QUICKSCAN CLIMATIC CHANGE AND URBAN DRAINAGE

Harry van Luijtelaar, Tauw bv, consulting engineers, PO box 133, 7400 AC, Deventer, The Netherlands, (hlj@tauw.nl).

Albert H. Dirkzwager, Institute for Inland Water Management and Waste water Treatment (RIZA: *Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling*), PO box 17, 8200 AA, Lelystad, The Netherlands.

KEYWORDS

Climate change, IPCC, urban drainage, meteorological, rainfall series, combined system, waste water system, CSO, flooding.

ABSTRACT

The advisory report ‘Water policy for the 21st century’ published on 31 August 2000 by the Commission for Water Management in the 21st Century refers to an increase in problems in water systems as a result of expected changes in the climate. Consideration must be given to higher precipitation intensities, more frequent periods of rainfall and longer periods of drought. This climatic change may also affect the functioning of urban drainage systems. It is important to clarify the technological, economic, ecological and social consequences of climatic change. Research is focusing on how to deal with the changing climate and which measures can be taken to avoid problems in the future. This project ‘ Quickscan Climatic change and the effects on functioning of urban drainage systems’ is carried out by Tauw bv consulting engineers, commissioned by RIZA, the Institute for Inland Water Management and water Treatment. This paper focuses on the effects of climatic change on the functioning of urban drainage systems.

INTRODUCTION

The purpose of this quickscan is to obtain a quick, general understanding of the effects of the expected climatic change on the functioning of common urban drainage systems and alternative systems. The expected worldwide climatic increase in temperature [1] in the Netherlands has been translated by the KNMI (Royal Dutch Meteorological Institute) into a precipitation forecast for

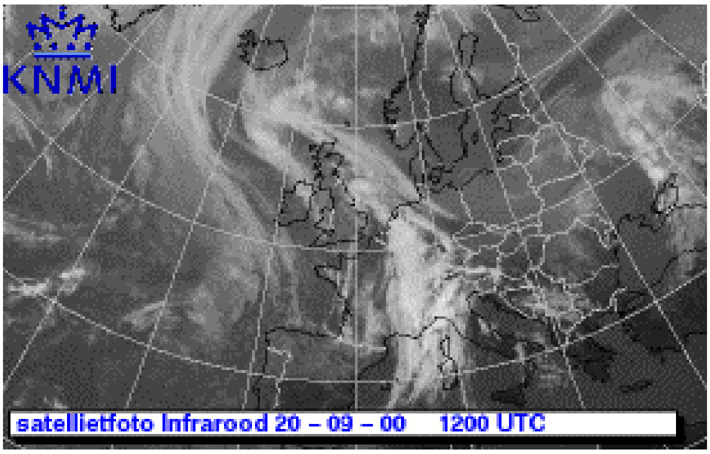

Figure 1 Infrared satellite photo 20-09-00 1200 UTC

2050 and 2100 [2,3]. For this project, the average expectation for 2100 was used and incorporated into the standard Dutch rainfall series (period 1955-1979). Two different climatic variants of the rainfall series were used.
The effects of these climatic rainfall series were then evaluated for three different types of drainage systems. The functioning of the systems was assessed by examining the effects on combined sewer overflows and flooding.

CLIMATIC CHANGE

Within the framework of the fourth Dutch Water Management Policy document the KNMI carried out a study [2] to estimate several climatic parameters that are relevant to water management in the Netherlands.

Table 1 Estimated precipitation parameters. KNMI study, Können et al,1997.

Temperature	+ 1 °C	+ 2 °C	+ 4 °C
Forecast	centre estimate 2050 lower limit 2100	upper limit 2050 centre estimate 2100	upper limit 2100
Precipitation			
Year	+ 3%	+ 6%	+ 12%
Summer*	+ 1%	+ 2%	+ 4%
Winter**	+ 6%	+ 12%	+ 25%
Intensity (30 min)	+ 10%	+ 20%	+ 40%

* summer period = April - September, ** winter period = October - March.

Table 1 presents the forecasted temperature increase for 2050 and 2100 and the expected effect on the general precipitation parameters. A distinction has been made between a centre (average) estimate and an upper and lower limit. For example, a temperature increase of 1 °C is a centre estimate for 2050 and a lower limit for 2100.

KNMI: Weather and Water in de 21st century
The KNMI climate scenarios for the Netherlands must be viewed as possible developments of the Dutch climate within the uncertainties as specified in the most recent IPPC report. These are based on a number of unverifiable assumptions. However the specified climatic scenarios are a plausible starting point for exploratory studies into the consequences of climatic change for the Netherlands.

RAINFALL SERIES

The precipitation forecasts specify the increase for specific parameters, which have been translated into effects on the standard De Bilt rainfall series for the period 1955-1979. This precipitation series is used to design and check the functioning of sewer systems in compliance with Dutch Guidelines for Sewer Systems [5].

It was decided to base this quickscan on a climatic temperature increase of 2^{o}C. This is the centre expectation for 2100 and the upper limit for 2050. The rainfall series of De Bilt was converted in two different ways, variant A en B:

Variant A is based on a perceptual increase of more extreme rainfall intensities (table 2). This is in line with current climatic studies. This variant was chosen as the starting point for the quickscan.

Table 2 Variant A, scenario with a temperature increase of + 2^{o}C

Period	30-minute precipitation intensity	Total precipitation intensity
Winter	Upper winter threshold +20%	+12%
Summer	Upper summer threshold +20%	+2%
Year		+6%

This interpretation of the climatic change is a simple extrapolation of the existing rainfall series. The number of wet days is kept the same and a linear increase in the rainfall intensity is only used above a certain threshold value in the 6-month winter and summer period.

Variant B is based on a larger variation in the increase of precipitation intensities throughout the entire year and less wet days in the summer period. This variant assumes a larger increase in peak intensities during warm and dry summers than during wet and cold summers. As the total precipitation during the summer period hardly increases at all (2%) and the contribution of the more extreme intensities is relatively large, compensations has to be made elsewhere. This is carried out by shortening the precipitation duration during the wet summers, by leaving out smaller events during the dry and average summers.

CHARACTERISTICS OF THE TEST-SYSTEMS

Three different test systems were used to study the climatic effects:

1 Reference system,
2 Emst combined sewer system,
3 Zandvoort waste water system.

Reference system

The reference system was defined as a sewer system with a storage capacity of 7 mm, a storage settling tank of 2 mm and a pumping capacity to the treatment plant of 0.7 mm/h. The discharge and storage capacities are expressed in the amounts of rainfall in mm per unit contributing (paved) catchment area.

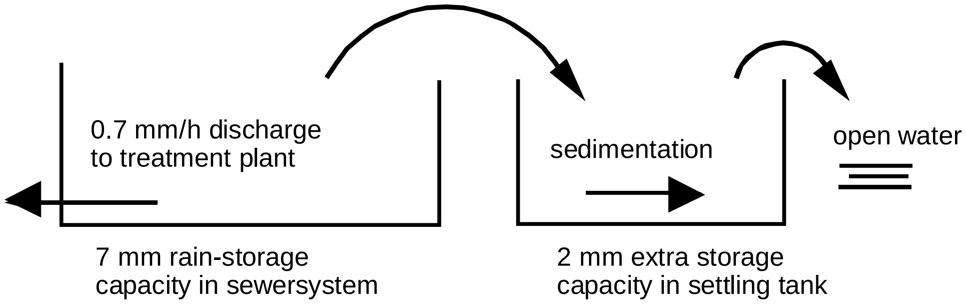

Figure 2 Characteristics of the sewer reference system with storage settling tank.

Emst combined sewer system

The major part of Emst village, in the municipality of Epe, is provided with a combined sewer system. The area slopes downwards from the north-west to the south-east. The system layout is specified in the accompanying figure. The system currently has a single combined sewer overflow (CSO) close to the pumping-station in the south-eastern border of the system. For this study, the system was provided with a second, higher overflow in the south-western edge of the system. This spillway is operating less frequently. A controlled orifice was installed in the main sewer, to be able to make maximum use of the storage capacity. The calculations show that the system is susceptible to flooding in the northern branches of the system. The lowest overflow in the south-east takes the largest portion of the total overflow volume, approximately 90%, and the higher spillway in the south-west takes the remaining 10%. This relationship can be influenced by controlling the orifice in the main sewer.

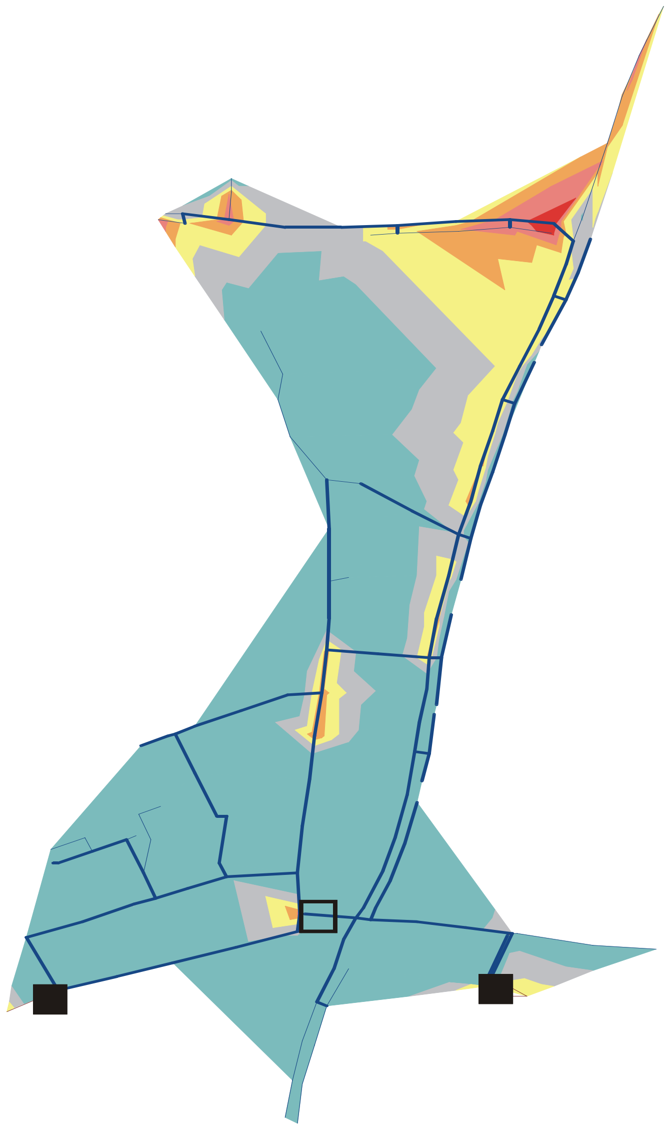

Figure 3 Emst sewer system: Infoworks simulation with standard rainfall T = 2 years. Areas expected to be liable to flooding are indicated in orange and red.

Zandvoort waste water system
The Zandvoort drainage system is a substantially closed system. The waste water treatment plant and the combined sewer overflow discharge into a local pond system. A pressurised system discharges the excess pond water to Haarlem, with a limited capacity. The transport capacity to Haarlem has recently been modified (increased) to provide a better management of the water level in the Zandvoort ponds.

The major part of Zandvoort is provided with a combined sewer system. The lower town centre area has a relatively large rainwater storage capacity to avoid flooding. There is a limited exchange between the ponds in the dunes and the groundwater. In the future, the groundwater level may rise further due to the ending of drinking water extraction.

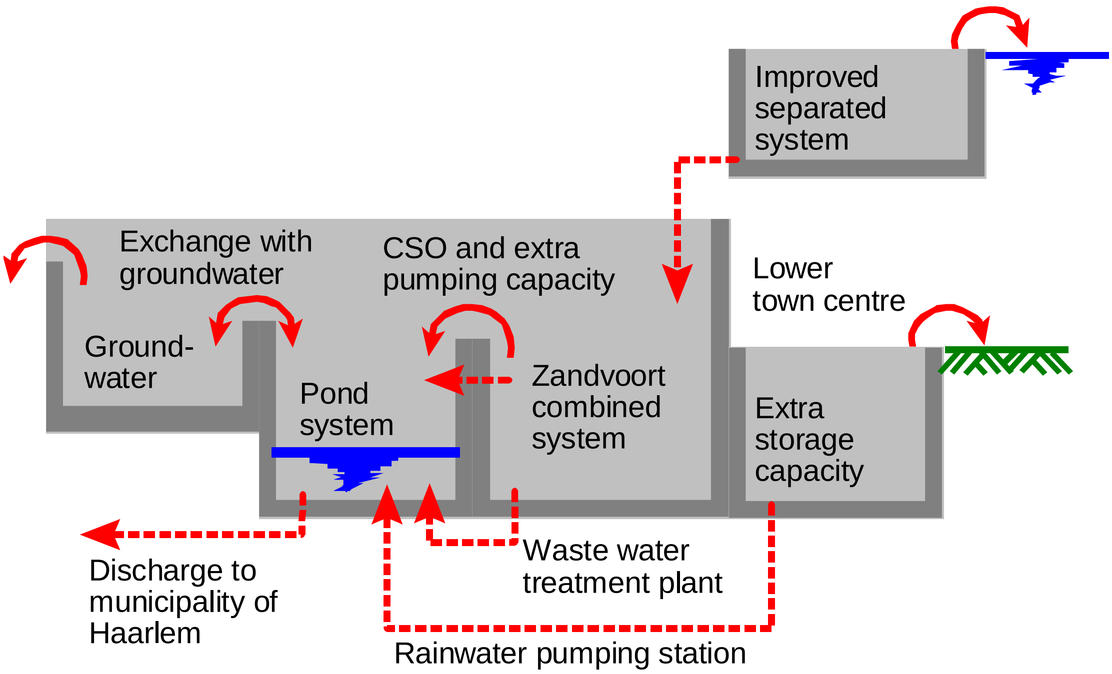

Figure 4 Zandvoort: combined sewer, pond and groundwater system.

CLIMATIC EFFECT ON REFERENCE SYSTEM

The functioning of the reference system was examined to understand the development of combined sewer overflows. This was carried out for two variants of the reference system: a) an additional storage capacity of 2 mm (storage settling tank) and b) an additional storage capacity of 2+13 mm (settling tank + extra storage).

Table 3 Percentage increase of overflows,
reference system **7+ 2 mm storage capacity**.

Climate series -	Volume mm/year	Frequency average per year	Max. intensity mm/15 min	Duration hours/year
Variant A	37%	29%	20%	24%
Variant B	48%	41%	20%	32%

Table 4 Percentage increase of overflows,
reference system **7+ 2 + 13 mm storage capacity**.

Climate series -	Volume mm/year	Frequency average per year	Max. intensity mm/15 min	Duration hours/year
Variant A	62%	45%	0%	77%
Variant B	67%	77%	0%	85%

The overflow volume increases by approximately 40 to 70%, depending on the storage capacity in the system. The overflow frequency increases by approximately 30 to 80% and the overflow duration increases by 25 to 85%. A relatively small increase in the total precipitation (average 6%) results in a considerably larger increase in the overflow volumes. The effects are clearly smaller for series A than for series B. As expected, the concentration of higher precipitation intensities in fewer events with more extreme peak intensities has a significant effect on the emissions.

CLIMATIC EFFECT ON EMST DRAINAGE SYSTEM

The occurrence of flooding was calculated for periods of five years. The following figures present the calculated maximum water levels for the period 1960-1964. The results are presented per period for the standard series and for climate series variant B. The orange and red areas in the figures indicate locations where water levels above ground elevation were calculated, green indicates a water level well below ground level.

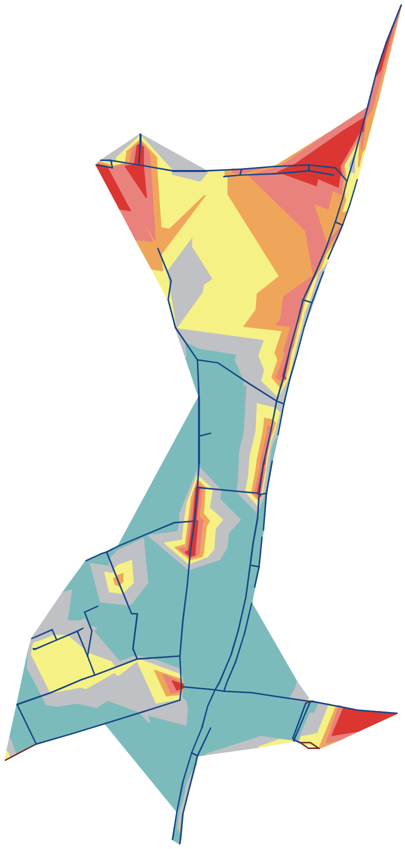

Figure 5 Simulated flooding, De Bilt 1960-1964

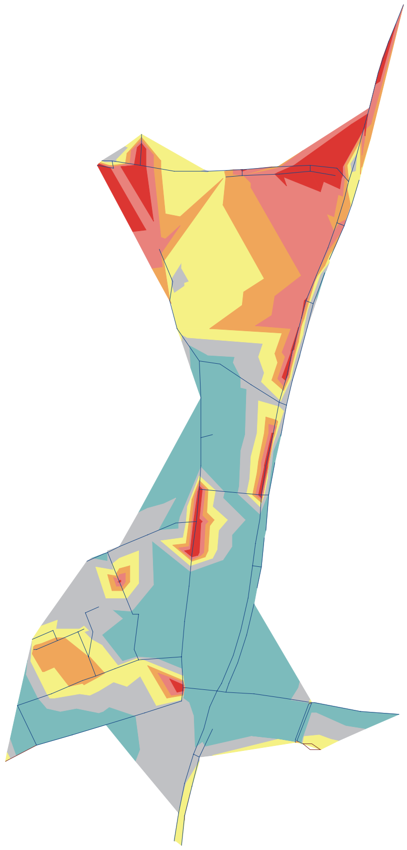

Figure 6 Simulated flooding, Climate scenario B

A more relevant insight on the occurrence of water levels above ground elevation (flooding) emerges from the calculated duration and frequency. The average duration of flooding increases by between 50 and 80%, and the increase in frequency lies in the same order of magnitude. The occurrence of flooding is determined primarily by the increase in the more extreme intensities, which according to climatic expectations are substantially greater than, for example, the increase in annual precipitation.

Additionally, an investigation was also carried out into the effects on CSO's. This investigation focused on the increase in total overflow volume per location. There are two overflows in the modified Emst system, one low threshold overflow in the south-East that takes by far the greatest volume and a higher threshold overflow in the south-West functioning only incidentally.

Analogous to the reference system, the results showed that approximately 40 to 70% more water is discharged via both spillways. The distribution of discharges over the high and low spillways depends on the increase in the more extreme precipitation intensities.

CLIMATIC EFFECT ZANDVOORT WASTE WATER SYSTEM

The Zandvoort waste water system is a substantially autonomous system in an inclined dune area. The ponds in the dunes serve as a buffer for the water that is discharged via the waste water treatment plant and the CSO's. The excess water is transported from the ponds through pressure pipelines to the system of the municipality of Haarlem. The pond water level drops slowly, because the discharge capacity to Haarlem is small compared to the storage capacity of the pond. After a substantial volume of rainfall, it takes days before the water level in the pond returns to the basic level of NAP +1.40 m. It is important for Zandvoort to keep the water level in the pond below a certain level in order to prevent flooding in the lower areas of the town.

The functioning of the Zandvoort waste water system was simulated using climate series A as specified in the following figure.

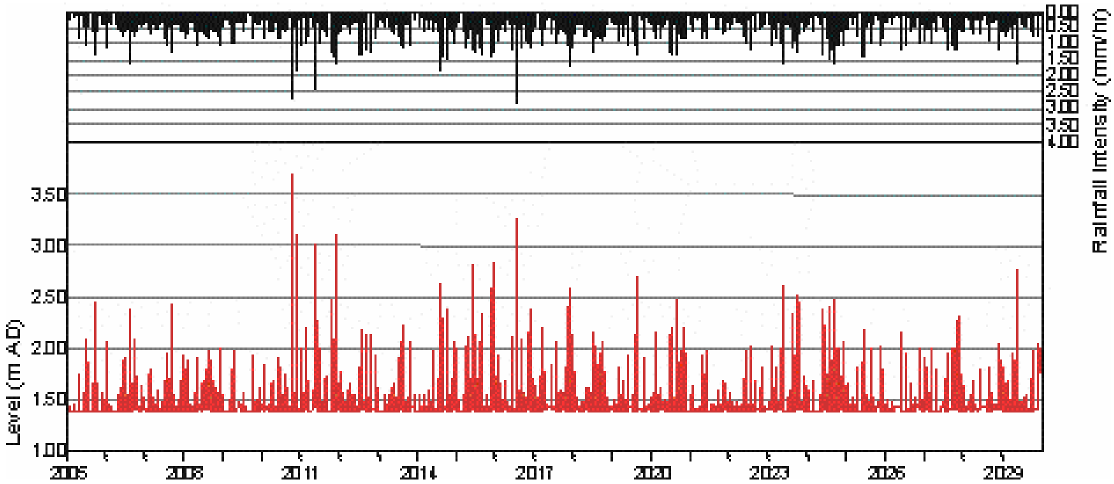

Figure 7 Calculated pond water levels: Climate series A: De Bilt - 25 years.

The simulation showed that the number of times the threshold water level of NAP +2.50 m was exceeded increased considerably from 10 to 18 occurrences in the 25-year period for which calculations were carried out. Due to the increase in rainfall, the frequency of exceeding the critical water level of NAP +3.00 m increased from 2 to 5 times in the 25-year period. *The level of safety with respect to flooding is therefore considerably reduced.*

CONCLUSIONS ON SIMULATIONS

The climatic change based on the scenario of a temperature increase of 2 degrees as the central (average) estimate for 2100 and upper limit for 2050, has a considerable effect on the functioning of the sewer systems.

Figure 8 Flooding and floating manhole covers

According to this scenario, the highest precipitation intensities will increase by an average of 20%. The precipitation volume will increase by approximately 2% in the summer period and approximately 12% in the winter period.

The calculated increase in overflow volume from a sewer system is about 40%. This increase is in the same order of magnitude as the reduction that has been achieved in recent years with measures to reduce combined sewer overflows. The frequency and duration of flooding increases by over 50%. These effects are difficult to translate into actual damage because the relationship between a calculated water level above ground elevation and actual inconvenience (damage?) strongly depends on local circumstances. In inclined areas and in systems that are operating below optimum, the effects will be visible first and more pronounced.

CONSIDERATIONS

In general, the assessment of sewer systems is focused on the reduction of CSO's. Flooding is clearly receiving less attention, particularly in those situations where little or no inconvenience is signalled in practice. Frequently, measures are only implemented when it is (almost) too late.

Another phenomenon is that the discharging catchment area in urban areas is gradually increasing. More and more people chose to completely pave their garden. This can be a considerable additional burden on a sewer system.

The assessment of sewer systems has traditionally focused on analysing the calculated water levels at intersections. However, this is an indirect parameter that is "controlled" by the capacity of the pipelines. Pipelines with an insufficient capacity will result in higher water levels. For a more efficient assessment, the capacity of the sewer system should be assessed, and if necessary modified, on the basis of the capacity of the pipelines.

Figure 9 Increase of paved area: parking space in the front garden.

In general, the Netherlands are a flat country. The storage capacity of water on streets is in fact an extra safety factor whose effect is difficult to quantify. We benefit from this additional safety, often without realising it. This phenomenon is better recognised in inclined areas because the water there seeks out the lowest point and can result in a major inconvenience over a small area. Many designers fail to take this phenomenon into account when assessing the functioning of sewer systems.

In addition, there is the fact that overflows are often removed to reduce the number of emission points in a system. Although compensatory measures are taken to guarantee the system has ‘sufficient’ discharge capacity, the level of safety with respect to water on the street will reduce in most systems simply because the route of the water to the emergency exit (remaining overflows) will be longer.

Finally, there is also a trend towards optimising measures for the lowest social cost. The arguments for these measures are often based on models that at most can only provide an approximate description of the practical situation, but in which the investments can be compared with a high degree of “accuracy”. The consequence of this is that the flexibility of the storage capacity is gradually being removed from the systems. Aspects such as flexibility and safety are often not properly considered because the considerations would then become considerably more complex.

RECOMMENDATIONS

The effects of a climatic change are not isolated issues. The recommendations are therefore linked to other developments in current practice.

The effect of an increase in catchment area in existing systems is a factor that is comparable to and reinforces any increase in precipitation that may occur. Therefore, in the design and evaluation of the functioning of systems, safety and flexibility should also be considered. A broader consideration should be made than we are traditionally used to. The purposeful over-dimensioning of important drainage processes can result in often limited higher costs in the short term but fewer problems in the long term.

The assessment of the functioning of systems should be based on proper test criteria. The assessment of water levels on the street is considerably less effective than the assessment of pipeline capacities [6].

The more the risk of damaging floodings increases, the more important it becomes to monitor the development of floodings. This begins with registering complaints from residents and extends to the local registration of the precipitation and the water levels at crucial points in a system.

The understanding of the actual functioning of waste water systems should be increased to provide better arguments for measures that may be needed. In particular, the inflow in a sewer system deserves special attention, such as the input of precipitation via catchment areas, drainage discharges, groundwater leakage, and industrial discharges.

The increase in precipitation due to climatic change will be visible first in inclined areas Also in systems that are now functioning critically and where problems can currently be absorbed by the temporary storage of water on the street increase of rainfall will result in more flooding.
To reduce future problems, attention should be focused on room for water on the street in urban areas. Uncoupling of rainwater from waste water systems can be extra effective here. In many situations, rainwater use, infiltration into the ground or discharge into the surface water is an important sustainable option for relieving the load on existing systems.

Follow-up studies can be carried out into the development of long-term measures and strategies to be able to absorb the effects of climatic change. The traditional method of gradually modifying a system to meet the minimum requirements can be compared to alternatives such as the large-scale uncoupling of drainage areas or implementing more flexibility and safety in existing systems. A broad consideration of the costs and effectiveness of measures forms a basis for the choice of a sound strategy to respond to the effects of a possible change in climate.

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