CITY AND WATER

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Prague -
the Growth Pole of the Czech Republic

PRAHA PRAGUE PRAGA PRAG

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Photo on the title page:

Retention pond delaying water from the roofs of the Delta office building in Prague-Michle

Rainwater does not have to disappear into the sewer, even in densely built-up areas. In the immediate vicinity of the Delta building, integrated in the park greenery, are the unusual water reservoirs improving the microclimate in their surroundings, contributing to biodiversity, and increasing the aesthetic value of the location. They even improve the environment of other distant places, as they prevent the overloading of the combined sewerage system, resulting in a decrease in rainwater and sewage mixture discharged into watercourses and thus decreasing the water and stream channel pollution (in this case, the Botič Creek).

Author of photography: Martina Peláková

City and Water

T. G. Masaryk Water Research Institute, Public Research Institution
Prague 2020

Dear readers,

We live in a time when climatic conditions are changing not only in the Czech Republic, but also on the whole Earth. Recent years have shown the inertia of the entire natural system and the water cycle and the impacts changes may have, not only on management of water.

For already more than 20 years, the professional community is drawing attention to the shifting of the growing season beginning, significant increase in temperature and the uneven distribution of precipitation totals. The aim of the publication, *City and Water*, is to familiarize the general public with the basic aspects of occurrence and movement of water on Earth, in natural environments and in the cities. It is to the cities (represented by Prague) and the urban areas that we pay great attention here. In this publication, you will find answers to a number of questions, including: How have the temperature and precipitation totals changed? What is the impact of expanding the urban landscape on water quantity and quality? How do the sewerage systems work? How does the water regime change because of built-up area expansion? How to retain rainwater and then use it? What are the possibilities of recycling water locally? In addition to the texts, the publication also contains graphical statistics and simple figures and diagrams for an easier understanding of the individual phenomena.

The publication is available free of charge in printed form from the authors' team at the TGM Water Research Institute and in an electronic form on the website heis.vuv.cz/projekty/praha-adaptacniopatreni. We hope you enjoy the publication. It will help to deepen your knowledge and answer your specific questions, but we will also be happy if many other questions will come to your mind. The publication is part of a 3-part series that includes the following titles: *City and Water, Groundwater in the City* and *Adaptation of the City to Floods and Droughts.*

Team of authors

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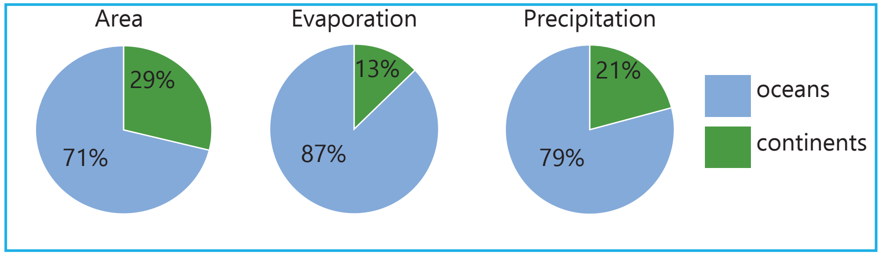
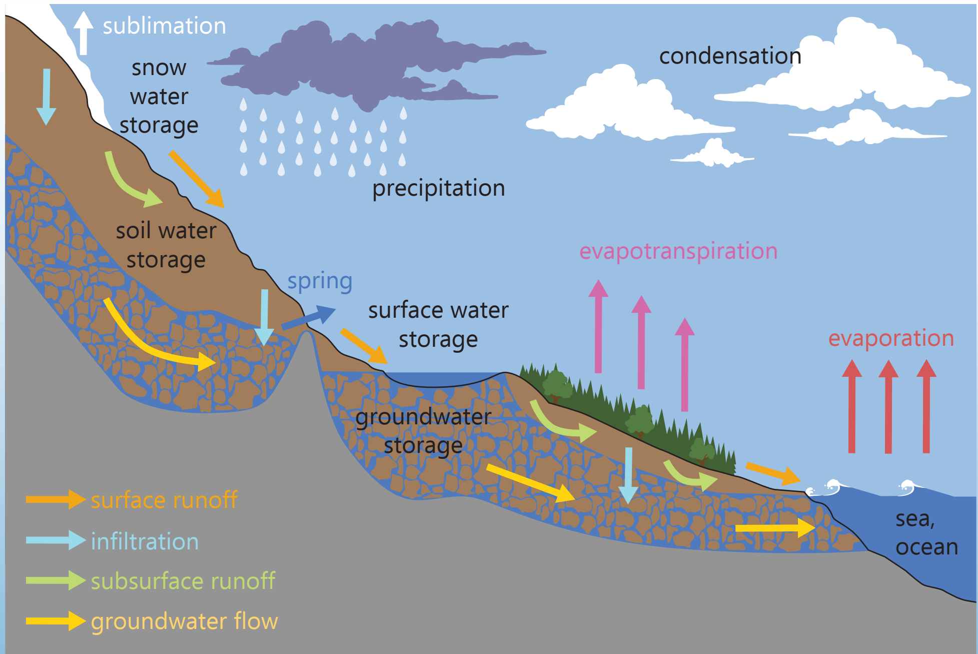
1. HYDROLOGICAL CYCLE

Water on Earth is set in motion by solar energy and gravity. Thanks to the radiation of the Sun, evaporation and sublimation occurs. Most water vapor is formed over oceans, from where it is transported by air currents, condenses when cooled and falls back into the ocean in the form of precipitation (small water cycle). A smaller part also gets transported to the continents, where it receives water vapor from the land and as it cools, e.g. by ascending on the windward side of the mountains, it condenses and falls to the surface due to gravity. Gravity transports water even on the land surface and under the surface. Precipitation fallen to the ground evaporates, flows into streams, rivers and seas or remain temporarily on land in endorheic basins, in snow, ice or in groundwater aquifers.
To a lesser extent, water vapor from the land moves over the ocean, where it condenses and falls into the ocean.



Ratios of areas and components of hydrological balance between the oceans and continents



Hydrological cycle scheme

How is the hydrological balance calculated?

The hydrological balance of a given river basin can be expressed by the equation:

PRECIPITATION = EVAPOTRANSPIRATION + SURFACE RUNOFF + SUBSURFACE RUNOFF + GROUNDWATER FLOW ± CHANGE OF WATER STORAGE

PRECIPITATION in the form of rain, snow, hail, dew, hoarfrost, ice, etc. are the only entry into hydrological balance.

EVAPOTRANSPIRATION includes evaporation (evaporation from the water surface, soil, and surface of moist plants) and plant transpiration.

- POTENTIAL EVAPOTRANSPIRATION is the maximally possible, it expresses the ability of the air environment to remove water from the surface – it corresponds approximately to the evaporation from a free water surface or evapotranspiration from a lawn with optimal humidity.
- ACTUAL EVAPOTRANSPIRATION depends on the amount of water available. From dry, bare or heavily built-up landscapes, very little water evaporates.

SURFACE RUNOFF occurs in two situations – if the upper soil profile is saturated or if the intensity of precipitation exceeds the infiltration rate. Water enters a watercourse quickly, in the order of minutes to hours.

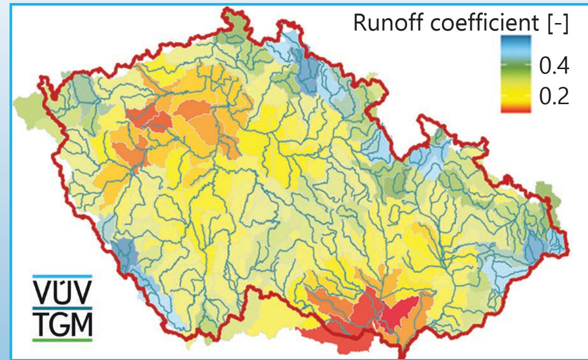
SUBSURFACE RUNOFF (INTERFLOW) takes place in the upper layer of soil and subsoil without contact with groundwater table. It enters the watercourse within a few days after the rain.

GROUNDWATER FLOW (BASEFLOW) is water flowing from groundwater storage in the form of springs or is hidden below the surface in watercourses and reservoirs. It reaches the watercourse within weeks to months after the rain.

WATER STORAGE is located in groundwater aquifers, in soil, in wetlands, in water reservoirs or in snow and ice, usually for a temporary period.

Hydrologic balance of the Czech Republic

Long-term average annual total precipitation in the Czech Republic is 680 mm, the actual evapotranspiration is 490 mm, total runoff is 190 mm, i.e. only 28% of precipitation. The ratio of runoff and precipitation is expressed as the runoff coefficient.
While the distribution of precipitation and runoff is very uneven on the territory of the Czech Republic, the actual evapotranspiration is similar in the mountains and in the lowlands, because there is enough water in the mountains, yet low temperatures; on the contrary, temperatures are high in the lowlands, yet precipitation is small.



Evapotranspiration exceeds runoff in most of the Czech Republic

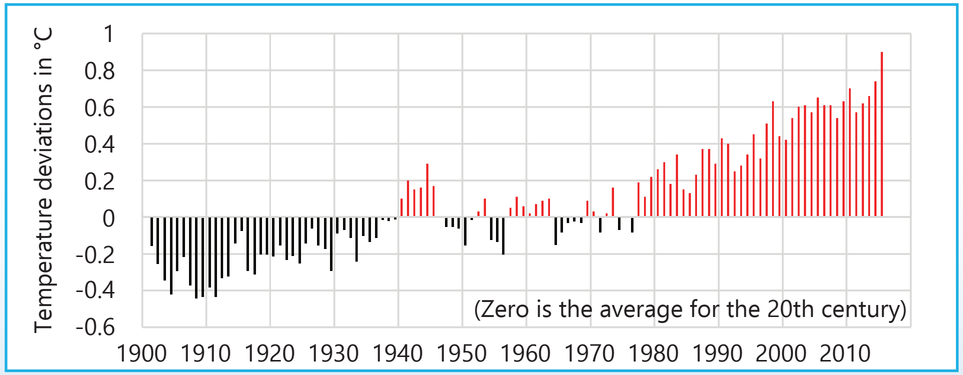
2. CLIMATE CHANGE

The climate is the result of the general circulation of the atmosphere, which is affected by the Sun's irradiation, by rotation of the Earth around its axis, the tilt of the Earth's axis, Earth's orbit around the Sun, position of the continents and mountain massifs, sea currents, albedo of the Earth's surface, volcanic activity and, in recent centuries, also by human activity.

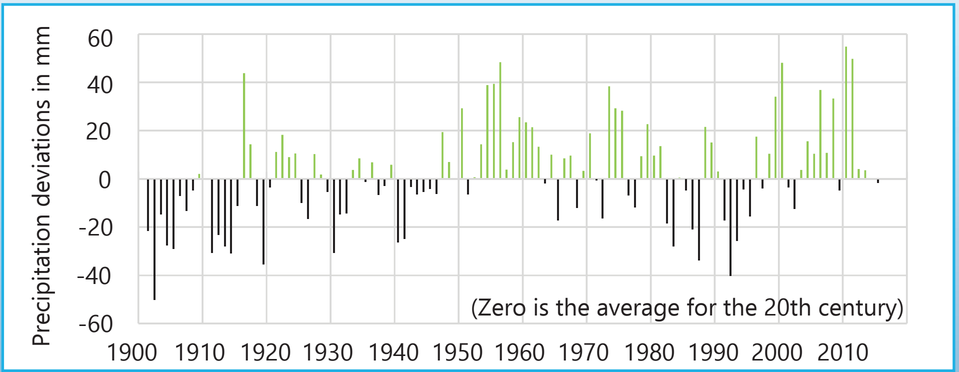
The so-called greenhouse effect has a significant effect on the Earth's climate. The atmosphere contains gases such as water vapor, carbon dioxide, methane, nitrous oxide, freons, ozone and others that transmit short-wave radiation of the Sun to the Earth, but absorb the long-wave radiation of the Earth's surface and thus heat the lower part of the atmosphere and the Earth's surface. The greenhouse effect increases the temperature on Earth by 33 °C, without it, Earth's surface would be entirely frozen.

How has the temperature and precipitation changed?

The temperature on Earth has changed many times in the past. After the end of the ice ages, during the Holocene (last 11,700 years), when humans have been engaged in agriculture, the global average annual temperature has been relatively stable, in the range of about 4 °C. The relatively stable and warm climate in the Holocene enabled the development of human civilization.



Fluctuations in average annual temperature on Earth 1901–2015 (Data source: NOAA)

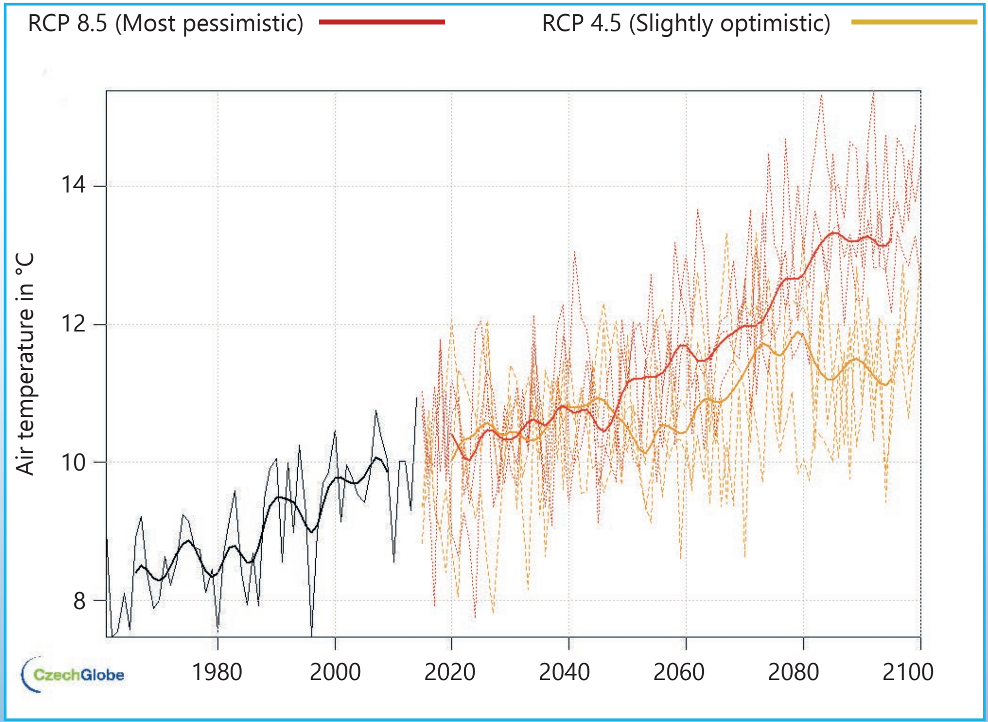


Fluctuations in annual precipitation on Earth 1901–2015 (Data source: NOAA)

Over the last 50 years, there is a clear upward global trend in temperatures, where the average annual temperature increased from 14 °C to almost 15 °C, even in the Czech Republic, where it increased from 7 °C to 9 °C. The average annual total precipitation on Earth is 990 mm and has not shown any significant trend in the last century. In the Czech Republic, the long-term average annual rainfall is 680 mm and there is also no demonstrable trend. The higher temperature results in more evaporation (especially from the oceans) and more water vapor in the air. Warmer air can hold more water vapor, so the total precipitation on Earth does not increase, but the absolute humidity of the air increases. This can result in stronger torrential rains. The increasing quantity of greenhouse gases in the atmosphere from human activities is considered to be the most likely cause of the observed warming in recent decades, especially due to the combustion of fossil fuels. The concentration of greenhouse gases is growing sharply and currently reaches the highest values for the last 800,000 years.

Greenhouse gas quantity scenarios

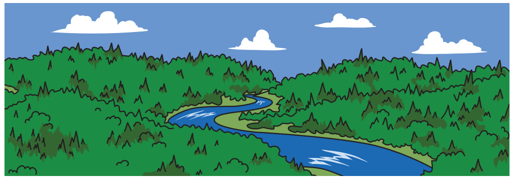
According to the greenhouse gas production scenarios using global climate models, future temperature, precipitation, and other meteorological elements are estimated. The SRES (Special Report on Emission Scenarios) scenarios from 2000 combine different alternatives of population development on Earth and the technologies used (material intensity, energy-saving technologies, fossil and non-fossil energy sources). There are many other emissions scenarios, so from 2014 four representative directions of development of greenhouse gas concentration in the atmosphere, called RCP (Representative Concentration Pathway), are used. They are marked with numbers that express how much more heat will be retained by the atmosphere in 2100 due to the added greenhouse gases (in watts per square meter).



Average annual temperature in Prague and its projections according to outputs of EURO-CORDEX models

3. LANDSCAPE URBANIZATION

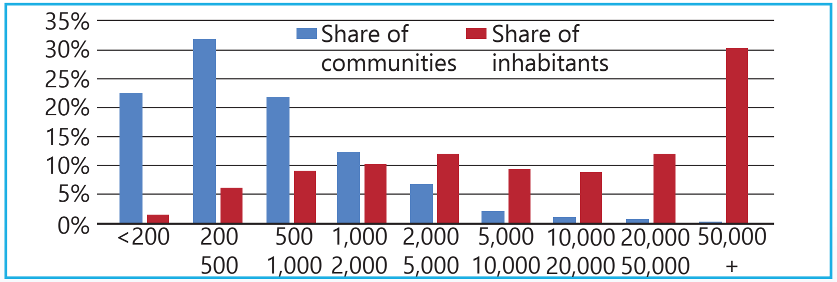
Urbanization is the process of man's acquisition of the natural environment with the SETTLEMENTS and CULTURAL LANDSCAPE as its products. Nowadays, new settlements are rarely established, more often we encounter suburbanization – expansion of the suburbs and increasing population concentration.



Unaffected natural landscape

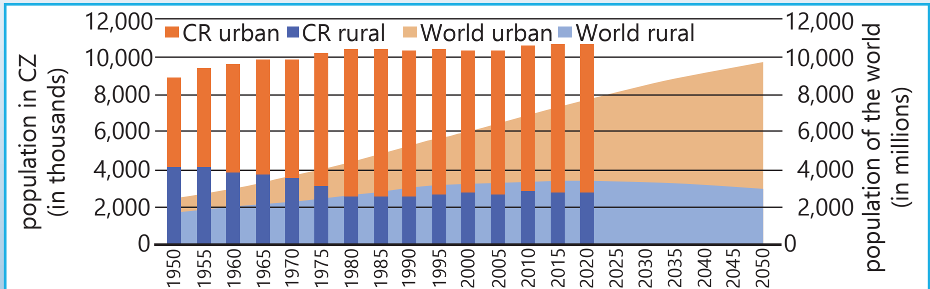
Urbanized urban landscape

Settlements can be divided into rural and urban. Urban settlements are denoted according to the number of inhabitants as a town or city. The delimiting is not globally uniform. In the Czech Republic more than 3,000 inhabitants live in a town and more than 100,000 in a city. Urban settlements differ from villages e.g. by high population density, demographic, social or professional structure of the population (lower employment in agriculture, higher in services).



Czech Republic population according to community population size (Source: CZ Stat. Office)

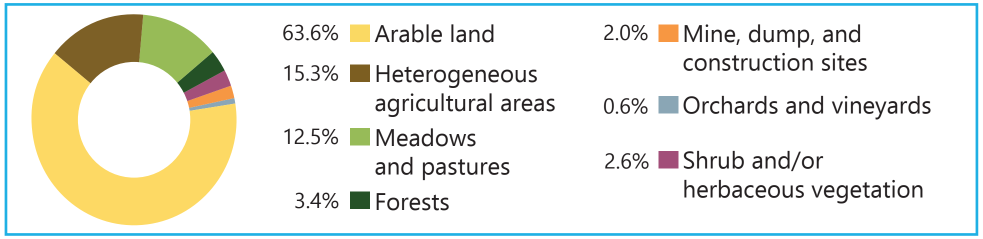
More than half of the world's population lives in urban areas, and its share is constantly growing. It is assumed that in 2030, it will reach up to 60%. However, the area of cities and towns covers only 2.5% of the land area. In the Czech Republic, approximately 70% of the population lives in urban areas and despite large local differences, on average it does not change.



Historical and predicted population living in urban and rural areas in the world and in the Czech Republic (Source: https://ourworldindata.org)

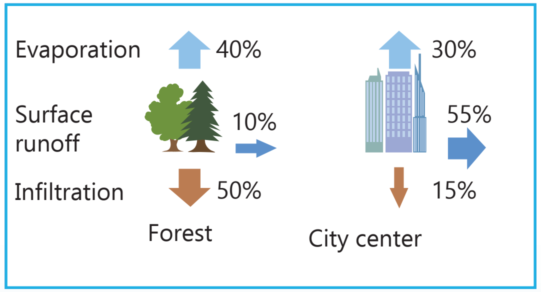
The administrative area of towns occupies 20% of the Czech Republic territory, their built-up area then about 4%.The urbanized areas of all settlements occupied a total of 5,100 km² in 2018 (an increase of more than 400 km² since 2000), which represents 6.5% of the country area.

The most visible sign of suburbanization is the URBAN SPRAWL – the non-conceptual spatial expansion of the town core into the surrounding landscape. A disconnected mosaic of residential and commercial areas is created. Since 2000, almost two thirds of newly urbanized areas were created at the expense of arable land, more than a quarter on other agricultural plots.



Share of land-cover classes occupied by urbanization in 2000–2018 (Source: CORINE)

Urbanization has a strong impact on the water regime of the area. Under natural conditions, most of the water coming from precipitation seeps in or evaporates, only a small part runs off directly. The expansion of impermeable surfaces leads to the predominance of surface runoff and a number of related problems.

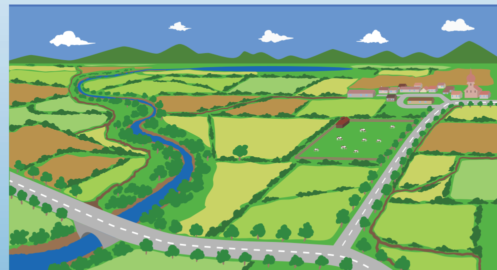


Distribution of long-term total precipitation into water balance elements

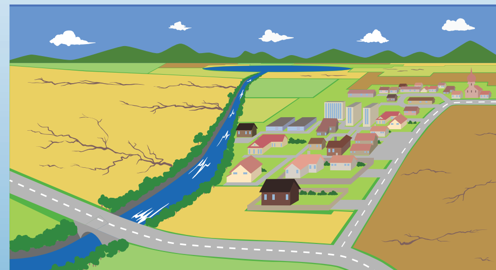
- Reduced evaporation and lower water availability for urban greenery worsen the microclimate of the city, the air is drier and warmer, dustiness increases.
- Recharge to groundwater is reduced, urban creeks are drying up.
- Increased surface runoff overloads urban sewerage systems, causes more frequent floods around urban watercourses, causes their degradation by erosion, bank failures, flushing out the organisms or overloading by pollutants.

The degree of urbanization of the landscape outside the settlements cannot be described by summarizing numbers only. For example, the share of forests is now the highest since the end of the 19th century, yet today's landscape is less diverse, and all its components have suffered significant damage due to urbanization.

Under the pressure of intensive agriculture, many hedgerows, copses, alleys, and wetlands have disappeared from the landscape. Watercourses were straightened and deepened; arable land drained by drainage systems. This has led to an overall loss of water in the landscape and a higher propensity for erosion, floods, and drought.



Slightly urbanized rural landscape

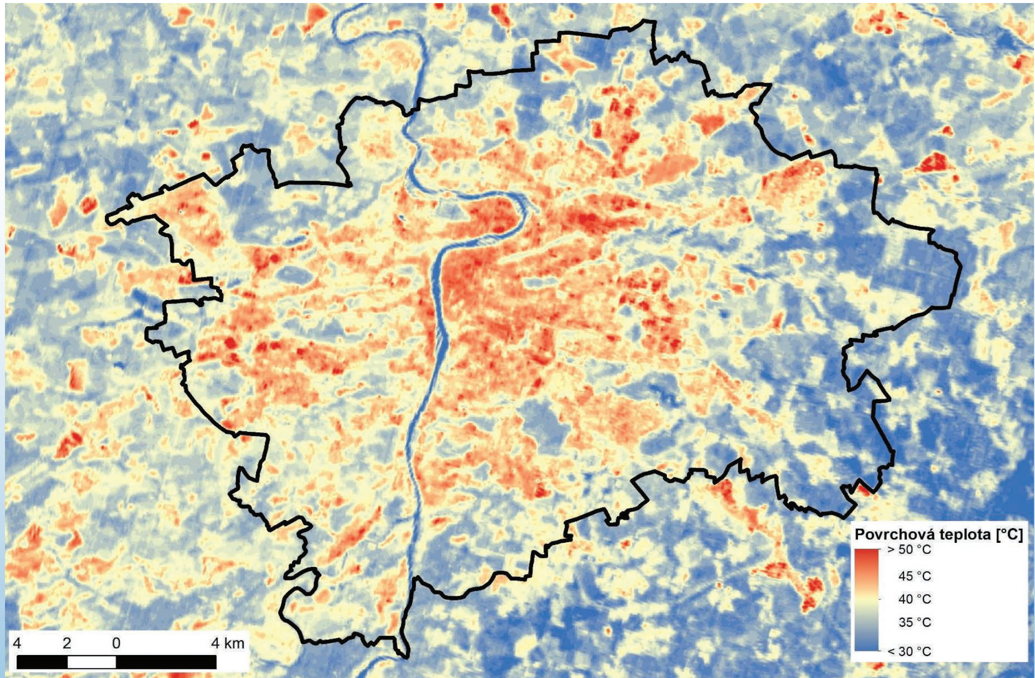


Heavily urbanized rural landscape

4. CITY MICROCLIMATE

The climate of the city differs from the surrounding climate mainly in temperature. The urban heat island is a consequence of two factors. First, the effect of the Sun's irradiation is different. If a large part of the surfaces in the city consists of asphalt, concrete, stone, fired clay or sheet metal that absorb solar energy, these materials heat up and then radiate heat to the surroundings and the air temperature rises. In contrast, water bodies can reflect the Sun's radiation and remove heat from the surroundings to heat and evaporate water. Green areas consume energy from the Sun for photosynthesis and transpiration. Plants cool themselves by absorbing water by roots from the ground and then releasing it through leaves, thus cooling the surroundings. The second factor creating an urban heat island is the secondary heat arising from the leakage of buildings (heat loss of building structures, ventilation, air conditioning), from motor vehicles and from industrial production.

That is why cities are currently focusing on building blue-green infrastructure. Ideally, a city should have as many areas overgrown with greenery (including green roofs) or covered with water as possible. Road traffic should be restricted or at least routed underground. In new buildings, attention is paid to thermal insulation and ventilation systems (heat recovery). Attempts to utilize surfaces capable of reflecting the Sun's radiation in construction are, so far, unique.



Surface temperature on the territory of Prague and its surroundings on June 20, 2017 (from satellite data LANDSAT-8) © GISDAT (On this day, the maximum air temperature, 33 °C, was measured at the Prague-Libuš station.)

Nevertheless, the urban landscape has one advantage during the heat waves. The buildings provide shade similar to trees and thus reduce overheating of surfaces and people. However, this does not apply to buildings that have large roof areas and lack height fragmentation, such as train station halls, warehouses, depots and shopping malls.

How do the individual surfaces heat up?

Very strongly
Warehouses and industrial areas, shopping centers, markets, depots, asphalt areas

Strongly
Rocks, dense development of the center, panel housing estates

Medium
Dry meadows, parks, low-density development of family houses

Slightly
Wet meadows, forests

Very slightly
Rivers, streams, lakes, water reservoirs

The heating of fields depends on the state of the vegetation. Bare soil heats up very strongly. On the contrary, dense mature vegetation with sufficient water heats up only slightly.

Presence of vegetation and water are the key elements to cool the cities. And vegetation needs water.

5. SOIL IN URBAN AREAS

Urban soils are under strong human influence and this is reflected by their properties, having an undeniable effect not only on water infiltration and on the water capacity of the soil layer, but also on how the vegetation utilizes soil moisture.

While the soil in rural areas is subject to continuous development, which gives rise to natural soil stratification, usually adapted to the effective penetration of water through the soil horizon, the soil in an urbanized area has a number of characteristics, especially negative ones, caused by human activity. Because of the processes the soil in an urbanized area undergoes, it has significant horizontal and vertical variability, it is often very compacted, which is associated with a limited possibility of water flow and aeration, resulting in reduced soil biota activity and nutrient movement. On such soil, an impenetrable crust is often created, deepening these negative phenomena even more. This creates a "dead" soil with low infiltration capacity, low water retention and accumulation capacity.

Properties of urban soil

The physical and chemical properties of soils in cities are characterized by high variability, depending on its use. Typically, the upper horizon is disturbed and mixed by heavy machinery and affected by technical interventions that affect the following processes:

- INFILTRATION

In urbanized river basins, the topsoil is often compacted. As soil particles are squeezed together, pores are reduced in size and number. Therefore, the infiltration rate is decreased. Furthermore, infiltration is completely disabled on paved areas, built-up areas, etc. because the water is diverted into the sewer without reaching the soil profile at all.

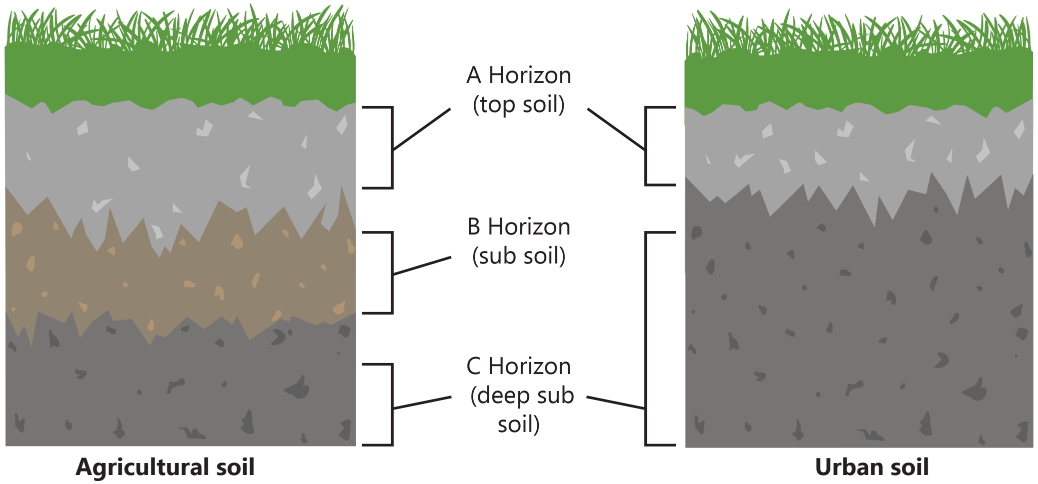
- RETENTION

In hydrology, soil water retention presents the ability of the soil profile to temporarily hold water. The main component defining the retention capacity of the soil is the organic matter (humus), which is usually very limited in urban soils. Drainage systems and other forms of de-watering also have a negative effect on retention, as they accelerate water runoff from the soil.

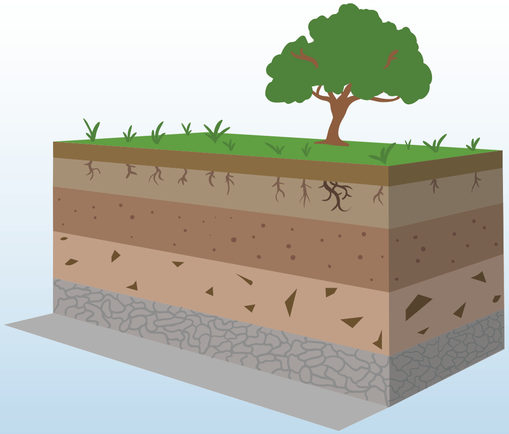
- SOIL CHEMISTRY AND SOIL WATER POLLUTION

Abnormal chemistry is typical for urban soils due to the presence of foreign substances. Contaminants such as heavy metals, salts and other substances enter the soil water during surface runoff and by leaching when water seeps through the soil profile. Increased content of salts and calcium causes higher pH values. These issues create an unnatural environment that is unfavorable for soil organisms.

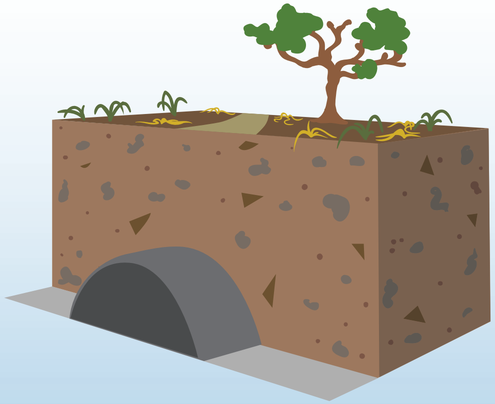
Typical layering of the soil profile



An extreme case of soil disturbance, or rather its destruction, occurs as a result of cut-and-cover tunnel construction, where all the soil layers are removed, and after the construction of the tunnel, the pit is backfilled. In such conditions the soil is dysfunctional, and the plants suffer on it, especially in dry periods.



Natural soil stratification (before the tunnel construction)

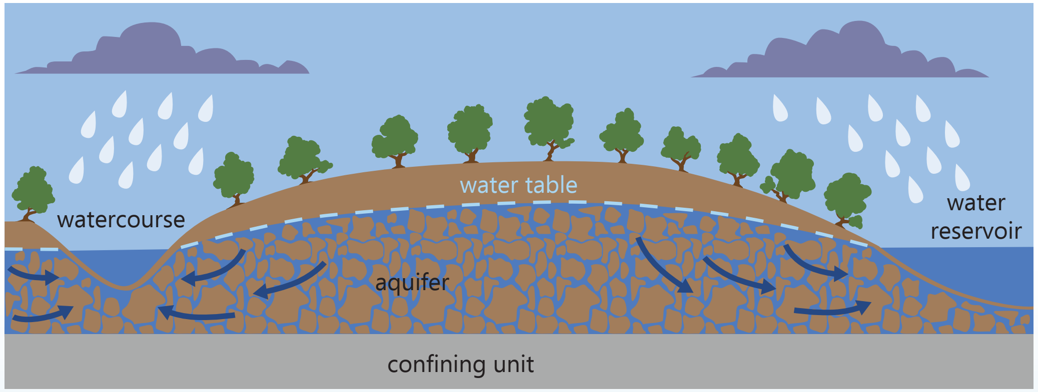


Soil horizons are mixed (after the tunnel construction)

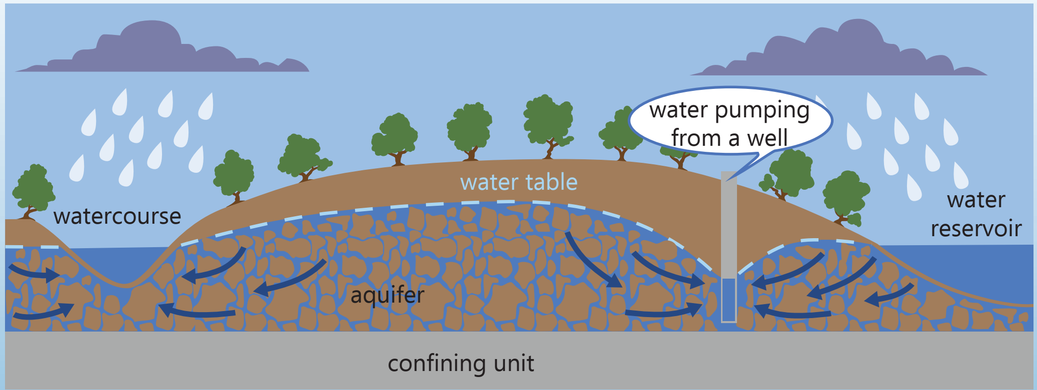
6. GROUNDWATER

Water that exists in fully saturated fractures and pores in rock and sediment beneath the Earth's surface is called groundwater. It enters the underground mainly by surface infiltration during the rainy days and during the snowmelt period. Rainwater first passes through the soil layer, where part of the water is retained and used by plants or drained by natural or artificial drainage into watercourses, the remaining part percolates deeper and becomes groundwater. Groundwater is set in motion by external forces (especially gravity).The emergence of groundwater on the Earth's surface takes the form of springs or hidden discharge into watercourses and reservoirs. Man uses wells or boreholes to draw on groundwater resources.

Groundwater discharge, which is an important part of the flow in watercourses, is called the baseflow. It makes up an average of 25% to 80% of the total runoff, but in times of drought it is up to 100%. For example, river basins consisting of claystone, slate or granite have smaller baseflow than sandstone river basins.



Groundwater infiltration, flow and outflow

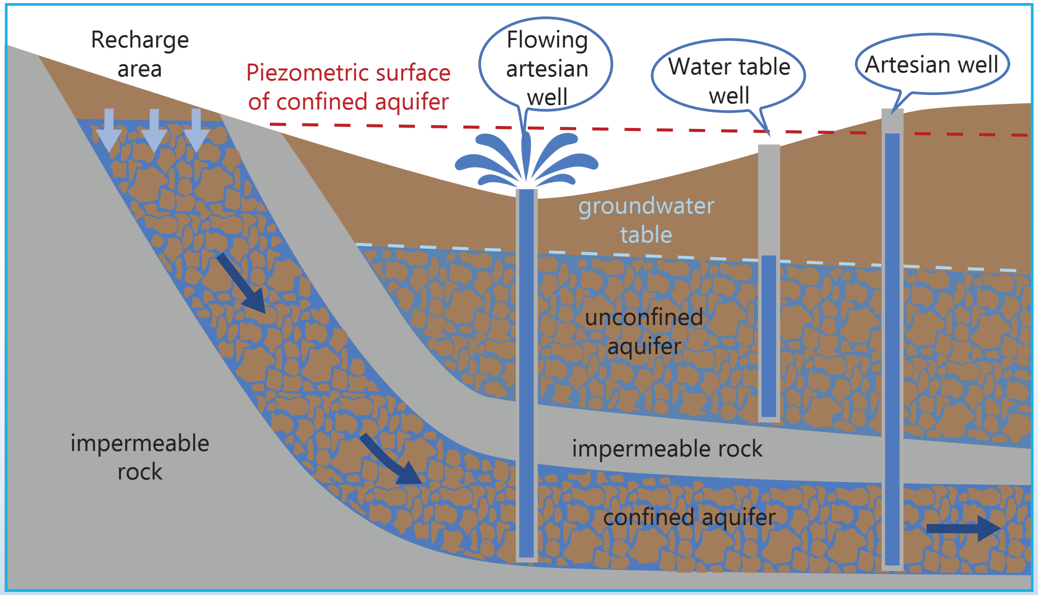


Influence of groundwater pumping on groundwater flow and water table

Groundwater quality

The chemical type of groundwater depends on the chemical composition of the atmospheric precipitation at the site of infiltration, type of rock environment and residence time, activities of organisms, etc. The natural composition of groundwater is also affected by human activities. Anthropogenic pollution progresses through the rock environment at different speeds. The vulnerability of groundwater to pollution depends on the type of aquifer, the character of groundwater circulation and the water permeability of the rock environment. In general, well-permeable shallow Quaternary aquifers (in floodplains) are more vulnerable because of the environment consisting of sand and gravel; here, the pollution spreads rapidly. In contrast, in large aquifers with deep circulation of groundwater, with the exception of areas of recharge, the vulnerability is low, especially when overlaid by low permeability overburden (siltstone, claystone, clay). On the other hand, remediation of shallow aquifers is easier to implement than removing contamination penetrated into deep aquifers (e.g. remediation after chemical uranium mining in Stráž pod Ralskem).

Groundwater is a natural source of quality drinking water, which often requires none or only minimal treatment. Approximately half of drinking water in the Czech Republic comes from underground sources.



Boreholes in confined and unconfined aquitards

Hydrogeological terms:

Aquifer – permeable rock allowing water accumulation

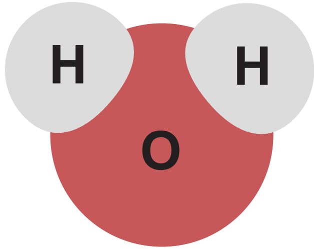
Aquitard – impermeable rock

Groundwater body – a continuous body of water located in an aquifer

7. NATURAL WATER QUALITY

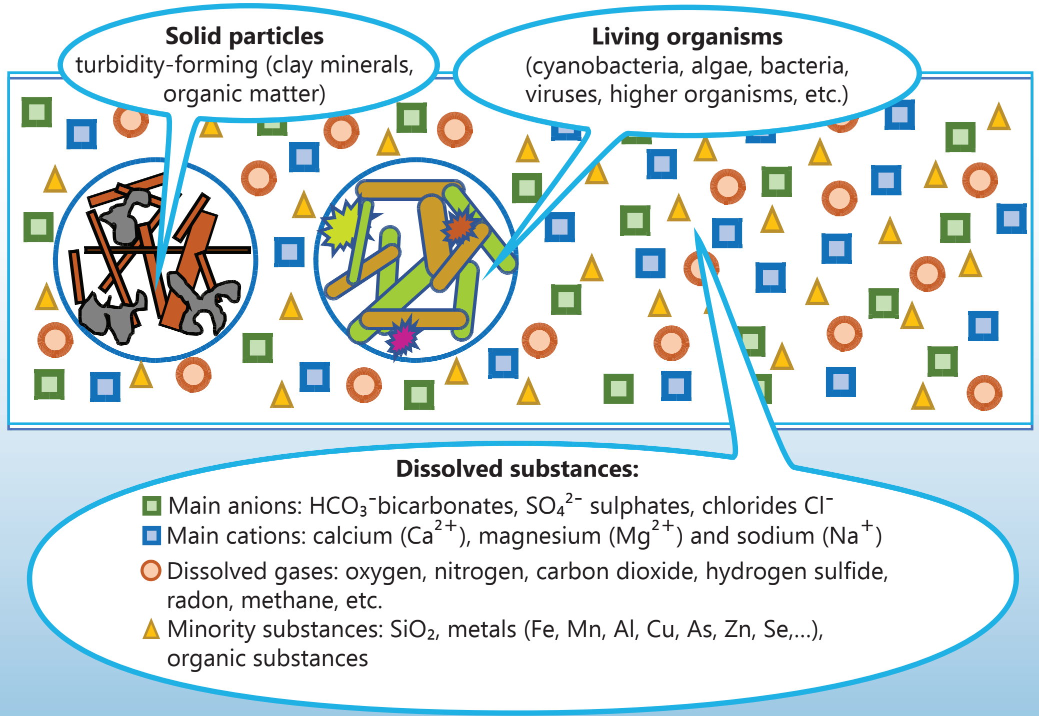
Chemically pure water is a compound with a chemical formula H_2O. It consists of two stable isotopes: hydrogen 1H and 2H (deuterium) in the ratio of 5,000 : 1, and of three stable oxygen isotopes 16O, 17O and 18O in the ratio 3,150 : 5 : 1.

Water in nature is not chemically pure, it is a complicated mixture of many substances. Knowledge of the composition of water is important both for humans (use of water as drinking water) and for organisms, which depend on water. In an urban environment, natural water is usually negatively affected by humans (pollution).



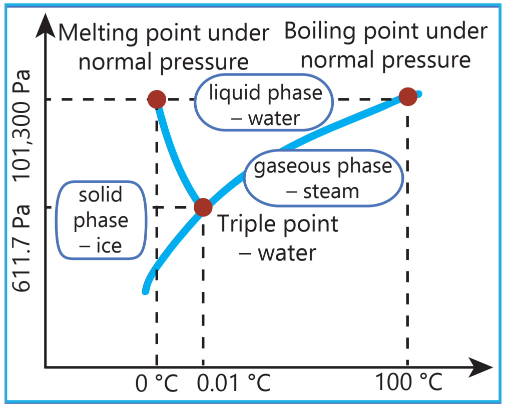
Water molecule H_2O

What is the composition of natural water? What components do we find in the water?



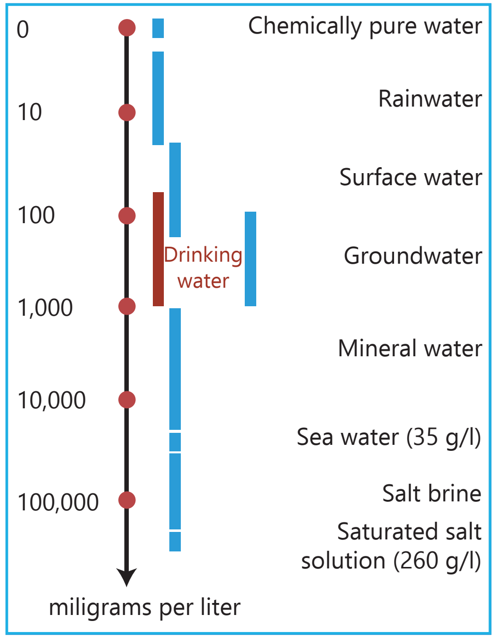
The main anions and cations usually make up 90–95% of the constituent composition of natural waters. Using the predominant main ions, the chemical type of water is determined, e.g. Ca-Mg-HCO_3. Based on the chemical type, mainly groundwater and mineral waters are classified.

The hardness of water depends mainly on the amount of calcium and magnesium dissolved in water. Upon heating, the so-called lime scale precipitates from water (mostly calcium carbonate and magnesium), which damages boilers, washing machines, dishwashers, kettles.



Simplified water phase diagram

Water occurs in the gaseous state (steam), liquid or solid (ice) depending on the temperature and pressure. The triple point determines at which pressure and temperature all three phase can occur simultaneously (611.7 Pa and 0.01 °C).



Dissolved substances in natural water

Different types of natural water also vary according total mineralization, i.e. according to the concentration of dissolved solids.

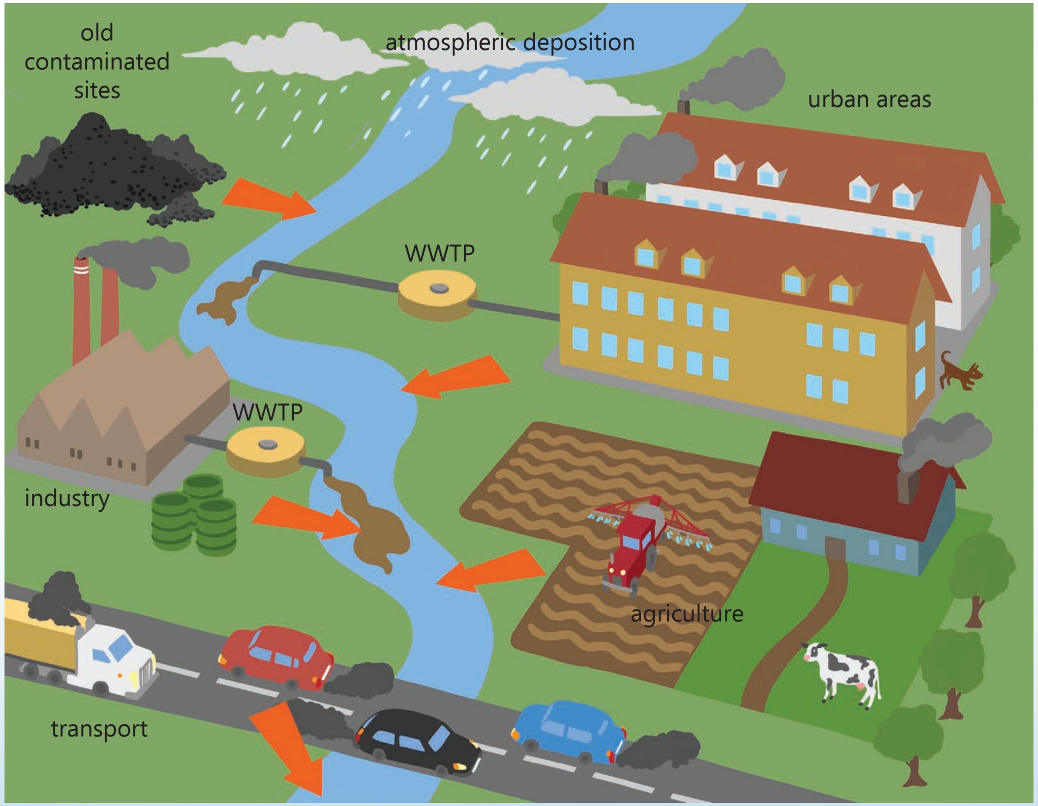
According to Decree No. 252/2004 Coll., drinking water must meet these health requirements:

- Biological safety (without bacteria, viruses and other organisms)
- Satisfactory chemical composition
- Good sensory properties (turbidity, color, odor, taste)

The waterworks monitor the quality of drinking water at specified intervals for 65 indicators in total, other verification analyses are provided by the government through the sanitary service. The capital city of Prague is supplied with drinking water from two main sources: from the Švihov reservoir on the Želivka River (approximately 70% of consumption), and from the Káraný waterworks on the Jizera River (30% of consumption). Both waterworks provide the Prague population with quality water meeting all sanitary requirements.

8. SOURCES OF WATER POLLUTION

Human activities can cause surface and groundwater pollution to a varying degree. The pollution sources are divided into point and nonpoint sources. Point sources include wastewater discharges, leaks from industry and transport, or even pollution from (old) contaminated sites (e.g. landfills, industrial plants or mining areas). Nonpoint sources of pollution represent the consequences of fertilization and the use of pesticides in agriculture and the deposition of air pollutants (atmospheric deposition).



Sources of water pollution

What pollutes the water?

- MICROORGANISMS
  Research of springs and streams in urban areas has shown that the most common contamination is microbiological (including fecal bacteria). This is caused both by leaks from sewers and, for example, intensive walking of dogs. Bacteria such as *Escherichia coli, Clostridium perfringens* or enterococci cause infectious diseases.

- NUTRIENTS
  Nitrogen and phosphorus compounds are very common contaminants. They come from municipal wastewater and from agriculture. Among other things, they cause the growth of cyanobacteria and algae, which limit the possibility of bathing in natural swimming pools, because they cause digestive, skin, and respiratory problems, possibly even liver problems or cancer. In addition, aquatic organisms, including fish, are damaged or killed as a result oxygen depletion in water.

- ACIDIFICATION
  The acidification of water is mainly caused by the leaching of inorganic pollutants from air. These enter the city air both from heating (sulfur dioxide) and from intensive traffic (nitrogen oxides). From the air they get back to the ground by deposition or together with precipitation. In acidic water fish and other animals and plants die.

- SALINIZATION
  Excessive loading of water by salts may occur, for example, by the introduction of chlorides from either wastewater or even such common activities as winter maintenance of roads and sidewalks by salt application or intensive walking pets.

- HARMFUL ORGANIC SUBSTANCES AND TOXIC METALS
  Leaks of industrial wastewater and traffic accidents and leaching from (old) contaminated sites can have even more significant consequences. These sources of pollution often contain a whole range of especially harmful organic substances and toxic metals such as mercury, cadmium, and lead, which cause poisoning.

- THERMAL POLLUTION
  Cooling water from power plants and industrial production or from municipal wastewater treatment plants discharged into watercourses tends to have higher temperature than water in watercourses. Higher water temperature means lower dissolved oxygen content, faster decomposition of organic matter, and also an increase in toxicity of certain chemicals. All this affects aquatic organisms, their species composition, vitality, and quantity. Some organisms multiply (cyanobacteria, algae), others disappear (e.g. native fish species).

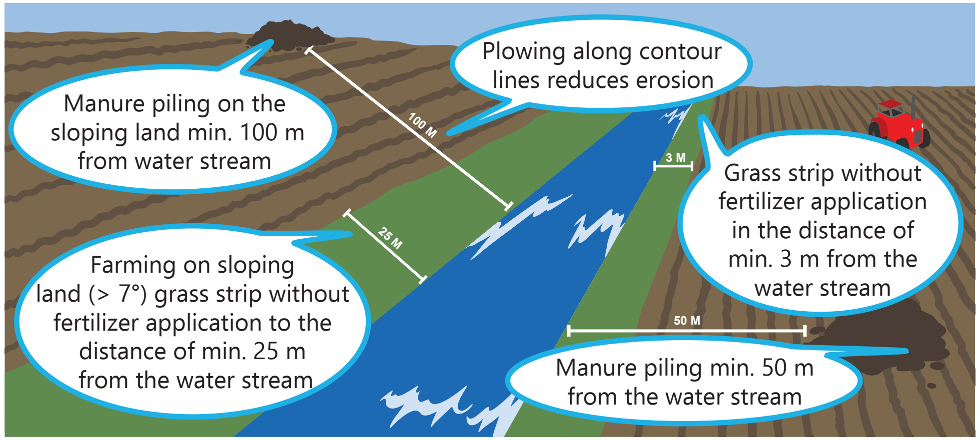
- WATER TURBIDITY
  The presence of larger quantity of solid particles floating in the water impairs the water transparency. Turbidity can be caused by soil erosion and also by poorly treated wastewater, e.g. from construction sites. Turbid water endangers aquatic organisms – photosynthesis of aquatic plants is reduced, fish gills become clogged, sediment changes the character of the bottom, etc.

Is it possible to combat water pollution?

In recent decades, the emphasis has been on preventing water pollution and thus better health of humans and other organisms. For example, the use of certain toxic substances has been banned, thermal power plants have been desulfurized, waste management improved, production and heating technologies shifted to more environmentally friendly operations, there is better treatment of wastewater and old contaminated sites are remediated. In some cases, including agriculture, however, we have had limited success in reducing water pollution. When dealing, for example, with streams pollution by medicinal drug residues from wastewater, we are only at the beginning of reducing their impact.

9. IMPACTS OF AGRICULTURE ON WATER QUALITY

Nitrogen is an essential nutrient supporting the growth of plants and crops, but its high concentration is harmful to man and nature. The agricultural use of nitrates is one of the main sources water pollution. There is a natural nitrogen cycle in nature: plants receive nitrogen from the soil and animals feed on plants. After their death, the plants decompose and thus the nitrogen returns back to the soil, where it is transformed by bacteria. Excessive fertilization disrupts this cycle and leads to water pollution, eutrophication, and the greenhouse gas effect. This is non-point pollution, influenced by climatic events, natural conditions and land use. Changing agricultural management practices makes the elimination of pollution possible.



To protect water from agricultural pollution, rules are laid down to regulate fertilizer application and manure storage at prescribed distance from the watercourse.

The protection of waters against nitrate pollution is addressed by the European Union and Czech legislation.

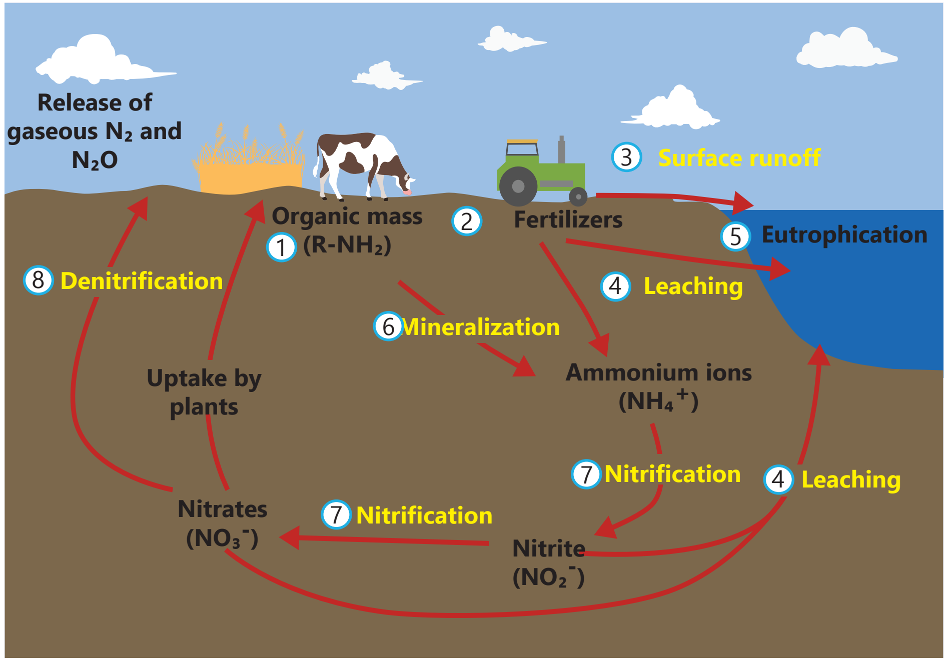
VULNERABLE AREAS:

- Areas where nitrate-contaminated water from agricultural sources occurs
- Areas where nitrate concentration in water is 50 mg/l or more
- Areas in which water eutrophication occurs as a result of agricultural activity

SET OF MEASURES TO REDUCE WATER POLLUTION BY NITRATES:

- Prohibition of fertilizer application in winter
- Setting a maximum fertilizer application limit of 170 kg N/ha per year
- Determination of the minimum storage capacity for livestock manure
- Determination of land use and management on sloping land
- Introduction of maximum fertilization limits for individual crops

Nitrogen cycle in agricultural landscape



(1) Fertilization of fields with organic matter (manure)

(2) Fertilization with artificial (mineral) fertilizers

The right dose of fertilizer is consumed for growth by the plants in the fields. Nitrogen, which plants do not consume for their growth, causes water pollution:

(3) Direct flushing to surface waters

(4) Seeping the surface of the terrain into the soil and groundwater, and subsequent leaching into surface water.

(5) EUTROPHICATION OF WATER is the process of enriching water with nutrients, especially nitrogen and phosphorus. They originate from agricultural fertilizers or sewage. In an environment with excess nutrients, cyanobacteria, algae, and other organisms excessively multiply. After their death, organic matter decomposition occurs, toxins form and the lack of oxygen in water occurs, which has an impact on fish and other aquatic organisms.

Biogeochemical processes affect the nitrogen cycle (with the interaction of microorganisms):

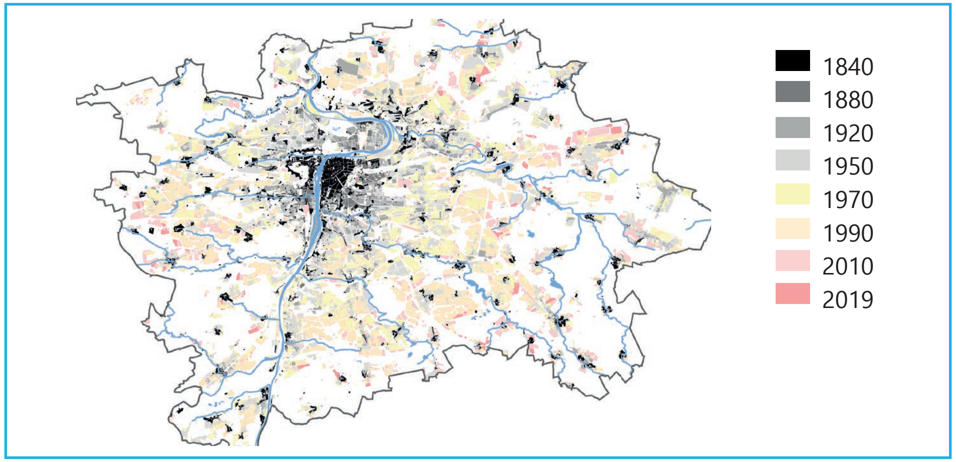
(6) MINERALIZATION – decomposition of organic matter into simple inorganic compounds ammonium ions NH_4^+

(7) NITRIFICATION – process of oxidation of ammonium nitrogen NH_4^+ to nitrites NO_2^- and nitrates NO_3- – compounds suitable for nutrition of higher plants.

(8) DENITRIFICATION – the process of conversion of nitrates NO_3^- to gaseous nitrogen N_2, which escapes into atmosphere.

10. IMPACT OF URBANIZATION ON WATER IN PRAGUE

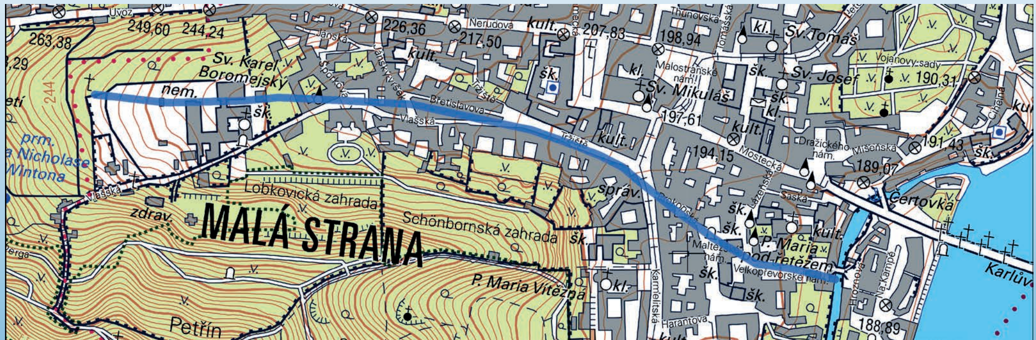
The gradual expansion of settlements on the Prague territory carried with it changes in water regime. As far back as the Middle Ages, the construction of the fortification systems, such as ramparts, walls and ditches, changed the runoff of groundwater and surface water similarly to the tunnels and bridges for railways, roads and subways later on.



Development of built-up areas on current Prague territory in the period 1840–2019

Changes in the hydrographic network

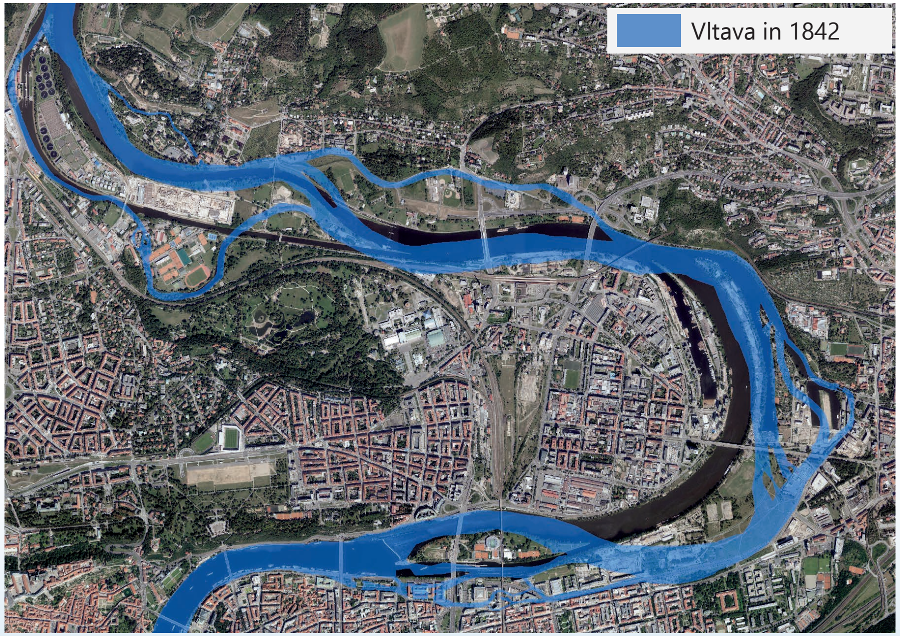
Recharge areas are often reduced in built-up watersheds, which results in less water in streams during dry periods. Some springs and creeks have been diverted to local water mains or sewers. E.g. springs from the slopes of the Petřín hill were used for the Strahov Monastery, the springs of Brusnice Creek supplied water to the Prague Castle. Thus, for example, Malostranský Creek, Veleslavínský Creek, creek in the Jeremenkova Street and the creek in Kateřinská Street all disappeared. Some streams just disappeared from sight in a pipe below the street level because they bothered their surroundings by spilling out of banks, by erosion or pollution and odors caused by sewage discharged to them or due to the lack of space. Among the creeks diverted underground into pipes, Radlický and Motolský Creeks were the most affected.



Approximate route of the former Malostranský Creek with a length of 1 km

Changes in the Vltava riverbed

The shape of the Vltava riverbed has been modified because of various economic interests. Weirs, millraces, ports, timber raft sluices, etc. were built. Probably the most extensive changes were brought by the Vltava navigability project at the end of the 19th century. Some islands disappeared, parts of the riverbed were filled, and others excavated. The largest earthworks affected the area of Holešovice, Karlín, Libeň, Bubeneč, and Troja. However, the benefits of the river were offset by frequent floods, sometimes reaching the Old Town Square. Therefore, elevated reinforced embankments were constructed in the period 1841–1913. After the 1997 flood in Moravia, flood protection was supplemented and improved by a system of flood defense walls, temporary barriers, levees, etc. The Vltava flow rate has been increased to 40 m^3/s during dry periods since 1954, thanks to the Vltava cascade of reservoirs, which is also capable to protect Prague from moderate floods (up to 20-year flood). In addition, the Vltava in Prague no longer freezes in winter.



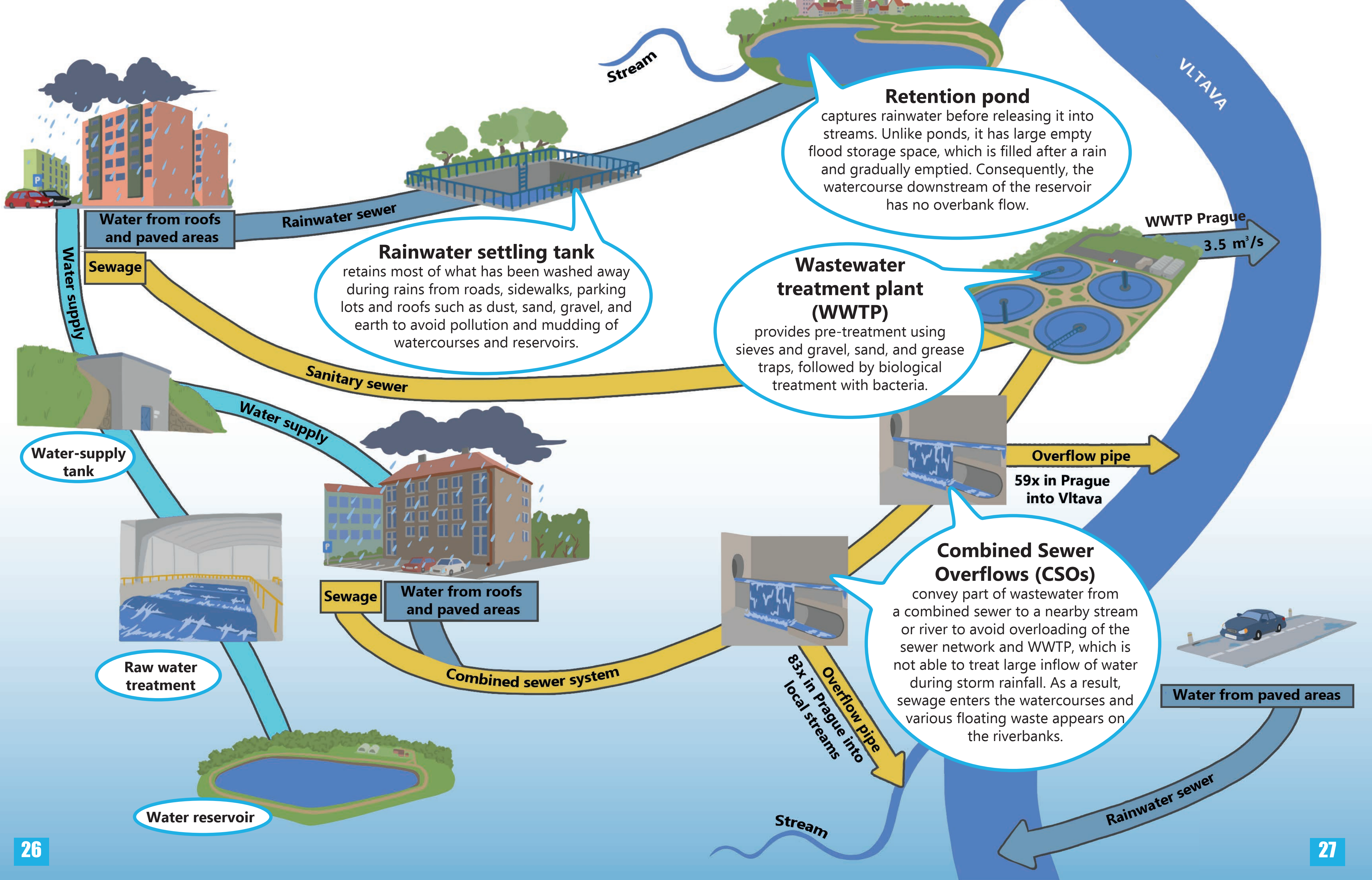
Channelization of the Vltava River at the turn of the 19th and 20th centuries determined its present form

Development of water management infrastructure

From the start of the settlement until the 19th century, the main sources of drinking water were the local springs and the Vltava River. Increasing demand for good-quality drinking water had led to the construction of waterworks in Káraný, which has been supplying Prague with infiltrated water from the Jizera River since 1914. After expanding its territory in 1929, Prague built new waterworks in Podolí. Nowadays the Želivka raw water treatment plant is the most important source of drinking water for Prague, operating since 1972.

The sewer network has been under construction since 1787. Sewage was initially discharged into the Vltava River. Since 1906, wastewater in Prague had been directed to the wastewater treatment plant in Bubeneč. Another turning point was the construction of the Central wastewater treatment plant in 1966 together with the construction of a separate sewerage systems for new housing estate developments, separating rainwater from sewage.

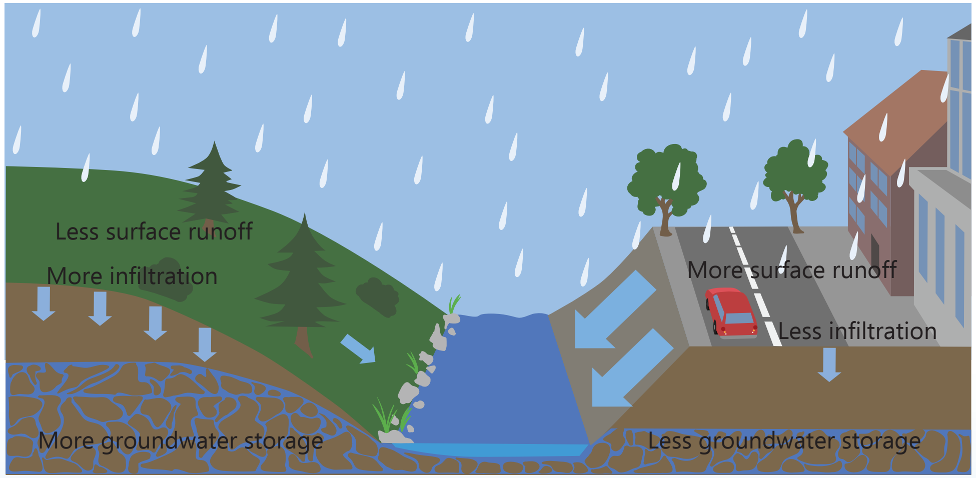
11. SEPARATE AND COMBINED SEWER



12. INFLUENCE OF URBANIZATION ON RUNOFF

In the natural landscape, runoff from precipitation is slowed down and reduced due to the high degree of infiltration, retention in soil, vegetation that retains rainfall, river meanders that prolong the runoff time and channel roughness. In the long run, the total runoff is also smaller in natural landscape because water is absorbed by plants through transpiration and evaporates from the soil and water bodies.

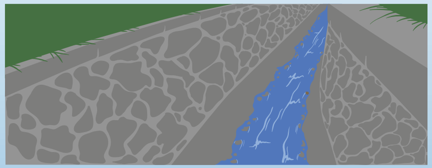
Densely built-up areas include large areas of impervious surface. Surface runoff predominates because water from streets, roofs, and other paved surfaces flows immediately into the sewers, which also accelerate runoff. Watercourse channels are often straightened and reinforced. Most of the precipitation runs off shortly after the rain, yet the total runoff is greater in urban areas.



Natural landscape **Urban area**

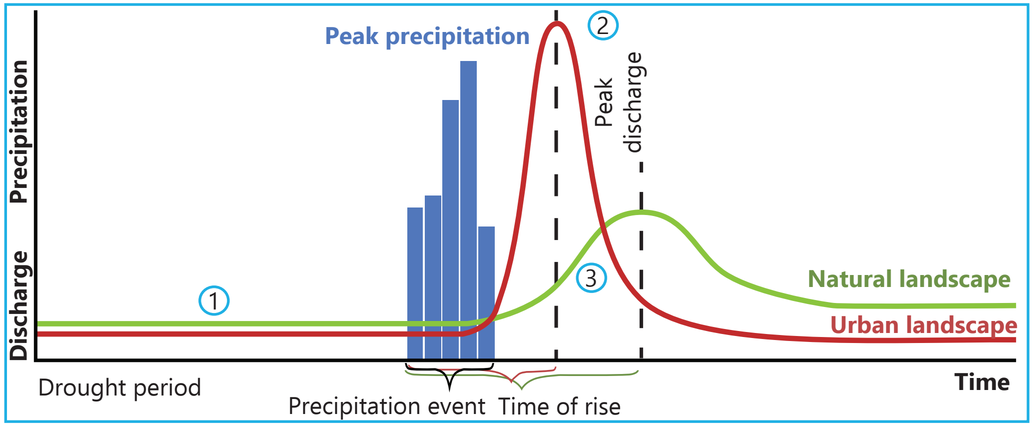
There is usually less groundwater in an urban area because much of the rainfall flows off on surface. In addition, aquifers are disturbed by underground structures such as the metro and other tunnels, road cuts, pipes and cables with permeable backfill, etc. In heavily urbanized areas, small creeks often disappear because they lose their water sources. Some small creeks and springs were routed into the sewer. Some streams were put into tubing and besides some rain sewers were introduced into them, so they became rather a part of the sewerage system.

Watercourses in open channels are also used as rainwater drainage. To avoid spilling over the banks and its erosion during heavy rains, cities build retention ponds and high-capacity reinforced channels.



High-capacity reinforced channel

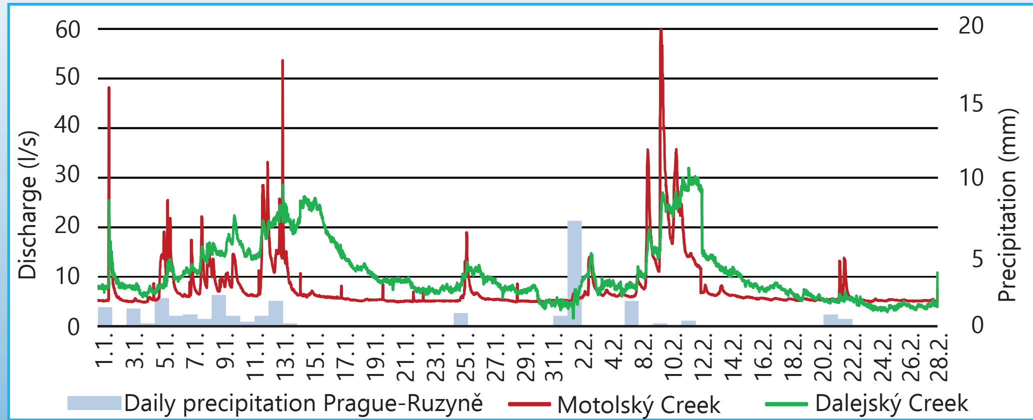
Nowadays, the approach to water drainage is changing. Infiltration and retention of rainwater represents a new sustainable approach. Reduction of the surface runoff can help to diminish floods and droughts.



Flood hygrograph

1. In a rainless period, there is a decrease in discharges in rivers and streams. The natural runoff consists of groundwater only. In a natural landscape, groundwater storage is greater than in a comparable urban landscape.
2. Watercourses in urbanized river basins respond to precipitation with a rapid rise in discharge and a rapid recession. The peak discharge is high. In a natural landscape, the peak discharge is delayed, lower and recession is slower.
3. Flood volume is usually greater in urbanized river basins, due to limited infiltration and retention.

Two left-hand tributaries of the Vltava in Prague, which originate near the border of Prague, were selected as an example. Motolský Creek originates at the foot of the Cenomanian sandstones, wherein precipitation water accumulates well, guaranteeing stable discharge throughout the year. The area of its natural catchment area up to the measurement profile is only 1.5 km^2. However, it receives rainwater from rainwater sewers draining large industrial and shopping areas in Zličín, which causes a rapid increase of discharge after rain or snow melt. Dalejský Creek originates in the loess in Chrášťany, and often almost dries up in the summer. The measurement profile is located in Řeporyje. The built-up areas constitute only about 20% of its basin area covering 7.5 km^2. Part of its basin is drained by a rain sewer into the Motolský Creek. The rest of the basin is mostly arable land. The peak discharges are not as high as in Motolský Creek and the discharge recession curve is gradual.



Hydrographs January/February 2019, precipitation as rain and snow

13. RAINWATER USE IN CITIES

The past generations have pursued land drainage and "rainwater elimination". During the last warm and dry years, we began to appreciate water and we detain it, whether in different types of reservoirs or natural underground pools – aquifers. However, the impulse for the analysis of possibilities, how to deal with rainwater, is often the insufficient capacity of sewers or wastewater treatment plants. Several legal regulations have been in force for many years (Decree No. 501/2006 Coll., Decree No. 268/2009 Coll., Regulation No. 10/2016 Coll. of the Capital City of Prague), which for new construction determine the order of how to deal with rainwater. Rainwater infiltration is preferred over discharge to the rainwater sewer, eventually to the combined sewer.

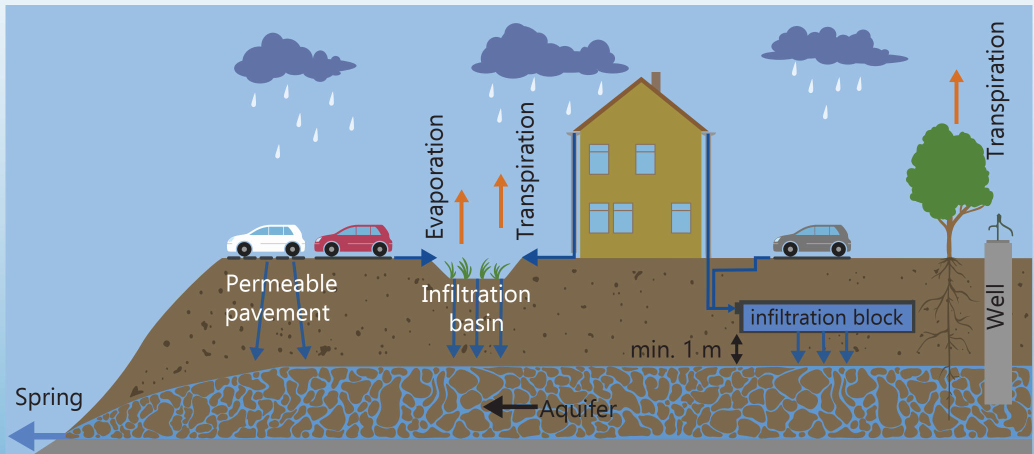
What options we have to combat drought, heat, floods, and water pollution at the same time?

Water infiltration

SURFACE infiltration is the most natural way of rainwater utilization. In the cities, it needs a little help – to divert water from roofs and paved areas into green areas, terrain depressions or ponds with a permeable bottom; replace impervious pavement with pervious paving or porous concrete. Water passing through the soil profile gets cleaned, so there is no groundwater pollution. Infiltration can be supported by adding gravel or sand.

UNDERGROUND infiltration is not entirely natural. It is necessary to excavate a pit and part of the excavated material needs to be removed. Plastic perforated blocks, tunnels, shafts, eventually gravel, are placed into the pit. Afterwards entire area is covered by soil. Rainwater is conducted by a pipeline into the underground chamber. Water must be filtered before entering the infiltration element. The disadvantage is that the infiltration element can cause drying of the overburden because it has a draining effect, which is unfavorable for plants.

In both cases, the appropriate solution is based on a geological survey.



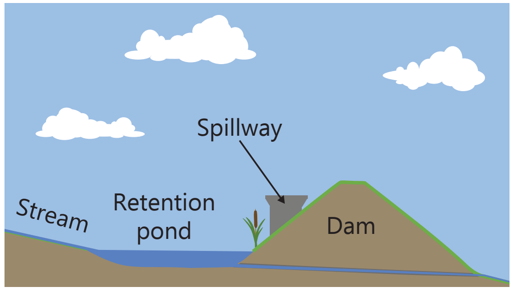
Surface and underground rainwater infiltration

Temporary water retention

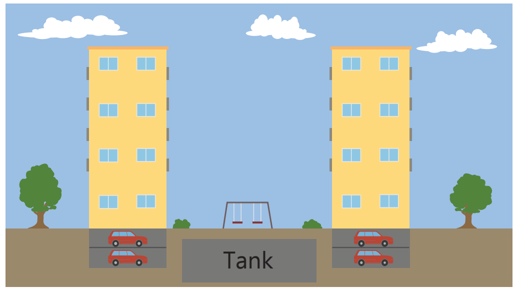
RETENTION AND DETENTION PONDS both have a large flood storage. The difference between them is that retention pond has a permanent pool of water and detention pond remains dry until a storm occurs. They protect the downstream area from floods. Another small reservoirs closer to rainwater sources can also protect the sewer system from overloading (see underground detention tanks). The secondary effect is improving the microclimate. Ponds complete the landscape together with riparian vegetation.

UNDERGROUND DETENTION TANKS are built to temporarily hold rainwater before it is gradually discharged into a sewer or a watercourse because of their insufficient capacity. For newly connected buildings limits are set for discharge into sewer and streams by their respective management authority or by local regulations. In Prague it is 10 l/s from a hectare of land in a 10-year thirty minute rain. There is no other added value of these tanks.

Both types protect from floods and from bypassing the sewage into watercourses. After rain they augment discharges in watercourses for several hours or days.



Retention pond



Underground detention tank

Water accumulation

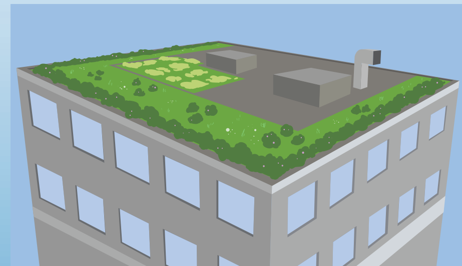
RESERVOIRS collect water for further use (fish farming, recreation, low-flow augmentation, improvement of microclimate and biodiversity).They usually have a source of water for replenishing during the rainless period, most often a watercourse. The flood storage space is generally small.

UNDERGROUND STORAGE TANKS have an advantage over reservoirs. They do not lose water by evaporation, water does not overheat and does not suffer from excessive algae and cyanobacteria growth. On the contrary, they lack living organisms, they do not complete the landscape, etc.

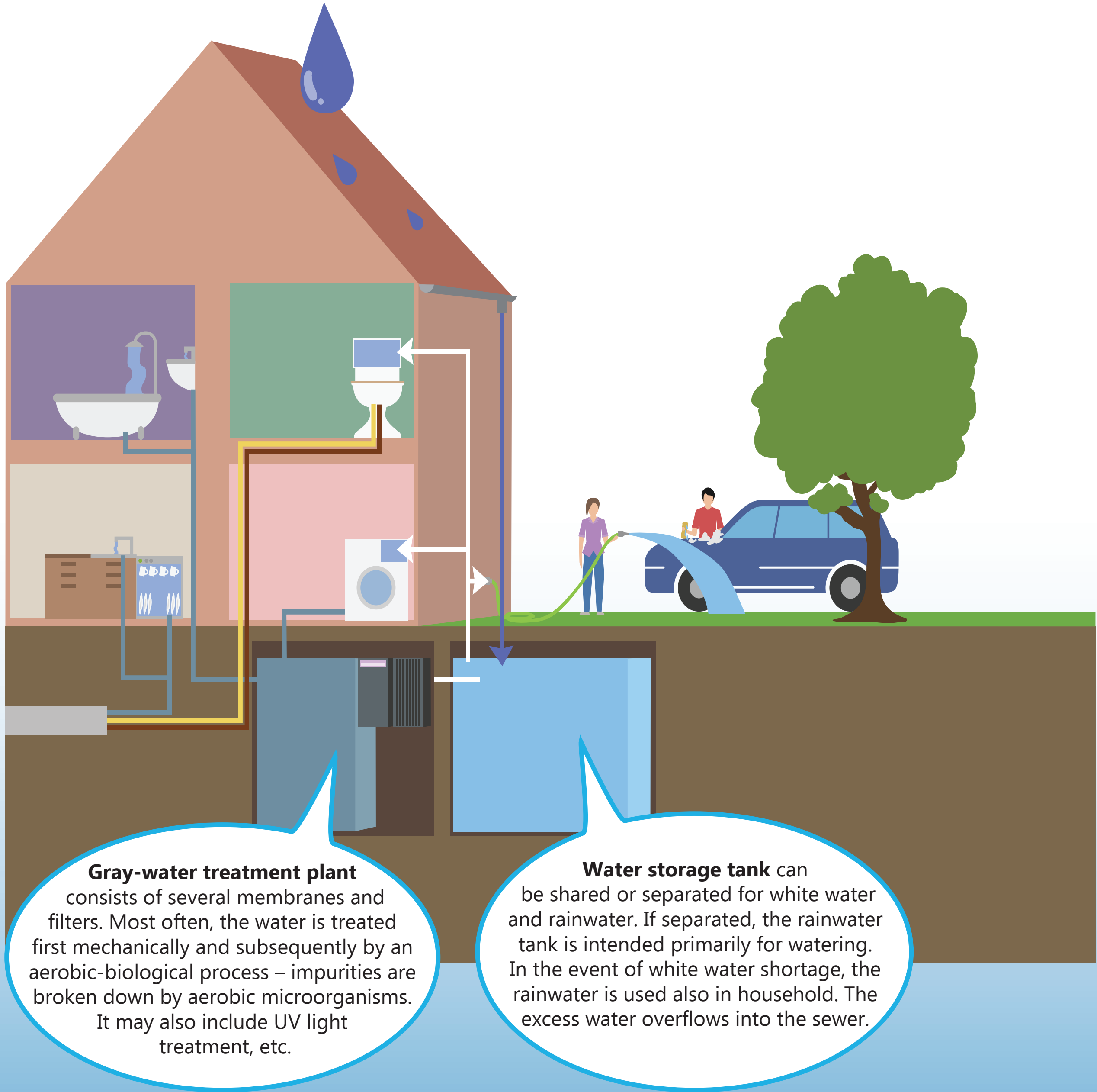
Use of both types: watering, car washing, cleaning, washing, toilet flushing, fire water

Green roofs

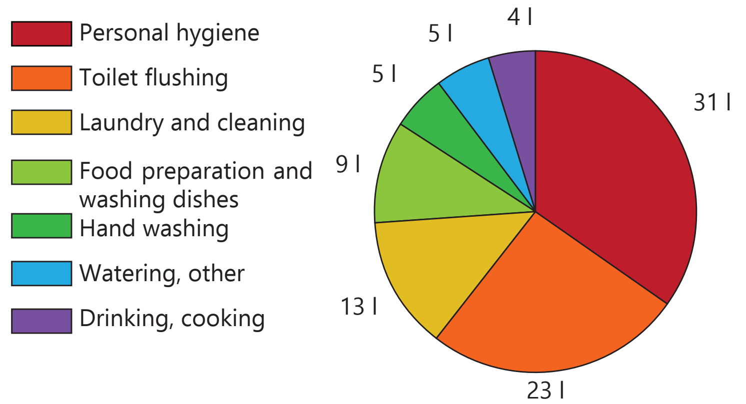
In dense urban areas, roofs are often the only option where to implement measures to retain rainwater and reduce runoff. At the same time, they improve the microclimate and fulfill several ecological functions. Therefore, in some cities, it is already mandatory for certain new construction projects to implement green roofs.



14. WATER RECYCLING IN HOUSEHOLDS



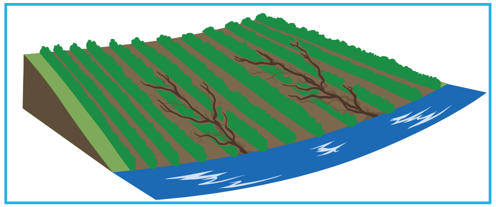
Water consumption in households (person/day)



Rainwater	Rain water, as a substitute for drinking water, is ideal for watering, flushing toilets, washing clothes, cleaning floors, or washing cars. Mechanical cleaning is usually sufficient to treat the water.
Yellow water	Yellow water, i.e. urine, consists of a metabolic waste solution. It contains urea and other organic substances and salts, e.g. sodium chloride.
Brown water	Brown water represents faeces containing especially carbon. Also, nitrogen, phosphorus, potassium, calcium, magnesium and iron.
Black water	By drainage of wastewater from toilets – i.e. brown and yellow waters at the same time – we obtain black water.
Gray water	Gray water is wastewater drained from washbasins, bathtubs, showers, washing machines, etc. and does not contain faeces or urine. After treatment, gray water can be used as service water (so-called white water). The most significant gray water pollution is caused by detergents from washing powders, shampoos, soaps, toothpastes and the like. Therefore, it is advisable to use environmentally friendly and degradable detergents. Water from sinks and dishwashers contains a large amount of organic material, especially grease, which is difficult to degrade and clogs the filters of the treatment plant, so it is usually drained into the sewer.
White water	When gray water is cleaned, it becomes white water. It can be used as service water, suitable for flushing toilets, laundry, mopping floors, washing cars and watering plants (if biodegradable detergents are used).

15. MEASURES IN THE AGRICULTURAL LANDSCAPE

While arable land in extensive and flat lowlands is drier and more prone to wind erosion due to lower precipitation and higher temperature, arable land in the highlands suffers more from water erosion due to greater land slopes and higher precipitation. Another cause of erosion is the way of farming. Both wind and water erosion are fomented by extensive, unbroken fields and bare soil. In addition, water erosion is enhanced by cultivation across the elevation contours. The measures on agricultural land are aimed at reducing surface runoff, absorbing more water and preventing erosion. At the same time, they protect the surrounding land from local floods, water streams and reservoirs from mudding or erosion.



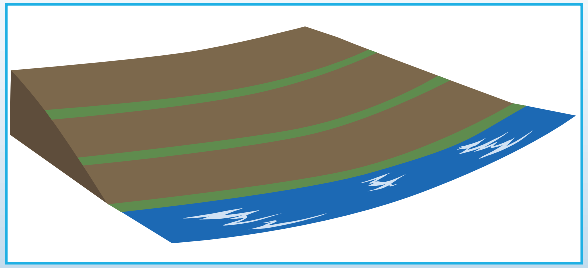
Rill erosion

How to slow down runoff and prevent water erosion?

The longer and steeper the slope, the more measures will be needed. In the direction of the slope, the length of an uninterrupted slope must not exceed a certain limit (depending on the slope, soil type and precipitation), so that more water is infiltrated and the surface runoff does not become a concentrated surface runoff with devastating effects.

Organization of farmed plots

- ADJUST THE SHAPE OF THE LAND PLOT so that its longer side copies the elevation contour allowing cultivation along the contours.
- STRIP CROPPING alternating crops prone to land erosion (corn, beets, potatoes, sunflowers) with the ones less prone to erosion (wheat, barley, rye, oats, clover). The strips run ideally along the contour lines.
- BUFFER STRIPS running along the contour lines should be at least 20 m wide and are planted by grass, shrubs, or trees. Water streams and reservoirs are protected by buffer strips from mudding by washed soil.
- PLANTING GRASS is recommended when the slope exceeds 20%.
- AFFORESTATION is recommended when the slope exceeds 30%.



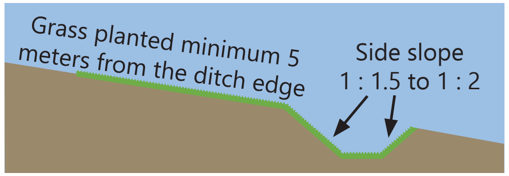
Buffer strips interrupt surface runoff

Form of farming

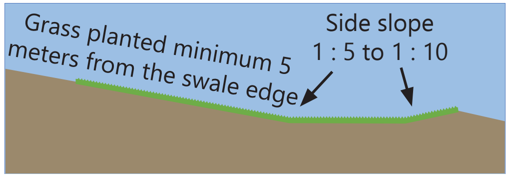
- CONTOUR-PLOUGHING reduces surface runoff.
- MULCHING, LEAVING CROP RESIDUES or COVER CROPS ensures that the soil is covered, protected from washouts and surface runoff is reduced
- SMALL DIKES AND HOLES when cultivating potatoes will keep rainwater in small depressions in the furrows and also at the tops of ridges.

Landscaping

- CONTOUR DITCHES are used to capture surface runoff. Water is retained and gradually seeps in or it evaporates, the excess flows into the drainage way and then into the watercourse or a reservoir. They are routed along the contour line, with a slight inclination (longitudinal slope max. 1%). They have a trapezoidal, triangular, or parabolic profile and a depth up to 1 m.
- CONTOUR SWALES are similar to the contour ditches, but have a flatter side slope, so they are significantly wider and allow the passage of agricultural machinery.

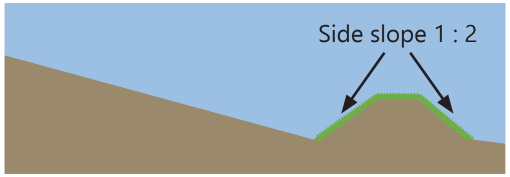


Contour ditch

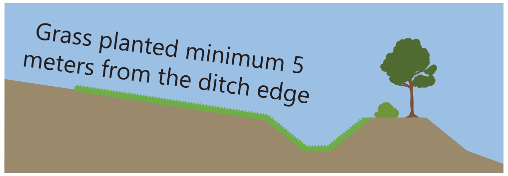


Contour swale

- EARTH DIKES have the same function as ditches and swales. They are built, for example, at the foot of gentle slopes to protect the down gradient settlements. Their height does not exceed 1 m.
- ANTI-EROSION BALK consists of a ditch or swale and an earth dike planted with woody plants. The advantage is the use of the excavated material on site.

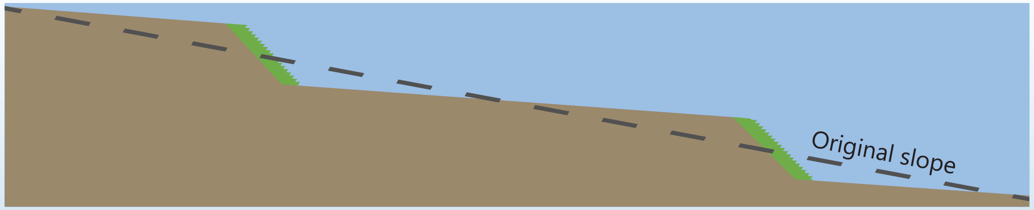


Earth dike



Anti-erosion balk

- TERRACES are recommended for slopes greater than 15% if other options are exhausted. The soil the profile must have a sufficient depth (minimum 1 m).



Terracing a slope

- STABILIZATION OF CONCENTRATED RUNOFF PATH by planting grass or rock chutes prevents creating rills, slows down runoff and supports infiltration.
- CHECK DAMS interrupt the paths of concentrated surface runoff. They are known mainly from damming torrents, in agricultural landscape they are usually lower (earth dams, gabions, etc.).
- SEDIMENT BASINS function by intercepting and detaining runoff, which allows soil particles to settle out prior to discharge. They attenuate flow and reduce runoff volume; some water may soak in.

Most measures require changes in the layout and shape of land plots. A comprehensive solution can be implemented within the process of LAND CONSOLIDATION.

16. MEASURES IN WATER MANAGEMENT

Due to its size and requirements, the human population cannot rely only on natural water storage in the landscape. In addition, natural resources are often polluted by human activity. Human settlements built on the floodplains of streams and rivers are threatened by floods. The solution to all these problems is a job for water managers.

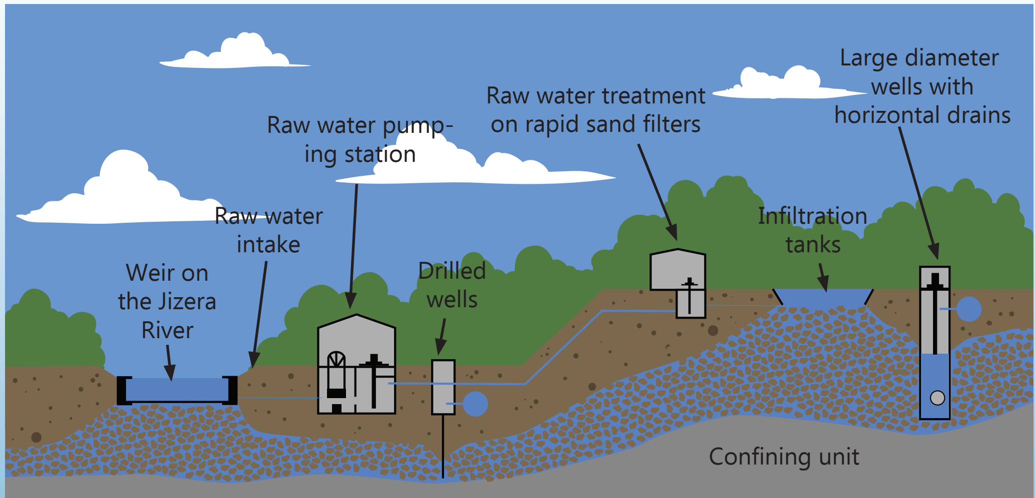
In densely populated areas, the need for water is most often satisfied by water reservoirs, filled at the time of discharge surplus (in the conditions of the Czech Republic, periods of high flow occur in March and April). It is a sustainable way as opposed to uncontrolled or excessive pumping of groundwater. Reservoirs provide water for households, industry, agriculture, energy, or shipping.

In the Czech Republic, the growing population is not currently a problem of water management as in other parts of the world, but it is rather the climate change. The warming causes an increase in evaporation resulting in lower flows in rivers. Extreme weather fluctuations such as droughts and floods are reaching the limits of the current water management infrastructure. The existing systems are therefore strengthened by the following measures.

How do water managers deal with climate change?

Water management measures

- Construction of water reservoirs (used for water supply, irrigation, industry, energy, flood control, settling, fire protection, low-flow augmentation)
- Artificial recharge (e.g. in Káraný it has been operated since 1968)



Scheme of artificial recharge at Káraný

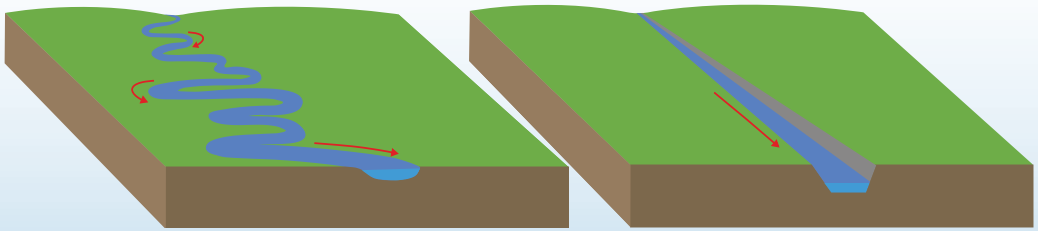
- Increasing the integration of water management systems (joint management of several reservoirs – e.g. Vltava dam cascade)
- Interconnection of water supply systems and connection of group and local water mains to water supply systems
- Modernization of sewerage systems and wastewater treatment plants
- Modernization and development of irrigation

Drip irrigation can save a significant amount of water, which evaporates when using sprinklers

Besides technical measures, close-to-nature measures are also realized, focusing on retaining water in the landscape, flood control, and erosion prevention.

Close-to-nature measures

- Restoring streams and floodplains (removal of bank and bottom reinforcements, shallower riverbed, capacity reduction of the river channel, enabling spilling of water into undeveloped floodplains, lenghtening of the stream flow path, breakdown of banks and bottom contours, variation of segments of different longitudinal slopes)

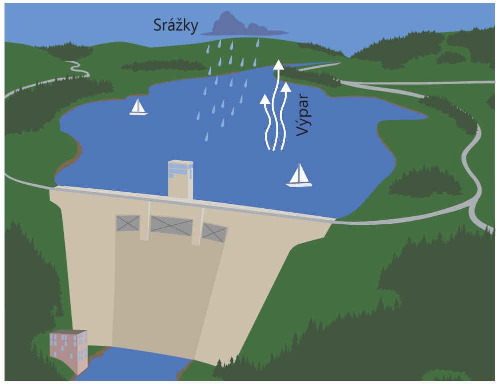


Natural stream does not cause excessive drainage of the floodplain and slows down runoff

- Construction of dry detention ponds that retain water only during floods, otherwise the flood plain areas can be used for agriculture or recreation
- Damming of torrents and ravines (e.g. check dams trapping sediment and controlling floods and erosion)
- Restoration of wetlands (e.g. by removing the drainage systems it is possible to create a wet meadow, which will positively affect the microclimate in its surroundings)
- Strict protection of water sources (e.g. recharge areas)

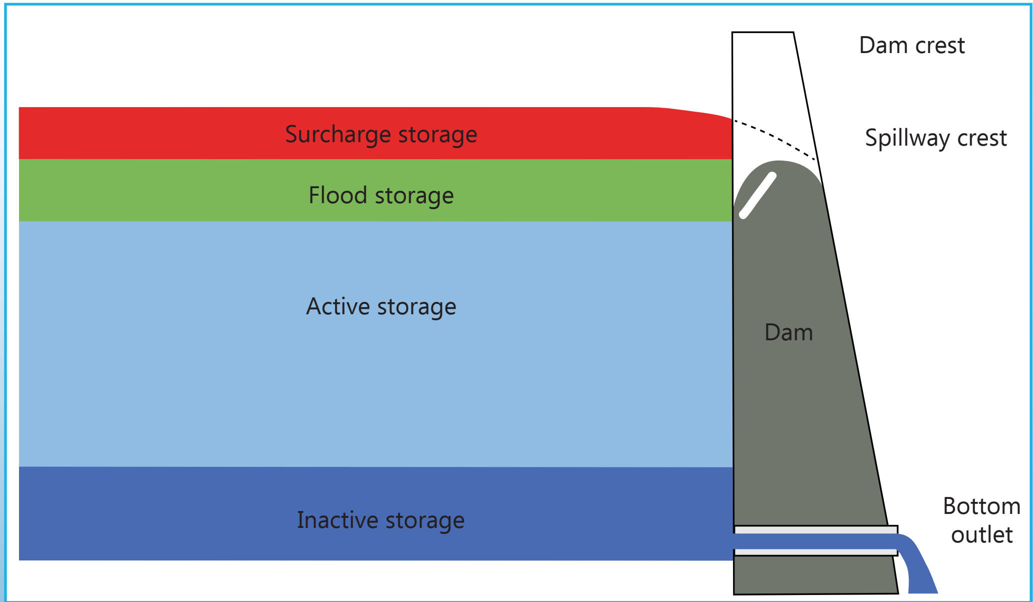
17. WATER RESERVOIRS

Water reservoirs are most commonly created by building dams on watercourses and enabling efficient water management. Earth dams are usually built using local materials and include an impervious core. Higher dams were built from the end of the 19th century of stone masonry and since the mid-20th century they have been almost exclusively made of concrete. The reservoirs mostly serve multiple purposes and function simultaneously as water storage and flood control. The water storage can be used for production of drinking water, low-flow augmentation, electricity generation, industry and irrigation. Finally, many reservoirs are a popular place for recreation. Flood control spaces are reserved to retain floods. If a flood is predicted in advance, the active storage is also pre-emptied to retain the flood.



Water reservoirs with concrete dam

In addition to the advantages, the reservoir disadvantages are as follows: Dams represent barriers for migration of aquatic animals. The reservoir operations change the flow regime. The temperature regime is also often altered, as water is discharged from the deep reservoirs through the bottom outlet causing relatively cold water in summer and conversely warmer water in winter. This is due to the stable temperature of 4 °C at the bottom.



Scheme of storage zones in a reservoir

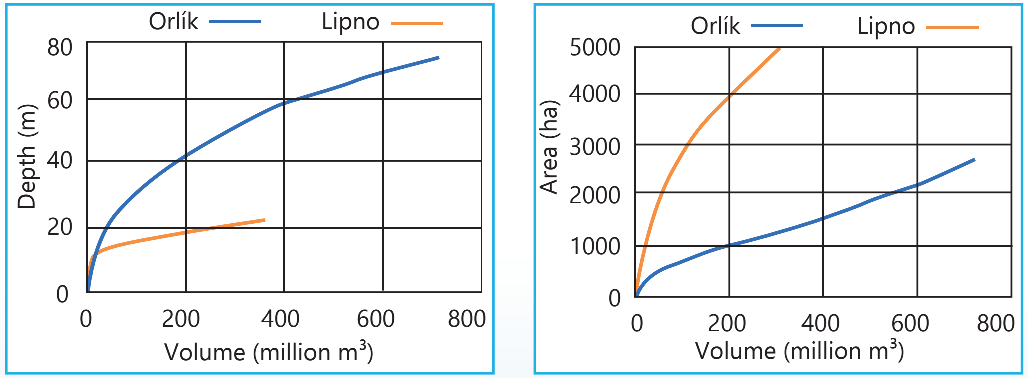
Small water reservoirs

Most small reservoirs in the Czech Republic are historic artificial ponds with an earth dam. Nowadays, small water reservoirs are built mainly under the support of subsidy programs for retaining water in the landscape. These reservoirs cannot be used for intensive fish farming. The reservoirs should provide water accumulation for low-flow augmentation, for increasing the groundwater level and for abstractions (irrigation, firefighting); reduction of flood discharges, improving water quality and promoting biodiversity. Designing small water reservoirs is governed by the national standard ČSN 75 2410, where their maximum volume is set at 2 million m^3 and a maximum depth of 9 m.

Major water reservoirs

These are defined by the volume of at least 1 million m^3 and at the same time a dam higher than 15 m. There are 165 major water reservoirs in the Czech Republic, holding 3.36 billion m^3 of water in total and occupying an area of 300 km^2.

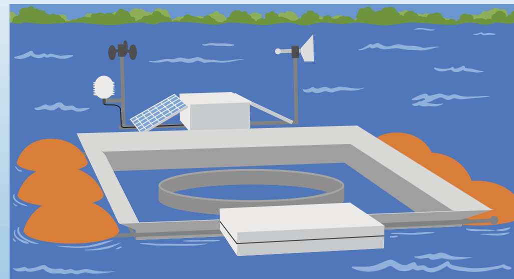
The largest reservoir by volume: Orlík (volume 716.5 million m^3, area 27.33 km^2)
The largest reservoir by area: Lipno (volume 309.5 million m^3, area 48.70 km^2)



Comparison of characteristics of the deep reservoir Orlík and relatively shallow reservoir Lipno

Water loss due to evaporation from water surface

The Orlík reservoir evaporates approximately 600 mm/year, whereas the annual rainfall is only 550 mm. Evaporation withdraws about 16 million m^3 per year from the Orlík, which makes 0.6% of the annual inflow volume. In case of Lipno reservoir, which lies at a higher altitude, the annual evaporation rate is lower (approximately 550 mm) and rainfall is greater (850 mm). However, due to its larger area, it evaporates more water, about 27 million m^3 per year, which makes 6% of the annual inflow volume.



Floating evaporimeter

Evaporation from a water surface is measured using an evaporimeter. The water level in a circular container is monitored by means of a pressure sensor.

18. MONITORING IN HYDROLOGY

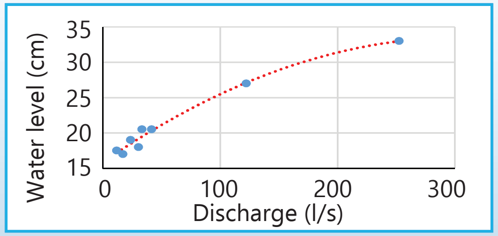
Hydrology deals with the occurrence and movement of water on Earth. Since water is in motion all the time, it is necessary to monitor the individual phenomena related to the hydrological cycle, to be able to correctly derive the hydrological balance. The movement of water depends mainly on the weather, therefore monitoring of meteorological quantities such as air temperature, air relative humidity, precipitation totals (rain and snow) and more, is crucial. Precipitation affects the quantity of water in the river basin, air temperature determines the state of water (ice, snow, water, water vapor), and the weather affects e.g. the water evaporation as well. Meteorological quantities are measured by meteorological stations, observation network in the Czech Republic is operated by the Czech Hydrometeorological Institute.

Monitoring of rivers and streams

People have been recording the water levels in watercourses since ancient times. The water level marks were wisely left to the future generations especially after floods or droughts (so called hunger stones). At the end of the 19th century, water levels started to be recalculated into discharges, which allowed better comparison of water quantity. One of the methods to determine discharge is to find out the velocity of the flowing water. This can be done by calculation or measurement.
Using a propeller-type current meter, point velocities in a cross section are measured, afterward the average velocity is calculated. By multiplying the velocity by the cross-sectional area, the discharge is obtained.

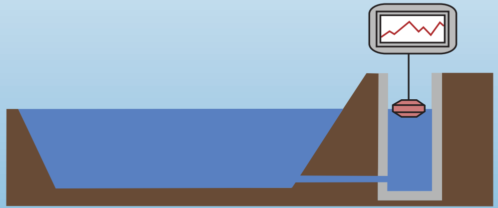

Field hydrometry

On a particular profile, a relationship between the water level and discharge exists, expressed by a rating curve. If we measure discharge several times at different water levels, we can derive an empirical rating curve and then we can record only the water level, discharge can be comfortably obtained from the curve.



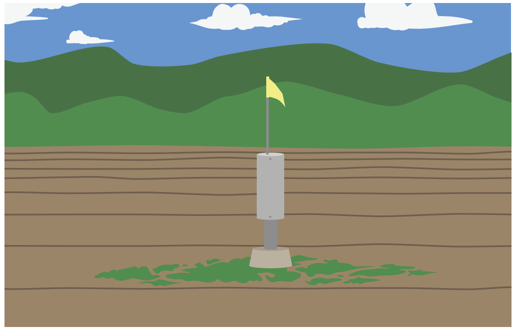
Example of a rating curve

Water level records are generated by an extensive network of stream gauge stations or water level recorders. Today, we get information on discharges thanks to remote data transmissions and automatic calculations immediately, which significantly helps the reporting and forecasting service tasked to provide warning of floods.

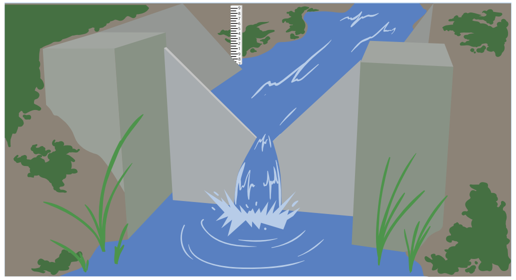

Float-type water level recorder

Groundwater monitoring

The condition of groundwater storage is examined in boreholes or wells where groundwater level is measured. For manual measurement, a measuring tape with an electric level meter or an acoustic level meter (e.g. Rang's well whistle) is dropped into the borehole to indicate the water table. For continuous monitoring, automatic recording devices are used, these are recording the water pressure which is consequently recalculated to water level. The older type of measuring/registration instrument is float water level gauge. Both pressure and float gauges are used also for the recording of surface water levels.

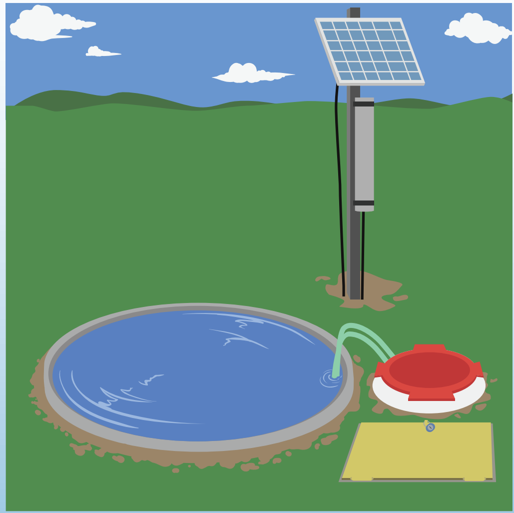

Monitoring borehole

The second option is to monitor the yield of a spring. Weirs are often used to measure flow (e.g. Thomson weir), this is also one of the methods of surface water observation. For standard measuring weirs, rating curves are known. It is sufficient just to know the water level above the weir and then calculate discharge according to the equation.


Thomson weir

Evaporation monitoring

Evapotranspiration includes evaporation of water from plants, from soil and water bodies. It is an essential component of the hydrological cycle and it is gaining still greater importance with the ongoing warming. Evaporation from soil and plants is difficult to measure and is usually obtained by calculation. Evaporation from water surface can be measured quite easily using an evaporimeter, which is a vessel where the water level is monitored. A more accurate device is the floating evaporimeter that better simulates real conditions of water surface. Loss of water by evaporation from water reservoirs is more and more significant in water management because of the rising air and water temperature. Other factors influencing evaporation are wind, humidity, air pressure and solar radiation. Evaporation from the water surface may reach in the conditions of the Czech Republic up to 900 mm per year, which is more than the average annual precipitation.


Evaporimeter

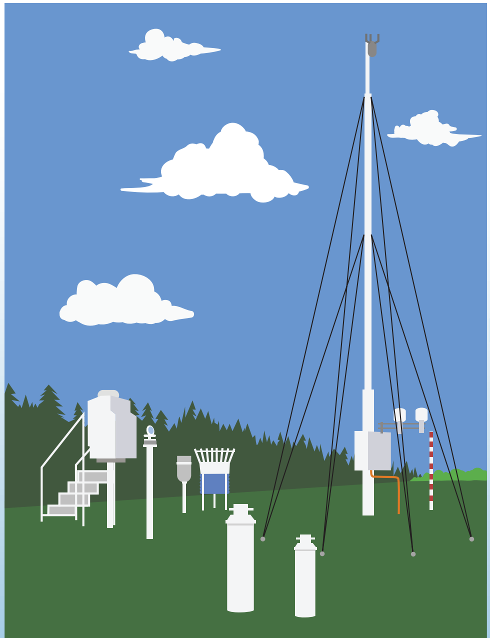
19. INFORMATION AND COMMUNICATION TECHNOLOGIES

As in all sectors of the economy, also in water management, the information and communication technologies (ICT) have played an important role in recent decades. ICT are technologies that allows the users to access, store, transmit, process, and manage information. The status of ICT systems, owing to rapid development, now allows to examine in detail the hydrodynamic processes associated with the geometry complexity of the continental and marine environment.

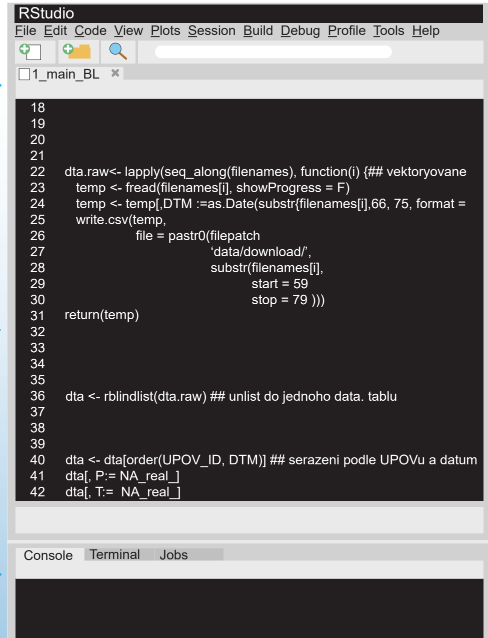
Data control and acquisition – SCADA

A very important part of ICT are the control and data acquisition SCADA (Supervisory Control and Data Acquisition) technologies. SCADA includes (but is not limited to) software packages that may be integrated into the system of hardware and software to improve the safety and efficiency of process operations in data acquisition. The main functions of the SCADA systems are data acquisition via sensors, transmission of acquired data among several remote sites, presentation of data through a central host computer and data management on the operator terminal or workstations. This is the most common method currently used, for example, in systems such as the distribution of drinking water and wastewater collection systems.

SCADA systems are gaining in importance especially in times of crisis, such as floods or drought, when it is necessary to have always the most up-to-date data available.



Data collection at a meteorological station



Data processing

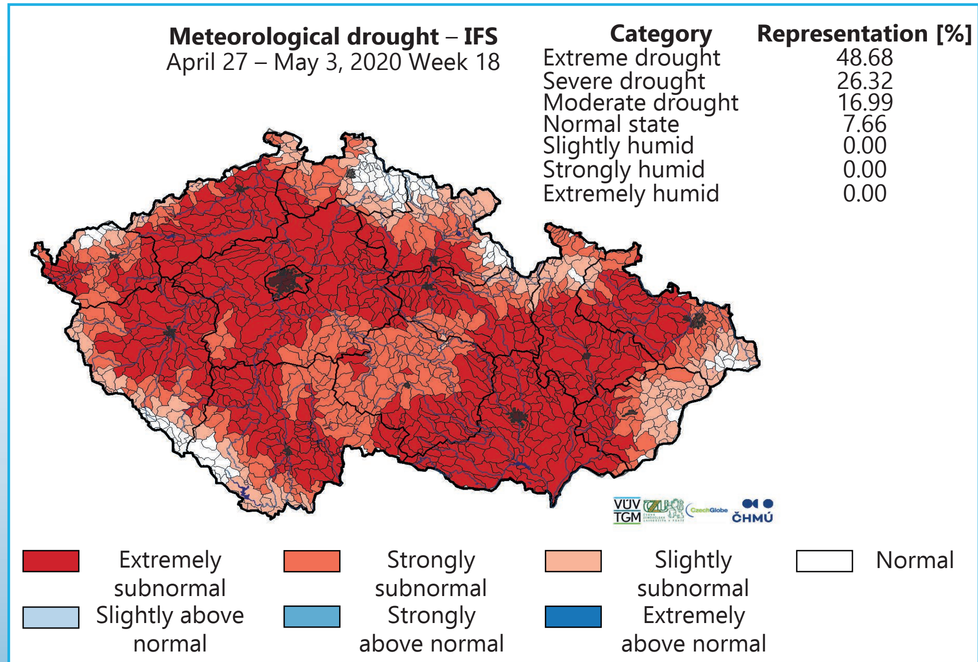
Geographic Information System (GIS)

GIS is an effective tool for storing, managing, and displaying spatial data often used and encountered in the management of water resources. GIS is mainly used in water management in the following areas:

- Storage and management of geo-spatial data
- Drinking water supply management
- Groundwater modeling
- Sewer system management
- Water quality analysis
- Flood forecasting service

Water management in urbanized zones

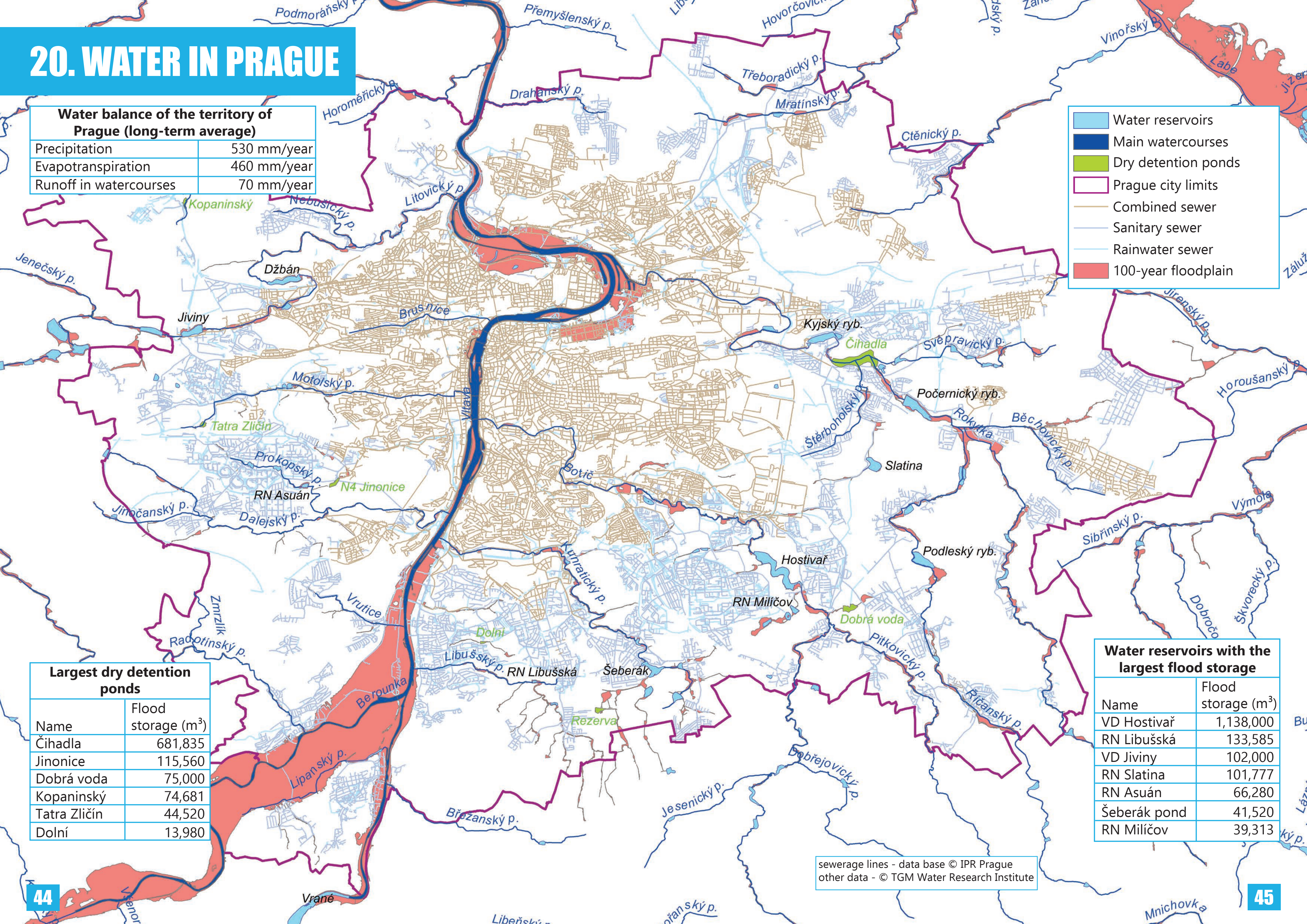
Water management in urban areas goes beyond drinking water supply or collection and treatment of wastewater. There is a growing interest in ICT use, resulting in a significant number of new applications, which provide access to a huge amount of information generated by the SCADA systems. This greatly facilitates the operation, maintenance and management tasks related to the efficient and sustainable development of cities. In this context, water management is particularly important, especially when we take it into account the substantial growth in water demand in recent years in developed areas. Proper use of ICT used in urban water management allows the collection of data and makes it possible to have real time information on supply and demand, and put this information in the hands of the managers, to help them to predict and manage the demand or adjust prices based on demand.



The resulting HAMR application, which serves as a drought prediction service

20. WATER IN PRAGUE

Water balance of the territory of Prague (long-term average)	
Precipitation	530 mm/year
Evapotranspiration	460 mm/year
Runoff in watercourses	70 mm/year



Largest dry detention ponds	
Name	Flood storage (m^3)
Čihadla	681,835
Jinonice	115,560
Dobrá voda	75,000
Kopaninský	74,681
Tatra Zličín	44,520
Dolní	13,980

Water reservoirs with the largest flood storage	
Name	Flood storage (m^3)
VD Hostivař	1,138,000
RN Libušská	133,585
VD Jiviny	102,000
RN Slatina	101,777
RN Asuán	66,280
Šeberák pond	41,520
RN Milíčov	39,313

sewerage lines - data base © IPR Prague
other data - © TGM Water Research Institute

Notes

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