect dischargers)
- Some 900 facilities which route purified wastewater directly into the bodies of water (direct dischargers)
- About 4,250 hydroelectric power-plants
- Approximately 100,000 kilometres of bodies of water, of which
- 4,200 kilometres are of 1st degree (large, pan-regionally significant rivers and lakes)
- 4,800 kilometres are of 2nd degree (regionally significant flowing waters and lakes)
- 25 state-managed river dams and flood water containment basins
- Other objects, such as the commercial operations that handle water-polluting substances

Bio-monitoring is the continuous observation, measurement and monitoring in order to take action on a timely basis.

Water research

Practice-orientated basic research examines the river and lake ecology, as well as water pollution control.

In particular, the water contamination by pollutants, and their effects on the aquatic communities, are ascertained. Basic studies on species protection for ecological river restoration, and the restocking with endangered fish species, are also some of the water research tasks.

Environmental analytics

To avert hazards to our environment, it is first necessary to know exactly which pollutants are present in our environment and in what quantities. This is why the Bavarian Environment Agency, using the most state-of-the-art analytical technology, tests samples of waste material, soil, water and air for environmentally relevant substances and their concentrations.

Additionally, examinations are conducted as to how substances behave in nature – whether they spread-out or are degraded. The Bavarian Environment Agency has developed a multitude of bio-monitoring procedures for this. Accordingly, the substance accumulations in aquatic animals are monitored, as are the long-term effects of micro-contamination – i.e. through oestrogen – on an organism.

Water management planning

Based on comprehensive water management plans, interdisciplinary and long-term strategies for the sustainable utilisation and economic development of the water and nature balance are established.

Drawing on the results of the basic research, increasingly complex and extensive, or even global ecological relationships, are being recognised. Water management planning must, therefore, place greater emphasis on considering the relationships between the water cycle and other substance cycles, as well as societal developments. This is because expanded residential and commercial building activity, land usage, road traffic and recreation all have a direct effect on the water and nature balance.

Governmental water engineering

The Bavarian Water Administration is responsible for the development and maintenance of class I and II bodies of water. These include the largest pan-regional or regionally significant rivers, with a total length of 9,000 kilometres, as well as all the larger lakes, with a total surface area of 270 square kilometres. Here, the priorities are:

- Preserving or developing natural – or as near-natural as possible – river and wetland landscapes.
- Improving the vitality of the aquatic ecosystems through measures to restore them to their natural state and preserve them this way.
- Carrying out engineering measures to prevent damage along banks and riverbeds in accordance with the reference conditions, and
- Setting up technical flood protection structures wherever necessary to protect settled areas.

The municipalities are responsible for all the other bodies of water (class III water body rules). They receive advice and active support from the water administration offices. The developed mountain torrents are an exception. Due to the high degree of damage potential, the Bavarian Water Administration is responsible for these.

Specialist advice

The water administration offices are official experts in approval proceedings for legal matters concerning water. In other proceedings, such as planning approval or zoning proceedings, for example, they act as water advocates for the public interest – and thus in the interest of society in general. In particularly difficult cases, the Bavarian Environment Agency is responsible for issues pertaining to the handling of water-polluting substances and, in certain simpler matters, the specialist departments of the county offices are responsible. Since 1994, some of these tasks have also been handled by recognised private experts in water management.

Good water for little money

Since the beginning of the 1950s, the state funding of water supply systems and wastewater treatment plants has contributed to a highly effective infrastructure and to ensuring the purity of our bodies of water. The aim of state funding is to attain an equivalent standard of living in all regions of the country.

Thanks to the high state subsidies, Bavarian municipalities can levy the lowest fees when compared with the average for Germany. The mean price for drinking-water (including the basic charge; status 2016) is 1.69 euros per cubic metre; the mean wastewater treatment fee (factored from the fresh water fee) is 1.96 euros per cubic metre (source: Destatis).

There are also financial incentives for the development and maintenance of the running waters and for flood protection. Municipalities that implement ecologically-orientated measures receive a bonus. The Free State of Bavaria invests about 20 million euros per year in this field.

Subsidies for certain water management measures will remain an ongoing commitment. The focal point for these subsidies lies in rural areas where, with regard to the infrastructure, there is some catching-up to do, and where, at the same time, a compensatory function for the water balance must be assumed.

Subsidies from the state ensure low water usage fees in Bavaria.

Test set-up of mobile flood defence elements in the town of Miltenberg

State subsidies

Since the 1950s, local authorities have invested around 11 billion euros in the water supply and around 35 billion euros in wastewater disposal. The Free State of Bavaria has supported them with around 3.5 and 9 billion euros respectively. Since 2016, the free state has been supporting the municipalities with around 70 million euros annually, but only in cases of hardship. In 2003, a programme was launched to support the retrofitting of small wastewater treatment plants with biological purifying stages. By 2015, support grants totalling around 187 million euros had been disbursed to operators (private households).

Bavaria's investments not only ensure the comprehensive usability of water, they also create jobs.

We advise on all matters concerning water

Experts from all fields, in which water plays a role, are available to handle your questions and problems: biologists, chemists, geologists, IT specialists, engineers, landscaping specialists, meteorologists and, and, and … Bavaria's water specialists are ready to provide helpful, expert and non-bureaucratic assistance and information to citizens, municipalities, associations and companies. We would be pleased to advise and help you find tailored and sustainable solutions.

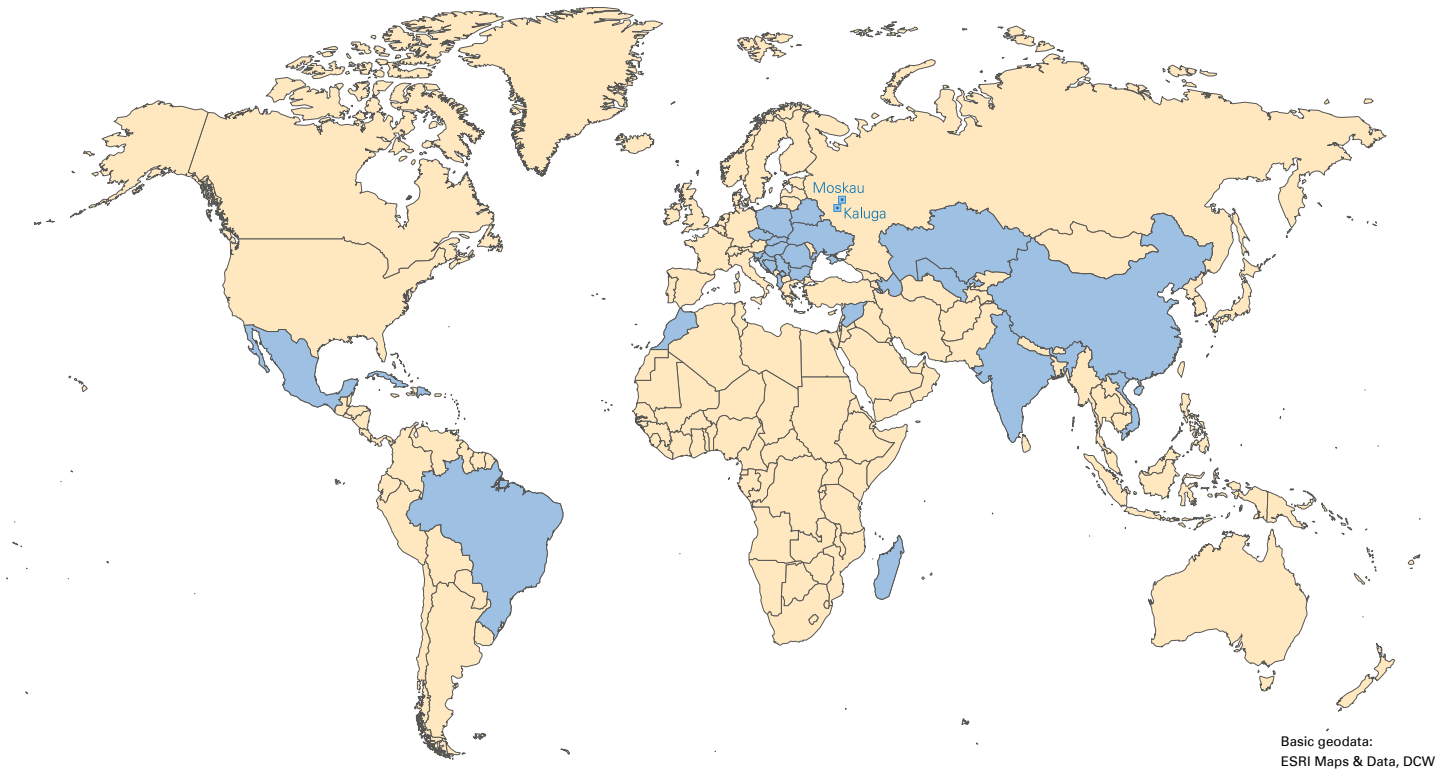
To find out who is responsible for your particular case, please contact the relevant water administration office.

For further information

www.lfu.bayern.de > Wasser > Fachübergreifendes > Projekt Technologietransfer Wasser – TTW

Bavaria is active around the world

As a member of several international river commissions (for the Rivers Danube, Elbe and Rhine) and task forces (ARGE Alp, Arge Alpen-Adria), the Free State of Bavaria plays an active role in defining a common water policy in Europe. The Bavarian Water Administration also considers itself obliged to share its knowledge and experience beyond the scope of these international organisations. The focus is on all countries and regions in which the supply of drinking-water and the wastewater disposal, as well as the maintenance of rivers and lakes, cause problems. By the same token, this obligation represents the opportunity to put the field-tested Bavarian environmental technology to good use to improve the environmental and living conditions in these regions, to jointly gain more experience in the process, and to also secure and expand Bavaria's position as a centre of business and science. To this end, the Water Technology Transfer (Technologietransfer Wasser; TTW) project was launched by the Bavarian Environment Agency in Hof. Firstly, to fulfil its mission, TTW draws on its expert partners in the science and business sectors; secondly, and above all else, it makes use of the Bavarian Water Administration's knowledge and experience.



Bavaria's knowledge of water and environmental technology has been made available around the world. Countries and regions, with which TTW mutually shares water management experience, are coloured blue.

The training of supply specialists and municipal employees helps ensure local drinking-water quality.

To excellent collaboration

In Bavaria, cities and municipalities have three main statutory duties in the Bavarian Water Administration:

- Safely supplying residents with drinking-water.
- Collecting wastewater through an intact sewer system and purifying the wastewater in correctly functioning wastewater treatment plants.
- Providing and maintaining flood prevention measures at smaller running waters (class III water body rules, excluding torrents).

To accomplish these important and highly responsible duties, the municipalities need up-to-date information, trained personnel and knowledgeable contact partners. In Bavaria, they are helped beyond their own municipal boundaries.by 'neighbourhoods' – regional training platforms that are usually located within the same county. With practical orientation and local proximity, experienced leaders and trainers ensure a high technical standard in regular training sessions. The municipal umbrella associations are members of the supervisory or management boards. They control the work of the neighbourhoods and set the guidelines.

At the regularly-held neighbourhood meetings, sharing experiences and learning about specific projects are in the foreground. Transferable experience that can be put to use in one's own municipality makes an important contribution to quality assurance. Each year, more than 10,000 municipality employees and special-purpose associations take part in neighbourhood meetings in Bavaria. Neighbourhoods are thus effective networks and self-help groups that work without a great amount of administrative effort.

Waterworks neighbourhoods

Bavaria's water supply system is organised with particularly small-scale facilities: some three-quarters of all providers supply fewer than 4,500 residents. The big plus here is that citizens identify more closely with 'their' water, if it is locally obtained and protected. The challenge is that day in, day out, supply specialists and municipality employees need to ensure perfect quality drinking-water. 73 waterworks neighbourhoods support the municipalities, special-purpose associations and public utilities in fulfilling this duty. Usually about twice-a-year, they provide specific neighbourhood assistance, convey technical knowledge and, for over 30 years, they have been providing advanced training to supply personnel. The former local State Water Management Office played a leading role in setting up this network. Since 2009, the waterworks neighbourhoods have been organised as a registered, non-profit association. The Bavarian Environment Agency is active on the management board and supports the association in producing work documents. In addition, the water administration offices are important partners for the waterworks neighbourhoods in terms of subject matter and expertise.

'Neighbourhoods' support the water management tasks of the municipalities.

For further information

Waterworks neighbourhoods.
www.wwn.bayern.de

For further information

Sewer system and wastewater treatment plant neighbourhoods:
www.dwa.bayern.de

'Neighbourhoods' on the internet:
Stream neighbourhoods:
www.lfu.bayern.de > Wasser > Flüsse und Seen > Wasserbau und Gewässerschutz > Gewässer – Nachbarschaften

Sewer system and wastewater treatment plant neighbourhoods

The proper and economic operation of the approximately 2,486 municipal wastewater treatment plants, and the more than 100,000 kilometres of public wastewater sewer pipes, are an ongoing task for the Bavarian municipalities. To accomplish this, they need dedicated and well-trained employees. The sewer and wastewater treatment plant neighbourhoods are an important forum and network in this regard. It was established nearly 40 years ago by water management specialists and the municipalities. Supported respectively by a neighbourhood instructor who is an experienced wastewater master specialist or engineer, the operational personnel in 92 regional neighbourhoods and 20 special neighbourhoods (concerned with special topics, such as phosphorous removal during wastewater purification, for example) receive regular training.

Together with the Bavarian Environment Agency, the German Association for Water, Wastewater and Waste (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V.) co-ordinates the neighbourhoods. They also provide advanced training to the instructors and draw up work documents for optimum facilities operation. The very practice-orientated work often involves scheduling the neighbourhood meetings; for instance, when the topic is operational analysis. After all, proven quality is what it is all about when it comes to verifying the purification performance of one's own facility. An overview of all the operating results flows into an annual performance comparison in which 90 percent of all municipalities participate. This important status-check confirms that the Bavarian wastewater treatment plants make a key contribution to our water pollution control. It also shows where individual wastewater treatment plants possibly need to take action, and aids decision-making as to priority action items for the water administration and municipalities.

Stream neighbourhoods

While the approximately 9,000 kilometres of larger bodies of water in Bavaria are taken care of at a state level, the more than 90,000 kilometres of streams fall under the authority of the municipalities. Vital and ecologically intact streams enrich landscapes and local scenery. They are topographic lifelines, since this finely veined network is of great value for biodiversity. To no small extent, streams make a valuable contribution to flood retention over a wide area.

Streams do not stop at municipal boundaries though. The network of stream neighbourhoods therefore places emphasis on the sharing of experience beyond municipal boundaries. At the neighbourhood meetings, employees from municipalities, interest groups and landscape conservation associations take part; mayors also often participate to stay directly informed. This network is co-ordinated by the Bavarian Environment Agency. The tasks involve theory and practice in developing and maintaining the streams, caring for trees and shrubs, or in improving the biological continuity, so that fish and other organisms can migrate unimpeded in the streams. In many areas, dedicated citizens also contribute to maintaining and taking care of these valuable habitats and recreational areas by 'adopting' a stream.

Some 90 percent of all Bavarian bodies of water are under the authority of the municipalities. Sharing experiences, and providing training within the framework of the stream neighbourhoods, helps to improve the condition of these smaller streams.

Getting down to business

The 'Agile Iller' project – for more life in and around the river

The Lower Iller, from its confluence with the Danube to Aitrach, is in a moderate to unsatisfactory ecological condition, its riverbed straightened, its banks blocked. This is because a large number of transverse structures were built to stabilise the riverbed and to harness hydropower. Fish and other aquatic organisms can now no longer cross the river, as the necessary habitats along the river are missing. Lateral tributaries and floodplains have been cut off by the deepening of the Iller – valuable spawning habitats and nursery grounds for fish have been lost.

The Iller is a transboundary water between Bavaria and Baden-Württemberg. To fulfil the obligation to manage the waters in such a way that a good ecological status is achieved, the two states signed a state treaty in November 2017 with the content of the 'Agile Iller' work programme. This includes 59 measures over a stretch of 57 kilometres, and an investment framework of 70 million euros has been set for the next ten years.

The Kempten and Donauwörth Water Administration Offices and the Tübingen Regional Council are in charge of planning and implementing the measures. Top priority is given to the construction of fish ladders and the conversion of riverbed sills into 'rough ramps', so that the Iller can once again be navigated by fish and other aquatic organisms.

Furthermore, the structure of this body of water is to be improved. In addition to the ecological improvements, the local recreational value is to be increased; the river is to be brought to life again. The riverside paths will be relocated and the river cross-section widened. The gravel extracted from the widened areas will be returned to the river as debris. The barriers are removed and the steep embankments are cleared, making the river accessible for animals and people. By flattening the mouths of tributaries to the Iller, habitats along the river will be connected and important dispersion space for flood waters created.

The Arlach weir and the Heimertingen sill are to be converted into a more natural condition.

A better future for the Donaumoos – one model is paving the way

With an area of about 120 square kilometres, the Donaumoos is the largest lowland fen in southern Bavaria. After being drained and cultivated more than 200 years ago, the Donaumoos is now home to about 20,000 people and is mainly used for intensive agriculture.

However, the constant drainage of the fen has caused a number of problems.

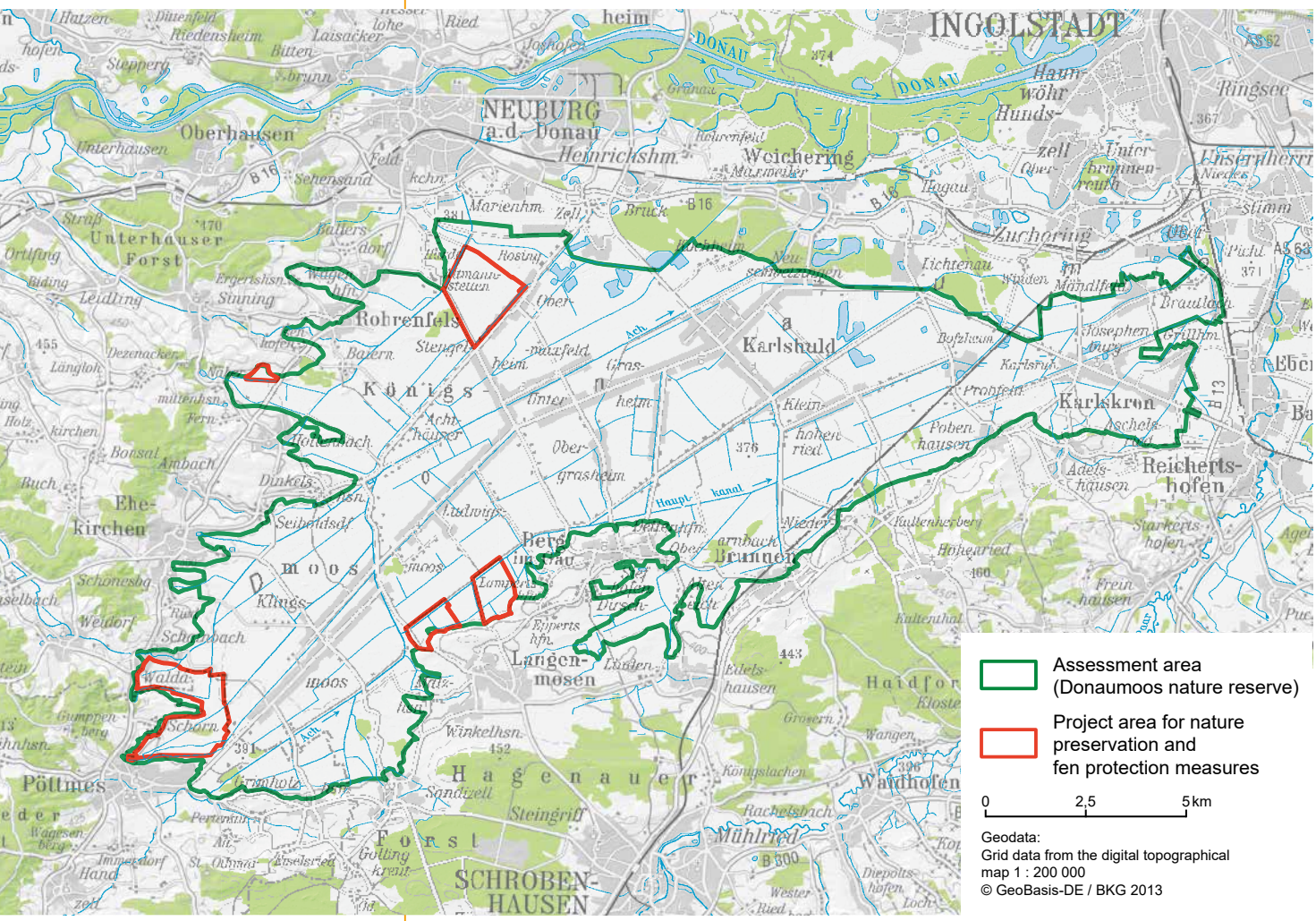
With the decreasing level of the fen, the drainage function of the artificial ditches has been increasingly impaired, making agricultural use more difficult. The shrinking of the fen also released a considerable amount of climate-damaging CO_2 and reduced the retention function of the Donaumoos. Habitats and species typical for the fen were lost.

For this reason, the Donaumoos interest group has drawn up a development concept for the Donaumoos. It is intended to enable the protection and sustainable use of the fen. However, specific measures have only been implemented hesitantly so far, due to the complex inter-relationships and reservations among the population.

With the 'Digitalisation, modelling and visualisation of the Donaumoos water system' project, which ran until 2020, the Ingolstadt Water Administration Office developed a tool that is able to calculate the potential and effects of specific measures on the groundwater situation, as well as the run-off. Thanks to a clear visualisation of the results, the effects of the measures can be presented in a way that can also be understood by laypersons, thereby removing any reservations.

The project thus creates a sustainable and secure basis for decision-making for the planned measures, supports them in the context of approval procedures, and creates acceptance among the public.

The project areas within the Donaumoos natural habitat



The Isar near Landau: A new habitat for Huchen & Co. is being created here.

LIFE Nature Project, 'Isar River Experience'

In 2015, the EU-funded LIFE Nature project entitled 'Isar River Experience' was approved. Since then, the Landshut Water Administration Office and the Government of Lower Bavaria, as the higher nature conservation authority, have been working together to restore the Lower Isar from Loiching to Ettling to a more natural state.

After restoring the canalised Isar in Dingolfing and near Loiching, the third major hydraulic engineering measure was the near-natural redesign of the Isar near Landau over the winter of 2019/2020.

The core element is an approximately 600-metre-long tributary of the Isar, which is to provide new habitats for river fish species that have become rare, such as the Danube salmon. To this end, the riverbed and the bank zones of the new tributary will be designed to be as structurally rich and close to nature as possible, containing elements such as shallow water zones, driftwood and a shallow oxbow with adjacent retention surfaces and depressions.

In addition, in keeping with the stepping stone principle, there will be many smaller measures focusing on water, forest and meadows in the Isar wetlands. These include, for example, the creation of lowland meadows and semi-arid grasslands with the aid of sowing with native threshing material, or the optimisation of existing riparian forests through partial clearing with subsequent reforestation.

The stepping stone principle safeguards existing species and their habitats whilst, at the same time, stimulating their spread into adjacent areas; in the long-term, an ecological connection of the stepping stones should create a coherent and species-rich river landscape that is closer to nature.

All these measures contribute to the implementation of the EU Water Framework Directive and the Natura 2000 Habitats Directive. The project is the first to be jointly supported by the water administration and nature conservation administration and, with a budget of around 6.4 million euros, it is the largest LIFE Nature project in Bavaria to date.

The 'waterwheel' mascot accompanies young and older visitors on the nature trail

'How far can I push a column of water upwards?' Try it out!

The 'Water Power Trail' at the great Brombach Lake

The adventure trail of the Ansbach Water Administration Office at the dam of the great Brombach Lake, which opened in 2019, shows a varied development of hydropower utilisation. Through the use of different media, it can be experienced interactively for all generations over the course of time. For example, you can feel the strength of the force of water in your own body. "How far can I push a column of water upwards?" Guests are rewarded with an X-ray view into the lake at the site of the sunken mills. At the power house below the dam, information is vividly provided on current conventional hydropower technology and innovative developments towards a more fish and environmentally-friendly use of hydropower.

Following in the footsteps of the past, visitors to the historic Mandlesmühle mill can experience how old waterwheels worked, and gain insights into the grinding room and the life of a miller. In addition, a game invites visitors to compete in the adjacent former sawmill: Handsaws versus hydropower – which is faster? The virtual 'waterwheel' takes young guests on a journey into the exciting world of hydropower and guides them around the adventure trail and the accompanying app.

For further information

www.wwa-an.bayern.de > wasser erleben > erlebnispfad

This station invites you to take part in a competition: Handsaws versus hydropower – which is faster?

Licca liber – the free Lech

In recent decades, the Lech has steadily deepened between barrage 23 near Königsbrunn and the Gersthof weir, causing valuable habitats for fish and other aquatic organisms to disappear. The groundwater level sank, which had negative consequences for the drinking-water supply near the river and the floodplain.

Today, numerous uses, such as drinking-water protection areas, restricted-access forests and hydroelectric power-plants along the straightened Lech pose a great challenge for the intention to return the river to its natural state.

For this reason, the Donauwörth Water Administration Office launched the Licca liber project in 2013 to restore the Lech to its original character as far as is possible and to prevent it from deepening further. Part of the project was a 'river dialogue' with various stakeholders and citizens of the city of Augsburg and the municipalities of Kissing, Königsbrunn and Mering. Shared development goals for the Lech were defined, taking into account the possible impacts on groundwater and the stability of the riverbed.

Following the original Lech, with its widely ramified riverbed, additional tributaries are now being created, between which the terrain is partly removed. In this way, floodplain areas are reclaimed and are once again frequently flooded and connected to the groundwater. Fish and other aquatic life can now once again migrate through the Lech following the removal of weirs and the conversion into bottom-supporting and passable ramp structures.

The hard shoring of the Lech bank and the chains of barrages above the project area prevent the transport of gravel into the riverbed. The river dialogue called for impetus for the Lech.

Regular additions of gravel downstream from barrage 23 return the dynamics to the further flow section, so that migrating gravel banks can develop. With the removal of numerous riverbank obstructions, soft banks are to now be created, drawing on the dynamics of the Lech itself.

Given its meandering course, it can erode outer bank areas itself and create a wide, varied riverbed. Concealed safety barriers restrict the new course of the Lech from a width of about 130 metres in order to avoid adverse effects on drinking-water wells, among other things.

Before/after: In the summer of 2019, the Lech in the project area looks as shown at the top. The photomontage below shows how it could look there in the future.

The total area of the Weidachwiesen flood polder covers approximately 180 hectares, and provides a flood retention volume of around 6.3 million cubic metres.

Flood protection on the Upper Iller – Weidachwiesen flood polder

The flooding and dike breaches during the Whitsun Flood of 1999 caused damage to the Iller River amounting to 60 million euros. As the floods of the Iller occur in the Alpine catchment area, the need to improve flood protection during extreme flooding in the upper reaches of the Iller was recognised.

Flood protection was therefore improved to a uniformly higher protection level over a total stretch of 25 kilometres, and the canal-like Iller was transformed into a richly structured, ecologically valuable river landscape.

The Weidachwiesen flood polder has a key position in the project.

In the area of the Seifen Basin on the Iller River, the topographical conditions made it possible to create a controlled retention area covering 180 hectares, with a retention volume of 6.3 million cubic metres.

The task of the polder is to lower extreme flood peaks in order to protect the built-up areas from damage. The degree of protection was determined by the past Whitsun flood of 1999. With six weir fields, up to 140 cubic metres of water per second can be siphoned off from the Iller and fed into the polder via a flood channel and held back, depending on the flood forecast and course. However, the polder is also used during minor flood events, where it counteracts an increase in runoff for the people directly downstream resulting from the expansion of the Iller. The project was financed with funds from the EU, the Free State of Bavaria, neighbouring municipalities, the district of Oberallgäu and the Federal Republic of Germany.

Since the Weidachwiesen flood polder was put into operation in 2007, it has already been used successfully several times to retain smaller floods.

Wöhrder See Water World

In 1981, the damming of the Pegnitz created an attractive recreational area in the middle of Nuremberg, the Lake Wöhrder See.

However, the lake had silted up over the years and algae carpets marred its appearance. With the 'Wöhrder See Water World' project, the Nuremberg Water Administration Office has been restoring the lake since 2011. A key aspect of the implemented measures is the narrowing of the watercourse profile to increase the flow velocity within the reservoir between the intake and outflow of the Pegnitz. This increased flow reduces siltation from the depositing of fine sand, while counteracting the growth of algae at the same time.

The lake is divided into two areas: The Lower Wöhrder See, completed in 2018, invites visitors to relax on its sandy beach and Norikus Bay. The Upper Wöhrder See is reserved for nature with the aim of increasing the biodiversity of flora and fauna within the city. The raising of islands creates ecologically valuable shallow banks, and the construction of a fish pass links diverse habitats.

The 'Wöhrder See Water World' project is an example of the successful linking of water use by the population, and the increased biodiversity around a body of water within a large city.

The sandy beach at Wöhrder See – shown here in the aerial photo – is a special attraction.

Aerial view of the Wöhrder See: on the left, the sandy beach completed in 2018, opposite the Norikus Bay

Service Section –

for those who want to know more …

Bavaria, Land of Water poster series

www.bestellen.bayern.de > Niederschläge

www.bestellen.bayern.de > Grundwasser

www.bestellen.bayern.de > Seen

www.bestellen.bayern.de > Fließgewässer

www.bestellen.bayern.de > Trinkwassergewinnung

www.bestellen.bayern.de > Abwasserentsorgung

www.bestellen.bayern.de > Grundwasserlandschaften

www.bestellen.bayern.de > Grundwasserschutz

Accompanying the brochure entitled 'Bavaria, Land of Water', a series of posters (DIN A2 format, horizontal) illustrates various water management topics in loving detail: Precipitation, groundwater, lakes, watercourses, extraction of drinking-water, wastewater disposal, groundwater landscapes and groundwater protection in house and garden.

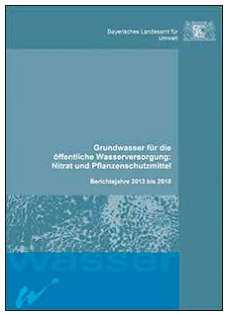
Publications

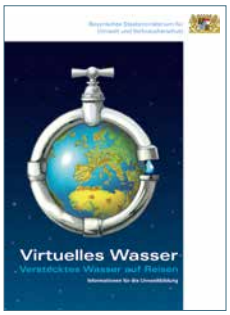
www.bestellen.bayern.de > Umwelt und Verbraucherschutz > Wasser

All the publications about water management – most of which are free-of-charge – can be ordered or downloaded as a PDF document from the Bavarian State Government's webshop.

All materials published by the Bavarian State Ministry of the Environment and Consumer Protection can be explored on its website.

www.lfu.bayern.de > Publikationen





Water management: local, regional and national – strategies, concepts and projects

The 17 local state offices for water management in Bavaria are contact partners for local water management topics, such as flood prevention projects, water supply or watercourse development. On its websites, you can find general information on water management in Bavaria, and learn about particular local topics, such as water construction projects and the reservoirs in its area of responsibility.

The Bavarian Environment Agency, as the specialist state-wide higher-level environmental authority, ensures, for example, uniformity in environmental standards in Bavaria and provides general, as well as more detailed, specific information on water management topics.

The Bavarian State Ministry for the Environment and Consumer Protection develops strategies, guidelines and concepts for Bavarian water management. To achieve this, in addition to information on local and regional features of Bavaria, national and international technical and legal content must be co-ordinated with the federal government and the European Commission. On its website, the ministry presents specialised content related to water management, including strategic concepts.

www.stmuv.bayern.de > Themen > Wasser > Wasserwirtschaft > Wasserwirtschaftsämter

www.lfu.bayern.de

www.stmuv.bayern.de > Themen > Wasser

Warning services

Warning services offer up-to-date environmental information. Using highly sensitive measuring equipment from a number of networks that extend across Bavaria, such as water level or rainwater gauges, the latest measurements are constantly presented online. In addition, some data is measured manually, for example, snow profiles for the avalanche warning service. For local residents, the emergency services and experts, the online information services form the basis for preventative and prudent action: in particular, the continual observation of the data trends enables co-ordinated planned action and quick reaction to changes in the environment.

The Flood Information Service (HND) publishes water levels and warning levels, flood reports and flood warnings.

The Low Water Information Service (NID) gives timely information to water users, such as water suppliers, power-plant operators and farmers, about low water threats, for example, with the low water status report.

The Avalanche Warning Centre issues a daily status report during the winter months, with information on the present danger level, the snow cover, and the number and distribution of hazardous areas for the six Bavarian alpine regions. Webcams and data from the monitoring stations, as well as road closure information, complement the winter online services which are not only for winter sports enthusiasts.

www.hnd.bayern.de

www.nid.bayern.de

www.lawinenwarndienst-bayern.de

Photo, left: Repair work at the avalanche warning service monitoring station on the Zugspitz plateau

Photo, right: Water level monitoring station with the batten gauge on the Lothdorfer Stream, Dürnhausen

Map service

www.lfu.bayern.de > Umweltdaten > Kartendienste Umweltatlas

Presenting environmental data that has been gathered for the whole of Bavaria or for a limited area, not only in tables or diagrams, but prepared in map form, is a vital part of an environmental information service. Our presentation tool in Bavaria is the UmweltAtlas Bayern (Environmental Atlas Bavaria), the central map service that provides geospatial data in a web application.

The water management theme palette is located in the main categories of 'basic watercourse data', 'geology', 'applied geology', 'natural hazards', 'waters classification and directories' and 'water management'.

Under these themes, with their various aspects, the Environmental Atlas offers a palette of various functionalities, a clear operating structure with data masks, a visually intricate design and the option to print the maps generated according to query.

Examples from the natural hazards and water management categories:

- Geohazards: Mass movements, hazard index maps …
- Flood hazards:
  Risk waters, flood hazard areas, torrent incidents …
- Avalanches.
- The European Water Framework Directive: Bodies of water (lakes, watercourses, groundwater), status, action planning …
- Water protection: Wastewater treatment plants (local authority wastewater treatment plants, industrial/commercial direct dischargers).
- Protected areas and sites relevant to water protection: Water supply, water-dependent features of Natura 2000 sites.

Only a few map services are currently separate from UmweltAltas Bayern, such as the Information Service on Flood-Prone Areas (IÜG), which particularly focuses on flood hazards and risks.

www.lfu.bayern.de > Wasser > Hochwasser > Informationsdienst Überschwemmungsgefährdeter Gebiete

Information services

A responsible society puts large-scale water management projects on its future agenda. Online platforms are available to provide comprehensive information about these activities to businesses, local authorities and residents. There is information on the stakeholders involved in environmental protection, especially water protection, and special tools for querying specific starting points. However, strategies and concepts for sustainable behaviour are also mentioned. These enable the users to recognise and optimise economic synergy effects.

The Environmental Economics Information Centre (IZU) of the Bavarian Environment Agency offers information on industrial environmental protection of a legal and technical nature.

As a portal on energy transformation and climate protection, the Bavarian Energy Atlas provides information on the expansion of renewable energies, such as hydroelectric power and shallow geothermal energy.

Natural Dangers Management is concerned with the control, the regeneration and the prevention of danger. In view of geological dangers, flooding and low water levels and avalanches, the necessity to co-ordinate activities, exchange knowledge and experiences, and develop mutual understanding was the primary reason for establishing the Bavarian Natural Dangers platform.

The Flooding Information portal takes up the theme of flood prevention. The six target groups – residents, local authorities, town and landscape planners, architects, home-owners, industry and agriculture each find information here that has been tailored to them:

What can I do before, during and after a flood in order to prevent or reduce damage? A Twitter channel is also included.

In order to interest school children in the theme of water, the Groundwater Protection Campaign and the Bavarian Water School supply information and teaching materials.

www.naturgefahren.bayern.de

www.hochwasserinfo.bayern.de

twitter.com/Hochwasser_Info

www.lfu.bayern.de:
Wirtschaft > Infozentrum UmweltWirtschaft

www.energieatlas.bayern.de

www.grundwasserschutz.bayern.de

www.stmuv.bayern.de >
Themen > Wasser >
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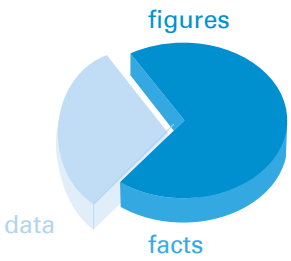
Key Figures on Water in Bavaria



Bavaria

Area	approx. 70,540 km²
Residents	approx. 13,067,300
Municipalities	2,056

Bodies of water

All streams and rivers	approx. 100,000 km
Class I. Order (large, nationally significant rivers)	4,200 km
Class II Order (regionally significant rivers)	4,800 km
Larger natural lakes/number	150
Larger natural lakes/area	270 km²
State-managed river dams and floodwater containment basins	25
Hydroelectric power-plants	approx. 4,200

Water cycle in Bavaria (1971–2000)

Average annual precipitation	939 mm
Average annual precipitation	422 mm
Average actual annual evaporation	517 mm

Public water supply system

Connection rate	99.2 %
Per capita usage [litres per resident and day]	131 l/E x d
Water suppliers	2,232
Water catchments	approx. 8,400
Water extraction plants	2,922
Drinking-water protection areas	approx. 3,100

Public wastewater disposal system

Connection rate to public sewer system	approx. 97 %
Connection rate to public sewage treatment plants	approx. 97 %
Length of public sewer system	approx. 95,300 km
Number of public sewage treatment plants	2,486
Facilities channeling treated wastewater directly into water bodies (direct dischargers)	approx. 900
Facilities discharging wastewater into sewer system (indirect dischargers)	approx. 1,700

An overview of the environmental administration in Bavaria

Local state water management offices (WWA)

On the Environment Ministry website, you will find links to the websites of the local state water management offices.

- WWA Ansbach
  Dürrnerstraße 2, D-91522 Ansbach
  Tel. +49 981 9503-0, Fax +49 981 9503-210
- WWA Aschaffenburg
  Cornelienstraße 1, D-63739 Aschaffenburg
  Tel. +49 6021 5861-0, Fax +49 6021 5861-840
- WWA Bad Kissingen
  Kurhausstraße 26, D-97688 Bad Kissingen
  Tel. +49 971 8029-0, Fax +49 971 8029-299
- WWA Deggendorf
  Detterstraße 20, D-94469 Deggendorf
  Tel. +49 991 2504-0, Fax +49 991 2504-200
- WWA Donauwörth
  Förgstraße 23, D-86609 Donauwörth
  Tel. +49 906 7009-0, Fax +49 906 7009-136
- WWA Hof
  Jahnstraße 4, D-95030 Hof
  Tel. +49 9281 891-0, Fax +49 9281 891-100
- WWA Ingolstadt
  Auf der Schanz 26, D-85049 Ingolstadt
  Tel. +49 841 3705-0, Fax +49 841 3705-298
- WWA Kempten
  Rottachstraße 15, D-87439 Kempten
  Tel. +49 831 5243-01, Fax +49 831 5243-216
- WWA Kronach
  Kulmbacher Straße 15, D-96317 Kronach
  Tel. +49 9261 502-0, Fax +49 9261 502-150
- WWA Landshut
  Seligenthalerstraße 12, D-84034 Landshut
  Tel. +49 871 8528-01, Fax +49 871 8528-119
- WWA München
  Heßstraße 128, D-80797 München
  Tel. +49 89 21233-03, Fax +49 89 21233-2606
- WWA Nürnberg
  Allersberger Straße 17/19, D-90461 Nürnberg
  Tel. +49 911 23609-0, Fax +49 911 23609-101
- WWA Regensburg
  Landshuter Str. 59, D-93053 Regensburg
  Tel. +49 941 78009-0, Fax +49 941 78009-222
- WWA Rosenheim
  Königstraße 19, D-83022 Rosenheim
  Tel. +49 8031 305-01, Fax +49 8031 305-179
- WWA Traunstein
  Rosenheimer Str. 7, D-83278 Traunstein
  Tel. +49 861 70655-0, Fax +49 861 13605
- WWA Weiden
  Gabelsbergerstraße 2, D-92637 Weiden in der Oberpfalz
  Tel. +49 961 304-0, Fax +49 961 304-400
- WWA Weilheim
  Pütrichstraße 15, D-82362 Weilheim
  Tel. +49 881 182-0, Fax +49 881 182-162

District governments

The following are responsible for health, the environment, and consumer protection in the various Bavarian districts.

- Government of Upper Bavaria
  Maximilianstraße 39, D-80538 München
  Tel. +49 89 2176-0, Fax +49 89 2176-2914
  www.regierung.oberbayern.bayern.de
- Government of Lower Bavaria
  Regierungsplatz 540, D-84028 Landshut
  Tel. +49 871 808-01, Fax +49 871 808-1002
  www.regierung.niederbayern.bayern.de
- Government of the Upper Palatinate
  Emmeramsplatz 8, D-93047 Regensburg
  Tel. +49 941 5680-0, Fax +49 941 5680-1199
  www.regierung.oberpfalz.bayern.de
- Government of Upper Franconia
  Ludwigstraße 20, D-95444 Bayreuth
  Tel. +49 921 604-0, Fax +49 921 604-1258
  www.regierung.oberfranken.bayern.de
- Government of Middle Franconia
  Promenade 27, D-91522 Ansbach
  Tel. +49 981 53-0, Fax +49 981 53-1206
  www.regierung.mittelfranken.bayern.de
- Government of Lower Franconia
  Peterplatz 9, D-97070 Würzburg
  Tel. +49 931 380-00, Fax +49 931 380-2222
  www.regierung.unterfranken.bayern.de
- Government of Bavarian Swabia
  Fronhof 10, D-86152 Augsburg
  Tel. +49 821 327-01, Fax +49 821 327-2289
  www.regierung.schwaben.bayern.de

Bavarian State Ministry of the Environment and Consumer Protection

Rosenkavalierplatz 2
D-81925 Munich
Tel. + 49 89 9214-00,
Fax + 49 89 9214-2266
www.stmuv.bayern.de

Bavarian Environment Agency

Bürgermeister-Ulrich-Straße 160
D-86179 Augsburg
Tel. + 49 821 9071-0,
Fax + 49 821 9071-5556
www.lfu.bayern.de

Local state water management offices

www.stmuv.bayern.de > Ministerium > Behörden im Geschäftsbereich > Wasserwirtschaftsämter

District administration offices and urban districts

The district administration authorities also attend to environmental protection, focusing particularly on nature protection, soil protection, technical environmental protection, waste management and water management.
BayernPortal > Behörden > Kreisverwaltungsbehörden

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District government seat

Independent city /
seat of the county administrative office

A County license plate number

Munich Domicile of the Lokal
State Water Management Office

National border

State border

County and independent
city border

Border of the Lokal
State Water Management Office

River

Channel

Lake

0 25 50 km

This brochure takes you on a journey through Bavaria, the land of water. It depicts the water cycle – rainfall, groundwater, the various rivers and lakes – and how we can use water sustainably and maintain it for future generations.