Multi-Layer Safety against Flash Floods

A study of Limburg 2012

(De Limburger, 2018)

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Abstract

In the Netherlands a policy approach has been created to reduce flood risks. This policy is called multi-layer safety and consists of measures in three layers; prevention, spatial planning and crisis management. It has been created to deal with normal floods, however flash floods are a relatively new phenomenon in the Netherlands that will probably occur more often due to climate change. The purpose of this research is to explore the differences in how multi-layer safety is applied in measures against flash floods as opposed to normal floods. Government documents are used to identify the general implementation of multi-layer safety in regard to normal floods. Then this research examines the measures that have been taken after the flash flood in the south of Limburg. The report in which the measures have been summarised is analysed and additional information about the measures is gained from government documents and websites. The analysis places the measures into the layers of multi-layer safety, and this is compared with the implementation of multi-layer safety in regard to normal floods. The results indicate that measures against normal floods are typically classified as prevention measures, and that a common approach is to only reinforce dikes. In contrast, measures against flash floods are more often classified into the second layer of spatial planning, although there are also measures that belong in the first layer, making measures against flash floods more diverse than measures against normal floods. Measures regarding crisis management are generally neither taken against normal floods nor against flash floods. It is recommended to do further research into the reasons for this difference and whether the type of flood matters for the effectiveness of measures.

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Introduction

On the evening of July 28 in 2012, heavy precipitation fell in the Belgian city of Hombourg, at a distance of approximately five kilometres from Slenaken in the Netherlands (Heeringen et al., 2012). Normally, in the month of July roughly 80 mm of precipitation falls (Nu.nl, 2012). In this evening alone presumably 40 mm, possibly even 60mm fell (Heeringen et al., 2012). The chances of this happening are roughly between 1:35 and 1:100 (Heeringen et al., 2012). Due to the 70 metre height difference between Hombourg and Slenaken, a large amount of water flows at high speed towards Slenaken and beyond (Heeringen et al., 2012). The water level rose with 90 cm within 15 minutes around 23.15, and it has led to the highest water level that has ever been measured since the measurements started in 1978 (Heeringen et al., 2012). The water level during normal circumstances is approximately 137.03 m above NAP, however during the flash flood the water level became at the maximum 138.53 above NAP, as is illustrated in Figure 1 (Heeringen et al., 2012). The peak discharge was calculated to be almost 12 m^3/s (Heeringen et al., 2012). This flash flood has led to flooding and damage at Slenaken, Beutenaken and Pesaken (Heeringen et al., 2012). In Slenaken the Dorpsstraat and the Waterstraat were underwater, two hotels and a restaurant flooded, cars were being dragged along with the water flow, and one person was even injured (Nu.nl, 2012a & 2012b). Fortunately, nobody passed away, however that is a realistic risk with flash floods (Gaume et al., 2009). Other risks of floods include power failure, mixture of drinking water with sewage water, and experiencing flooding, or even living in a flood prone area can cause a lot of stress for people (Atlas Leefomgeving, n.d.). Due to climate change, precipitation events will become more intense, which increases the risks of floodings (Trenberth, 2011), and the intensifying rainfall increases the probability of flash floods (Marchi et al., 2010). Therefore, it is important to make sure that the rivers in the Netherlands are able to discharge all the water in periods of heavy rainfall. In 2009, the minister of Infrastructure and Water Management introduced Multi-Layer Safety to address the issue of increasing flood risks (Algemene Rekenkamer, 2023). This policy was aimed at flood risk in general, and flash floods were not a significant concern at the time. Now that they are, it is important to investigate whether there is a distinction in implementation of this policy between normal floods and flash floods. This research will study the flash flood of 2012, because this is the most recent flash flood after which measures have been implemented.

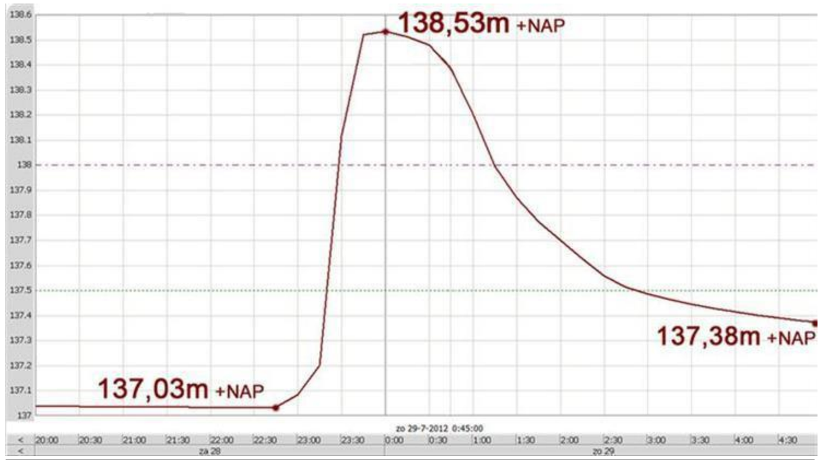


Figure 1: Water level downstreams of the Slenakerbridge (Heeringen et al., 2012, p.9)

Flash floods are a relatively new phenomenon in flood risk management. Existing literature has focused on the dynamics of flash floods (Brauer et al, 2011), and discussed the potential measures in various countries, including among others, Germany (Bone et al, 2023). However, Bone et al (2023) lay their focus on mapping rainfall and flood risks which can be used as a basis for selecting suitable measures to the risks they identify. Flash floods have not been researched in relation to multi-layer safety. This Dutch policy is important for flood management, but has only been researched in the context of normal floods, therefore it is not known whether there is a distinction in implementation between normal floods and flash floods. This research will thus aim to fill this gap. The main purpose of this research is to explore the difference in implementation of multi-layer safety in regard to flash floods as opposed to normal floods. The research question therefore is:

What are the differences in implementation of the multi-layer safety policy between normal floods and flash floods?

To help answer this research question, the following sub questions are used:

1. How is multi-layer safety implemented in the context of normal floods?
2. What measures have been/are going to be taken after the flash flood in 2012?
3. How is multi-layer safety implemented in the context of flash floods?

To answer those questions, this study will first explain what flash floods and multi-layer safety are in the theoretical framework. Then the methodology will be described, and thereafter the results will be discussed. At last conclusions will be drawn and further recommendations will be made.

Theoretical framework

Flash Floods

A flood that occurs within a short period of time after heavy precipitation is called a flash flood (Brauer et al., 2011; Burke et al., 2023). Flash floods generally occur in basins smaller than 1000 km^2, as the rainfalls are often of convective origin and occur locally, for example due to storms that are slow-moving or quasi-stationary (Marchi et al., 2010; Meyer et al., 2022). Flash floods usually have a response time of a couple of hours, sometimes less (Marchi et al., 2010). The response time depends on the size of the catchment, and on surface runoff (Marchi et al., 2010). The amount of surface runoff depends on the amount of rainfall, soil moisture and the hydraulic properties of the soil (Marchi et al., 2010). This can be affected by land use modification, urbanisation and alterations in the soil due to a fire (Marchi et al., 2010). The soil can become highly moist from precipitation during the days before the flash flood, which can cause quick saturation and extreme runoff (Meyer et al., 2022).

Flash floods are natural disasters that can be responsible for many lost lives and large economic damage (Gaume et al., 2009). For instance, in 1962 in Barcelona (Spain) over 400 people died due to a flash flood, and in 1952 in Lynmouth (UK) 34 people passed away (Gaume et al., 2009). A flash flood in Gard (France) caused an estimated damage of 1.2 billion euros, and another flood caused approximately €3.3 billion damages in Aude (France) in 1999. Due to social and economic development and the increasing land usage that comes with it, the risks of casualties and damage during a flash flood is also increasing (Marchi et al., 2010). Furthermore an increasingly warming earth is causing an increase in intense precipitation (Marchi et al., 2010). This also increases the risk of flash floods in both frequency and severity (Marchi et al., 2010). However, quick response times and the need for a local forecast, make it hard to provide flash flood forecasts (Marchi et al., 2010).

Gaume et al (2009) researched seven areas throughout Europe (in France, Italy, Slovakia, Greece, Romania and Austria). Their research suggests that flash floods in the mediterranean area generally are more extreme than in inland continental regions. Other research (Marchi et al., 2010) also claims that major flash floods mostly occurred in Spain, Italy and the south of France. Flash floods happen in the United Kingdom, Belgium and Germany too (Marchi et al., 2010). Gaume at al. (2009) further found that there is a seasonal difference in when major flash floods occur. In the mediterranean region they mostly occur during the autumn and in the inland continental region major flash floods generally happen during the summer. According to Meyer et al (2022) the amount of flash floods within Europe has become more than twice as high at the beginning of the 21st century compared to the end of the 1980s. In central western Europe flash floods were quite unusual, however recently there have been extreme precipitation events that have led to flash floods in this region. These floods usually occur in May and July, and the affected areas are relatively small (Meyer et al., 2022). The flash flood in 2012 was not the first flash flood in the Netherlands, and not the last. In 2010 there was one in the Hupsel Brook catchment (Brauer et al., 2011). In 24 hours, more than 120 mm of precipitation fell, which caused flooding and financial damage (Brauer et al., 2011). And in 2021 there was another one in Limburg, in the river basin of the Geul fell on average a 128 mm of precipitation in two days (Asselman & Heeringen, 2023). To be prepared when there is another flash flood, this research will aim to analyse how the different layers of multi-layer safety reduce risk of flash floods and whether that is implemented in practice.

Multi-Layer Safety

Traditionally, the Netherlands has focussed on diminishing the probability of flooding by constructing dykes, dams, dunes and other barriers (Ritzema & Loon-Steensma, 2018). The Netherlands began using a risk based approach after major river floods in 1993 and 1995, and in 2009 the multi-layer safety approach was introduced (Bosoni et al., 2023). The multi-layer safety approach relates to the European Flood Risk Directive of 2007 (Algemene Rekenkamer, 2023). The European Flood Risk Directive provides a guideline regarding assessment and management of flood risks, and aims to reduce the effects of floods on human health, economic activity, the environment and cultural heritage (Algemene Rekenkamer, 2023). It further encourages to implement measures that decrease the likelihood of a flood and measures that reduce the consequences, to reduce the flood risk in its entirety, as risk = probability x consequence (Algemene Rekenkamer, 2023). The multi-layer safety approach consists of three layers; direct flood protection, resilient spatial planning and crisis management, as can be seen in Figure 2 (Oukes et al., 2022). The first layer is direct flood protection and aims to reduce the probability of floods with defence structures (Oukes et al., 2022). This can be done by reducing the chances of dike failure, improving dams, levees and other infrastructural measures or widening rivers (Oranjewoud & HKV, 2011; Oukes et al., 2022). Resilient spatial planning, the second layer, aims to reduce the consequences in case of a flood (Oukes et al., 2022). This layer can for example be achieved by changing the pattern of flooding, by constructing guidance works, compartmentalisation works or compartmentalisation of the basin water or main water system (Oranjewoud & HKV, 2011). Another approach is to be conscious of risks when choosing a site for potentially vulnerable land use activities, or risk conscious planning of development sites and restructuring of existing buildings and other vulnerable objects (Oranjewoud & HKV, 2011). Vulnerability can further be reduced by making vital infrastructure floodproof (Oranjewoud & HKV, 2011). The third and last layer is crisis management, it aims to reduce the number of victims and damage (Algemene Rekenkamer, 2023), by improving preparedness and creating emergency plans in case of a disaster and calamities (Oukes et al., 2022; Oranjewoud & HKV, 2011). Table 1 provides an overview of the tree layers and provides examples of measures that fall into each category.

Figure 2: three layers of multi-layer safety (Stuurgroep Water, 2018, p.7)

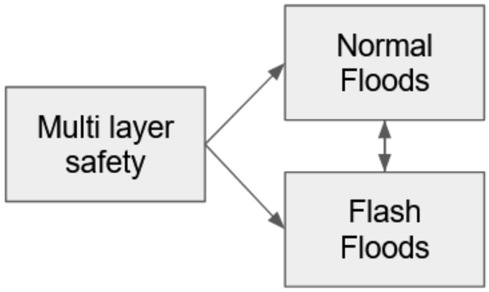
Table 1: layers and measures (Oranjewoud & HKV, 2011, p.18 & Algemene Rekenkamer, 2023)

1: direct flood prevention	2: resilient spatial planning	3: crisis management
- Dike reinforcement, dike elevation or dike relocation - Delta dikes - River widening - Higher dike ring norm, which leads to reinforcement, elevation or relocation - Spatial differentiation of water safety levels within a dike ring	- (Undo) Compartmentalisation of the floodplain or water system - Divert the water flow - Elevate new main infrastructure building sites and create barriers in underpasses - Store water temporarily elsewhere or create emergency overflow areas - Adjust residential houses, built on poles or place the fuse box on the highest floor - Elevate roads and buildings when reconstructing them - Use existing buildings as shelter - Construct mounds	- Increase self-reliance of citizens and companies - Take emergency measures such as sandbags and temporary quays - Evacuate preventive - Provide shelters in high risk areas - Improve communication - Improve disaster management - Define routes to shelters - Emergency kits and rescue equipment

Multi-layer safety and flash floods

As has been mentioned before, flash floods will most likely occur more often due to climate change (Marchi et al., 2010), also in the Netherlands. Therefore it is important to be prepared and take safety measures to reduce the risks of such a flash flood. Multi-layer safety is a policy strategy that can be used to achieve this, as it aims to reduce the risk of floods (Algemene Rekenkamer, 2023). As mentioned before this research will explore the difference in implementation of multi-layer safety between normal floods and flash floods. This is visualised in the conceptual model. This research initially examines the implementation of multi-layer safety in the context of normal floods, then it does the same in the context of flash floods, and those results are compared with each other.

Conceptual model



(made by author)

Methodology

The objective of this research is to gain more familiarity with the subject and to give direction to future research, and there are few studies about flash floods in the Netherlands, therefore this research employs an exploratory design (USC Libraries, 2024). Further, the study focusses on the case of the flash flood in Limburg in 2012, as this is the most recent flash flood after which measures have been taken. It has not been decided yet what measures will be taken after the flash flood in 2021, and little information could be found about measures taken after the flash flood in 2010. Thus this study provides a detailed description of the case in Limburg 2012, and therefore also has some characteristics of a case study (USC Libraries, 2024). However, as this is a single case, the basis for generalising the findings is not particularly robust (USC Libraries, 2024), hence the need for further research.

This research makes use of secondary data, consisting of academic literature, governmental documents and reports, and websites of government officials and collaborating partners. The application of multi-layer safety in the context of normal floods is researched by examined using two governmental reports; Oranjewoud & HKV (2011) and Algemene rekenkamer (2023). Then the measures taken after the flash flood in 2012 are summarised, making use of the report of Van Dijk et al. (2020) and additional information from governmental websites and the websites of collaborating organisations. Thereafter the report of Van Dijk et al. (2020) is analysed with Atlas.ti in order to categorise the measures into the three layers of multi-layer safety. Table 2 displays the codes that have been used during the analysis, and the code tree and report are included in the appendices. The code tree can be found in appendix A, and the code report in appendix B. The codes are based on the theoretical frame work and Table 1. One sub-code [Remove] and one code [Cancelled] were found during the analysis of the document of Van Dijk et al. (2020). Remove has been included in the second layer, and cancelled is a separate code. Finally, the results of the analysis are compared with the theory that had been identified for the first sub-question.

Ethics

The addresses in this research are mentioned to indicate location, and are from publicly available government documents. No information about the inhabitants will be discussed. Further no additional safety or privacy measures will be taken regarding the data, as these are all publicly available documents.

Table 2: Code scheme (made by author)

Code group	*Codes*	*Sub codes*	*Meaning*
Multi-layer safety	Prevention	Dike	Reinforcement, elevation or relocation of dike/dam/wall
		Widening	Widening the river
		Norm/Differentiate	Higher dike ring norm or spatial differentiation within dike ring
	Spatial Planning	Compartmentalisation	(Undo) compartmentalisation of floodplain/water system
		Store/Divert	Store water temporarily, divert river flow, create emergency overflow areas
		Elevation	Elevate infrastructure/houses, construct mounds
		Remove	Remove obstacles from the river and surrounding areas
		Adjust	Adjust houses/infrastructure (e.g. fuse box on highest floor)
	Crisis Management	Self-reliance	Increase self-reliance of citizens and companies
		Preparation	Indicate routes to shelters, improve communication/disaster management, evacuation
		Emergency	Emergency measures (e.g. sandbags), emergency kits and rescue equipment
-	Cancelled	-	Measures of which is was decided not to implement them

Results

1. *How is multi-layer safety implemented in the context of normal floods?*

Findings in Oranjewoud & HKV (2011) indicate that almost always that the first layer of prevention is most prevalent. The reasons therefore are that measures in this layer reduce the expected amount of damage and victims considerably, and they are cost effective (Oranjewoud & HKV, 2011). Therefore, this category is most important for risk reduction (Oranjewoud & HKV, 2011). Further, dikes have to adhere to legal standards, and Rijkswaterstaat and the waterboards have to make sure they meet these standards by 2050 (Algemene Rekenkamer, 2023). Under conditions, dike reinforcement can be supplemented or replaced with other multi-layer measures to fulfil the legal standard (Algemene Rekenkamer, 2023). However, only when provided with evidence that those multi-layer solutions fulfil the norm, are less expensive then dike reinforcement and are executable, will the Minister of Infrastructure and Water Management contribute financially (Algemene Rekenkamer, 2023). If that is not the case, the measures can be linked to the reinforcement project, but finances therefore have to come from other sources, which requires more time, and due to the fast paced dike reinforcement these measures are often not implemented (Algemene Rekenkamer, 2023). Other large scale measures, besides dike reinforcement, that fall into this layer, for instance a bypass, an extra lock or river widening, are often not taken, as the costs until 2050 are higher than the benefits and there is little public support, even though measures like river widening could contribute significantly to water safety (Algemene Rekenkamer, 2023). On the positive side, small scale measures, such as deepening floodplains and constructing channels, are often taken besides dike reinforcement (Algemene Rekenkamer, 2023).

Measures that fall into the category of spatial planning are effective in reducing consequences, however they are not cost effective (Oranjewoud & HKV, 2011). Particularly in areas with large scale floods and high water levels, measures in this layer, such as elevating new residential and business locations, are too costly compared to the benefits (Oranjewoud & HKV, 2011). The difference between cost and benefits are more favourable when the measures are applied to regional floods (Oranjewoud & HKV, 2011). The effectiveness of measures in this layer is highly dependent on the characteristics of an area (Oranjewoud & HKV, 2011). An issue regarding these measures is that they have to be implemented on the domain of the province and municipalities, as they decide about spatial planning (Algemene Rekenkamer, 2023). This means that the design, licencing, implementation, maintenance and management of the measures all depend on multiple parties, whereas dike managers can decide about dike reinforcement themselves (Algemene Rekenkamer, 2023). Further there is little knowledge about how much these measures contribute to water safety, as there are no norms for these measures, and there is little public support (Algemene Rekenkamer, 2023).

The third layer is effective in reducing the risk of victims, and when economic considerations are taken into account measures to improve disaster management are still viable (Oranjewoud & HKV, 2011). Although, a differentiation needs to be made in regard to organisational measures and infrastructural measures, as the latter does not tend to be cost effective (Oranjewoud &

HKV, 2011). However, according to the Algemene Rekenkamer (2023) crisis management is often not considered or implemented, because either is not clear what the exactly the costs and benefits are, there is not enough knowledge about the subject, or because it is not clear how responsibilities are divided. Other reasons are the lack of involvement from the safety regions, and the low risk awareness of Dutch people, they feel safe behind the dikes and are not well prepared for disasters (Algemene Rekenkamer, 2023).

Thus layer 1 is most efficient and most cost efficient (Oranjewoud & HKV, 2011). The Minister of Infrastructure and Water Management has also made clear that this layer is the main focus point of multi-layer safety (Algemene Rekenkamer, 2023). Measures in the second and third layer need to be incorporated alongside preventive measures (Algemene Rekenkamer, 2023). Layer 1 can provide basic safety, which make it possible to take additional spatial measures that solve local bottlenecks, and the third layer reduces risk of victims (Oranjewoud & HKV, 2011). Customised measures and local interventions within different layers can strongly influence the risk and make it possible to be more cost efficient (Oranjewoud & HKV, 2011). However, due to before mentioned issues, such as less financial efficiency, unclear cost and benefits, lack of knowledge and public support, usually only dike reinforcement is implemented (Algemene Rekenkamer, 2023).

The research in regard to multi-layer safety and the different layer is written in the context of normal floods. In the next section an overview will be given of the measures taken after the flash flood in 2012, and thereafter they will be placed in the context of multi-layer safety.

2. What measures have been/are going to be taken after the flash flood in 2012?

Section 2.1 up to and including 2.6 provide a short description of the measures that were planned to be taken after the flash flood of 2012 in Limburg. The information about these measures all comes from the report of Van Dijk et al. (2020), unless mentioned otherwise. The report of Van Dijk et al. (2020) has been commissioned by the waterboard of Limburg, and concerns an analysis of the flash flood in 2012 and a package of measures that will be taken to prevent another flood such as this one.

2.1. Retention with adjustable passage

Nearby Slenaken a retention with adjustable passage was planned to be constructed. The measure consisted of a dam with a vertical slide, essentially, the dam would hold and gradually allow the water to pass. It was going to be placed below Slenaken and as close as possible to Belgium without the retained water crossing the border or affecting the alluvial forest nearby. Initially, the concept was a passage where 8 m^3/s of water could flow through without obstruction, because then no flooding would occur in sensitive areas downstream. However, such a dam would inflict visual harm to the landscape, and thus it was decided to downscale and allow the dam to squeeze the flow rate to 10-12 m^3/s. This would mean there would be some issues downstream, but these could be resolved by local measures. To increase the retention capacity of the dam, the area would also be excavated by on average 0,5 metres. In case of the same discharge levels as in 2012, the water levels would decrease by a maximum of 30 centimetres. The excavation would be used to partially disguise the retention dam, and it would be beneficial to biodiversity. As a result of the excavation, more sparse soils types would surface, and the area would be more humid, bringing out different fauna and a different habitat. However, local citizens and nature conservation organisations protested against this measure, as the dam would not belong in the landscape of southern Limburg (Kennisportaal Klimaatadaptatie, n.d.; ARK Rewilding Nederland, 2020). Due to the large impact on the Natura-2000 area and high financial costs, it was decided not to implement this measure (WSP, 2024; Staatsbosbeheer, 2020).

2.2. Coarsening valley slope

For areas nearby Slenaken, Roebelsbosch, and Heijenratherweg it was planned to coarsen the valley slopes. By coarsening the valley slopes, the water will be retained for a longer period of time. Due to the longer retention time, the precipitation will take longer to infiltrate the soil, and therefore reach the river Gulp more gradually. In Slenaken a slope of approximately 2,2 hectare, east of the Grensweg is planned to be coarsened. West of Roebelsbosch is a plot of approximately 2,6 hectares, consisting mostly of grassland rich with herbs and fauna. On this plot strips of thicket-like vegetation, such as blackberries can develop. On the last location, a site north of the Heijenratherweg of approximately 4,6 hectares, the herb- and fauna- rich grassland on a steep hill is planned to be transformed into an orchard or forest.

After the dam with adjustable passage had been cancelled it was decided to take a measure that both increased water safety and the beauty of the surrounding nature (Staatsbosbeheer, 2020). The State Forestry Organisation, Staatsbosbeheer, and ARK Natuurontwikkeling have planted over 100.000 trees and scrubs spread over an area of 20 hectare. This vegetation retains the water, giving it more time to infiltrate the soil and reduces the peak discharge in the Gulp in case of heavy precipitation (Staatsbosbeheer, 2020).

2.3. Divert water

Excess water is to be directed past the right side of the Heijenratherweg and towards the river Gulp. This is to prevent the water from reaching a hotel, restaurant and farmstead via the Waterstraat and the Haenenbergpad. To achieve this a small wall can be relocated to increase the discharge capacity of the gutter besides the Heijenratherweg, causing the water to flow over a lowered part of a parking area. The flow direction is visualised in point 5 in figure 3.

2.4. The ford

Behind the bridge near Slenaken, the ford poses an issue when water levels are high (see figure 3, point 2). It forms a barrier and functions as a recessed spillway, pushing up water and it causes additional sanding. To reduce floodings in Slenaken, the flow profile will be widened over a length of 125 metres (figure 3, point 3). Further the current bank wall will be replaced with stacked walls in locations where buildings, cables and pipes need protection (figure 3, point 3 & 1A) (Van Dijk et al., 2020; Waterschap Limburg, 2021b). Besides these measures, a culvert, consisting of two pipes of 2,5m x 1,25m, was planned to replace the ford. However, the culvert could fully submerge and the road on it could flood when the water level is high, as the deck of the bridge is at NAP137,20m and the water level during the flash flood of 2012 was

NAP138,7m. Instead it has been decided that the ford will be removed (Waterschap Limburg, 2021b). Then the water will no longer be pushed up and excess sludge will be removed and replaced with a natural gravel substrate, to create a more fast flowing hillside stream, which will also improve the habitat for certain fish species (Waterschap Limburg, 2021b). In Provincie Limburg (2020) it is stated that the current entrance road will be modified from an unpaved road to a lane made from Hydromix, however this is not the case, nor will there be a plate bridge (Waterschap Limburg, 2021b).

2.5. Customised measures

A few years ago at Hoeve A Gen Water, Waterstraat 2 (figure 3, point 4), a shed was renewed and placed upon a mound. A quay, that will protect the residential house and holiday houses, will be attached to the mound. The grass field between the shed and residential house will be raised. Furthermore, the yard at Waterstraat 4 will have to be heightened too, to prevent water from entering the holiday homes from the east side.

Around Hotel Slenaker Hof, Waterstraat 1 (figure 3, point 6), a quay wall with a height of NAP+139,05m will be placed. The wall will contain three doors to keep entrances and exits accessible. A similar wall of the same height will be placed around Hotel Restaurant Slenaker Vallei, Dorpsstraat 1 (figure 3, point 1B).

At Broekermolen, water is able to flow past a dam besides a turn in the river Gulp, this can cause nuisance and flooding. Another issue are the deceased trees adjacent to the Gulp, as they could obstruct the river flow. Measures to counteract this consist of low quay surrounding the mill, and removing the deceased poplars. The quay has already been constructed and the dam has been improved and fortified.

To prevent the water of the Gulp from flowing onto the ford and the Slenakerweg, a cut-through in the forest south of the turn in the Slenakerweg was going to be constructed. However, after consideration, it was realised that this measure could instigate the water to flow more swiftly and cause higher water levels downstream. Therefore it was decided to not implement this measure. To increase safety, a bump could be built on the Slenakerweg nearby house number 29. Other options are constructing a new wall around the house or raising the current wall. Together with the inhabitants it has been decided and thus implemented to raise the current wall around the house.

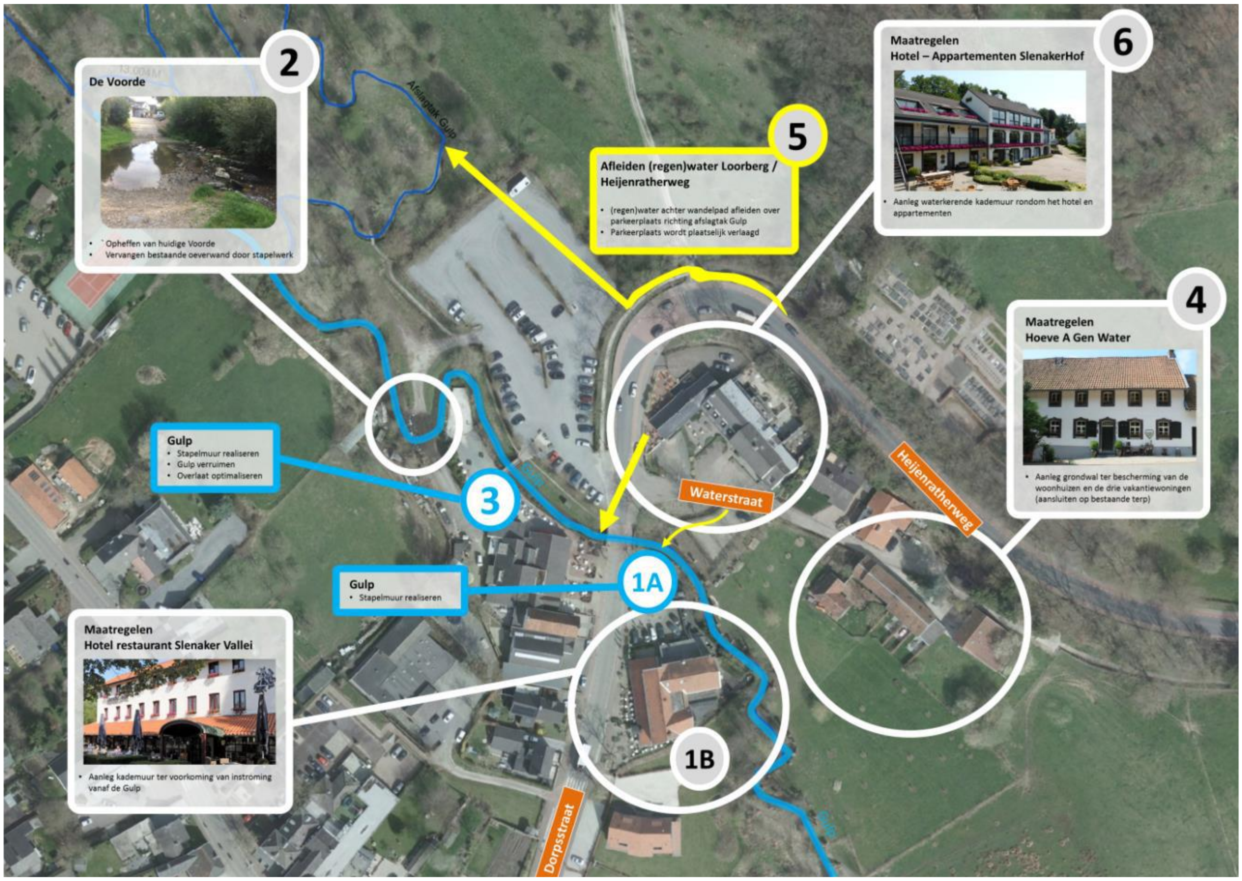


Figure 3: Location of measures in Slenaken (Waterschap Limburg, 2021a, p.4)

2.6. Ground level reduction and Water storage

A measure to decrease the chances of flooding that could be taken in Beutenaken is lowering the ground level, as this increases storage capacity. The ground will be lowered with a maximum of one metre and mostly around 0,5 metre, as the area already inundates during high water levels. Water levels will decrease at the site of storage when this measure is taken, however the water level does not decrease further down the river. This measure can be combined with improving biodiversity. This will be achieved by having a variety of higher and lower areas within the excavation.

In the area of Karsveld a similar measure will be taken. This area also inundates when water levels are high, therefore it merely needs to be excavated by a maximum of 0,75 centimetres. This is enough to increase storage capacity and reduce water levels at the site by 10 centimetres and downstream by one centimetre. Similar to Beutenaken, biodiversity will be taken into account here as well by similar means.

In the north of Karsveld the ground level will also be reduced to create more storage capacity and improve robustness and biodiversity of the system of the Gulp. Lowering the ground level here has little to no impact on the maximum water levels, but it does cause delay in the discharge. The same measure will be taken at the Pesakerweg.

At Pesaken the ground level will be lowered too, in order to increase storage capacity. For this to be achieved, a metre and a half of the soil will have to be excavated. This is deeper than at the other previously mentioned sites, for the reason that the area near Pesaken inundates only partially as opposed to the aforementioned sites.

North of Euverem in the Molenbeeklandschap the storage capacity will be increased by reducing the ground level. Contrary to the other sites, here in the Molenbeeklandschap it is necessary to excavate until two metres deep, to improve water storage at the location of excavation. The water levels downstream are barely affected by the measure. Excavation in this site will be limited to the uppermost layer of the soil, as it is necessary to reduce the ground level relatively much compared to the other areas, to gain any storage capacity.

3. How is multi-layer safety implemented in the context of flash floods?

How is multi-layer safety implemented in the context of flash floods?
Of the measures mentioned in the section of sub-question 2 there were four measures of which it was decided that they would not be implemented. These cancelled measures are; the retention with adjustable passage (2.1), the culvert (2.4), the cut-through (2.5), and a bump on the road (2.5). These measures are therefore not divided into the categories of multi-layer safety.

The prevention layer contained mostly measures that related to building or improving walls, this occurred six times. One measure was widening part of the river, and there were no measures in norm/differentiate. Replacing the existing bank wall with a stacked wall (2.4), has been allocated to this layer, because it reinforces the river bank, and therefore has been labelled; prevention: dike. A quay wall will be constructed around hotel Slenakerhof and the apartments (2.5), and a similar structure will be built around Hotel Restaurant Slenaker Vallei (2.5). An approximately 1 metre high quay or stacked wall is going to be constructed around the mill in Broekermolen (2.5), and at Slenakerweg 29 the current wall will be elevated and new pieces of wall will be added (2.5). At Waterstraat 2 a quay is going to be constructed north west of the residential and holiday homes (2.5) and will be attached to the newly constructed mound. All these walls and quays prevent water from entering the buildings, and function as small dikes, therefore these measures are coded as; prevention: dike. There is one measure that has been coded as prevention: widening. This is the measure taken behind the bridge of Slenaken, where the river Gulp will be widened over a 125 metre long section (2.4).

The measures that fall in to the second layer of resilient spatial planning are mostly store/divert, there are eight measures with this code. The second most prevalent measure in this category is elevation, this occurred three times. The code remove occurred twice, and the codes adjust and compartmentalisation were not used. The measure coarsening the valley slope (2.2) is coded as Store/Divert. The rationale behind this decision is that by coarsening the slopes the precipitation will be stored in the soil for a longer period of time. Placing a shed upon a mound at Waterstraat 2 (2.5) is included in this layer under the code elevation, because the shed has been raised.

Lifting the field of grass between the shed and residential house (2.5), and raising the yard of Waterstraat 4 (2.5) are all classified with the same sub-code: elevation. By removing the Voorde in Slenaken and dead poplar trees near Broekermolen (2.5), they no longer form an obstacle for the river during high water, and therefore both categorised as spatial planning; remove. Diverting the water from the Waterstraat and the Haenenbergpad (2.3) is placed in the store/divert code as well. Increasing storage by reducing the ground level is a measure that will be taken in multiple locations, it will take place in Beutenaken, Karsveld, north of Karsveld, at the Pesakerweg, Pesaken and north of Euverem (2.6). As the measure aims to increase storage capacity it will be coded as spatial planning; store/divert.

There were no measure that fit into the third layer of crisis management. The table 3 provides a summarised overview of how the measures are categorised.

Table 3: summary of categorised measures (made by author)

1: prevention	2: spatial planning	3: crisis management
- Replacing the existing bank wall with a stacked wall (2.4) - Widening part of the Gulp (2.4) - Constructing a wall or quay (2.5)	- Coarsening the valley slope (2.2) - Diverting water (2.3) - Removing the ford (2.4) - Constructing a shed on a mound (2.5) - Elevating a grass field, and a yard (2.5) - Remove dead trees (2.5) - Increasing storage by ground level reduction (2.6)	- No measures

When comparing the measures in the first layer to the first sub-question, it would be expected that this layer would be the main focus of the measures and that a dike or dam would be constructed as one of the measures. Initially, that was going to happen, as the plan was to construct a dam with an adjustable passage (Van Dijk et al., 2020). However, the measure would damage the landscape and nature, therefore the Dutch State Forestry Organisation, Staatsbosbeheer, Nature and Environment Federation Limburg, and local inhabitants appealed against this measure (WSP, 2024). Staatsbosbeheer (2020) has argued from the beginning for a more natural approach in the entire stream valley of the Gulp by retaining the water as long as possible, storing it and gradually discharging it. This approach is supported by the province, waterboard and municipality Gulpen (Staatsbosbeheer, 2020). Another contrast in this layer with research mentioned in sub-question 1, is that part of the Gulp has been widened. Research mentioned that this kind of measure is often not implemented due to lack of financials and support (Algemene Rekenkamer, 2023). In this case however, it could be realised. Besides the river widening, the bank wall was replaced with a stacked wall, and in Slenaken and Broekermolen walls are constructed. These are local customised measures, which is in line with expectations from the Algemene Rekenkamer (2023) and Oranjewoud & HKV (2011), as such measures can be cost effective and have a strong influence on the risk, and are often implemented alongside larger measures.

An observation that can be made regarding the second layer, is that there are more measures here than in the first layer. This is in contrast with what was expected based on sub-question one. Generally, measures in the second layer are lacking, as they are not always cost effective (Oranjewoud & HKV, 2011), have to depend on collaboration between multiple parties, and it is more difficult to indicate the precise contribution to water safety (Algemene Rekenkamer, 2023). However an alternative solution had to be found for the rejected dam, and to find one that is both feasible and adheres with the natural values of the landscape, involved parties decided to start a joint planning process (WSP, 2024). From this process emerged measures that were custom made for Slenaken and the surrounding area, and measures that are climate adaptive (WSP, 2024). The targeted small scale local measures are less prone to the above mention issues and are effective (Oranjewoud & HKV, 2011). And as a replacement of the dam, Staatsbosbeheer, along with ARK Natuurontwikkeling, planted more than 100.000 trees and shrubs (Staatsbosbeheer, 2020). ARK received funding from the National Postcode Lottery and POP3water-project, a European fund for developing rural areas (ARK Rewilding Nederland, 2020). Due to funding being available it is not an issue that measures in this layer are less cost effective.

Lastly, it is notable that there are no measures in the third layer. This is in line with previous research mentioned in the first sub-question. There could be multiple explanations for this; the costs and benefits of these measures could be unclear or it might not have been clear who would be responsible for crisis management. These are common motives for not implementing this kind of measures according to the Algemene Rekenkamer (2023). Or the costs could simply outweigh the benefits.

After these measure have been taken, damage caused by a flood will on average only happen once every hundred years (Provincie Limburg, 2023). Therefore, the province of Limburg initiated an amendment to raise the protection standards from 1:10 and 1:25 to 1:100 (Provincie Limburg, 2023).

Conclusions

On the 28th of July the water level of river Gulp increased with approximately with a metre and a half and flooded the village of Slenaken in the south of Limburg shortly after heavy precipitation in Belgium. Floods occurring within a short period of time after precipitation are named flash floods. They are a relatively new phenomenon in the Netherlands, and this research explores the difference between how the multi-layer safety policy is implemented in regard to normal floods and flash floods. Multi-layer safety contains three layers in which measures can be taken. The first one contains preventive measures, the second layer consists of spatial planning measures that reduces consequences, and the last layer encompasses all measures that manage crisis situation. From this research it can be concluded that in case of a normal flood the most common measure taken dike reinforcement, as this is the most effective measure in terms of both financial costs and risk reduction. This measure falls into the first category of multi-layer safety, measures from the other two layers are often not taken due to less cost efficiency, lack of public support and knowledge, or the costs and benefits are unclear. In the case of the flash flood however, the analysis showed that the majority of the measures that have been taken, can be categorised as spatial planning. This is partially due to an appeal against a retention dam, and advocacy for measures more in line with the Natura-2000 environment. Thus approximately a 100.000 trees and scrubs have been planted that increase retention time and infiltration, making precipitation reach the river more gradually. Further local measures have been taken that both fit into the first and second layer. They consist of constructing walls around buildings, widening part of the gulp, those belong in the first layer, and elevating buildings and removing obstacles from the river, which belong in the second layer. Measures in the third layer are generally not taken after either a normal flood nor a flash flood. Based on this comparison, it could be concluded that measures against flash floods are more diverse than measures after a normal flood, as more measures have been taken in different layer after the flash flood. However if in both situations more measures regarding crisis management would be taken, then there would truly be safety on multiple layers.

There have been limitations to this research, as it is only based on literature. Further research on this topic could include interviews with involved organisations or investigate the reasons for the differences on a deeper level. In addition, research into whether or not measures against flash floods have the same effectiveness as compared to normal floods would also be recommended.

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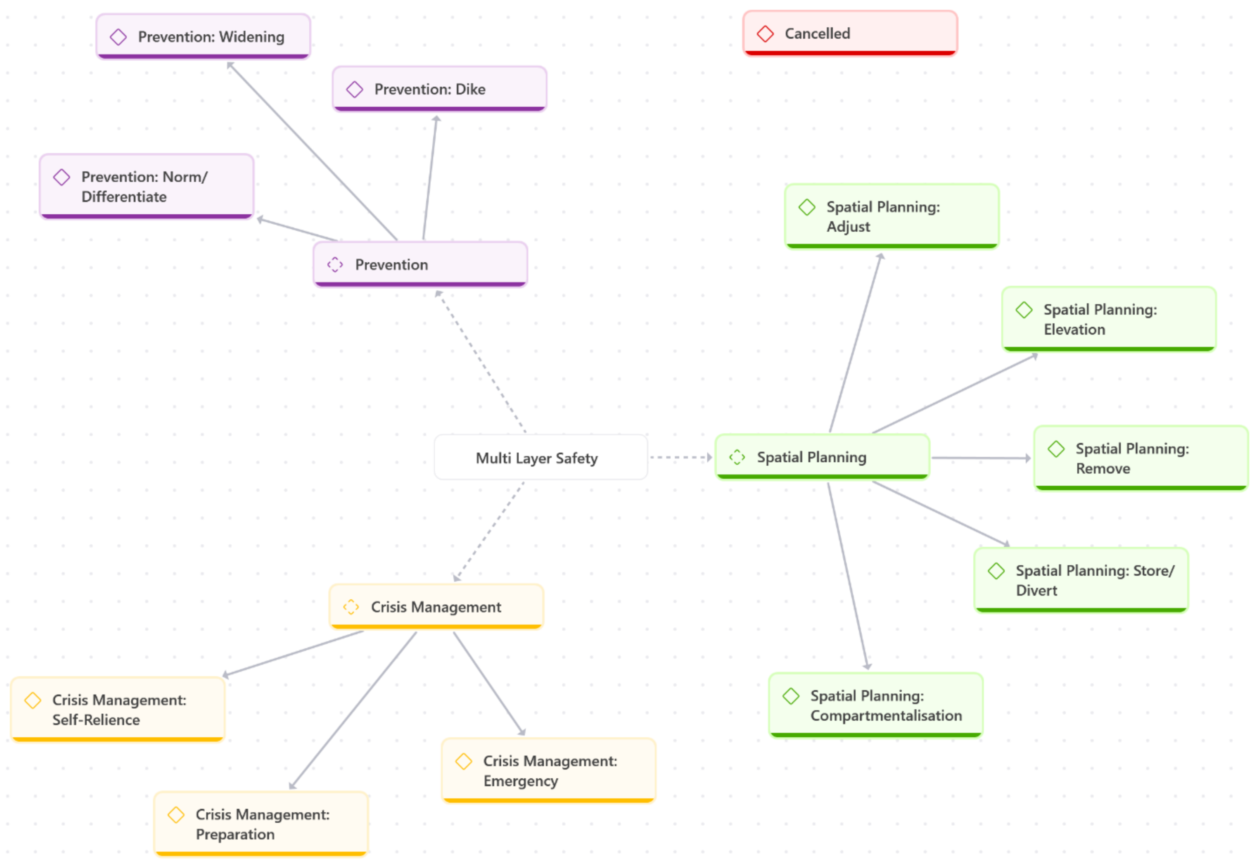
Appendices

Appendix A



Appendix B

Project: Measures against Flash Floods
Report created by Esther Baarda on 6-6-2024

Quotation Report – Grouped by: Codes

All (23) quotations

Cancelled

4 Quotations:

1:2 p 27 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Retentie met regelbare doorlaat bij Slenaken (A5-1)

1:6 p 42 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Ter plaatse van de voorde is een duiker gepland, bestaande uit twee kokers van 2,5m x 1,25m.

1:15 p 56 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Om deze overlast te voorkomen is gedacht om een doorsteek te maken door het bos, wat ten zuiden van de bocht in de Slenakerweg ligt.

1:17 p 56 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Aanleg van een drempel. In het verleden is een plan gevormd voor de aanleg van een drempel in de Slenakerweg in de bocht bij woning nummer 29.

Prevention: Dike

6 Quotations:

1:5 p 42 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

vervangen van de bestaande oeverwand door stapelwerk.

1:8 p 47 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

De aan te leggen kade ter bescherming van het woonhuis en de drie vakantiewoningen kan aan de noordwestzijde worden aangesloten op deze terp;

1:11 p 47 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Het kademuurtje rondom het hotel en de appartementen kan grotendeels aangelegd worden zoals op de door de hoteleigenaar gemaakte schetsen;

1:12 p 48 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Maatwerklocatie bovenstrooms (Hotel Restaurant Slenaker Vallei, Dorpsstraat 1) • Rondom het gebouw wordt een kademuur aangelegd om instroming vanaf de Gulp te voorkomen; • De aanleghoogte van het muurtje bedraagt, inclusief waakhoogte van 0,25 meter, NAP+139,05m;

1:13 p 53 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

De oplossing is om rondom de molen een lage kade (of stapelwerk) van ca. 1 m hoog aan te brengen.

1:16 p 57 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Nieuwe stukken muur rondom het huis aanbrengen en/of verhogen bestaande muur.

● Prevention: Widening

1 Quotations:

1:4 p 42 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Deze uitwerking bestaat uit het verruimen van het doorstroomprofiel van de Gulp over een lengte van 125 m

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● Spatial Planning: Elevation

3 Quotations:

1:7 p 46 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

De schuur naast de woning is een aantal jaar geleden (na het hoogwater van 2012) herbouwd en opgehoogd, deze staat nu op een terp (Figuur 42); de hoogte is NAP+139m (AHN).

1:9 p 47 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Het grasveldje tussen de woning en de schuur/terp moet dan worden opgehoogd, zo ontstaat een flauw talud (maximaal 1:3) vanaf het terras naar de aan te leggen ‘kade’;

1:10 p 47 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

De inundatieberekening met een doorvoer van de retentie met 12 m3/s laat zien dat het erf van Waterstraat 4 ook opgehoogd moet worden (tot aan de erfgrens) zodat in geval van hoog water ook vanaf deze oostzijde geen water richting de vakantiewoningen kan stromen.

● Spatial Planning: Remove

1 Quotations:

1:14 p 53 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

De aanleg van deze kade wordt gecombineerd met regulier onderhoudswerk rondom de beek, onder andere de verwijdering van dode bomen, om te voorkomen dat tijdens hoge afvoeren blokkades ontstaan.

1:26 p 42 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Aanpak Voorde (A6-1)

● Spatial Planning: Store/Divert

8 Quotations:

1:1 p 21 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Door deze verruwing wordt overtollig water, wat tot afvoer komt meer vastgehouden en komt de afvoer via waterlopen vertraagd en meer gedoseerd over de tijd in de Gulp terecht.

1:3 p 38 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Afleiden water Dorpsstraat (A2-1) en Afleiden water Loorberg / Heijenratherweg (A2-2)

1:18 p 57 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Berging Beutenaken (A4-1)

1:19 p 62 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Berging Karsveld (A4-2)

1:20 p 66 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Maaiveldverlaging ten noorden van Karsveld (A3-1)

1:21 p 71 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Maaiveld verlaging Pesakerweg (A3-2)

4.12.1 Beschrijving Ter plaatse van dit gebied wordt het maaiveld verlaagd om hiermee extra berging te creëren, mits op de juiste hoogte aangelegd.

1:22 p 75 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

Cascadesysteem Pesaken (A5-2)

4.13.1 Beschrijving Ter plaatse van dit gebied wordt het maaiveld verlaagd om hiermee extra berging te creëren, mits op de juiste hoogte aangelegd.

1:23 p 79 in Van Dijk et al (2020) [Flash flood Gulpdal 2012]

De locatie van de maatregel is gelegen ten noorden van Euverem. Ter plaatse van dit gebied wordt het maaiveld verlaagd om hiermee extra berging te creëren, mits op de juiste hoogte aangelegd.