LITERATURE REVIEW OF GREY, GREEN AND HYBRID MEASURES FOR FLOOD PROTECTION

In this section literature review on grey, green and hybrid flood protection measures is presented. Here, such aspects as feasibility, cost-effectiveness, flexibility, maintenance procedure, impact on and mitigation of climate change were considered during the review of the selected measures. In addition, short summary and case study is presented for each particular measure. However, before going deep into details about each measure, first it is important to mention how these measures were distributed between these three different categories.

Thus, with respect to grey measures, traditional and more or less conventional flood mitigation infrastructure was chosen. Compared to other flood risk reduction techniques, grey measures visually represent rigid infrastructure usually made of non-degradable materials, such as concrete or steel, and are known to have prevailing “grey” visual effect. Furthermore, this kind of measures usually provide restricted or almost no ecosystem services. Green measures, on the other hand, tend to have prevailing ecosystem functions compared to other flood risk reduction categories and are mainly made of degradable materials. Even though certain technical equipment is usually needed during the implementation stage to build green flood protection measures, subsequently after the set-up procedure these measures tend to have only “green” visual effect. With regard to hybrid measures, flood mitigation solutions that include functions of both grey and green measures were selected. It should be also mentioned that in this case hybrid measures refer mostly to those solutions that visually look greener and provide ecosystem services; however, they still contain elements of grey infrastructure that help the system to properly perform its functions.

Following that, Table 1 and 2 represent a list of the selected grey, green and hybrid measures and description of the parameters that were investigated during the literature review for each particular measure, respectively.

Table 1. *Selected measures for grey, green and hybrid flood mitigation measures*

Category	Selected measures
Grey	dams, floodwalls, underground stormwater detention tanks, permeable concrete pavements, infiltration shafts/drywells.
Green	afforestation, river re-meandering and floodplain restoration, rain gardens, urban parks and urban forests, infiltration ponds/basins.
Hybrid	Retention (wet) reservoirs, detention (dry) reservoirs/basins, green roofs, stormwater tree trenches, permeable vegetated surfaces.

Table 2. *List of descriptors and their explanation*

Descriptor	Explanation
Short summary	Short explanation/description of the selected grey, green or hybrid measure.
Feasibility	How difficult it is to implement the measure in terms of design, implementation procedure, etc. In addition, durability (lifetime) of the measure can be also considered in this section.
Cost-effectiveness	How effective is the measure in terms of flood mitigation and other aspects (if applicable) based on the number of investments (e.g., construction costs).
Flexibility	Influence of the selected measure on the risk of any other hazard, such as landslides, erosion, sedimentation, groundwater contamination, etc. (if applicable).
Maintenance	Maintenance activities (efforts) needed to keep the structure in the desirable conditions. In addition, maintenance costs can be also considered in this section.
Climate change	Influence of the selected measure on climate change. Here, depending on the selected measure, mitigation or, in contrast, negative impact on the climate change can be considered.
Case study example	Description of a case study where the selected measure was implemented or where its implementation was tested.

Floods - grey measures

<table>
<tr><th colspan="2">Measure: dams</th></tr>
<tr><td>Real case example where the measure was applied: Wivenhoe Dam in Australia (ASDSO, 2023).</td><td>
Figure 1. Concrete dam (Malm et al., 2016).</td></tr>
<tr><td>Short summary</td><td>According to the EEA (2017) report, dams are hydraulic structures that regulate flow of water in a river. Unlike dikes, which are usually constructed parallel to the riverbanks, in most cases dams are built perpendicular to the river, thereby, creating a barrier for the water to pass and, as a result, regulating the water flow further downstream.</td></tr>
<tr><td>Feasibility</td><td>The EEA (2017) report states that construction of dams requires huge investments due to their complex engineering structure. Ansar et al. (2014) mentions that building a dam is an extremely expensive process, which is also associated with further large maintenance costs after its construction.</td></tr>
<tr><td>Cost-effectiveness</td><td>Dams are known to be effective in protecting downstream regions from floods by regulating water discharge in the upstream section of the river. In addition, dams can have multifunctional purposes, such as provision of water for irrigation, electricity generation, etc.
With respect to costs, the following table summarizes the costs of dams at different locations in Europe:
<table>
<tr><th></th><th></th><th></th><th colspan="3">Costs</th></tr>
<tr><th></th><th></th><th></th><th>Land acquisition and compensation</th><th>Construction and rehabilitation</th><th>Operation and maintenance</th></tr>
<tr><th colspan="6">Longitudinal barriers</th></tr>
<tr><th>Case</th><th>River/Location</th><th>Source</th><th colspan="2">EUR/m</th><th>EUR/m/y</th></tr>
<tr><td>1</td><td>Maas (NL)</td><td>Hillen et al. (2010)</td><td colspan="2">1.82 M</td><td></td></tr>
<tr><td>2</td><td>Hartel (NL)</td><td>Hillen et al. (2010)</td><td colspan="2">0.84 M</td><td></td></tr>
<tr><td>3</td><td>Scheldt (NL)</td><td>Hillen et al. (2010)</td><td colspan="2">1.68 M</td><td></td></tr>
<tr><td>4</td><td>Ramspol (NL)</td><td>Hillen et al. (2010)</td><td colspan="2">0.55 M</td><td></td></tr>
<tr><td>5</td><td>Ems (DE)</td><td>Hillen et al. (2010)</td><td colspan="2">1.02 M</td><td></td></tr>
<tr><td>6</td><td>Thames (UK)</td><td>Hillen et al. (2010)</td><td colspan="2">2.73 M</td><td></td></tr>
<tr><td>7</td><td>Venice Lagoon (IT)</td><td>Hillen et al. (2010)</td><td colspan="2">1.46 M</td><td></td></tr>
<tr><td>8</td><td>Europe</td><td>Linham and Nicholls (2010)</td><td colspan="2"></td><td>5–10 % of investment</td></tr>
</table>
The report states that the total average cost of dam construction including land purchase of the 7 investigated cases in Europe was 1.6 million euros.
Figure 2. Costs of dams (EEA, 2017)</td></tr>
<tr><td>Flexibility</td><td>Tiessen et al. (2011) point out that large dams/reservoirs can be relatively effective in managing sediment loads. In particular, the study shows that the two investigated dams, Steppler multipurpose and Madill dry dam, were able to retain 77 and 66 percent of sediments, respectively.
Except the above-mentioned information, no particular influence of dams on any other hazards, such as landslides, erosion, etc., was found in the literature.</td></tr>
<tr><td>Maintenance</td><td>Hughes (2023) mentions that regular inspections should be carried out to check whether there are no cracks, defects or other imperfections that may put safety of the structure in danger. As for cracks, one should remember that not all cracks are dangerous. During the inspection procedure it is important to pay attention to the following features to define the severity of cracking: length and width of cracks, depth, direction, and their location. Besides that, it is necessary to properly distinguish different types of cracks, such as thermal, shrinkage, structural cracks and others. Usually, constant monitoring of the identified cracks is suggested. Furthermore, besides cracks, concrete and masonry</td></tr>
</table>

	elements should be checked against other deterioration features, such as leakage along structural elements, surface defects such as honeycomb and stratification, displacement, seepage through foundation, etc. Records of the detected defects also need to be kept. In addition, as a regular maintenance, debris and undesirable vegetation should be constantly removed (Hughes, 2023; Klun et al., 2021).
Climate change	International Rivers (2007) states that dams exert a negative impact on climate change by producing dangerous gas - methane (CH_4). In fact, the gas is produced at the bottom of the dam and is released into the air after a sudden pressure drop when water from the dam is released. However, when the gas rises up by itself and becomes in contact with the air, it is converted to CO_2. In addition, according to the Portland Cement Association (2023), the cement manufacturing process is considered to be one of the emitters of carbon dioxide into the atmosphere. However, the same source states that around 60 percent of the carbon dioxide released throughout the cement production process is very gradually absorbed by the concrete surface, when it becomes in contact with air.
Case study example	Galoie and Motamedi (2014) studied the effectiveness of a retention dam located in a small catchment in Austria in terms of flood control. The study revealed that availability of the 215,000 m^3 volume dam is not sufficient enough to reduce inundation extent in all investigated regions, caused as a result of a 100-year return period flood event. In fact, the dam was only able to manage half of the floods, making it necessary to construct another retention dam in this region in order to deal with the rest of the areas that were inundated the most.

Measure: floodwalls	
Real case example where the measure was applied: Bratislava, Slovakia (Kryžanowski et al., 2014)	 ***Figure 3.*** *Different types of flood walls as a flood protection measure in the city of Bratislava, Slovakia: (a) concrete (b) sealing (underground), (c) reinforced concrete and (d) mobile walls (Kryžanowski et al., 2014)*
Short summary	According to the FEMA (2013), floodwalls is an engineering structure typically made of reinforced concrete and steel and is designed to protect buildings in flood-prone areas from floodwaters.
Feasibility	Kádár (2015) mentions that the installation procedure, for example, of the mobile floodwalls usually takes not much time since its structural elements are quite light and, therefore, easy to move and transport. A manpower of 8 people is typically required to construct 300-m long floodwall in one day. Furthermore, another advantage of mobile flood barriers refers mainly to the possibility to maintain the natural landscape when the walls are removed after a flood event. However, the same source indicates that mobile walls for flood protection also have a number of disadvantages. For example, the installation costs are relatively high and, furthermore, place for storing the walls is required. Rickard (2009) states that in general floodwalls are one of the most favorable solutions for the flood-prone areas, where the available space for other flood mitigation defenses is restricted. Furthermore, the author mentions, even though this type of flood defense may seem relatively strong, it can still be damaged. When the structure becomes overtopped, it can lose its structural stability as a result of destabilized foundation, which eventually can lead to immediate collapse. To solve the problem a special hard surfacing should be implemented for the defense to reduce the probability of failure.
Cost-effectiveness	The cost of floodwalls mainly depends on the type of material, which is used to construct the flood defense (Rickard, 2009). According to the RetainingWall Solutions (2023), there are many factors that affect price formation of the floodwalls, in particular, type of material used, height of the structure, specific site constraints, soil characteristics and project scale. In general, for 0.675 m high flood wall built on clay soil the cost is around 300 pounds, which equals to nearly whereas for sandy soil the price is nearly 350 pounds for the wall of the same height (RetainingWall Solutions, 2023). This, in turn, corresponds to nearly 342 and 399 euros, respectively.
Flexibility	No influence of floodwalls on mitigation of erosion, landslides or any other hazards was found in the literature. In contrast, Rickard (2009) states that this type of flood defenses can be quite vulnerable to riverbank erosion, which usually leads to damage and final collapse of the structure.
Maintenance	Regular inspections should be conducted in order to check the condition of floodwalls. In particular, floodwalls should be periodically checked against seepage, sand boils, etc. Besides that, it is necessary to periodically inspect riverbanks to make sure that the floodwalls are stable and there are no saturated areas that may also affect the structure. In addition, any sort of debris should be regularly removed and the walls need to be inspected against encroachment to exclude any damages to the flood protection structure (NRC, 1982). Rickard (2009) argues that although floodwalls require regular inspections to be carried out in order to check their functionality, in general they need little maintenance.

<table>
<tr><td>Climate change</td><td>No evidence of the influence of floodwalls on climate change mitigation was found.</td></tr>
<tr><td>Case study example</td><td>Flood Control International (2023) presents one example of the flood defense system in Wakefield, England. The system was designed to protect the city from constant floods from the River Calder. The unique feature of these floodwalls is that they are operated using a special main control unit, which initiates the system as soon as its water sensors detect the risk water level. The flood defense was built in 2008 with the goal to sustain the maximum projected hydraulic load including additional 30 percent for safety reasons.

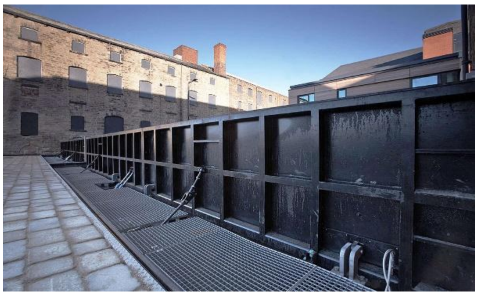
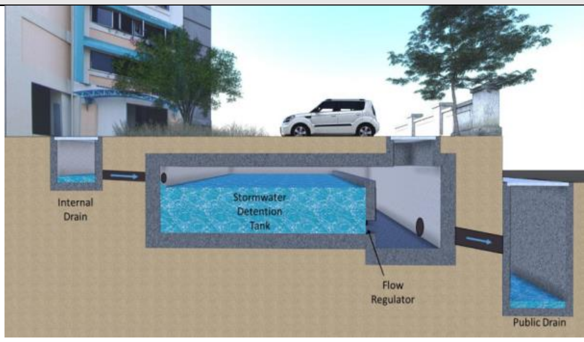
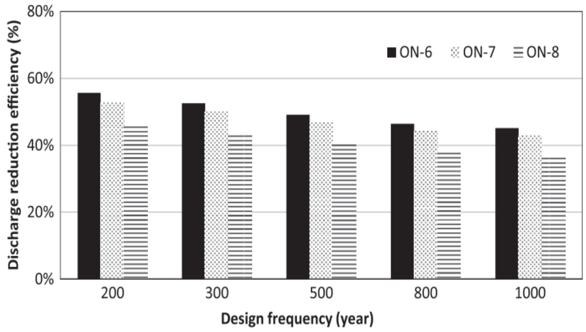



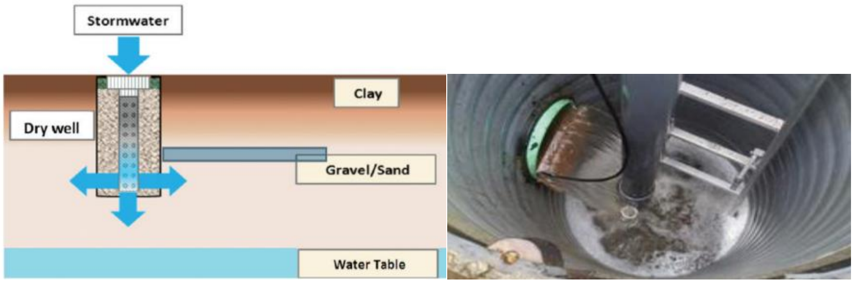
Figure 4. Flood defense in Wakefield (Flood Control International, 2023)</td></tr>
</table>

Measure: underground stormwater detention tanks	
Real case example where the measure was applied: Gomeznarro Park in Madrid (Climate-ADAPT, 2022).	 ***Figure 5.*** *Visual representation of the underground stormwater detention system (PUB, 2021)*
Short summary	A stormwater detention tank is a special water storing facility that is used to keep stormwater runoff during flood events in order to reduce flood peak and then slowly release it into a drainage system. With respect to the PUB (2021), Singapore's National Water Agency, detention tanks can be categorized into two categories: aboveground and underground tanks. In this section the second type is considered.
Feasibility	According to the US EPA (2020), it is usually quite complicated to find a proper and favorable place for location of the USTs, since areas that are frequently inundated are most of the time covered with muddy soil and debris. Another problem that can be faced is related to buoyancy forces acting on the underground structure. If the UST is located in an area with highly saturated soil content, the structure becomes subjected to the upward buoyancy force that pushes up the tank, thereby, creating damages to pipes, pavements and other infrastructure elements that are located above the tank. Therefore, it is important to make sure that the tank won't go up as a result of the uplift force. To accomplish this, heavy sandbags or containers with rocks can be placed on the top of the UST as an additional load that can prevent the structure from going up (US EPA, 2020). The PUB (2021) states that the system should be designed in such a way that it is capable of releasing the accumulated water inside the tank after 4 hours when the flood event has happened. This, in turn, is done to make sure that there is available space in the tank in case the next flood event occurs.
Cost-effectiveness	The price of underground stormwater storage tanks is significantly higher than of the aboveground ones due to the more complicated procedure of tank installation and maintenance. However, at the same time the UST system can be more affordable in locations where land acquisition is relatively expensive and when there is a problem of land availability (Lakesuperiorstreams, 2009). As for many other flood mitigation measures, the cost of USTs highly depends on the site characteristics and location, type of tank material, amount of tank volume required to store stormwater, labor costs, volume of excavated soil, size of pipes and other factors. In general, the cost of USTs varies between 3-10 dollars per ft^3 of the volume stored, which equals to nearly 97-325 euros per m^3 (Lakesuperiorstreams, 2009).
Flexibility	No effect of underground stormwater detention tanks on risk reduction of any other hazards was observed in the literature.
Maintenance	With respect to maintenance activities, the Lakesuperiorstreams (2009) states that every month site inspection should be carried out to check the condition of the inlet and outlet pipes and inspect the inlet gates against accumulated debris. Furthermore, in case there is a need to repair any elements of the structure, it should be done on time to exclude the risk of poor functioning of the tank during a flood disaster. It is also recommended to mechanically remove accumulated sediments in the water storing facility minimum ones a year. If there is a filtering

	system installed for stormwater purification, the manufacturing company should be responsible to check its proper functionality.
Climate change	No particular influence of the USTs on climate change was detected in the literature.
Case study example	Shin et al. (2022) studied the effectiveness of the USTs implementation in the most urbanized regions of the Oncheon stream basin in Korea. The study revealed that the USTs can be quite effective in reducing flood discharge and, as a result, protecting flood-prone areas from an upcoming flood disaster. For example, for the 200-year return period around 56, 55 and 53 percent reduction in flood discharge was observed in the Sa-jik stream (ON-6), before Geo-je (ON-7) and after Geo-je stream (ON-8), respectively (Figure 5). In general, for all flood frequencies reduction in the inundation extent in all investigated regions was found to be more than 40 percent. The highest decrease in the area of inundation was observed for 200- and 300-year return periods (88 and 79 percent, respectively).  ***Figure 6.*** *Reduction in the discharge after implementation of the USTs in the Sa-jik stream (ON-6), before Geo-je (ON-7) and after Geo-je stream (ON-8) (Shin et al., 2022)*

Measure: permeable concrete pavements	
Real case example where the measure was applied: parking lots of the Finley Stadium in Chattanooga, Tennessee (US EPA, 2013).	 ***Figure 7.*** *Permeable concrete (Upper Midwest Water Science Center, 2019)*
Short summary	With the expansion of urbanized areas, the number of impervious surfaces also increases. When flooding occurs, the city drainage system plays an important role in removing excess stormwater from the streets (Huang et al., 2020). However, as there are many surfaces that don't allow water to be infiltrated during floods, the drainage system experiences additional pressure when the amount of water is too high (Bae and Lee, 2020; Mu et al., 2021). Consequently, the situation is worsened as the capacity of the drainage system is not enough to process the whole amount of water that can be accumulated as a result of the impermeability of many surfaces. In this case, permeable concrete pavement can be considered as an additional measure to reduce the risk coming from floods by allowing retained water to be slowly infiltrated, reducing at the same time additional pressure on the drainage system (Ma et al., 2020; Qin et al., 2013).
Feasibility	To implement permeable concrete surfaces, built-up areas should be removed, therefore, at a large scale it would be quite difficult and almost impossible to accomplish. Thus, in this case usually small areas such as parking spaces and bicycle roads can be selected to turn the idea into reality. Additionally, in order to implement this measure special soil should be selected, in particular, soil with high infiltration capacity is required (Bezak et al., 2021). With respect to its lifespan, according to the (Green Building Alliance, 2023), the expected lifetime of permeable concrete is between 20 and 40 years.
Cost-effectiveness	Costs of permeable concrete typically include costs of installation of the pervious surfaces and their further maintenance (Bezak et al., 2021). The Environment Agency (2015) states that the cost of permeable pavement varies between 30-40 per m^2 of the pavements, which equals to nearly 34-46 euros per m^2. Benefits are usually the following: runoff reduction, recharging of groundwater, and reduction of surface temperature (Green Building Alliance, 2023). The Stormwater Management Calculator of the CNT (2020a) indicates that in the United States construction cost of pervious parking, sidewalks, and streets corresponds to 8.68 dollars per ft^2 (~0.0929 m^2), which equals to 67.9 euros per m^2, whereas annual maintenance cost is accounted for 0.02 dollars per ft^2 (~0.2 euros per m^2).
Flexibility	The US EPA (2021a) states that permeable pavements are able to remove pollutants from the stormwater. Depending on the layering system of the pavement, concentration of contaminants in the water can be reduced as a result of physical filtration. Except this information, no particular influence of concrete pavement on any hazard was found in the literature.
Maintenance	During the maintenance of permeable concrete one important aspect that should be considered concerns mainly clogging of its pores with contaminants (Kryeziu et al., 2013). As a result of pore blocking, permeability of material is decreasing leading even to a shorter lifetime (Kia et al., 2017). Power vacuuming and pressure washing are two main maintenance techniques for permeable concrete. Both methods prevent pore clogging with contaminants to allow stormwater to pass into the ground easily (Kryeziu et al., 2013).

Climate change	Permeable pavement is known as one of the contributors to the reduction in the so-called Heat Island effect of cities. Haselbach (2009) found that if permeable concrete with 23 percent porosity is used, the heat transfer rate for non-pervious pavement is 41 percent higher than for pervious one. The study concluded that pervious concrete could reduce the Heat Island effect by evaporating water from its pores. As it was previously mentioned in the section for dams, being one of the components of the concrete, cement is also known to be one of the emitters of carbon dioxide into the atmosphere during its manufacturing process (Portland Cement Association, 2023), which can exert a negative impact on climate change.
Case study example	A case study of the Shoreview city, where permeable concrete has been implemented for road pavements since 2009, can be demonstrated. Before 2009 the city was implementing conventional hydraulic infrastructure to manage stormwater runoff, however, to promote a more sustainable design of the city and reduce pressure coming from excess precipitation, pervious pavements were introduced. The study revealed that the costs of traditional concrete pavements considerably outweigh the costs of permeable pavements. In general, permeable concrete has a significant advantage over its non-pervious alternative due to its ability to infiltrate water. However, on the other hand, it was also shown that the performance of permeable pavements decreases with time due to clogging, which shows the need for constant maintenance and control (Izevbekhai and Schroeder, 2017).

Measure: infiltration shafts/drywells	
Real case example where the measure was applied: Oregon, Arizona, Washington (City of Elk Grove, 2023).	 ***Figure 8.*** *Drywell (City of Elk Grove, 2023)*
Short summary	Infiltration shaft, also called drywell or percolation shaft, is a special underground system composed of one main shaft and some other attributes necessary to collect stormwater runoff. The system allows excess amounts of water to infiltrate into the well, which then slowly releases the percolated stormwater runoff in the surrounding soil (City of Elk Grove, 2023; DWA, 2005).
Feasibility	Sasidharan et al. (2021) studied performance of two flood mitigation measures: drywells and infiltration basins. The study revealed several advantages of drywells over infiltration basins, in particular, percolation shafts occupy less surface area, which makes the process of land acquisition much easier. Furthermore, Sasidharan et al. (2021) argues that drywells don’t spoil the aesthetic appearance of urban parks, streets and other places as they usually look like utility holes. In addition, compared to infiltration basins, drywells allow water to be pretreated before entering the well without having any influence on the performance of the structure. With respect to the City of Elk Grove (2023), during the design and implementation stage a proper location needs to be selected for placing the percolation shafts. It is not recommended to locate the shafts in areas close to gas stations or any other facilities that utilize dangerous substances to reduce the risk of groundwater contamination. Furthermore, even though percolation shafts can use special filtration mechanisms to remove contaminated particles from the stormwater, the City of Elk Grove (2023) is not recommending placing the shafts in highly polluted soils to exclude the risk of soil contaminants entering the drywell. In addition, the source mentions that pre-treatment of stormwater is needed to reduce concentration of hazardous pollutants.
Cost-effectiveness	According to the Stormwater Management Calculator of the CNT (2020a), the medium capital cost of drywell construction in the United States is nearly 250 dollars (~230 euros), while the highest cost is around 5,000 dollars (~4,600 euros). Maintenance costs of the same drywell account for 20 dollars per year, which equals to nearly 18.4 euros per year. The useful life of this flood mitigation infrastructure is around 70 years. However, it should be also noted that the cost also depends on the size of the drywell. For example, in the United States for 1,500-gallon MaxWell Type IV (~5.7 m^3) and 2,500-gallon MaxWell Plus (~9.6 m^3) the cost varies between nearly 25,750-32,200 and 34,950-41,400 euros, respectively (Sasidharan et al., 2021; Torrent Resources, 2023). Regarding the effectiveness of this measure, the same Stormwater Management Calculator was used to define the number of 265-gallon (~1 m^3) drywells needed to have around 90 percent reduction in stormwater runoff in a manually defined area. Site characteristics are presented in Figure 8:

<table>
<tr><td></td><td>
<table>
<tr><th colspan="3">Total Land Use</th></tr>
<tr><th>Land Use</th><th>Original Area</th><th>Area including BMP(s)</th></tr>
<tr><td>Total Impervious Area</td><td>1,885 ft^2</td><td>1,885 ft^2</td></tr>
<tr><td>Flat Roof</td><td>400 ft^2</td><td>400 ft^2</td></tr>
<tr><td>Pitched Roof</td><td>900 ft^2</td><td>900 ft^2</td></tr>
<tr><td>Sidewalk</td><td>585 ft^2</td><td>585 ft^2</td></tr>
<tr><td>Total Landscape Area</td><td>4,190 ft^2</td><td>4,190 ft^2</td></tr>
<tr><td>Lawn/Turf</td><td>3,850 ft^2</td><td>3,850 ft^2</td></tr>
<tr><td>Flower Bed/Garden</td><td>340 ft^2</td><td>340 ft^2</td></tr>
<tr><td>Total BMP Area</td><td></td><td>0 ft^2</td></tr>
<tr><td>Total Lot Area</td><td>6,075 ft^2</td><td>6,075 ft^2</td></tr>
<tr><td>Other Volume Control</td><td></td><td>530 gallons</td></tr>
<tr><td>Drywell</td><td></td><td>530 gallons</td></tr>
</table>
Figure 9. Land use characteristics of the investigated urban home (BMP – best management practice) (CNT, 2020a)
As a result, it was found that for the area specified in Figure 8 and with average rainfall of around 830 mm per year, and 59 mm per storm, 2 drywells are required in order to reduce the runoff volume by 90 percent. In this case, the volume of the drywell was taken as 265 gallons, which corresponds to around 1 m^3.</td></tr>
<tr><td>Flexibility</td><td>Drywells are considered a good solution for aquifer recharge. In 2005 a 10-year study was conducted in Los Angeles aiming to identify the recharging performance of underground drywells. It was found that in this region implementation of drywells could satisfy in total 750,000 houses in terms of water supply for the household needs (City of Elk Grove, 2023).</td></tr>
<tr><td>Maintenance</td><td>Similar to many other flood mitigation measures, infiltration shafts need regular maintenance. It is important to constantly clean the structure by removing accumulated debris, vegetation such as silt and other sources of litter to make sure that there won’t be any stagnant water inside the well (Torrent Resources, 2023).
The City of Elk Grove (2023) mentions that purification of stormwater is always needed before it enters the drywell to reduce concentration of hazardous pollutants, which can create the risk of groundwater contamination. The DWA (2005) states that a filter sack can be installed in the infiltration shaft and utilized for a pre-treatment process.</td></tr>
<tr><td>Climate change</td><td>No effect of drywells on climate change was observed in the literature.</td></tr>
<tr><td>Case study example</td><td>The study of Sasidharan et al. (2021) analyzed the performance of the 38-m deep percolation shaft and 70-m wide infiltration pond with the total surface area of 3,847 m^2. Having compared both flood mitigation measures, the study concluded that implementation of five infiltration shafts can reduce significantly more stormwater runoff than one single infiltration pond, which shows a comparative advantage of drywells over infiltration basins.
Sasidharan et al. (2018) analyzed performance of the Maxwell Type IV implemented in Fort Irwin and Torrance in California. The former one is the National Training Center, whereas the latter one is a commercial organization. The study revealed that the infiltration performance highly depends on the hydraulic conductivity of a soil. It was found that the first drywell located in Fort Irwin could infiltrate nearly 53.2 m^3, while the second drywell only 12.6 m^3 during the period of around 18 hours. With the given characteristics for both wells, the study concluded that the Torrance well performed less effectively due to the lower hydraulic conductivity, which could even result in shaft clogging and subsequent overflow.</td></tr>
</table>

Floods – green measures

Measure: afforestation	
Real case example where the measure was applied: United Kingdom (Open Access Government, 2022).	 ***Figure 10.*** *Afforestation in the United Kingdom (Open Access Government, 2022)*
Short summary	Afforestation is a process of converting agricultural lands, marginal lands, or other types of land cover to forests. Here, as a result of the expansion of tree cover in the regions where previously there were no trees, carbon concentration in the air and flood peak discharge can be reduced (Arora and Montenegro, 2011; Johnen et al., 2020).
Feasibility	To implement this measure, first, it is required to find and prepare a land, where afforestation is going to take place. Following that, necessary tree species are selected and suitable fertilizers depending on the selected vegetation type are picked up. When the trees are planted, they should be maintained during the first years (Climate-ADAPT, 2020).
Cost-effectiveness	Afforestation as a flood mitigation option was already studied in previous works of Johnen et al. (2020) and Bezak et al. (2021), who explored the measure in terms of its effectiveness for flood risk management. The former one conducted a cost-benefit analysis to investigate the effect of tree cover expansion on peak flow in the Glinščica River for three return periods: 2, 10, and 25 years. They revealed that with 15-60 percent afforestation, the inundation peak can be decreased by 9-14 percent. In particular, for 2, 10, and 25-year return periods the flood peak was diminished by 14, 10, and 9.5 percent, respectively. Thus, in this case, economic losses can be also reduced as the extent of the inundated area becomes lower as a result of afforestation. Johnen et al. (2020) found that among three investigated return periods, for the 25-year return period the process of afforestation contributed to the flood damage reduction the most. Here, the initial damage costs for the case with the current land-use practices were computed to be around 610,752 euros, whereas with the expansion of forest cover upstream, downstream, and throughout the whole area the total flood damages were significantly lower. Here, as a result of the increase in the tree cover in the upstream, downstream, and in both sections the total damages were reduced by 78, 65, and 80 percent, respectively. However, for the other two return periods, on the other hand, the total damages for all four cases were much lower and didn't vary a lot with the difference in tree cover. Besides, the study also analyzed the effectiveness of the investigated measure on different ecosystem services based on the three different afforestation scenarios. For example, Johnen et al. (2020) revealed a positive effect of afforestation on biodiversity, water quality, and carbon concentration. With respect to costs, the same study found that for 1 ha (10,000 m^2) of land around 3,500 trees are needed. Considering the fact that each tree needs around 1 euro to be planted, the total cost of planting 3,500 trees on 1 ha would be around 3,500 euros. The average price of the cropland that can be used for afforestation, in turn, was found to be around 60,000 euros per ha (Johnen et al., 2020).

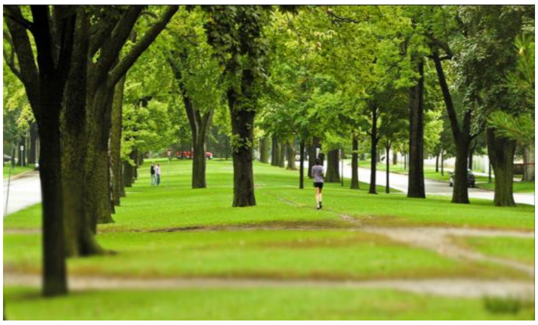
Flexibility	By reducing soil moisture content, trees help to decrease the likelihood of landslides. Tree roots act as a barrier against soil displacement, at the same time they strengthen soil layers and attach the soil to bedrock. In addition, forests can also prevent fall of rocks and debris, shorten the run-out distance of landslides, and decrease the risks of soil erosion (RECOFTC, 2012). However, Forbes and Broadhead (2013) state that this is only true for shallow landslides.
Maintenance	According to the Climate-ADAPT (2020), during the first year after afforestation the average maintenance cost of tree cover is around 300 euros per ha (10,000 m^2), whereas during the third year the costs can go down to 100 euros per ha. In general, the maintenance process should be carried out during the first 3-5 years.
Climate change	According to the United Nations, afforestation can be considered as one of the most effective measures in relation to climate change mitigation (Arora and Montenegro, 2011). Trees are known to absorb carbon dioxide, which helps to combat the problem of climate change. For example, 0.8 tons of CO_2 per ha (10,000 m^2) of green cover per year can be processed by urban greenery (CNT, 2020b). At the same time, trees are also known to mitigate the impact of climate change on stormwater runoff. In fact, the effect of climate change on generation of higher amount of precipitation and, as a result, subsequent increase in frequency and magnitude of floods is well known. With the help of rainfall interception forests tend to reduce some amount of precipitation that could potentially reach the ground and produce excess amount of runoff (Zabret and Šraj, 2015). Being more precise, Zabret and Šraj (2015) found that, for example, both *Pinus nigra* and *Betula pendula* could produce substantial results in terms of rainfall interception. In particular, the latter one could intercept up to 51 percent of the precipitation, while the latter one around 30 percent less. However, at the same time, according to Bonan (1997), forests tend to have a lower albedo coefficient, which, in turn, is proportional to the amount of solar radiation being reflected. This implies that croplands are more reflective than trees and, therefore, with the increase in the forest cover over a specific land, the amount of solar radiation absorbed by the trees is also increasing leading to the net climate warming, in particular, in the regions with higher elevations (Arora and Montenegro, 2011).
Case study example	Here, the case study of the upper Chao Phraya River Basin in Thailand can be highlighted. The study was conducted not only to investigate the effect of afforestation on flood risk, but also to compare it with the changes caused by climate change. It was found that afforestation can have a positive effect on flood mitigation; however, this impact is relatively small if compared with the rate of global warming, which we are facing today (Takata and Hanasaki, 2020).

Measure: river re-meandering and floodplain restoration	
Real case example where the measure was applied: Nijmegen, The Netherlands (World Landscape Architecture, 2017).	 ***Figure 11.*** *Room for the River, Nijmegen, The Netherlands (World Landscape Architecture, 2017)*
Short summary	Straightening of rivers as a flood risk reduction measure has faced a lot of disputes due to its negative effects on environmental aspects. Furthermore, river straightening can eventually contribute to a significantly higher discharge at the downstream part of the modified river channel, thereby, causing severe floods. Subsequently, as a result of numerous negative consequences, river restoration has taken place in many places to return rivers back to their original state, thereby mitigating flood impacts (Bechtol and Laurian, 2005).
Feasibility	To turn rivers back to their natural state can be quite problematic when the question concerns urban areas, as there is usually not enough available space for natural river meanders in cities (Guimarães et al., 2021).
Cost-effectiveness	Transforming meandering rivers that have previously been straightened back to their natural shape helps to make rivers more morphologically stable, reduce river slope and flow velocity, thereby, reducing risks of bank erosion and the amount of transported water per unit of time. Besides that, river meandering promotes both biological and hydrological diversification of rivers (Bechtol and Laurian, 2005). With respect to costs, Szalkiewicz et al. (2018) analyzed 119 river restoration projects in Europe, in particular, their investments in reinstating their natural characteristics. They found that 310,000 euros per ha (10,000 m^2) was the average cost of the river restoration in Europe.
Flexibility	Floodplain restoration can prevent deposition of sediments in the river and decrease the rate of deposition further downstream of the river by allowing sedimentation to occur, namely in the floodplain itself. As a result of the sediment deposition soil quality and fertility can get better. The erosion process can be further reduced by creating a small stone dam on the sides of the floodplain. Converting a land from a simple agricultural area to a forest area with some wetlands can also improve the protection of the soil (Natural Water Retention Measures, 2013).
Maintenance	Maintenance of rivers typically includes the following practices: repair of riverbed, removal and control of unnecessary vegetation, regular inspections, removal of rubbish and obstructions, and other activities. According to the Environment Agency (2015), river cleaning costs depend mainly on how this process is done, in particular, whether it is done manually or implementing, for example, special cleaning equipment (mechanically). Furthermore, for rivers that are already properly maintained, the costs for the mechanical cleaning are typically lower than for the manual one. For the former one they vary usually between 1,680–17,096 dollars per km annually, which equals to nearly 1.6-15.7 euros per m per year, whereas for the latter one this number is accounted for 5,730–51,311 dollars per km per year (~5.3-47.2 euros per m per year). Besides that, the same source indicates that the river maintenance costs also depend on the final target state of the river that is planned to be achieved. In addition, when evaluation tests and inspections of the river are carried out, this typically costs 4049 dollars per km (~3.7 euros per m) of the river length.

	Additionally, according to the Natural Water Retention Measures (2013), maintenance costs of restoration of the floodplain can usually correspond to 0.5-1.5 percent of the investment costs.
Climate change	Large scale floodplain restoration projects can greatly affect climate conditions. Floodplain restoration can have an impact on the amount of precipitation and peak temperatures as a result of land use changes and, in particular, afforestation practices. Large scale afforestation can influence the evapotranspiration rate leading usually to the higher amount of precipitation. As a result of increased evapotranspiration, reduction in peak temperatures can be noticed. Furthermore, as in this case agricultural and artificial lands usually become converted to forests, the carbon dioxide is absorbed more as a result of the photosynthesis process, which, in turn, can lead to mitigation of the climate change (Natural Water Retention Measures, 2013). According to the GeoForschungsZentrum Potsdam and Helmholtz Centre (2021), compared to straight manmade river courses, natural meandering rivers are more capable of removing CO_2 from the air. This happens because non-artificial rivers have much broader space for the erosion of their natural floodplains, thereby transporting accumulated carbon down the river right into the sea. However, artificially made straight rivers/channels cause the decomposition of carbon back to carbon dioxide allowing only suspended load to flow through the river section.
Case study example	"Room for the River" in The Netherlands is an example of the project where restoration of the river took place. The main objective of the project was to increase the capacity of the river discharge by implementing river modifications at 35 different locations on the Rhine River. This was accomplished by lowering the bed of the Rhine River with the following activities: river widening, riverbed excavation, putting dikes at a farther distance from the river, making floodplains lower as they were before, etc. The total investment costs of the project were calculated to be around 2.64 billion dollars, which equals to nearly 2.4 billion euros (Aerts, 2018). Bechtol and Laurian (2005) showed the Napa River Flood Protection Project as a sustainable flood risk reduction example. This study has demonstrated how fluvial floods can be mitigated with the help of the restoration of the natural characteristics of the Napa River. In particular, in this project original floodplains of the river were restored by straightening it to its natural state (Bechtol and Laurian, 2005).

Measure: rain gardens	
Real case example where the measure was applied: St. Paul campus rain garden (The University of Minnesota) (Asleson et al., 2010).	 ***Figure 12.*** *Rain garden (NOAA's Office for Coastal Management, 2015)*
Short summary	A rain garden represents a small garden with planted shrubs, flowers, grass and other vegetation, usually located in the low-lying areas down the slope in order to collect stormwater runoff (NOAA's Office for Coastal Management, 2015). The rain gardens are designed in such a way that they can receive excess amounts of water coming from roofs, roads, lawns and other ways, consequently infiltrating it into the soil (Groundwater Foundation, 2022).
Feasibility	Rain gardens should be placed near buildings to be able to capture stormwater runoff coming from roofs, lawns, different kinds of pavements and other ways. To build the rain garden it is important to replace natural soil with the porous one so that necessary vegetation can favorably develop, and excess amounts of water can be easily infiltrated. It is necessary to make sure that the garden gets dry fast enough after each rainfall event in order not to create a favorable medium for mosquitoes' growth (Qin, 2020).
Cost-effectiveness	The costs of rain gardens depend on different factors, in particular, what plant species are chosen, area of the garden, type of soil, etc. In addition, the costs depend on whether the garden is built hiring special landscaping company or if it is just a self-built rain garden. For the former one the installation costs vary between 10-15 dollars per square foot (nearly 100-150 euros per m^2), whereas for the latter one the price varies between 3-5 dollars per square foot, which equals to nearly 30-50 euros per m^2 (Groundwater Foundation, 2022). According to the Stormwater Management Calculator of the CNT (2020a), the capital cost of construction of a 100 ft^2 (~9.3 m^2) rain garden in the United States is nearly 607 dollars, which equals to nearly 558 euros, whereas maintenance costs of the garden with the same area is 41 dollars per year (~37.7 euros per year). In this case, the same source mentions that the useful life of the rain garden is 22.5 years. In general, rain gardens are considered as an effective way of regulating runoff as they collect stormwater and allow it to be infiltrated deep into the ground, thereby, producing groundwater recharge. At the same time vegetation can help to filter the water from contaminants, such as fertilizers, dirt, litter, machine oil, which are accumulated in water while it passes on the top of driveways, roofs and other ways (NOAA's Office for Coastal Management, 2015).
Flexibility	No particular evidence indicating effectiveness of rain gardens on risk reduction of any other hazards was found in the literature. However, there are some sources that describe less significant benefits of rain gardens compared to stormwater runoff reduction, such as removal of sediments and pollutants in the stormwater runoff (Dietz and Clausen, 2005; Groundwater Foundation, 2022).
Maintenance	Rain gardens usually don't require implementation of fertilizers or pesticides, except the first year, since in this case typically native plant species are used. In general, during the first couple of years when the rain garden is set up, it is required to remove unnecessary weeds, dead plants and other vegetation that can prevent sustainable growth of normal plants and degrade aesthetics. When native plants take root and become well-established, they will be able to displace the weeds by themselves. Additionally, during the first years in case of lack of

	rainfall, it may be required to water the gardens in order to sustain the normal plant growth (Groundwater Foundation, 2022).
Climate change	No relevant literature indicating significant influence of rain gardens on mitigation of climate change was found.
Case study example	Dietz and Clausen (2005) studied the effectiveness of rain gardens in terms of stormwater runoff reduction in Haddam. They found that this flood mitigation measure can be highly effective in mitigating flood impact, in particular, the study revealed that 98.8 percent of water, which came from the roof, infiltrated into the soil and the rest was observed as overflow.

Measure: urban parks and urban forests	
Real case example where the measure was applied: Danube-Auen National Park in Vienna, Austria; Parkforest in Ghent, Belgium; Forest Ostend in Belgium (Network Nature, 2023).	 ***Figure 13.*** *Urban park (Minnesota Pollution Control Agency, 2022)*
Short summary	In the past years with the expansion of cities and overall urban development there was a tendency in urban areas to cut down trees and remove vegetative canopy from the ground, at the same time increasing the number of impermeable surfaces, which consequently led to the dramatic increase in the stormwater runoff and, as a result, generation of floods. However, trees play an important role in the water cycle, in particular, its canopy can intercept rainwater allowing a part of it to evaporate back into the atmosphere, tree roots help stormwater runoff to percolate deeper into the soil and improve soil water holding capacity (Kuehler et al., 2017).
Feasibility	As impervious urban surfaces such as driveways are an integral part of an urban environment and it is quite difficult to remove all non-permeable pavements that are increasing stormwater runoff, urban forests on their own won't be able to combat the issue of high runoff volumes (Kuehler et al., 2017). Kuehler et al. (2017) also mentions that only in combination with other stormwater reduction techniques urban forests will be able to reduce sufficient amounts of runoff.
Cost-effectiveness	McPherson et al. (2005) argues that in the United States, for example, an average price of an urban tree is in the range between 12.87-65 dollars, which equals to nearly 11.8-60 euros. However, according to the Stormwater Management Calculator of the CNT (2020a), the capital cost of one tree in the United States is nearly 250 dollars (~230 euros), whereas maintenance costs of the tree is 180 dollars per year (~165 euros per year). In this case, the same source mentions that the useful life of one tree corresponds to 80 years.
Flexibility	As it was already mentioned in the section for afforestation, tree cover can only have an effect on shallow landslides, whereas for deep-seated landslides the impact is insignificant. In particular, trees can cope with minor landslides by preventing fall of rocks, strengthening and drying soil, which, in turn, helps to reduce water pressure in the soil (Forbes and Broadhead, 2013). In addition, with respect to the same section related to afforestation, as Zabret and Šraj (2015) mentioned in their study, trees can also mitigate the effect of climate change, particularly, by reducing the amount of precipitation reaching the ground as a result of the interception process.
Maintenance	With respect to Vogt et al. (2015), urban trees should be properly maintained through their whole lifetime, in particular, maintenance actions include pruning, disease and pests' control, mulching, watering, fertilizing, providing support system for trees and other activities. Tree support system, in turn, implies provision of various support structures for trees such as cabling or bracing that help to support the tree truck at a time when it is highly vulnerable. In addition, such a support system is usually implemented for young trees that are particularly vulnerable and unstable, especially in windy regions (Vogt et al., 2015). Following that, watering of urban forests is an important step in maintaining their life: without sufficient watering trees may not survive, especially when the tree is just getting established during the first years. Another important maintenance step refers to infrastructure repair. This includes damages to drainage pipes, driveways, parking lots and other types of pavements by the

	root system. The damaged surfaces are then fixed or replaced by the new ones, and the tree roots are pruned if necessary.
Climate change	According to Nowak and Crane (2002), trees in urban areas can store nearly 700 million tons of carbon. Safford et al. (2013) also mention that more than 708 million tons of carbon in the United States is stored by urban forests, which is estimated to be more than one-tenth of all CO_2 emissions that are produced in the country per year. Additionally, every year trees in urbanized regions of the United States also absorb 28.2 million tons of carbon.
Case study example	Rahman et al. (2023) analyzed 92 papers to investigate the effectiveness of urban tree cover on flood risk management. The study revealed that compared to different land use types, forests have the highest potential in reducing stormwater runoff. It was found that conifer is considered to be the most effective tree type in terms of annual flood risk management as it has the highest transpiration and interception characteristics. However, its soil infiltration capacity is inferior to broadleaved trees. In general, Rahman et al. (2023) concluded that additional 4 percent reduction in excess amount of stormwater can be achieved with the 30 percent increase in the conifer canopy in areas experiencing essential amount of precipitation during the cold season, whereas 20 percent increase is expected to provide the same amount of additional runoff reduction for regions with only wet climate conditions.

Measure: infiltration ponds/basins	
Real case example where the measure was applied: Lehigh County in Pennsylvania (Pennsylvania Department of Environmental Protection, 2005).	 ***Figure 14.*** *Infiltration pond (US EPA, 2021b)*
Short summary	Infiltration pond or basin is an example of a green flood mitigation measure that is used to reduce stormwater runoff usually generated as a result of the increased number of impervious surfaces in urban areas, which don't allow water to be infiltrated into the soil (Massmann, 2003).
Feasibility	The Environment Agency (2015) specifies that infiltration ponds or basins have unlimited service life; however, only if topsoil material is replaced and tilling is performed every 5-10 years. As Massmann (2003) states, the design procedure of infiltration ponds is usually quite complicated, since projections of infiltration rates are known to be highly uncertain. In addition, it is important to choose the right dimensions for the basin due to the unfavorable consequences the improper design can cause. In particular, an infiltration pond with dimensions less than it is required can lead to flooding and, on the contrary, a pond with over-sized dimensions can be relatively ineffective with respect to the amount of land used and money spent (Massmann, 2003). With respect to the US EPA (2021b), one of the limitations of this type of ponds is that not all soil types are applicable to them. For example, soil that infiltrates water at a slow rate or that is highly compacted is not considered as a good choice for this type of flood mitigation measure. In addition, before constructing the infiltration pond it is important to make sure that groundwater level is relatively low to allow excess stormwater to infiltrate easily.
Cost-effectiveness	As the Environment Agency (2015) states, in the United Kingdom the cost of one m^3 of the pond volume corresponds to nearly 10-15 pounds, which is close to 11.5-17 euros. According to King and Hagan (2011), in the United States the total construction cost of the retention basin is estimated to be around 55,000-85,000 dollars per acre of land, which, in turn, corresponds to nearly 12.5-19.3 euros per m^2. With regard to efficiency of infiltration basins, Sasidharan et al. (2021) argues that although infiltration basins are widely implemented for stormwater runoff management, this measure still cannot provide sufficient decrease in volume of the stormwater runoff in urban areas. Furthermore, clogging of infiltration basins always remains an issue. As a result of accumulation of contaminants and sediment disposal at the bottom of the pond, the infiltration capacity of the basin significantly decreases leading even to frequent overflows. To solve the problem regular maintenance is needed, which also requires sufficient financial resources (Sasidharan et al., 2021).
Flexibility	As the US EPA (2021b) states, infiltration ponds help to remove pollutants from the stormwater, thereby preventing these contaminants from entering groundwater.
Maintenance	According to the Environment Agency (2015), the cost of systematic maintenance of the infiltration basin is around 0.6 pounds per m^2 (~0.68 euros per m^2), while for periodic (less frequent) maintenance it goes up to 3.0 pounds for the same area, which equals to nearly 3.5 euros. For example, the same source states that one of the intermittent/periodic maintenance practices for ponds is silt

	removal once every three years, which usually costs around 500 pounds (~570 euros) for one infiltration pond. Besides that, another intermittent activity that the source specifies refers to removal of polluted sediments and plantation of new aquatic vegetation. For these activities the price varies between 50-60 pounds and 3-5 pounds per m^2 (~57-68.5 and 3.4-5.7 euros per m^2), respectively. However, the report doesn't specify how often these two maintenance activities should be carried out. With respect to the required maintenance activities for infiltration basins, the US EPA (2021b) states that in case of clogging, which leads to poor infiltration capacity of the pond, the top layer of the soil should be replaced with the new one. Furthermore, regular inspections, preferably once in a month, should be conducted to check the pond for debris, eroded areas, stability of the structure and to remove mow grass, if necessary. Once every five years the basin should be inspected for sedimentation: accumulated sediments should be removed from the bottom of the basin, if necessary.
Climate change	No particular evidence of the effectiveness of infiltration ponds in terms of mitigating impact of climate change was found in the literature.
Case study example	Helles and Mogheir (2022) investigated infiltration capacity and different factors affecting this parameter of three infiltration basins in the Gaza Strip. The study revealed that rate of infiltration of the basins highly depends on the amount of sedimentation that is accumulated inside these water infiltrating facilities as a result of clogging of the bottom layer. Furthermore, the study also concluded that infiltration capacity is directly proportional to the depth of the accumulated stormwater inside the basins. However, this is only true when the depth reaches a particular point after which the infiltration rate starts slowing down.

Floods – hybrid measures

Measure: retention reservoirs (wet reservoirs)	
Real case example where the measure was applied: Radzyny retention reservoir in Poznan, Poland (Waligórski et al., 2019).	 ***Figure 15.*** *Retention reservoir Radzyny located in Poznan, Poland (Waligórski et al., 2019)*
Short summary	Retention reservoir, also known as wet reservoir, is known as a special type of water storing infrastructure that is mainly used to reduce peak flow during floods. In contrast to detention (dry) reservoirs, retention one's store water on a permanent basis, which, in turn, also allows usage of the water for other purposes, such as agriculture, supply of water for residential areas, hydropower generation and others (Connecting Nature, 2020; Eastcoast Sitework, 2021).
Feasibility	During the implementation of the Podutik retention reservoir, for example, several difficulties were observed. In particular, it was quite complicated to get sufficient funds for the project and permissions from water-related organizations. Besides, poor communication between stakeholders was another factor hindering the process (Connecting Nature, 2020).
Cost-effectiveness	Bezak et al. (2021) mentioned in their study that the reconstruction of the Podutik retention reservoir was around 500,000 euros, whereas the construction cost, for example, of the Brdnikova detention reservoir located near Ljubljana accounted for 2,400,000 euros. According to the Connecting Nature (2020), the benefits of Podutik retention reservoir include the following: protection from floods, improvement in biodiversity, reduction in water pollution, recreational activities, irrigation purposes, etc.
Flexibility	As it was already mentioned in the section for dams, large reservoirs can be highly effective in reducing sedimentation in the downstream parts by retaining significant portions of nutrients (Tiessen et al., 2011).
Maintenance	According to the Eastcoast Sitework (2021), maintenance of retention ponds includes the following practices: regular removal of sediments, control of reservoirs against erosion, inspection of infrastructure to detect damages after heavy rainfall, removal of rubbish, unnecessary vegetation, etc.
Climate change	No proof of the influence of retention ponds for flood mitigation on climate change was found in the literature.
Case study example	Bezak et al. (2021) studied the effect of Podutik retention and Brdnikova detention reservoirs in the Glinščica River catchment on flood risk. The study revealed relatively high effectiveness of the Brdnikova detention reservoir in reducing peak discharge during floods for two investigated return periods. Here, for return periods of 2 and 25 years the percentage of reduced peak discharge was 32 and 45 percent, respectively. However, for the second Podutik retention reservoir the results were quite different with a 30-percent peak discharge decrease for 25- and only 5 percent for the 2-years return period (Bezak et al., 2021).

Measure: detention reservoirs/basins (dry reservoirs)	
Real case example where the measure was applied: Meissen, Saxony, Germany (Interreg Central Europe, 2020); Savinja Valley, Slovenia (Glavan et al., 2020).	  ***Figure 16.*** *Small detention basin (left picture) and clogging of outlet of the basin (right picture) (Sustainable Stormwater Management, 2009)*
Short summary	Implementation of detention ponds/reservoirs is one of the methods to manage flood risks. The main purpose of detention reservoirs during floods is to temporarily store water, thereby decreasing flood peak and subsequently mitigating its possible negative consequences (Ngo et al., 2016).
Feasibility	Detention reservoirs should be constructed above the flood-prone region. In general, marshy lands and natural lakes can be considered as a land for reservoir construction, since usually they cannot be used for any other economic purposes. During the design procedure of the reservoir, it is important to consider the probability of overtopping and perform the design of the flood mitigation infrastructure in the corresponding way (Majidi, 2020). With respect to the costs, Hettiarachchi (2011) argues that compared to other flood mitigation strategies, implementation of the detention reservoir for flood control can be seen as a sustainable and cost-efficient option.
Cost-effectiveness	As it was previously mentioned in the section for wet retention reservoirs, the cost, for example, of the construction of the Brdnikova detention reservoir was around 2,400,000 euros (Bezak et al., 2021).
Flexibility	As it was already mentioned in the section for dams, the study of Tiessen et al. (2011) demonstrated the effectiveness of large reservoirs in reducing undesirable sedimentation in the downstream regions.
Maintenance	Without proper construction and further maintenance, reservoir condition can rapidly deteriorate, eventually leading to a shorter service life and its inability to use. When the detention reservoir doesn't meet the desirable construction and maintenance standards, and is old enough, its reliability is in doubt. Thus, its regular maintenance is a crucial step in sustaining necessary reservoir characteristics and main purposes (Majidi, 2020). According to Rollins (2020), mechanical maintenance of structural elements of the basin, vegetation, debris and sedimentation control in the inlet and outlet pipes, and in the reservoir itself are the main maintenance steps during the lifespan of the reservoir. The Environment Agency (2015) mentions that 50 pounds (~57 euros) should be spent monthly to remove debris and any other source of litter from inlet and outlet pipes, whereas for valve inspection it is required to pay 10 pounds (~11.5 euros) once every six months. Visual control of the structure costs 15 pounds per month, which equals to nearly 17 euros per month.
Climate change	No relevant information about the impact of the dry reservoirs on mitigation of climate change was found.
Case study example	One example of such a reservoir is Olmos Creek detention reservoir located in San Antonio, Texas. The main purpose of the reservoir is regulation of floods during emergency events. However, the reservoir also serves for other additional purposes, such as sedimentation and debris control. The detention reservoir traps contaminants and litter, thereby, preventing different kinds of pollutants from entering the municipal water distribution system. Besides that, one of unique features of this water storing multifunctional facility is that it is located right in the urban area and additionally serves for recreational activities (Majidi, 2020).

<table>
<tr><th colspan="2">Measure: green roofs</th></tr>
<tr><td>Real case example where the measure was applied: Basel, Switzerland (Climate-ADAPT, 2016).</td><td>
Figure 17. Green roof (NOAA's Office for Coastal Management, 2015)</td></tr>
<tr><td>Short summary</td><td>Green roofs are one of the nature-based solutions that help not only to deal with increasing flood risks, but also have other no less important benefits such as creation of a proper environment for biodiversity development, provision of thermal comfort in buildings, reduction in energy consumptions and environmental pollution, improvements of the aesthetic appearance of buildings, etc. (Basu et al., 2021).</td></tr>
<tr><td>Feasibility</td><td>According to the Climate-ADAPT (2016), green roofs have a lifespan of around 50 years. With respect to implementation time, in Basel in Switzerland, for example, two governmental green roof initiative programs in 1996 and 2005 lasted for about 2 years each (Climate-ADAPT, 2016).</td></tr>
<tr><td>Cost-effectiveness</td><td>With one-tenth of buildings having green roofs installed, total stormwater runoff in the city can be reduced by 2.7 percent. Furthermore, in this case 54 percent decrease in runoff is estimated if considering buildings individually (Mentens et al., 2006). Furthermore, a study conducted by Jarosińska and Gołda (2020) revealed that a high number of green roofs in a city can contribute to the reduction of stormwater runoff and, as a result, improve its retention by 12.2-16.9 percent. Pervious concrete, for example, on the other hand, shows less effective results than green roofs in terms of rainwater reduction during floods improving retention just by 5.2-5.7 percent.
Despite the positive impact of green roofs on flood risks, green stormwater infrastructure can also contribute to energy savings. Green roofs can provide insulation and decrease interior temperatures in buildings, as a result, reducing utility costs, by shading the buildings from the sun with the help of vegetation cover (CNT, 2020b).
With respect to costs, as Francis and Lorimer (2011) state, installation costs are one of the major challenges of green roofs. From an economical perspective, the implementation of green roofs cannot be considered an economically feasible investment unless energy savings are taken into account. With the help of green vegetation on roofs, energy consumption can be improved saving up to 215 dollars per year per building (~198 euros per year). Considering the fact that it will take a lot of time to get payback, more aspects should be considered to analyze the feasibility of green roofs before their installation (Francis and Lorimer, 2011). Furthermore, in cold climates green roofs cannot be seen as the most feasible solution due to low heating energy savings (Feng and Hewage, 2014). However, this is only the case if except flood risk reduction, energy savings is also another important factor to be considered during implementation.
The Environment Agency (2015) mentions that depending on the cover material of the green roof the price is usually different. For example, for the sedum mat roof the cost is around 90 pounds per m^2, while for biodiverse one it is reduced to 80 pounds per m^2 (~103 and 91 euros per m^2, respectively).</td></tr>
<tr><td>Flexibility</td><td>No evidence indicating the effectiveness of green roofs on risk reduction of any other hazards was found in the literature.</td></tr>
</table>

Maintenance	Francis and Lorimer (2011) in their study highlight that the major limitation of this measure refers to their maintenance. The study conducted by Silva et al. (2015) on maintenance actions of green roofs in Mediterranean areas showed that green roof cover should undergo regular maintenance. Here, maintenance practices mainly concern gardening activities, which, in turn, include fertilization, removal of unnecessary and infested plant species, cleaning of roofs, a constant check of pests, etc. Furthermore, an irrigation system is another important aspect of green roofs that should be properly controlled and maintained. An irrigation system provides water for necessary plants to grow, thereby, also ensuring the proper development of vegetation. Besides, the drainage system of green roofs should be constantly cleaned of unnecessary debris and technical inspection on a regular basis should be present (Silva et al., 2015). According to the Environment Agency (2015), the maintenance costs also depend on the material, which is used to cover the roof, for example, sedum mat or biodiverse roof. The Environment Agency (2015) states that for the former one the price is around 2500 pounds (~2852 euros) per year during the first 2 years after implementation, while for the latter one the cost is 1250 pounds (~1426 euros) for the same period. After 2 years the annual maintenance cost is 600 and 150 pounds, which corresponds to nearly 685 and 171 euros, respectively.
Climate change	One of the positive aspects of green roofs refers to their ability to combat climate change (CNT, 2020b). At the same time roof vegetation promotes the adaptation of cities to rapidly changing environmental conditions (Jarosińska and Gołda, 2020). The same as for afforestation, green roofs help to sequester carbon dioxide from the air, thereby, slowing down the process of global warming. According to the CNT (2020b), in the United States the annual value of reduced carbon dioxide as a result of decreased energy consumption was around 129 euros per ha (~10,000 m^2) of trees. Besir and Cuce (2018) state that carbon dioxide emissions can be decreased annually by 2.2×103 kg by using double-skin green facades and at the same time approximately 133 kg of carbon dioxide can be decreased annually by a tree of a middle-size (Wong and Baldwin, 2016).
Case study example	Karteris et al. (2016) analyzed how effective it would be to implement green roofs at the Thessaloniki Municipality in Greece. Here, despite such benefits as energy savings and enhancement of biodiversity, the study revealed that the expansion of green roofs by 7 times in the municipality can reduce rainwater runoff up to 45 percent.

<table>
<tr><th colspan="2">Measure: stormwater tree trenches</th></tr>
<tr><td>Real case example where the measure was applied: the City of Vancouver, Canada (Vega, 2018).</td><td>
Figure 18. Schematic representation of stormwater tree trench system (NOAA's Office for Coastal Management, 2015)</td></tr>
<tr><td>Short summary</td><td>Stormwater tree trenches (STT) represent a sequence of trees joined to each other below the ground by a trench system to manage the excess amount of stormwater (NOAA's Office for Coastal Management, 2015). STTs also provide a healthy environment for trees for sustainable growth in urban areas where impermeable pavements are dominating. With the special underground system engineered with soil medium, inlet, outlet pipes and special water distribution system, which allows stormwater to infiltrate and drain into the drainage system.</td></tr>
<tr><td>Feasibility</td><td>For SSTs special tree species should be selected in order ensure that they will be able to survive in urban environment. For such a stormwater management system enough space for tree roots is required for a proper tree growth and development. Besides that, it is important to make sure that the tree roots won't touch any kind of underground structures, such as signs, pipes, building foundations, electric wires, etc.
The Environment Agency (2015) reports that infiltration trenches have unlimited service life; however, it is required to change the filtering material every 10-15 years.</td></tr>
<tr><td>Cost-effectiveness</td><td>Some of the benefits of STTs include groundwater recharge, regulation of the stormwater runoff, air quality improvement, water quality enhancement through uptake of contaminants by vegetation (vegetative filtering). Additionally, according to McPherson et al. (2005), trees in urban areas are expected to save 485.8 million dollars (~447 million euros) or 2.5 percent of energy spent on air conditioning per year. The energy consumption associated with trees occurs as a result of shading effect, decrease in the number of impermeable pavements, cooling due to evapotranspiration process that trees provide (Minnesota Pollution Control Agency, 2022).
With respect to costs, the Environment Agency (2015) reports that the cost of infiltration trenches is accounted for nearly 60 pounds per m^2, which corresponds to nearly 68.5 euros per m^2.</td></tr>
<tr><td>Flexibility</td><td>No evidence indicating the effectiveness of tree trenches on risk reduction of any other hazards was found in the literature, except stormwater filtration - removal of pollutants from the stormwater (US EPA, 2013).</td></tr>
<tr><td>Maintenance</td><td>The NOAA's Office for Coastal Management (2015) states that STTs require regular maintenance in order to keep the system in a desirable condition. In particular, it is necessary to water the trees, constantly make inspections in order to remove garbage and other sources of litter, control invasive species and maintain the pipes for stormwater to flow properly. In addition, the same source mentions that STTs have to be cleaned twice in a year.
With respect to maintenance costs, the Environment Agency (2015) states that maintenance of infiltration trenches usually costs around 0.2-1.0 pounds per m^2 (~0.23-1.14 euros per m^2).</td></tr>
<tr><td>Climate change</td><td>As it was already discussed in the sections for afforestation and urban forests, trees play an important role in climate change mitigation due to carbon sequestration. The US EPA (1998) states that depending on the type and the rate</td></tr>
</table>

	of development, a mature tree normally absorbs roughly 50 pounds (~57 euros), which equals to nearly 22.7 kg of CO_2 annually.
Case study example	Vega (2018) investigated the performance of the STTs in Vancouver, Canada. According to estimates of 2016, more than half of the surface area of the city was covered with impervious surfaces in this year. High number of impervious pavements leading to generation of relatively huge amounts of stormwater runoff made it necessary to promote sustainable design of the city, where the STTs were also implemented. Here, the report concludes that STT systems can be quite successful in managing stormwater runoff by allowing water to be infiltrated into the soil, especially in densely developed cities such as the City of Vancouver. Furthermore, based on the conducted literature review on the performance of STTs in Europe, United States and some other regions, Vega (2018) found STTs as a cost-effective infrastructure solution.

Measure: permeable vegetated surfaces (in parking lots)	
Real case example where the measure was applied: Horizon Village, Oregon (Environmental Oregon Council, 2014).	 ***Figure 19.*** *Grass-concrete pavement (Atelier GROENBLAUW, 2016)*  ***Figure 20.*** *Open paving pattern (Atelier GROENBLAUW, 2016)*
Short summary	Permeable surfaces in urban areas allow penetration of excess amounts of water during rain events. Although pervious pavements were already discussed in the section for grey measures, in this case permeable vegetated (grassed) surfaces are going to be analyzed. Permeable vegetated pavements, such as, for example, grass-concrete pavers, usually have concrete piles with vegetated spaces in-between, which allow water to be infiltrated into the soil. Road bricks filled with soil and vegetation, such as grass, can be also used as a type of pervious pavement (Atelier GROENBLAUW, 2016).
Feasibility	According to the Atelier GROENBLAUW (2016), in case of heavy rainstorm events such kind of permeable surfaces is not always a good solution for stormwater runoff management. For heavy rains permeable surfaces won't be able to process the whole amount of excess water, which makes it necessary to additionally implement other flood mitigation measures. In addition, this type of pavement is usually implemented in parking lots, surfaces near garages and other pavements, which are not utilized intensively. Furthermore, another limitation, for example, of the so-called open paving patterns (Figure 19) concerns mainly its inability to sustain heavy loads.
Cost-effectiveness	According to the Verity Supply (2023), a commercial building company, the cost of a 240 ft^2 (~22.3 m^2) grassed-concrete permeable pavement is 1,020 dollars, which equals to nearly 938 euros.
Flexibility	Besides reduction of the stormwater runoff, vegetated pervious pavements are also known to remove pollutants from the contaminated stormwater, but over time, this ability may deteriorate (Soil Retention, 2023).
Maintenance	The Soil Retention (2023) mentions that in general for all permeable pavement types including vegetated pervious surfaces the maintenance procedure is not complicated until there is no clogging of pavement pores. With respect to maintenance activities, it is important to carry out periodic site inspections in order to make sure that there is no flow of sedimented water from other facilities that may block pavement openings with sediments. Furthermore, it is necessary to control vegetation against undesirable diseases and better choose vegetation that is resistant to salt. In addition, after each flood event with the inundation depth exceeding 0.5 inch (1.27 cm), site check-ups should be conducted to exclude the risk of stagnant water (Soil Retention, 2023).

Climate change	Vegetation over pervious concrete surfaces is known to absorb CO_2 and reduce so-called Urban Heat Island effect as a result of the cooling process caused by evapotranspiration (Soil Retention, 2023).
Case study example	The Environmental Oregon Council (2014) presents one example of a residential area in the Horizon Village in Oregon where grassy pervious pavement was implemented its parking lots. Here, a combination of polyethylene panels and grass was introduced to create a permeable pavement able to manage stormwater runoff. The pavement itself is able to withstand 35.842 tons of load per ft^2 (~0.0929 m^2).  ***Figure 21.*** *Pervious pavement in the Horizon Village in Oregon (Environmental Oregon Council, 2014)*

REFERENCES

Aerts, J.C.J.H., 2018. A review of cost estimates for flood adaptation. Water (Switzerland). https://doi.org/10.3390/w10111646

Ansar, A., Flyvbjerg, B., Budzier, A., Lunn, D., 2014. Should we build more large dams? The actual costs of hydropower megaproject development. Energy Policy 69. https://doi.org/10.1016/j.enpol.2013.10.069

Arora, V.K., Montenegro, A., 2011. Small temperature benefits provided by realistic afforestation efforts. Nat. Geosci. 4. https://doi.org/10.1038/ngeo1182

ASDSO, 2023. Case Study: Wivenhoe Dam (Australia, 2011) [WWW Document]. URL https://damfailures.org/case-study/wivenhoe-dam-australia-2011/ (accessed 3.20.23).

Asleson, B.C., Nestingen, R.S., Gulliver, J.S., Hozalski, R.M., Nieber, J.L., 2010. Stormwater Treatment: Assessment and Maintenance. Minneapolis, MN.

Atelier GROENBLAUW, 2016. Water-permeable pavements [WWW Document]. URL https://www.urbangreenbluegrids.com/measures/porous-paving-materials/ (accessed 3.12.23).

Bae, C., Lee, D.K., 2020. Effects of low-impact development practices for flood events at the catchment scale in a highly developed urban area. Int. J. Disaster Risk Reduct. 44. https://doi.org/10.1016/j.ijdrr.2019.101412

Basu, A.S., Pilla, F., Sannigrahi, S., Gengembre, R., Guilland, A., Basu, B., 2021. Theoretical framework to assess green roof performance in mitigating urban flooding as a potential nature-based solution. Sustain. 13. https://doi.org/10.3390/su132313231

Bechtol, V., Laurian, L., 2005. Restoring straightened rivers for sustainable flood mitigation. Disaster Prev. Manag. An Int. J. 14. https://doi.org/10.1108/09653560510583806

Besir, A.B., Cuce, E., 2018. Green roofs and facades: A comprehensive review. Renew. Sustain. Energy Rev. https://doi.org/10.1016/j.rser.2017.09.106

Bezak, N., Kovačević, M., Johnen, G., Lebar, K., Zupanc, V., Vidmar, A., Rusjan, S., 2021. Exploring options for flood risk management with special focus on retention reservoirs. Sustain. 13. https://doi.org/10.3390/su131810099

Bonan, G.B., 1997. Effects of land use on the climate of the United States. Clim. Change 37. https://doi.org/10.1023/A:1005305708775

City of Elk Grove, 2023. Project Factsheets, Presentations And Documents [WWW Document]. URL https://www.elkgrovecity.org/dry-well-project-prop-84/project-factsheets-presentations-and-documents (accessed 3.10.23).

Climate-ADAPT, 2022. The refurbishment of Gomeznarro park in Madrid focused on storm water retention [WWW Document]. URL https://climate-adapt.eea.europa.eu/en/metadata/case-studies/the-refurbishment-of-gomeznarro-park-in-madrid-focused-on-storm-water-retention (accessed 3.26.23).

Climate-ADAPT, 2020. Afforestation and reforestation as adaptation opportunity [WWW Document]. URL https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/afforestation-and-reforestation-as-ada ptation-opportunity (accessed 3.18.23).

Climate-ADAPT, 2016. Green roofs in Basel, Switzerland: combining mitigation and adaptation measures [WWW Document]. URL https://climate-adapt.eea.europa.eu/en/metadata/case-studies/green-roofs-in-basel-switzerland-combining- mitigation-and-adaptation-measures-1 (accessed 3.10.23).

CNT, 2020a. Stormwater management calculator [WWW Document]. URL https://greenvalues.cnt.org/index.php (accessed 3.7.23).

CNT, 2020b. Green Values Strategy Guide: Linking Green Infrastructure Benefits to Community Priorities [WWW Document]. URL https://cnt.org/publications/green-values-strategy-guide-linking-green-infrastructure-benefits-to-community (accessed 3.15.23).

Connecting Nature, 2020. Water Retention Reservoir - Podutik [WWW Document]. URL https://connectingnature.eu/oppla-case-study/17577 (accessed 3.14.23).

Dietz, M.E., Clausen, J.C., 2005. A field evaluation of rain garden flow and pollutant treatment. Water. Air. Soil Pollut. 167. https://doi.org/10.1007/s11270-005-8266-8

DWA, 2005. Standard DWA-A 138E Planning, Construction and Operation of Facilities for the Percolation of Precipitation Water, Buildings.

Eastcoast Sitework, 2021. What is a retention pond and why is maintenance important? [WWW Document]. URL https://eastcoastsitework.com/what-is-a-retention-pond-and-why-is-maintenance-important/ (accessed 3.28.23).

EEA, 2017. Green infrastructure and flood management. Promoting cost-efficient flood risk reduction via green infrastructure solutions. https://doi.org/TH-AL-17-013-EN-N

Environment Agency, 2015. Cost estimation for SUDS - summary of evidence. Bristol.

Environmental Oregon Council, 2014. CASE STUDY: Horizon Village Grassy Pavers [WWW Document]. URL https://oeconline.org/stormwater/ (accessed 3.28.23).

FEMA, 2013. Floodwalls [WWW Document]. Free Univ. Berlin, Dep. Earth Sci. URL https://www.geo.fu-berlin.de/en/v/iwrm/Implementation/technical_measures/Flood-protection-measures/structural_measures/Floodwalls/index.html#:~:text=Floodwalls%2C which are typically constructed,ice away from the building. (accessed 3.20.23).

Feng, H., Hewage, K., 2014. Energy saving performance of green vegetation on LEED certified buildings. Energy Build. 75. https://doi.org/10.1016/j.enbuild.2013.10.039

Flood Control International, 2023. Wakefield Flood Defences [WWW Document]. URL https://floodcontrolinternational.com/case-studies/wakefield/ (accessed 3.5.23).

Forbes, K., Broadhead, J., 2013. Forests and landslides: The role of trees and forests in the prevention of landslides and rehabilitation of landslide-affected areas in Asia. RAP Publ.

Francis, R.A., Lorimer, J., 2011. Urban reconciliation ecology: The potential of living roofs and walls. J. Environ. Manage. https://doi.org/10.1016/j.jenvman.2011.01.012

Galoie, M., Motamedi, A., 2014. Flood Control using Retention Dams (Case Study: A Small Catchment in Austria). SimHydro 36, 1–10.

GeoForschungsZentrum Potsdam and Helmholtz Centre, 2021. Meanders in river beds help the climate: River beds that can shift naturally are more efficient carbon sinks than straightened rivers [WWW Document]. ScienceDaily. URL www.sciencedaily.com/releases/2021/10/211029113959.htm (accessed 3.16.23).

Glavan, M., Cvejić, R., Zupanc, V., Knapič, M., Pintar, M., 2020. Agricultural production and flood control dry detention reservoirs: Example from Lower Savinja Valley, Slovenia. Environ. Sci. Policy 114, 394–402. https://doi.org/https://doi.org/10.1016/j.envsci.2020.09.012

Green Building Alliance, 2023. Permeable Pavement [WWW Document]. URL https://gba.org/resources/green-building-methods/site-solutions/permeable-pavement/ (accessed 3.15.23).

Groundwater Foundation, 2022. What is a rain garden? [WWW Document]. URL https://groundwater.org/rain-gardens/ (accessed 3.16.23).

Guimarães, L.F., Teixeira, F.C., Pereira, J.N., Becker, B.R., Oliveira, A.K.B., Lima, A.F., Veról, A.P., Miguez, M.G., 2021. The challenges of urban river restoration and the proposition of a framework towards river restoration goals. J. Clean. Prod. 316. https://doi.org/10.1016/j.jclepro.2021.128330

Haselbach, L., 2009. Pervious concrete and mitigation of the urban heat island effect. Transp. Res. Board 88th Annu. Meet. No. 09-0098.

Helles, Z., Mogheir, Y., 2022. Factors Affecting the Infiltration Rate of Stormwater. Tech. Int. J. Eng. Res. 9.

Hettiarachchi, P., 2011. Detention Reservoirs as a Flood Control Measure. Eng. J. Inst. Eng. Sri Lanka 44. https://doi.org/10.4038/engineer.v44i2.7023

Huang, Y., Tian, Z., Ke, Q., Liu, J., Irannezhad, M., Fan, D., Hou, M., Sun, L., 2020. Nature-based solutions for urban pluvial flood risk management. Wiley Interdiscip. Rev. Water. https://doi.org/10.1002/WAT2.1421

Hughes, A., 2023. A Guide to Inspecting Concrete and Masonry Dams [WWW Document]. URL https://www.cedengineering.com/courses/a-guide-to-inspecting-concrete-and-masonry-dams (accessed 3.14.23).

International Rivers, 2007. Greenhouse Gas Emissions from Dams FAQ [WWW Document]. URL https://archive.internationalrivers.org/resources/greenhouse-gas-emissions-from-dams-faq-4064#:~:text=Most of the global warming,much less powerful greenhouse gas. (accessed 3.9.23).

Izevbekhai, B.I., Schroeder, C., 2017. Seven Year Performance of City of Shoreview's Pervious Concrete Project.

Jarosińska, E., Gołda, K., 2020. Increasing natural retention – Remedy for current climate change in urban area. Urban Clim. 34. https://doi.org/10.1016/j.uclim.2020.100695

Johnen, G., Sapač, K., Rusjan, S., Zupanc, V., Vidmar, A., Bezak, N., 2020. Modelling and Evaluation of the Effect of Afforestation on the Runoff Generation Within the Glinščica River Catchment (Central Slovenia), in: Handbook of Environmental Chemistry. https://doi.org/10.1007/698_2020_649

Kádár, I., 2015. Mobile flood protection walls. Pollack Period. 10. https://doi.org/10.1556/Pollack.10.2015.1.13

Karteris, M., Theodoridou, I., Mallinis, G., Tsiros, E., Karteris, A., 2016. Towards a green sustainable strategy for Mediterranean cities: Assessing the benefits of large-scale green roofs implementation in Thessaloniki, Northern Greece, using environmental modelling, GIS and very high spatial resolution remote sensing data. Renew. Sustain. Energy Rev. https://doi.org/10.1016/j.rser.2015.11.098

Kia, A., Wong, H.S., Cheeseman, C.R., 2017. Clogging in permeable concrete: A review. J. Environ. Manage. https://doi.org/10.1016/j.jenvman.2017.02.018

King, D., Hagan, P., 2011. Costs of Stormwater Management Practices In Maryland Counties.

Klun, M., Zupan, D., Kryžanowski, A., 2021. STRUCTURAL HEALTH MONITORING OF CONCRETE GRAVITY DAMS. Acta Hydrotechnica 34. https://doi.org/10.15292/acta.hydro.2021.09

Kryeziu, D.R., Qafleshi, M., Kadiu, F., 2013. Pervious Concrete-New Solution for Sustainable Urban Street Construction Case: Prishtina and Tirana. https://doi.org/10.33107/ubt-ic.2013.8

Kryžanowski, A., Brilly, M., Rusjan, S., Schnabl, S., 2014. Review Article: Structural flood-protection measures referring to several European case studies. Nat. Hazards Earth Syst. Sci. https://doi.org/10.5194/nhess-14-135-2014

Kuehler, E., Hathaway, J., Tirpak, A., 2017. Quantifying the benefits of urban forest systems as a component of the green infrastructure stormwater treatment network. Ecohydrology. https://doi.org/10.1002/eco.1813

Lakesuperiorstreams, 2009. Underground Storage [WWW Document]. URL https://www.lakesuperiorstreams.org/stormwater/toolkit/underground.html#:~:text=On-site%2C underground stormwater retention,interconnected storage pipes or chambers. (accessed 3.23.23).

Ma, Y., Jiang, Y., Swallow, S., 2020. China's sponge city development for urban water resilience and sustainability: A policy discussion. Sci. Total Environ. https://doi.org/10.1016/j.scitotenv.2020.139078

Majidi, A., 2020. Design of detention reservoir. https://doi.org/10.13140/RG.2.2.17345.02400

Malm, R., Nordström, E., Nilsson, C.-O., Tornberg, R., Blomdahl, J., 2016. ANALYSIS OF POTENTIAL FAILURE MODES AND RE- INSTRUMENTATION OF A CONCRETE DAM.

Massmann, J., 2003. IMPLEMENTATION OF INFILTRATION PONDS RESEARCH. Washington, DC.

McPherson, G., Simpson, J.R., Peper, P.J., Maco, S.E., Xiao, Q., 2005. Municipal forest benefits and costs in five US cities. J. For. 103.

Mentens, J., Raes, D., Hermy, M., 2006. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landsc. Urban Plan. 77. https://doi.org/10.1016/j.landurbplan.2005.02.010

Minnesota Pollution Control Agency, 2022. Green Infrastructure benefits of tree trenches and tree boxes [WWW Document]. URL https://stormwater.pca.state.mn.us/index.php?title=Green_Infrastructure_benefits_of_tree_trenches_and_tree_boxes (accessed 3.12.23).

Mu, D., Luo, P., Lyu, J., Zhou, M., Huo, A., Duan, W., Nover, D., He, B., Zhao, X., 2021. Impact of temporal rainfall patterns on flash floods in Hue City, Vietnam. J. Flood Risk Manag. 14. https://doi.org/10.1111/jfr3.12668

Natural Water Retention Measures, 2013. Floodplain restoration and management.

Network Nature, 2023. Case studies tagged with Urban Forests [WWW Document]. URL https://networknature.eu/network-nature-case-study-keywords/2284 (accessed 3.15.23).

Ngo, T.T., Yoo, D.G., Lee, Y.S., Kim, J.H., 2016. Optimization of upstream detention reservoir facilities for downstream flood mitigation in Urban areas. Water (Switzerland) 8. https://doi.org/10.3390/W8070290

NOAA's Office for Coastal Management, 2015. Green Infrastructure Options to Reduce Flooding.

Nowak, D.J., Crane, D.E., 2002. Carbon storage and sequestration by urban trees in the USA. Environ. Pollut. 116, 381–389. https://doi.org/https://doi.org/10.1016/S0269-7491(01)00214-7

NRC, 1982. A levee policy for the National Flood Insurance Program. https://doi.org/10.17226/19600

Open Access Government, 2022. Afforestation in temperate rainforests could lessen climate change [WWW Document]. URL https://www.openaccessgovernment.org/temperate-rainforests-climate-change/128532/

Pennsylvania Department of Environmental Protection, 2005. Case Studies: Innovative Stormwater Management Approaches and Practices.

Portland Cement Association, 2023. CARBON FOOTPRINT. Washington, DC.

PUB, 2021. ON-SITE STORMWATER DETENTION TANK SYSTEMS.

Qin, H. peng, Li, Z. xi, Fu, G., 2013. The effects of low impact development on urban flooding under different rainfall characteristics. J. Environ. Manage. 129. https://doi.org/10.1016/j.jenvman.2013.08.026

Qin, Y., 2020. Urban flooding mitigation techniques: A systematic review and future studies. Water (Switzerland). https://doi.org/10.3390/w12123579

Rahman, M.A., Pawijit, Y., Xu, C., Moser-Reischl, A., Pretzsch, H., Rötzer, T., Pauleit, S., 2023. A comparative analysis of urban forests for storm-water management. Sci. Rep. 13. https://doi.org/https://doi.org/10.1038/s41598-023-28629-6

RECOFTC, 2012. Forests and Landslides: The Role of Forests and Forestry in the Prevention and Rehabilitation of Landslides in Asia [WWW Document]. URL https://www.recoftc.org/publications/0000049 (accessed 3.8.23).

RetainingWall Solutions, 2023. Flood wall costs [WWW Document]. URL https://retainingwallsolutions.co.uk/flood-defence/flood-wall-costs/ (accessed 3.7.23).

Rickard, C.E., 2009. Floodwalls and flood embankments, Fluvial Design Guide.

Rollins, C., 2020. DETENTION PONDS: MAKING A CASE TO MAINTAIN YOUR POND REGULARLY [WWW Document]. Constr. EcoServices. URL https://www.constructionecoservices.com/blog/detention-ponds-do-they-really-need-to-be-maintained/#:~:text=What type of maintenance is,in and around the pond. (accessed 3.8.23).

Safford, H., Larry, E., McPherson, E.G., Nowak, D.J., Westphal, L.M., 2013. Urban Forests and Climate Change.

Sasidharan, S., Bradford, S.A., Šimůnek, J., DeJong, B., Kraemer, S.R., 2018. Evaluating drywells for stormwater management and enhanced aquifer recharge. Adv. Water Resour. 116. https://doi.org/10.1016/j.advwatres.2018.04.003

Sasidharan, S., Bradford, S.A., Šimůnek, J., Kraemer, S.R., 2021. Comparison of recharge from drywells and infiltration basins: A modeling study. J. Hydrol. 594. https://doi.org/10.1016/j.jhydrol.2020.125720

Shin, E.T., Lee, S., Lee, J., Song, C.G., 2022. Effectiveness of an adaptive flood management strategy using riparian risk assessment and a tolerability criterion. J. Flood Risk Manag. 15. https://doi.org/10.1111/jfr3.12756

Silva, C.M., Flores-Colen, I., Coelho, A., 2015. Green roofs in Mediterranean areas - Survey and maintenance planning. Build. Environ. 94. https://doi.org/10.1016/j.buildenv.2015.07.029

Soil Retention, 2023. Design Considerations for Vegetated Permeable Pavement. Creating open, multifunctional spaces and providing green benefits [WWW Document]. URL https://soilretention.com/wp-content/uploads/2015/06/0305151237SoilRetention_Final.pdf

Sustainable Stormwater Management, 2009. Stormwater 101: Detention and Retention Basins [WWW Document]. URL https://sustainablestormwater.org/2009/05/28/stormwater-101-detention-and-retention-basins/ (accessed 3.19.23).

Szalkiewicz, E., Jusik, S., Grygoruk, M., 2018. Status of and perspectives on river restoration in Europe: 310,000 Euros per hectare of restored river. Sustain. 10. https://doi.org/10.3390/su10010129

Takata, K., Hanasaki, N., 2020. The effects of afforestation as an adaptation option: A case study in the upper Chao Phraya River basin. Environ. Res. Lett. 15. https://doi.org/10.1088/1748-9326/ab7462

Tiessen, K.H.D., Elliott, J.A., Stainton, M., Yarotski, J., Flaten, D.N., Lobb, D.A., 2011. The effectiveness of small-scale headwater storage dams and reservoirs on stream water quality and quantity in the Canadian Prairies. J. Soil Water Conserv. 66. https://doi.org/10.2489/jswc.66.3.158

Torrent Resources, 2023. NEW DRYWELL INSTALLATION [WWW Document]. URL https://torrentresources.com/services/drywell-installation/maxwell-type-iv-drywell/ (accessed 3.14.23).

Upper Midwest Water Science Center, 2019. Evaluating the potential benefits of permeable pavement on the quantity and quality of stormwater runoff [WWW Document]. URL https://www.usgs.gov/centers/upper-midwest-water-science-center/science/evaluating-potential-benefits-permeable-pavement#overview (accessed 3.26.23).

US EPA, 2021a. Stormwater Best Management Practice. Permeable Pavements.

US EPA, 2021b. Stormwater Best Management Practice. Infiltration Basin.

US EPA, 2020. Underground Storage Tank FLOOD GUIDE.

US EPA, 2013. Stormwater to Street Trees. Washington, DC.

US EPA, 1998. Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings.

Vega, O., 2018. Application of Stormwater Tree Trenches in the City of Vancouver. Vancouver.

Verity Supply, 2023. Soil Retention, Inc - Drivable Grass® Permeable Pavement [WWW Document]. URL https://veritysupply.net/products/soil-retention-inc-drivable-grass®-permeable-pavement (accessed 3.27.23).

Vogt, J., Hauer, R.J., Fischer, B.C., 2015. The costs of maintaining and not maintaining the urban forest: A review of the urban forestry and arboriculture literature. Arboric. Urban For. https://doi.org/10.48044/jauf.2015.027

Waligórski, B., Sojka, M., Jaskuła, J., Korytowski, M., 2019. Analysis of the use of selected reservoirs in the Wielkopolska province. Ann. Warsaw Univ. Life Sci. – SGGW. L. Reclam. 50. https://doi.org/10.2478/sggw-2018-0029

Wong, I., Baldwin, A.N., 2016. Investigating the potential of applying vertical green walls to high-rise residential buildings for energy-saving in sub-tropical region. Build. Environ. https://doi.org/10.1016/j.buildenv.2015.11.028

World Landscape Architecture, 2017. Room for the River | Nijmegen, The Netherlands | H+N+S Landscape Architects [WWW Document]. URL https://worldlandscapearchitect.com/room-for-the-river-nijmegen-the-netherlands-hns-landscape-architects/?v=ce774d9cab3a (accessed 3.9.23).

Zabret, K., Šraj, M., 2015. Can urban trees reduce the impact of climate change on storm runoff? Urbani Izziv 26. https://doi.org/10.5379/urbani-izziv-en-2015-26-supplement-011