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Bepaling bijdrage overstorten in onttrekkingsgebied WPC Kluizen

KU LEUVEN

Bedrijfstakonderzoek

Rapport

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Dit onderzoek is onderdeel van het collectieve Bedrijfstakonderzoek van KWR, de waterbedrijven en Vewin.

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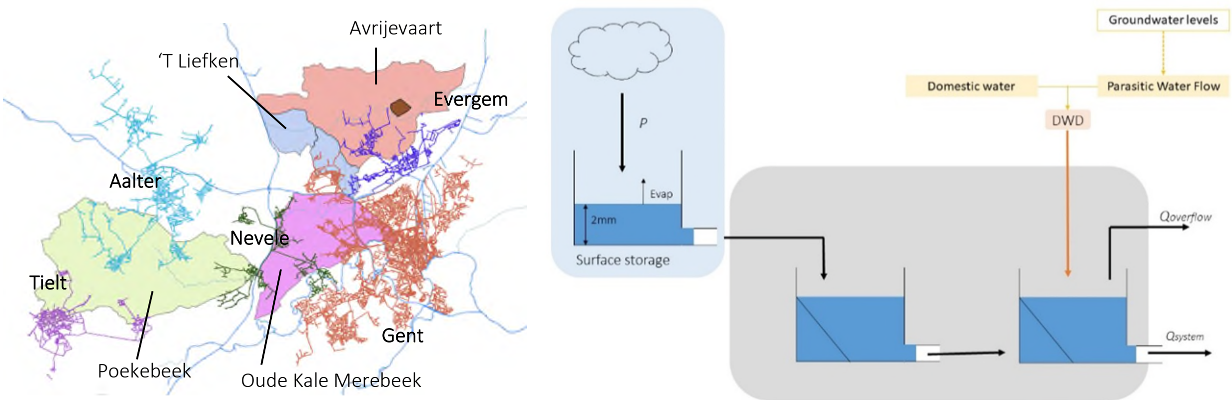
Managementsamenvatting

Nieuw ontwikkelde methodologie schat op basis van conceptuele modellen in welke bijdrage overstorten en permanente lozingen hebben in onttrekkingsgebied WPC Kluizen

Auteurs ir. Joke De Meester, prof. dr. ir. Patrick Willems

Wanneer een overstort in werking treedt, komt ongezuiverd afvalwater rechtstreeks terecht in de waterloop. Momenteel is onduidelijk hoe groot de rol van deze overstorten is op de waterkwaliteit in het onttrekkingsgebied van WPC Kluizen van De Watergroep. De bijdrage van overstorten in de rivierdebieten is nu bepaald in ruimte en tijd met een nieuwe methode, ontwikkeld op basis van een conceptueel model per rioolwaterzuiveringsinstallatie en een nabewerking per deelgebied. Dit model maakt een inschatting van de frequentie, het tijdsmoment en het volume van riooloverstorten. Uit de analyse blijkt dat de gemiddelde procentuele bijdrage van permanente lozingen over de periode 2006-2019 beperkt is tot 0-2%, waarbij de grootste bijdrage voorkomt in de Poekebeek en de kleinste in ’T Liefken. Daarnaast vindt er gemiddeld op 47 dagen per jaar een overstort plaats, waarbij de frequentie het hoogst is in het gebied van de Oude Kale Merebeek. De procentuele bijdrage van de overstortvolumes is het hoogst in de zomer, van 5.9% in ’T Liefken tot 28.5% in de Poekebeek.



Links - Afstroomgebied WPC Kluizen en de aanwezige rioleringssystemen en rioolwaterzuiveringsinstallaties. Rechts - structuur conceptueel model gebruikt om de voorkomingsfrequentie, het tijdsmoment en het volume van de riooloverstorten in te schatten per rioolwaterzuiveringsinstallatie.

Belang: bescherming drinkwaterbronnen
Het waterproductiecentrum in Kluizen, beheerd door drinkwatermaatschappij De Watergroep, levert drinkbaar water in het noorden van Oost-Vlaanderen. Het beschikt over twee spaarbekkens, met een totale capaciteit van 10.9 miljoen m^3. Het oppervlaktewater is afkomstig van onbevaarbare waterlopen in een 25.000 ha onttrekkingsgebied (zie figuur). In dit onttrekkingsgebied liggen vijf rioolwaterzuiveringsinstallaties (RWZI’s) en hun bijhorende rioleringssystemen. De drinkwatermaatschappij wil weten wat de invloed is van overstorten en permanente lozingen op de hoeveelheid water die beschikbaar is voor drinkwaterproductie.

Aanpak: ontwikkeling stedelijke module op basis van conceptuele en hydraulische modellen
Het watersysteem in het onttrekkingsgebied bij Kluizen is zeer complex en sterk ongemeten. In een

eerdere studie (De Meester et al., 2021) werd een conceptueel hydrologisch-hydraulisch waterbalansmodel opgesteld om onder andere het rivierdebiet in elk deelgebied te bepalen. Om de totale overstortvolumes en de tijdsmomenten van de overstorten te bepalen, is nu per rioolwaterzuiveringsinstallatie (RWZI) een conceptueel model opgesteld. Daarnaast is op basis van hydraulische modellen een inschatting gemaakt van de permanente, ongezuiverde lozingen en de hoeveelheid en locatie van de overstorten per gebied. Deze conceptuele modellen en analyses zijn samengevoegd tot een stedelijke module die op basis van data van neerslag, evapotranspiratie, en indien nodig gegevens over de grondwaterhoogten, inschattingen maakt van de voorkomingsfrequentie, de tijdsmomenten en de volumes van de overstorten per deelstroomgebied.

Resultaten: overstortbijdrage aan waterloopdebiet sterk afhankelijk van onttrekkingsgebied en RWZI
De gemiddelde procentuele bijdrage van de overstortvolumes ten opzichte van de rivierdebieten per onttrekkingsgebied, over de periode 2006-2019, gaat van 5.9% bij ’T Liefken tot 28.5 % bij de Poekebeek. De grootste bijdrage vindt plaats in de zomermaanden. Het aantal dagen dat er een overstort plaatsvindt, gemiddeld over alle afstroomgebieden, is gelijk aan 43.25, met een spreiding van 32 (Avrijevaart) tot 57 dagen bij de Oude Kale Merebeek. De bijdrage van de permanente lozingen is eerder beperkt en gaat van 0 tot 2 %.

De bijdrage van de overstortvolumes is dus het grootst voor het onttrekkingsgebied van de Poekebeek. Dit onttrekkingsgebied wordt in de zomerperiode niet gebruikt voor ruwwaterinname in het WPC Kluizen. Alleen wanneer het in de winter noodzakelijk is om de spaarbekkens te vullen, wordt dit deelgebied ingeschakeld. Kijkend naar het potentiële effect op de waterkwaliteit wordt daarom de bijdrage in de Oude Kale Merebeek (gemiddeld 16%) belangrijker geacht. Daarnaast kan ook de bijdrage van de riooloverstorten in het afstroomgebied van ’T Liefken tijdelijk belangrijk zijn, met piekwaarden voor de relatieve bijdrage van de riooloverstorten tot het waterloopdebiet tot 100%.

Toepassing: Inzicht verwerven in kwantitatieve bijdrage riooloverstorten en permanente lozingen
De ontwikkelde conceptuele modellen maakten het mogelijk om voor het onttrekkingsgebied van het WPC Kluizen het al dan niet optreden van riooloverstorten te relateren aan de neerslag-intensiteit. Dit gaf inzicht in wanneer en waar bepaalde riooloverstortvolumes of volumes aan permanente lozing kunnen worden verwacht. Hierdoor kon een inschatting gemaakt worden van het belang van de overstorten en permanente lozingen in elk onttrekkingsgebied. Hierbij worden de resultaten het best relatief bekeken en op dagschaal. In een vervolgonderzoek kan de relatieve bijdrage van de riooloverstortvolumes in de waterloopdebieten vertaald worden naar impact op de waterkwaliteit.

Het Rapport
Dit onderzoek is beschreven in het rapport *Bepaling overstorten in onttrekkingsgebied WPC Kluizen* (BTO-2022.048). Meer informatie over de vorige studie is beschikbaar in het rapport: *De Meester, J., Bertels, D., De Niel, J., Wolfs, V., Willems, P. (2021) Waterbeschikbaarheidsanalyse WPC Kluizen. Onderzoeksrapport van KU Leuven – Afdeling Hydraulica en Geotechniek, voor KWR en De Watergroep, mei 2021, 21 p.*

Inhoud

1 Introduction

The water availability of the water production centre (WPC) Kluizen is under pressure due to multiple external factors such as urbanization, climate change, rise in population etc. To assess the water availability a conceptual hydrological-hydraulic water balance model was developed to estimate water quantity in the water abstraction area of WPC Kluizen (De Meester et al., 2021). But to evaluate the water availability not only water quantity is of relevance but also the quality, since no water is taken for drinking water production if the quality is too low. Multiple factors can affect the water quality, of which external polluters. These polluters can be divided into two main categories: point polluters and diffuse polluters. Sources of point pollution are industries, Waste Water Treatment Plants (WWTPs), overflows of mixed sewage systems, non – connected households and accidental spillage of pesticides. The main source of diffuse polluters are nutrients and pesticides runoff from the surrounding agricultural areas. Up to now a conceptual and data-driven model has been developed to estimate the water quality in the water abstraction area of Kluizen (De Meester et al., 2021). These models can replicate the trend of several parameters, such as ammonium, over time. But since WPC Kluizen is located in a rural area water quality assessment needs to be expanded by exploring the effects of permanent discharges, more specifically the non-connected households, and the combined sewage overflows (CSO) on the water quality. Since CSOs are among the major causes for contamination during a rainfall event (Montalvo-Cedillo et al., 2020) CSOs can lead to long-term ecological damage (Even et al., 2007) and have a negative impact on human health. Beside this, it is predicted that the impact will be worse in the future due to climate change and the increase in urbanization (Jean et al., 2018). The relative contribution of the permanent flows and the CSOs to the river discharge in the water abstraction area of Kluizen is investigated in this report.

Sewage systems can affect the water quality of the surface waters in two ways: (1) the permanent discharges; more specifically, the non-connected households and the WWTPs, and (2) the overflows. In Flanders the percentage of treatment was 86% in April 2022 (VMM, n.d.), which means that about 12% (others have an individual purification station) release their used water untreated in the surface water system. Beside this, when the mixed water can't be brought to the WWTP or can't be temporarily stored in the sewage system, an overflow occurs. Each sewage system is designed to limit the frequency of overflow to 7-10 times a year (CIW, 2018).

To investigate the impact of sewage systems on the water quality, ideally impact modelling is applied. Hereby the sewage system, WWTP and the receiving surface water are modelled, since these different systems interact with each other and have a different system reaction (Vaes et al., 2009; Keupers et al., 2015 and CIW, 2018). In Flanders most models used for planning and support management for governmental agencies are physically based, detailed models. Often these models are implemented in MIKE11 or InfoWorks CS (Keupers et al., 2015). Since these models are highly detailed and complex, the computational time is high and the system should be very well understood. Due to the high calculation time often analysis are done using composite events or separate historical rainfall events. Nowadays the tendency is to go to more simple models to reduce complexity and calculation time, hereby conceptual models (CM) can be used as alternative (Vaes et al., 2004; Keupers et al., 2015; CIW 2018). These CM try to mimic the behaviour of more complex models and minimize the calculation time. Especially for impact assessment of overflows, CM are more beneficial since the use of composite events leads to an underestimation of overflow frequency (Vaes et al., 2004) and the reduced computational time of CM allows for long historical time simulations and scenario analysis such as climate change analysis.

This report presents the results of a research project where an urban module was created, which can simulate the frequency, moment and overflow volumes, together with the permanent discharges for each catchment area and each WWTP. A conceptual model is used to estimate the moment and total overflow volumes for each WWTP based on precipitation and evaporation data, and if necessary groundwater data. Therefore first, several conceptual models were tested to see which combination of attributes gave the best results. Next to this, information of available hydraulic models was used to divide the total overflow volume over the different catchment areas. In combination with results of the river discharges from previous made hydrological-hydraulic water balance model (De Meester et al., 2021), the percentage contribution of overflows towards the river discharge at the outlet of each catchment area can be obtained.

In the following paragraphs, first some background information is given about the processes, the used metrics, the available data and the CMs. Afterwards the results are discussed for each WWTP individually and a summary is given of the joined effect of the sewage systems on the water quantity. In the end a conclusion is given of the applied analysis.

2 Methodology

General

In total 12 sewage systems are located in the water abstraction area of Kluizen (see Figure 1– left). 7 stations are located downstream of the inlet point or at the edge of the water abstraction area, as a result these will have an smaller effect at the inlet of WPC Kluizen. Therefore five of the sewage systems are considered relevant for this study (see Figure 1 – right).

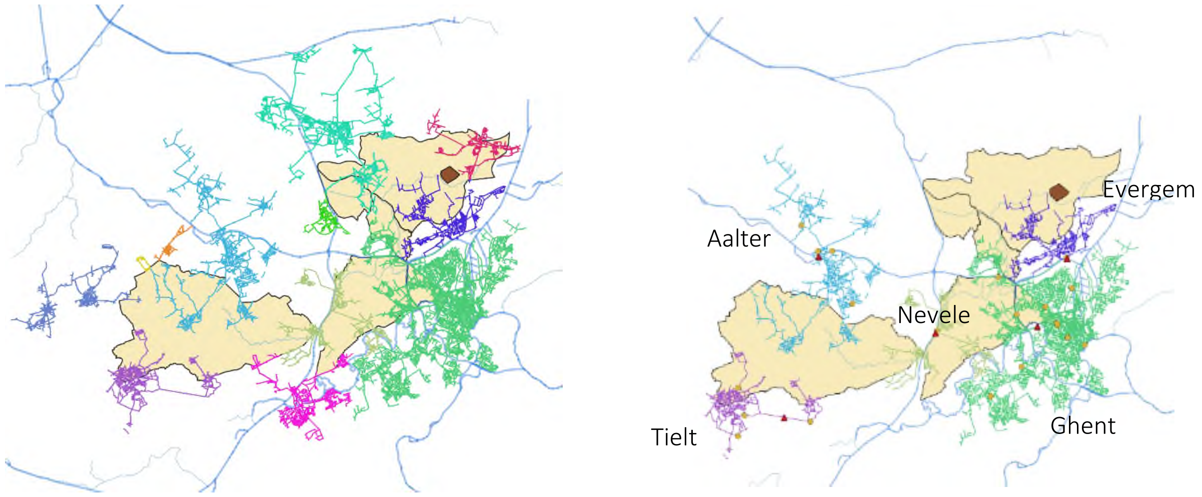


Figure 1: Left – The different sewage systems located in the water abstraction area of WPC Kluizen. Right – location of the sewage systems which are used in this study, more specifically this regards Nevele, Tielt, Aalter, Ghent and Evergem. The red triangles represent the location of the WWTP and the yellow dots indicate the presence of an observation regarding the frequency of overflows.

This report presents the research results on the quantitative contribution of the permanent flows and overflows towards the river system. The applied methodology can be divided in 5 steps. An overview of the steps and processes can be found in Figure 2 and are briefly explained below. The letters in between square brackets correspond to the letters in Figure 2.

1) Calibration and validation conceptual model (CM) for each Waste Water Treatment Plant (WWTP) [A]
2) The permanent discharges are calculated (for each WWTP in each catchment area) by using a constant factor and number of residents. [B]
3) The results of the hydraulic models are used for each WWTP to gain better insights in the locations of the overflows and the division of the overflows over the different catchments areas. In this step for each WWTP a relation is sought between the total overflow volume and the overflow volume in each catchment area. [D]
4) The results of the CM [A], in combination with the relation derived in step 3 [D] gives us the moment and volume of overflows for each WWTP towards each catchment area. Together with the permanent discharges [B] and the river discharges at the outlet of each catchment area, which are obtained from the previously made hydrological – hydraulic model [C], we are able to calculate the percentage contribution of each WWTP towards each catchment area
5) In this last step the total contribution of all the WWTPs to each catchment area is calculated [E].

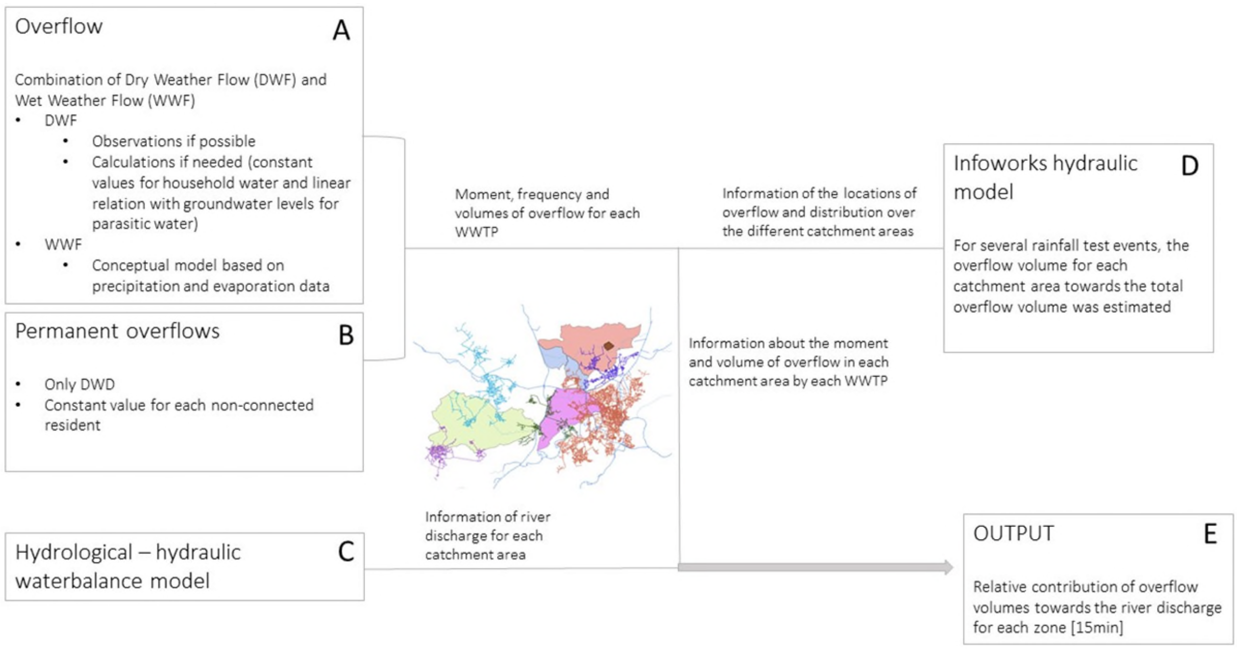


Figure 2: Overview of different processes and steps used in the Urban Module. Part A is further elaborated in the methodology paragraph 2.3, part B and D are shortly tackled in paragraph 2.2.2. More information about part C can be found in Appendix and part E is extensively discussed in chapter 3 'results and discussion'. The text in boxes give the different processes that are considered, the other texts give the information we've obtained from each part. DWF represents the Dry Weather Flow, WWF is the Wet weather Flow and WWTP stands for Waste Water Treatment Plant.

Part A is further elaborated in paragraph 2.3 (Conceptual model). Part B and D are shortly mentioned in paragraph 2.2.2 (Available data). Part C can be found in Appendix I (Conceptual hydrological-hydraulic water balance model), where also the comparison is made with the available PEGASE dataset. And the results for part E are extensively discussed in chapter 3 (Results and discussion).

Throughout this report some general principles are considered:

- When an InfoWorks CS model is available, the assumption is made that this model is well calibrated by Aquafin based on all available measurements, so that the model is correct. The model hasn't been changed or further calibrated, only results are deducted.
- When observations regarding domestic wastewater and parasitic water are available, these are used.
- The assumption is made that the water released through an overflow is a perfect mix between rainwater and dry weather drainage. Although we know there exist several types of overflows, where some of them are better in dividing the different flows during an overflow event (CIW, 2018).
- For the permanent flows, only the domestic wastewater is considered.
- Only the overflow locations and permanent flow locations which were found in InfoWorks CS (if an InfoWorks CS model was available) are considered. Even though the sewage system has changed over time (see the AWIS dataset).
- The same division in catchment areas is taken as used in the hydrological-hydraulic water balance model, made during a previous study (De Meester et al., 2021): Poekebeek, Oude Kale Merebeek (OKM), 'T Liefken (TLK) and Avrijevaart (AVV).
- In this report a constant value of 150 L/(resident * day) is used to represent the domestic wastewater values. This value is the same as used in the DIVA dataset and InfoWorks CS. This value is higher than the average water usage for each resident in Flanders, which is about 120 L/day, since wastewater from schools, KMOs and hospitals are also taken into account (Aquafin, n.d.). During one of the project meetings even a value 89-110

L/day was mentioned as average water usage/resident for average households in the distribution area of De Watergroep.

- In this report OKM is considered separately, without the influence of the Poekebeek.

2.1 Used metrics

Often in hydrological modelling a combination of several goodness-of-fit statistical parameters are used to get better insight in the general performance of the model. Since each statistical parameter focuses on a different aspect, together they are seen as a good tool, but they can be confusing or misleading (Vansteenkiste, 2012). In this report, the used statistics are root mean square error (RMSE), the average bias, the Nash–Sutcliffe model efficiency coefficient (NSE), the correlation (R^2) and the water balance discrepancy (WBD). The RMSE gives more insight in the extreme values. The bias focusses on the average magnitude of the error. The correlation gives an indication of the course of the time series, but is insensitive towards a proportional difference between the observations and simulations (Vansteenkiste, 2012). NSE is a combined measure, that takes into account the correlation, variance, standard deviation and mean of the observations and simulations. But NSE tends to favour models that underestimates the variability (Gupta et al., 2009) and a lot of weight is given towards the extreme values. If the NSE value is negative then the average of the observations is a better prediction than the simulations. If the NSE value is equal to zero than the simulations are as bad as the average of the observations. Both NSE and the correlation should be optimized while the RMSE, bias and WBD should be minimized. The mathematical formulas can be found in Table 1.

Since the models are also calibrated against the frequency of overflow, which can be seen as a classification problem, the F1 statistics is used. This statistic represents the harmonic mean of recall and precision and can give more insight in the performance of the binary classification. In this case, each day is categorized as one if an overflow occurs at any point during the day and categorized as zero if no overflow occurs. The F1 statistic is a commonly accepted performance measure for machine learning classification techniques, where both classes have an equal importance. But F1 has the tendency to favour the models with a higher sensitivity, true positive rate and disadvantages the models with a higher specificity, true negative rate (Sokolova et al., 2006).

Table 1: Formulas for the different goodness-of-fit statistics. N represents the number of samples. V represents the volume, TP is true positive, FP is false positive, FN is false negative. σ represents the standard deviation

Goodness – of –fit statistics	formula
RMSE	$\sqrt{\frac{\sum_{i=1}^{n}(obs - sim)^\wedge 2}{N}}$
Bias	$\frac{\sum_{i=1}^{n}(obs - sim)}{N}$
R	Pearson linear correlation coefficient
MSE	$\frac{\sum_{i=1}^{n}(obs - sim)^\wedge 2}{N}$
NSE	$1 - \frac{MSE}{{\sigma_o}^2}$
WBD	$\frac{\text{Vsim} - \text{Vobs}}{\text{Vobs}} * 100$
Precision	$\frac{TP}{TP + FP}$
Recall	$\frac{TP}{TP + FN}$
F1	$2 * \frac{\text{precision} * \text{Recall}}{\text{precision} + \text{Recall}}$

2.2 Available data

2.2.1 Meteorological data

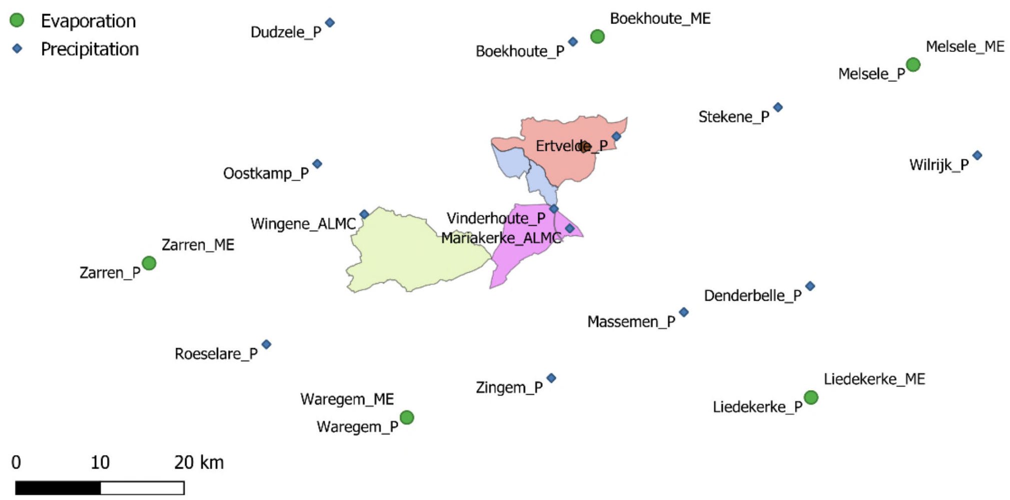


Figure 3: overview of the available precipitation and potential evaporation stations from Waterinfo which have data available every 15 minutes.

Since rainfall runoff is the main driver of the river and sewage system (Keupers et al., 2015), rainfall data is used as an input for the conceptual model (CM). Since the response time of sewage systems on rainfall is short, time series of 15 minutes are used (Keupers et al. 2015). Figure 3 shows the available rainfall stations, which have a time interval of 15 minutes. The stations of Mariakerke and Wingene are rather new stations, they only have observations starting from 2019, as a result these two stations won't be used. For the WWTP Ghent, Nevele and Evergem we focus on Vinderhoute, for WWTP Aalter on Oostkamp and for WWTP Tielt on Roeselare. The unknown values of Vinderhoute are set to zero, the NaN from Oostkamp are filled with the observations from Vinderhoute and the NaN from Roeselare are filled with the observations of Oostkamp and Vinderhoute (in that order). The decision was made to not work with Thiessen polygons, because this will flatten the rain events and we are interested in the peaks.

To incorporate evaporation losses, also time series of evaporation are used. Figure 3 gives an overview of the available reference evaporation stations at Waterinfo. These stations make use of the Penman–Monteith equation and have a value every 15 minutes. Looking at the locations, the most interesting stations are Waregem, Boekhoute, Zarren and Liedekerke. For each sewage system the same station is used, namely Waregem. The unknown values are estimated using Boekhoute, Zarren and Liedekerke respectively. Figure 4 shows the correlation matrix for the different evaporation stations, since the different stations have a high correlation, this method seems reasonable. If there are still unknown values, these are estimated using linear interpolation (629 times). The negative values in the time series (7.5 % of the time series) were replaced by zeros for practical reasons. Since these values are close to zero and mostly occur at night, this shouldn't create problems. During the night, the incoming radiation is often lower than the outgoing radiation and there is less, to no demand for water.

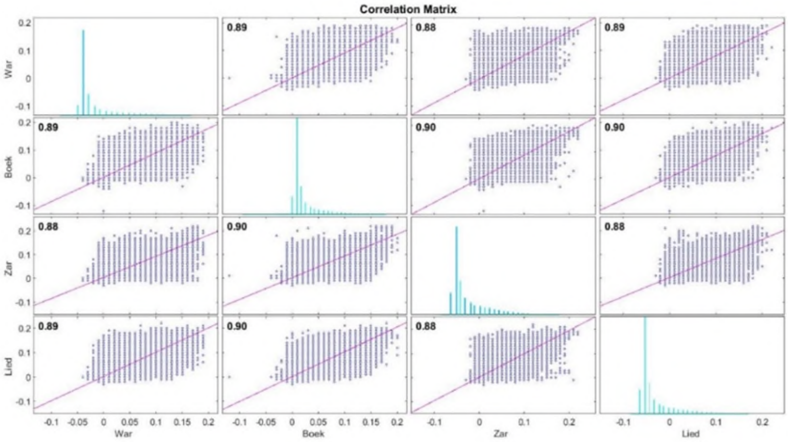


Figure 4: Correlation matrix of the different evaporation stations

2.2.2 Sewage stations

Figure 5 gives an overview of the used catchment areas (Poekebeek, OKM, TLK and AVV) and the considered WWTPs and their sewage systems (Nevele, Evergem, Tielt, Aalter and Ghent).

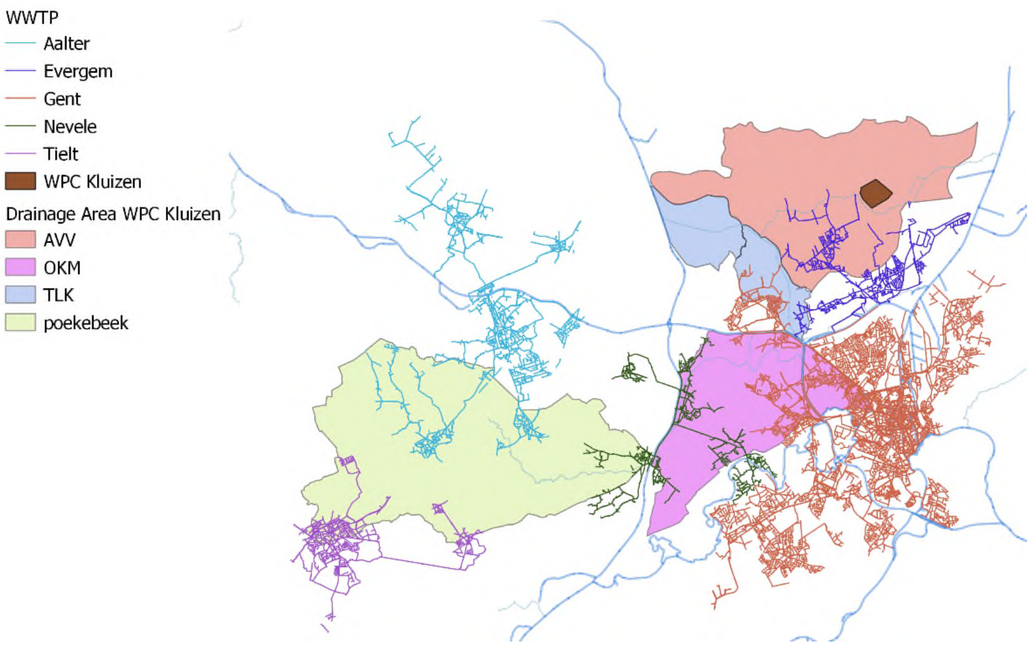


Figure 5: overview different catchmetns areas and considered WWTP

As mentioned before, the focus will be on five sewage systems. For each of these stations a conceptual model (CM) is calibrated and an estimation is made of the contribution of overflow volumes towards the discharges of the surface water system. To calibrate each CM, data from DIVA and MOS is used. DIVA delivers daily discharge data for each WWTP until 2017. Beside this, DIVA also gives an estimation of the connected area, up to 2017 and the domestic wastewater, up to 2019. To gain better insights in the overflow frequency, the *meetnet overstorten* (MOS) dataset from VMM is used. This networks exists since 2003, and is spread throughout Flanders. It consist of several automatic measuring stations, 309 in 2016, that measure the frequency of overflow events (VMM, n.d.). When comparing different locations of the MOS dataset from one sewage system, the frequency and moment of overflow coincides between the several locations of the same network. Therefore one location can be seen as a representative of the whole network. To estimate the permanent discharges, the released water, a constant factor is used and the number of non-connected residents are estimated through, if possible, the results from the hydraulic models. Otherwise the amount of non-connected residents is estimated based on the AWIS dataset. Table 2 gives an overview of the available data for each WWTP.

Table 2: Available data for each used WWTP, V indicates data is available, x indicates there is no data available. The number of residents which are not connected to the WWTP, and therefore have a permanent discharge of wastewater into the surface water systems are obtained from the hydraulic models. If there was no hydraulic model available, which is the case for Gent, the number of residents was estimated based on the AWIS dataset.

WWTP	WWTP Number	MOS ID	Range MOS data	DIVA data [2000-2017]	InfoWorks CS model	Number residents not connected [InfoWorks CS / Gent-AWIS]
Evergem	139	332	14/07/2010 - 22/12/2019	v	2015	AVV: 355.03 TLK: 0
Gent	20	48,49,50,316,318,320, 336,364,400,434,506	11/02/2005-14/12/2019	v	x	OKM: 135 TLK: 0
Nevele	123	492	9/11/2016-20/12/2019	v	2016	Poekebeek: 260.76 OKM: 63.47
Tielt	122	246,254,278,464	12/02/2006-21/12/2019	v	2011	Poekebeek: 749.79
Aalter	25	142,204,392,452	10/02/2005-31/12/2019	v	2006	Poekebeek: 498.55

For every WWTP, except for Ghent, a hydraulic model in Infoworks CS is available. InfoWorks CS solves the Saint-Venant hydrodynamic flow equation for certain conditions. The Wallingford model is used in InfoWorks CS to represent the rainfall runoff (Innovyze, 2022) and a constant value of 150 L/(d*capita) is considered as domestic wastewater. To divide the domestic wastewater during the day the function as can be seen in Figure 6 is applied. The simulations are exported with a time step of 15 minutes and the first 8 results (~ 2 hours) are seen as a spin-up period.

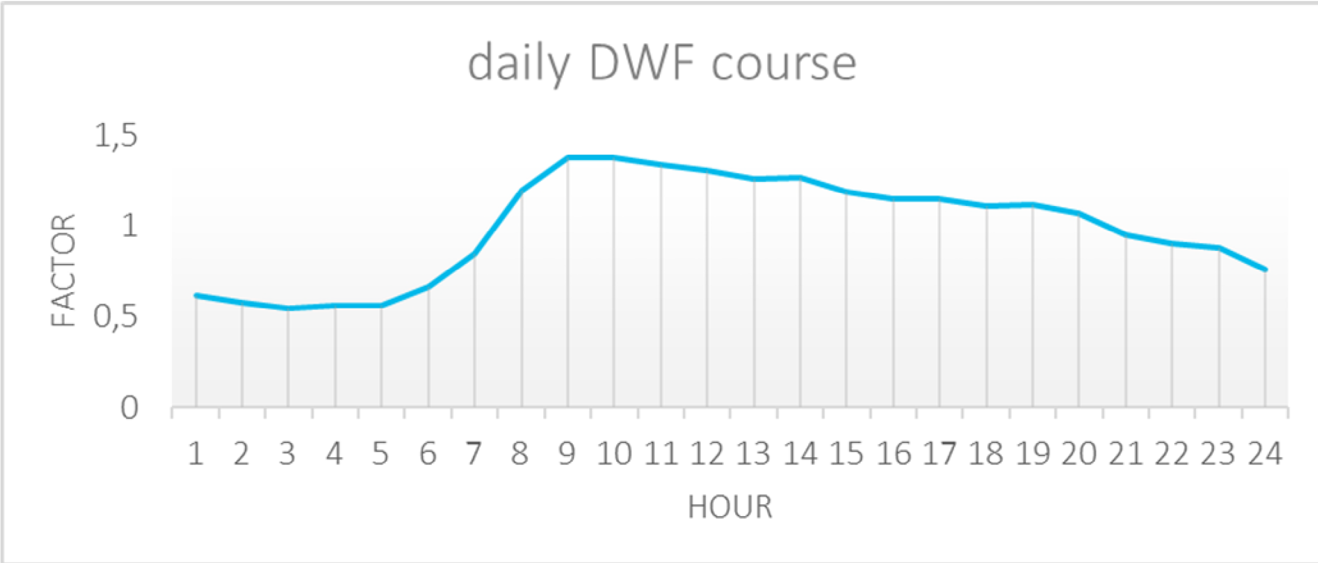


Figure 6: DWF course for 1 day

The models available in InfoWorks CS allows us to apply detailed simulations on a sewage system and gain more insight in the division of overflows over the different catchment areas. The outfall nodes represent the overflow locations in InfoWorks CS. Outfalls which are not connected to the WWTP have a permanent discharge, and should be taken into account separately. When these permanent flows only have WWF pipes, they are ignored in this study, since we are interested in the effect on water quality. For each sewage system there are several states available in InfoWorks CS. State A represent the situation at the moment the model was made (Aquafin, 2015). When a comparison is made between the different states and the AWIS dataset (2018), state A showed the highest resemblance for each WWTP. Therefore State A is used in further analysis.

Since InfoWorks CS is a detailed hydrodynamic model with very high computational demands it is not possible to have simulations over the period 2005-2020. Therefore some test events were used to obtain insights in the behaviour of the sewage system. The results if these test events were used to derive relationships between total overflow volume and overflow volume in each catchment area. The test events were distracted from the historical time series of the closest located precipitation station. If possible 12 precipitation events are selected with an intensity between 0 and 2 mm/h, using this interval: [0:0.1:1,1.5,2]. The intensity is calculated over two days (by taking the average and * 4 (since the precipitation is in mm/15min)) and events were considered independent if

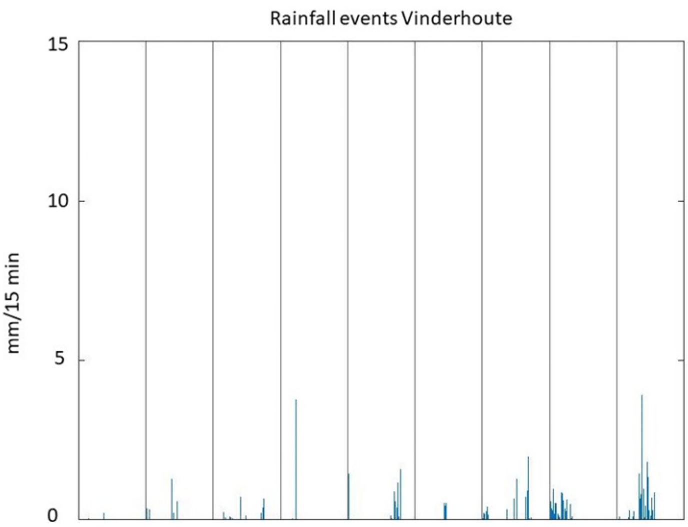


Figure 7: Used test events of precipitation station Vinderhoute

there was no rainfall 2 days prior. This is a conservative rule since in general the concentration time of sewage systems won't exceed 16 hours (CIW,2016). The test events of Vinderhoute can be seen in Figure 7, the test events used for the other precipitation stations can be found in Appendix II (Test events).

2.3 Conceptual model

The interaction between the storage and outflow can describe the behaviour of the sewage system (Vaes et al.,2004). The storage cell concept is frequently used to represent the sewage systems by a CM . In this concept, the sewer system is divided into several interconnected reservoirs. The processes between and in the reservoirs are lumped in space and time (Keupers et al., 2015). The used CMs should be physically based, adapted to the system and calibrated (Vaes et al., 2004; Keupers et al., 2015), as a result this method is a mix between data-driven and physically based.

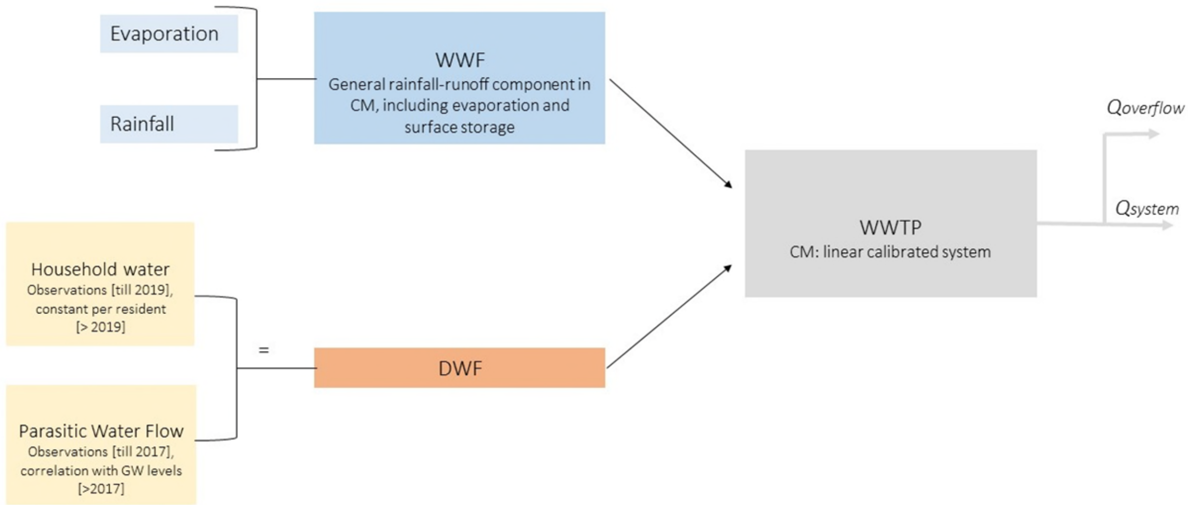


Figure 8: Overview of different processes considered for each sewage system for determining the overflow and effluent discharge. This figure can is part of box A in Figure 2. CM stands for conceptual model

The overflows, see box A in Figure 2, are estimated using a physically based conceptual model for each WWTP that is calibrated against the daily discharge of the WWTPs from the DIVA dataset and the available overflow frequency from the MOS dataset. The model incorporates both the dry weather flow (DWF) and wet weather flow (WWF) (see Figure 8). The DWF consist of domestic wastewater and the parasitic water flow (PWF). Sources of PWF are groundwater infiltration from leaking household connection and sewers, and inflow due to drainage from construction sites and crop fields. The PWF shouldn't be ignored since in Flanders more than 50% of the DWF is PWF (Dirckx et al., 2009). As can be seen in Figure 8 observations are used to represent the DWF. After 2019 there is no information on the domestic water, therefore a constant value is assumed. This constant value can be chosen by the user, in this report a value of 150 L/(d*resident) is used. Domestic wastewater usage changes during the day, to include this variability, a factor is applied each hour (see Figure 6). After 2017 there is no information of the PW. After 2017, the PWF is estimated based on its relation with the groundwater levels (see Appendix III (Parasitic water flow)). The WWF comes from rainfall and is represented by a physical based conceptual model, which includes the surface storage, rainfall runoff and retention of water.

In this study Five CMs were tested, which differ in amount of storages, depletion of each storage and calculation of overflow. CM 1, can be seen in Figure 9, consist of only one reservoir where the water decreases linearly, but since a sewage system often doesn't act linear (Vaes et al., 2014) this won't be sufficient. CM1b is partly based on the Wallingford model, which is used in the models of InfoWorks CS, here two reservoirs are placed in series. In each reservoir the outflow is calculated based on a linear relation which depends on the volume of the reservoir (see Figure 11). CM1c is equal to 1b but thresholds for each basin were applied. CM2 (see Figure 9) also consist of one reservoir, but here a linear reservoir model with an exponential decrease is applied and the rainfall runoff is averaged over the concentration time, as applied in Remuli (CIW, 2016). CM3, as can be seen in Figure 10, is the same as CM2 but here the overflow is not calibrated but estimated based on a threshold after Peak-over-threshold (POT) analysis. The third conceptual model uses the same method as applied in the study 'Impact beleidsplan ruimte Vlaanderen op rioleringen' (Wolfs et al., 2018). In this study, the conclusion was made that the sewage system reacts as a theoretical linear reservoir (Wolfs et al., 2018). The model structure includes a recession constant [k], which indicates how fast the system reacts on precipitation, and concertation time. If k is low, water is quickly discharged. The outflow follows an exponential decrease, as (natural) based on gravity emptying pipes (Wolfs et al., 2018). Since there are several datasets available regarding contributing area (see Appendix IV (Estimation contributing area)) and connected residence, a sensitivity analysis was carried out (see Appendix V (Sensitivity analysis CM3)). The conclusion was made that the DIVA dataset should be taken for representing the contributing area, the overflow frequency should be set on 30 and the dataset representing the population doesn't make a difference.

The losses due to surface storage, infiltration and evaporation shouldn't be ignored (CIW,2016). To include these losses, in all the different CMs, a reservoir was added at the beginning which represents the surfaces storage. This water doesn't lead to runoff but fills local depressions and moisten the surface (see blue box in Figure 9, Figure 10 and Figure 11). As explained in the code of good practise for design of sewer systems in Flanders (CIW, 2016) this surface storage is set at 2mm. This value is relatively high, but accountable since no distinction is made between tilted and flat roofs (CIW,2016). Beside initial losses (surface storage) there are also continuous losses; infiltration and evaporation. The evaporation of open water is added by using an evaporation time series from Waterinfo, see paragraph 2.2.1 (Meteorological data). To include other losses such as infiltration, a runoff coefficient is used (after the surface storage) of 0.8. This value is often taken for long term actual time series. In general this value lies between 0.5-1 and in real life this value won't be constant over time, since during extreme rainfall, less infiltration occurs (CIW, 2016).

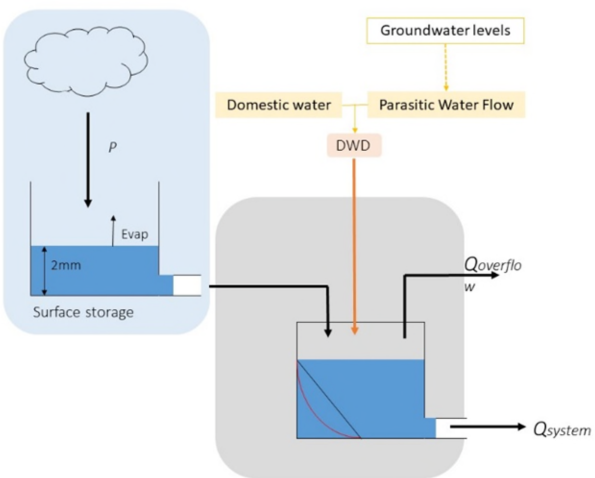


Figure 9: Representation of CM1 and CM2 (red line). The colour of the boxes refers to the colours in Figure 8. This figure can be subcategorized in box A of Figure 2

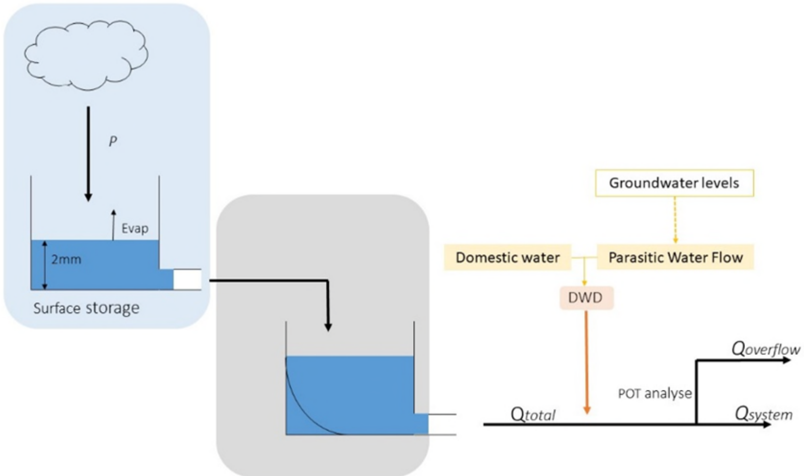


Figure 10: Representation of CM3, which is used for WWTP Ghent. The colour of the boxes refers to the colours in Figure 8. This figure can be subcategorized in box A of Figure 2.

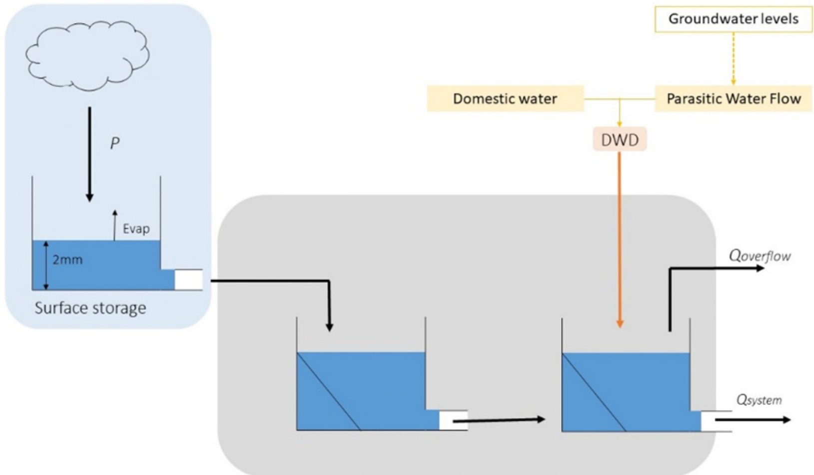


Figure 11: Representation of CM1b. The colour of the boxes refers to the colours in Figure 8. CM1b is based on the Wallingford model. This figure can be subcategorized in box A of Figure 2

The several CM are calibrated over the period 2006-2016, 2005 is used as a spin-up period and the models are validated using 2017. For each calibration the NSE, RMSE, Bias, WBD, F1 and number of overflows are calculated. Since attention is brought towards the frequency of overflow and the course of the time series, the CM which performs best when taking the average between the NSE value and F1 value are kept and used for the validation.

As a result, for each sewage system the moment and volumes of overflow can be estimated based on precipitation, potential evaporation and groundwater level data (only needed after 2017). After the conceptual models were calibrated for each WWTP, hydraulic models available in InfoWorks CS were used to gain more insight in the overflow locations and their division over the different catchment areas. For each WWTP a linear relation is sought between the total overflow volume and the overflow volume for each catchment area. Therefore several representative rainfall events of two days were simulated by the hydraulic models and the behaviour of the sewage systems was analysed.

3 Results and discussion

In paragraph 3.1 (Results per WWTP) the results will be discussed for each WWTP separately. First the results of the CMs are discussed. After calibration and validation of the several models (see Appendix VI (Modelling results)), CM1b is selected for WWTP Nevele, Evergem, Tielt and Aalter. For WWTP Ghent CM3 will be used, since these parameters are more physical interpretable. Afterwards the results of the hydraulic models will be analysed. Hereby an overview of the locations of the overflow and permanent discharges will be given. Next to this, also the comparison between the results of the hydraulic model, the CM and the observations will be elaborated. Then the division of the total overflow volumes towards the different catchment areas is given, both the used relations and the results. Afterwards the percentage contribution of the permanent discharges and CSOs for each WWTP towards the river discharge in each catchment area is discussed.

In paragraph 3.2 (total contribution to each catchment area) the percentage contribution of all the considered WWTPs towards each catchment area is given.

3.1 Results per WWTP

3.1.1 Nevele

Results CM

Table 3: Results of the validation [2017] for each WWTP when CM1b is used. Several metrics were calculated, namely the NSE value, RMSE, correlation, bias, WBD and the F1 score. Also the amount of days where an overflow occurred was compared between the observations and the simulations.

2017	Nevele	Evergem	Aalter	Tielt
NSE [-]	0.77	0.35	0.7	0.75
RMSE [m³/d]	268.88	422.13	171.01	1487.45
Correlation [-]	0.89	0.78	0.85	0.89
Bias [m³/d]	-286.88	-422.13	171.0118	1487.45
WBD [%]	9.63	6.82	-1.37	-14.79
F1 [-]	0.61	0.69	0.71	0.73
#sim	57	28	47	54
#obs	55	33	32	39

Table 3 gives for each WWTP the validation metrics when using CM1b. It can be noticed that for most WWTPs the results are acceptable (e.g. NSE values > 0.6), except for Evergem. In Evergem the NSE values are low (more details see paragraph 3.1.2 (Evergem)). Figure 12 shows the results at the outlet of WWTP Nevele when using CM1b. The time series of the simulations and the observations have the same course, but during the summer months CM1b tends to overestimate the observations. One of the reasons could be the used domestic wastewater values of the DIVA dataset. Figure 13 and Figure 14 give the moments of overflow according to CM1b and according to the MOS dataset. When looking at the frequency of overflow, it can be noticed that in 2019 (Figure 13), the frequency of overflows is strongly overestimated by the model, while in 2017 these are in line with the observations (see Figure

14 and Table 3). Since the frequency seems in line for the other years it looks like 2019 was an exceptional year and probably external factors influence the results. This is not further analysed in the scope of this study.

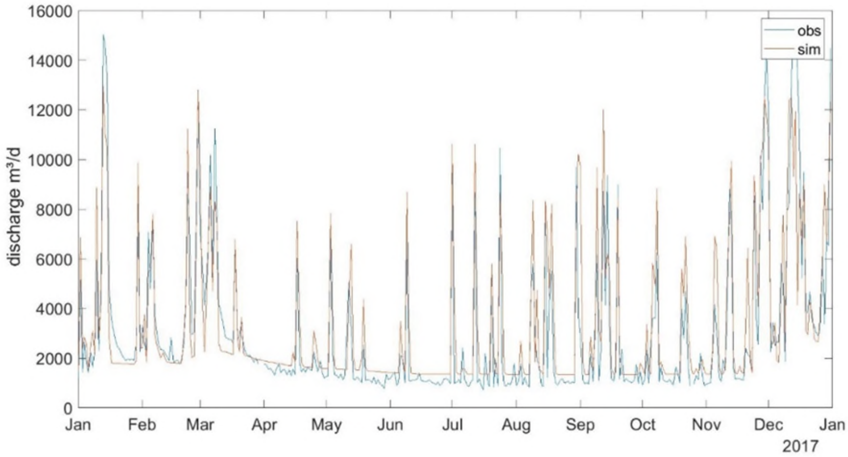


Figure 12: Daily discharge [m³/d] at WWTP Nevele in 2017. The blue line represents the observations from the DIVA dataset and the orange line represents the results from CM1b.

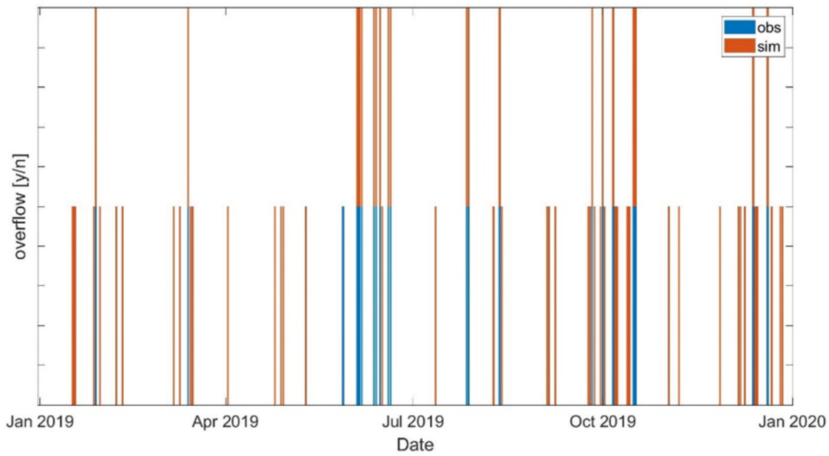


Figure 13: Representation of the moments of overflow using a categorical approach on a daily scale for WWTP Nevele in 2019. A day is categorized as one if during that day one or more overflows occurred, otherwise it is categorized as zero (so no bar visible). Both the observations (MOS dataset) and the simulations using CM1b are shown.

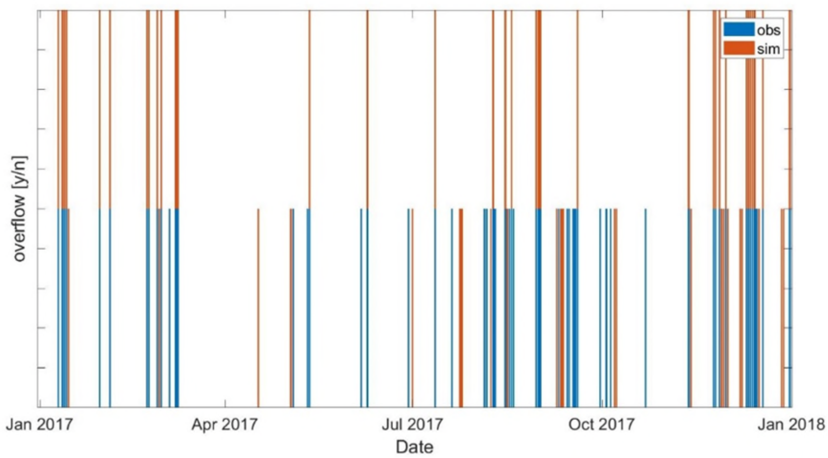


Figure 14: Representation of the moments of overflow using a categorical approach on a daily scale for WWTP Nevele in 2017. A day is categorized as one if during that day one or more overflows occurred, otherwise it is categorized as zero (so no bar visible). Both the observations (MOS dataset) and the simulations using CM1b are shown.

Results InfoWorks CS

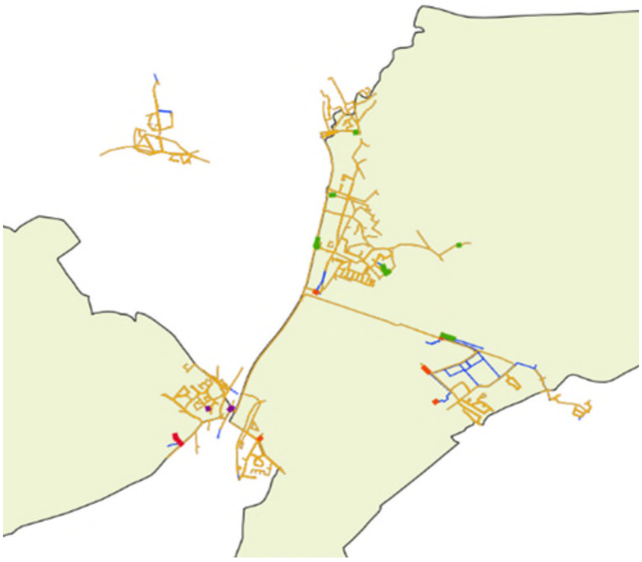


Figure 15: Left – yellow gives the pipes from state A in Infoworks CS that are connected to the WWTP. The red rectangles are permanent flows, the green and purple rectangles represent the locations of overflow at OKM and Poekebeek, respectively.

Figure 15 gives an overview of the overflow locations for the sewage system of Nevele based on the hydraulic model available in InfoWorks CS. Regarding the entire sewage system, there are 29 outfalls linked to the WWTP. To make a division between permanent discharges and overflows the results from the hydraulic models were analysed. It could be concluded that there are 20 overflows connected to the WWTP and 9 permanent discharges. Of these 20 overflows, 6 are located in OKM and 3 in Poekebeek.

Overflow OKM & Poekebeek

The results from the 9 test events in InfoWorks CS are used to find a relation between the total overflow volume of WWTP Nevele and the overflow volumes in OKM and Poekebeek. The overflow in OKM can be determined by dividing the total overflow volumes into three categories, based on the volumes (see Figure 16). It was noticed that Poekebeek only has an overflow when the total overflow volume exceeds 182 m³ (over 15 min) (see Figure 17). Figure 18 gives the results when these relations are applied on the total overflow volume found by InfoWorks CS. It seems that, on average, the overflow volume in OKM can be well represented by this relation. For Poekebeek the results will be scattered when only small events occur (see Figure 17).

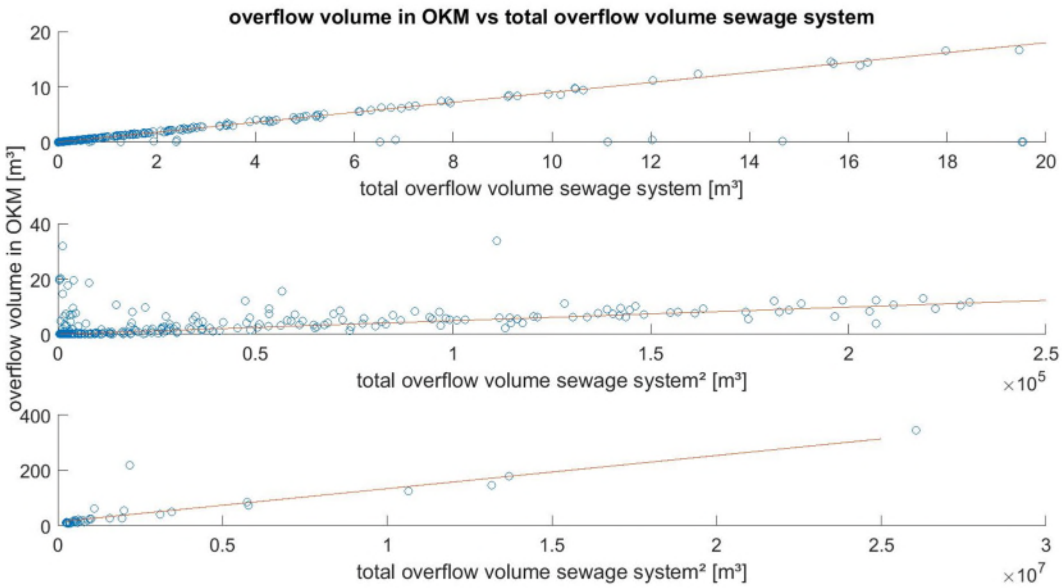


Figure 16: Linear relation between total overflow volume of WWTP Nevele models and the overflow volume in OKM according to the results from the test events in InfoWorks CS. The Pearson correlation coefficient [r] when the total overflow is lower or equal to 20m³ is 0.86 (subfigure A), when the total overflow volume is between 20 m³ and 500 m³ it is 0.5 (subfigure B) and above 500m³ [250000 m³ - squared] the Pearson correlation coefficient [r] is 0.9 (subfigure C).

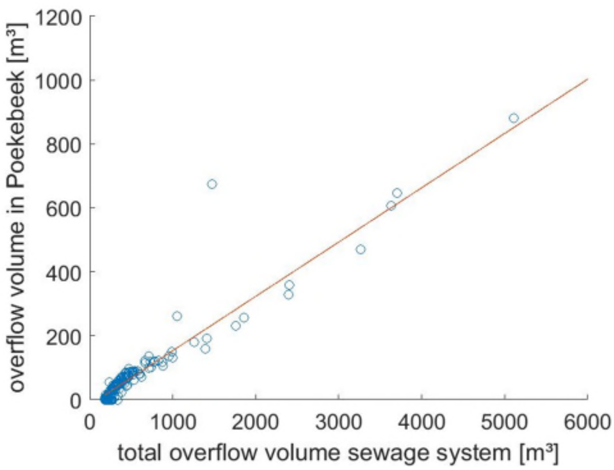


Figure 17: Linear relation between the total overflow volume of WWTP Nevele and the overflow volume in Poekebeek, according to the results obtained from the test events in InfoWorks CS. The Pearson correlation [r] is 0.9430.

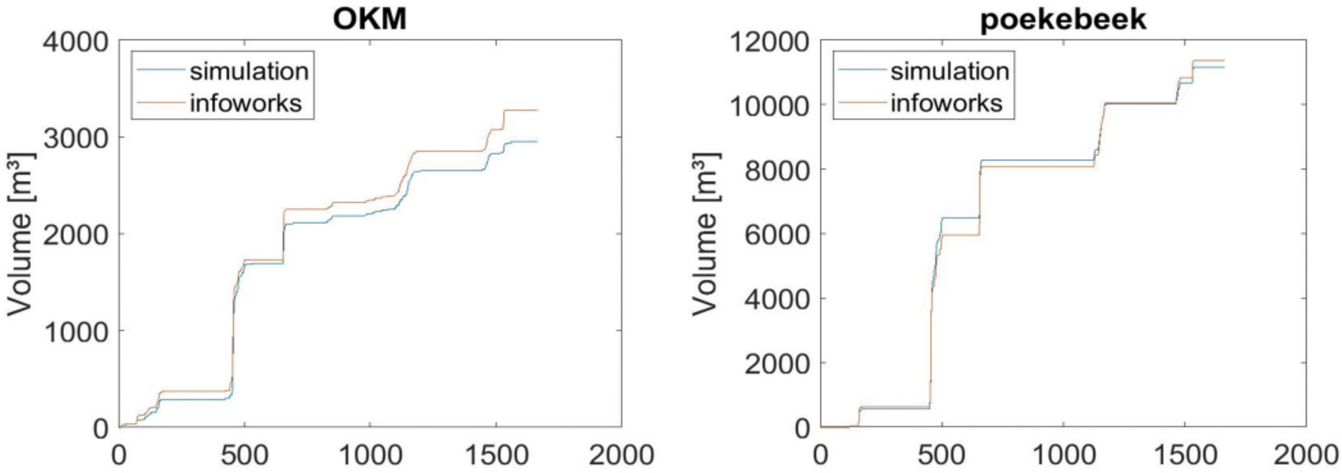


Figure 18: The cumulative results for the different test events after applying the relation between the total overflow volume and overflow volumes in each catchment area on the total volume obtained from Infoworks CS. For the overflows of WWTP Nevele in OKM and Poekebeek.

InfoWorks CS vs CM1b vs Observations

For the several test events the results from the hydraulic model, CM1b and the observations from DIVA were compared. Both the results at the WWTP outlet and the total overflow volumes of the system are analysed (see Figure 19). Left on Figure 19 , it can be noted that the conceptual model underestimates the peaks and overestimates the low discharges at the outlet of the WWTP compared to the observations. As a result the total cumulative volume is about the same. InfoWorks CS overestimates the total discharge at the WWTP, this is mostly due to an overestimation of the low values.

When looking at the overflow volumes (right part of Figure 19), CM1b generates higher overflow volumes than InfoWorks CS, especially during more intense rainfall events (rainfall intensity > 1mm/h). Figure 20 gives the relation between the rainfall intensity and the total overflow volume for results obtained from CM1b and the hydraulic model. One would expect the overflow volume to increase with higher precipitation intensities. This seems to be the case in general, but there is quite some scattering. Probably this is partly due to the limitation that only 12 events were analysed. Also here it can be noticed that CM has higher overflow volumes than Infoworks CS. One of the reasons could be that not all overflows are considered in the results from InfoWorks CS. Because when also WWF, DWF or mixed pipes are connected to the overflow outlet, and not to the WWTP, these overflows are not taken into account since the distinction between the effective overflow volume and the permanent flow cannot be made.

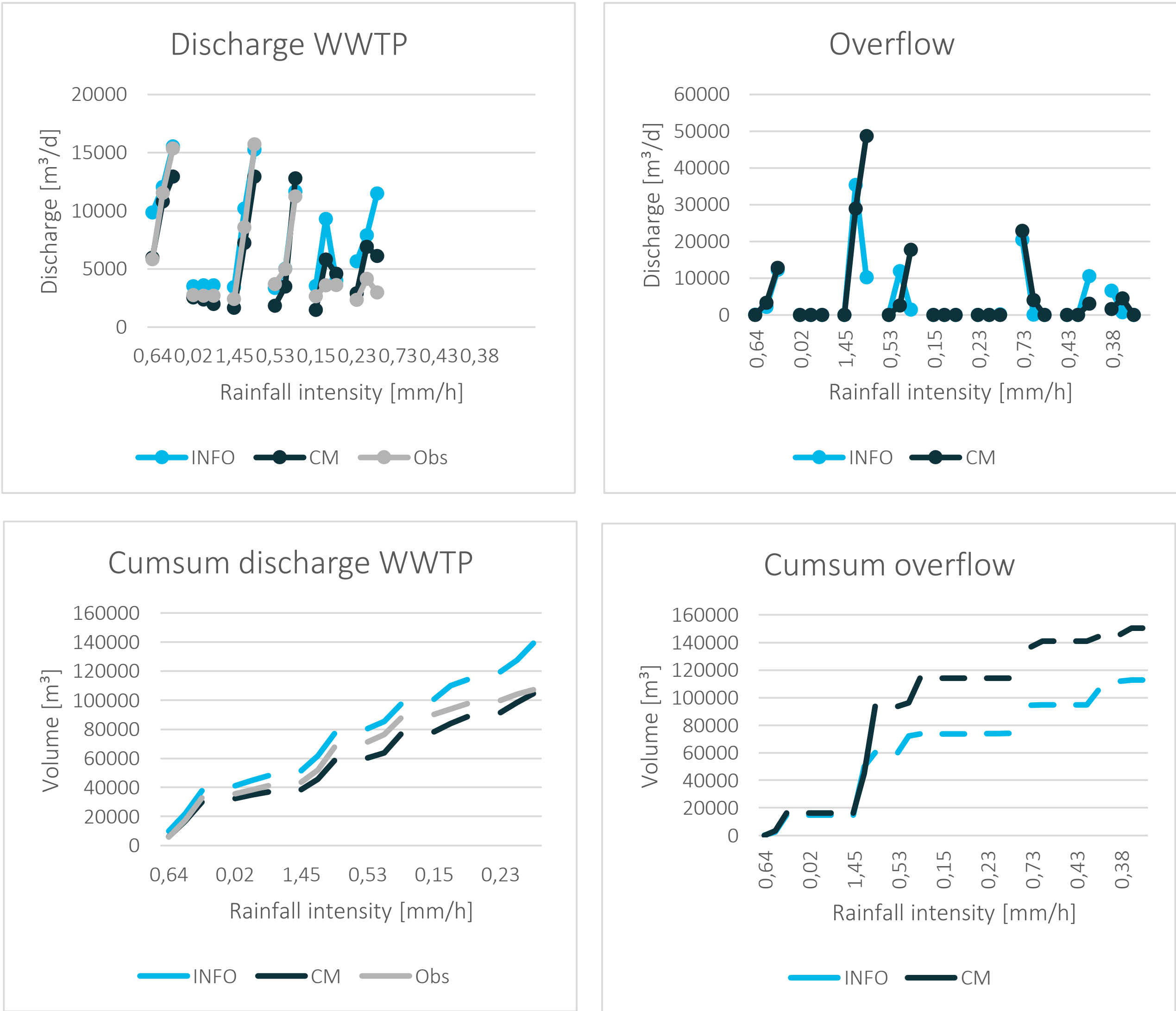


Figure 19: The results from the Infoworks CS model, the CM1b and the observations from the DIVA dataset are compared for the used test events. Left – the discharge at the outlet of the WWTP in Nevele is looked at, as well at the discharges for each event as the cumulative volumes. Right – the overflow volumes are examined. Here also both the time series, and the cumulative volumes are looked at. Since there are no observations of the overflow volumes only the results from the Infoworks CS model and CM1b are examined.

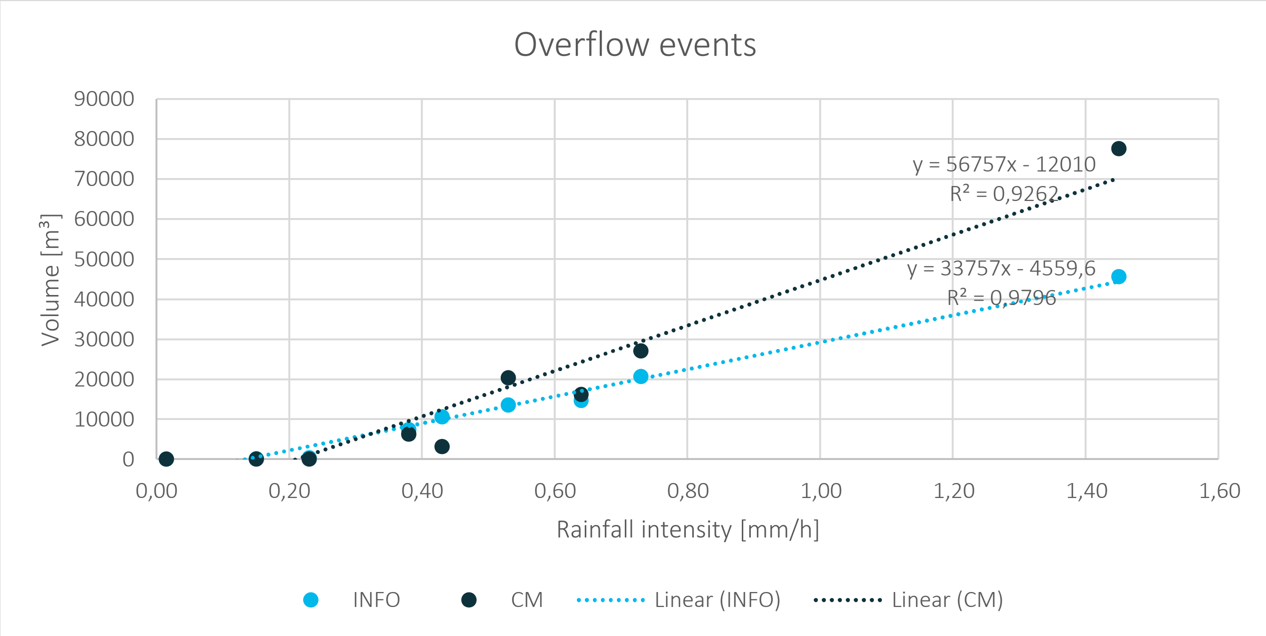


Figure 20: The different rainfall test events are ranked according to their intensity and the results from the Infoworks CS model and CM1b for WWTP Nevele are plotted to indicate the linear trend between the overflow volumes and the rainfall intensities.

Error! Reference source not found. compares the results for each overflow event between CM1b and InfoWorks CS. It can be noticed that the results of CM1b are smoothed, but that the moment of overflows coincide between the two models. InfoWorks CS also has a few overflow events in 2017 which do not occur in the results from the CM1b, but these events have a low overflow volume so can be neglected.

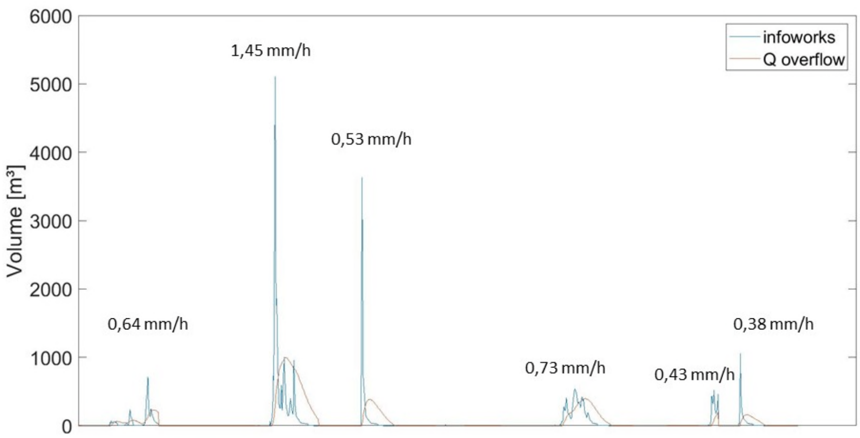


Figure 21: The total overflow volumes for the several test events of 2 days are given. The blue lines indicates the results obtained from the hydraulic models and the orange lines represents the overflow volumes according to CM1b. The rainfall intensities are shown above each event.

Contribution to OKM & Poekebeek

Figure 22,Error! Reference source not found. and Table 4 give more insights in the percentage contribution of the overflows towards the river discharges of OKM and Poekebeek. In general, the contribution is higher during the summer months. For both OKM and Poekebeek the average contribution of the permanent flows is rather low, 0.10-0.34%. The percentage contribution, looking at overflow volumes, from Nevele to OKM rises to 8%, but is on average 0.47%, which is rather low. When looking at Poekebeek the maximal contribution over the period 2006-

2019 rises to 54% and the average contribution is 5%. But since Poekebeek is quite far located from the inlet of WPC Kluizen the effect on the water quality at the inlet of WPC Kluizen is probably negligible.

Table 4: Results of the percentage contribution of WWTP Nevele towards the discharges at the outlet of the catchment areas OKM and Poekebeek. Both the percentage contribution of the permanent, untreated flows, are given and the percentage contribution of the overflow volumes. For the years 2017 and over the period 2006-2019, the maximum percentage contribution and the average percentage contribution is given. The two values given by the average contribution of overflow indicate the average when all the time steps are included/ average when only the time steps where an overflow occurs are included. For the average, the days where the percentage contribution exceed 100% the value is set to 100%. Also the number of days where the percentage contribution is higher than 100% is given, since these are not realistic values.

OKM [%]	**2017**		**2006-2019**	
	Max	Average	Max	Average
permanent	0.39	0.11	0.95	0.10
overflow	3.16	0.08/0.53	8.78	0.07/0.47
total	3.43	0.20/0.63	9.01	0.17/0.57
> 100 %	0.00		0.00	
Poekebeek [%]	**2017**		**2006-2019**	
	Max	Average	Max	Average
permanent	2.03	0.49	3.07	0.34
overflow	28.38	0.15/4.30	54.03	0.14/5.38
total	30.35	0.64/4.79	56.24	0.48/5.86
> 100 %	0.00		0.00	

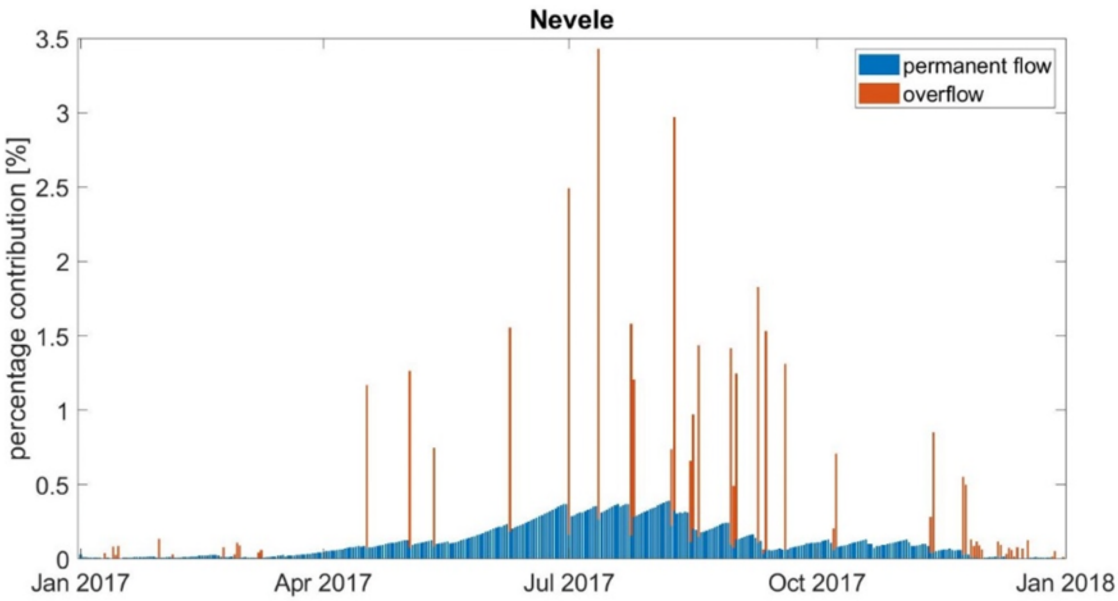


Figure 22: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Nevele to OKM for 2017

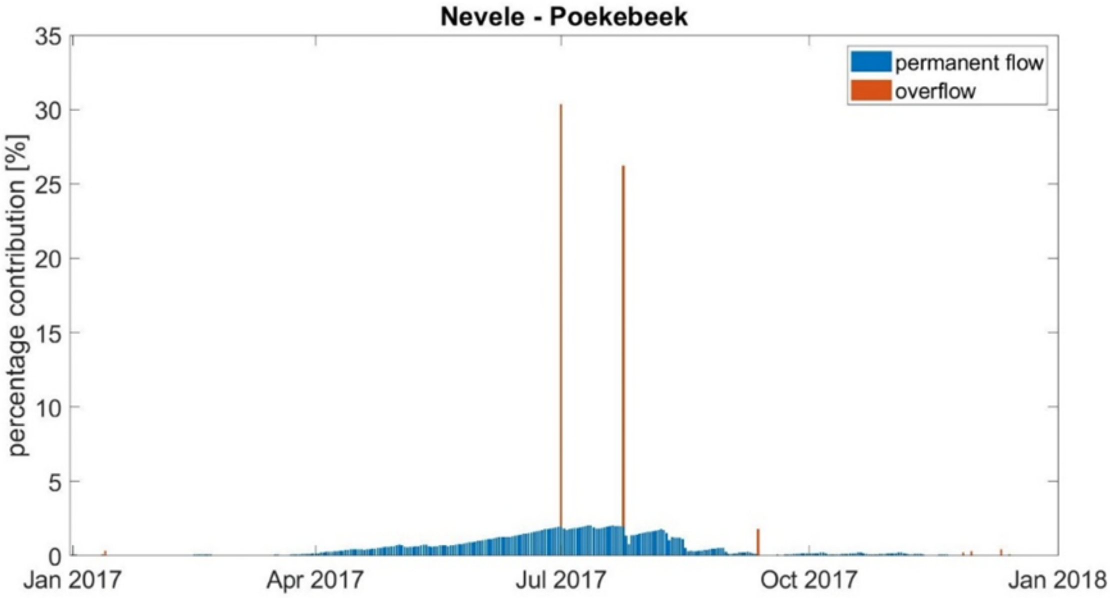


Figure 23: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Nevele to Poekebeek for 2017

3.1.2 Evergem

Results CM

As shown in Table 3 Evergem has negative NSE values. Figure 24

gives the course of the daily discharge, which doesn't represent a typical course. There is a jump in 2011 which can be explained by an expansion of the sewage system (see Figure 25). But beside this, the flattened top is also not as expected, which can explain the low NSE values. Since the course of the observations is not as expected, the decision was made to exclude the NSE values for the calibration of the WWTP station of Evergem but to focus on the WBD and F1 values. The time series of the simulations and the observations have the same course (see Figure 26), but during the summer months CM1b tends to overestimate the observations. Figure 27 shows the moments of overflow coincide between the results of CM1b and the MOS dataset.

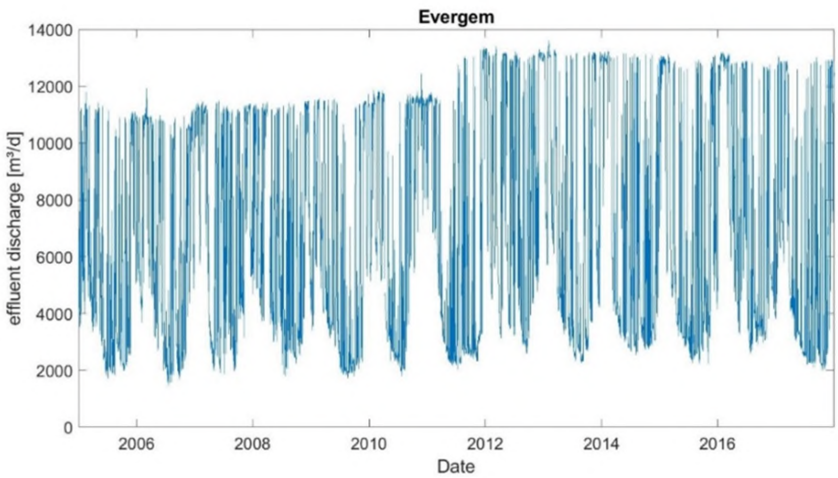


Figure 24: Daily discharge [m³/d] at WWTP Evergem

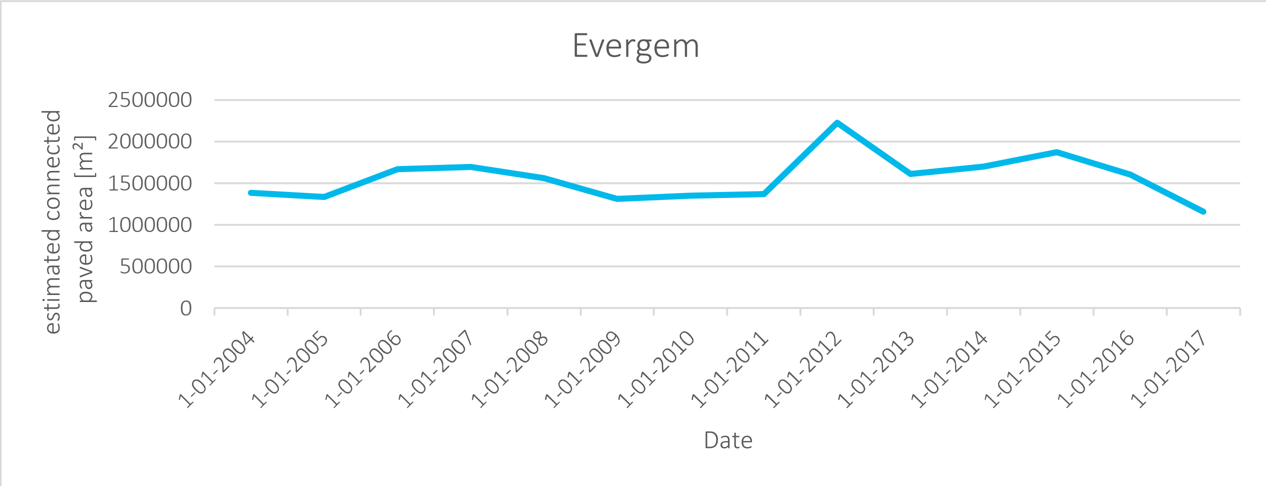


Figure 25: estimated connected paved area of Evergem according to the DIVA dataset

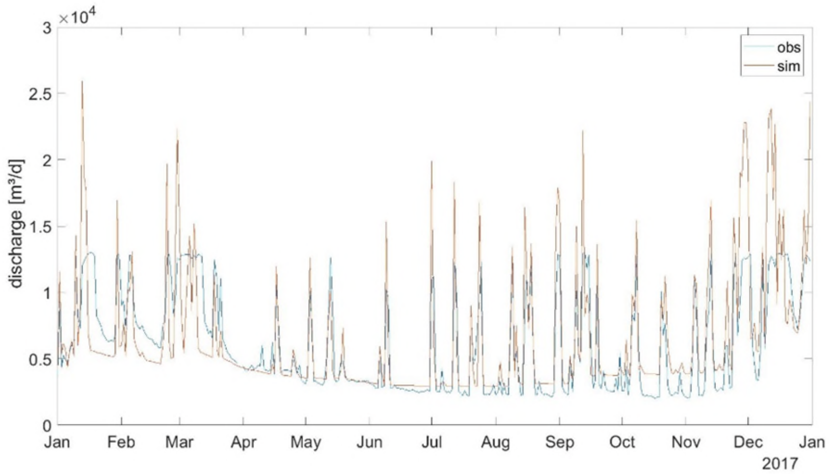


Figure 26: Daily discharge [m³/d] at WWTP Evergem in 2017. The blue line represents the observations, from the DIVA dataset and the orange line represents the results from CM1b.

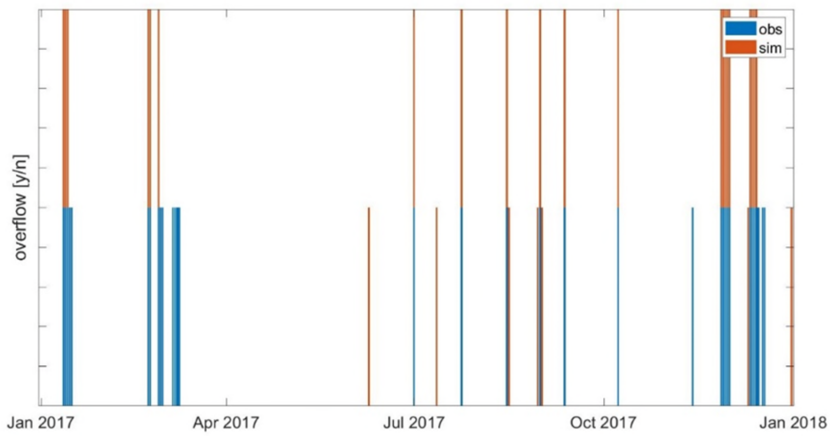


Figure 27: Representation of the moments of overflow using a categorical approach on a daily scale for WWTP Evergem in 2017. A day is categorized as one if during that day one or more overflows occurred, otherwise it is categorized as zero (so no bar visible). Both the observations (MOS dataset) and the simulations using CM1b are shown.

Results InfoWorks CS

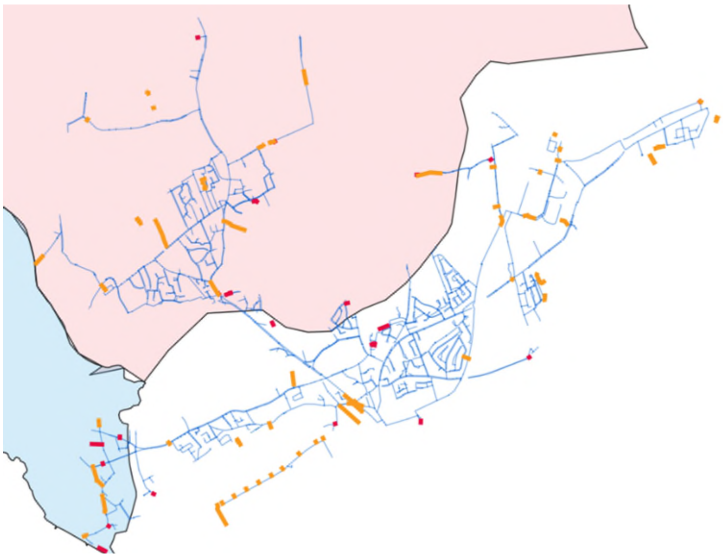


Figure 28: The blue line represents 'State A' from Infoworks CS. The orange rectangles are the outfalls which are not connected to the sewage system, indicating a permanent overflow. The red rectangles represent the locations of overflow. The faded red plane is catchment area AVV and the faded blue plane is the catchment area TLK.

As can be seen in Figure 28, 6 overflows are located in catchment area AVV and 4 in catchment area TLK.

Overflow AVV and TLK

For each catchment area, in this case AVV and TLK, a relation between the total overflow volume of the sewage system (over 15 min) and the overflow volume in each catchment area is derived based on the results of InfoWorks CS from the 9 test events (see Figure 29). It can be seen that for this station, the relations are not perfect (e.g. there is a lot of scattering at the lower values for AVV and TLK) but acceptable.

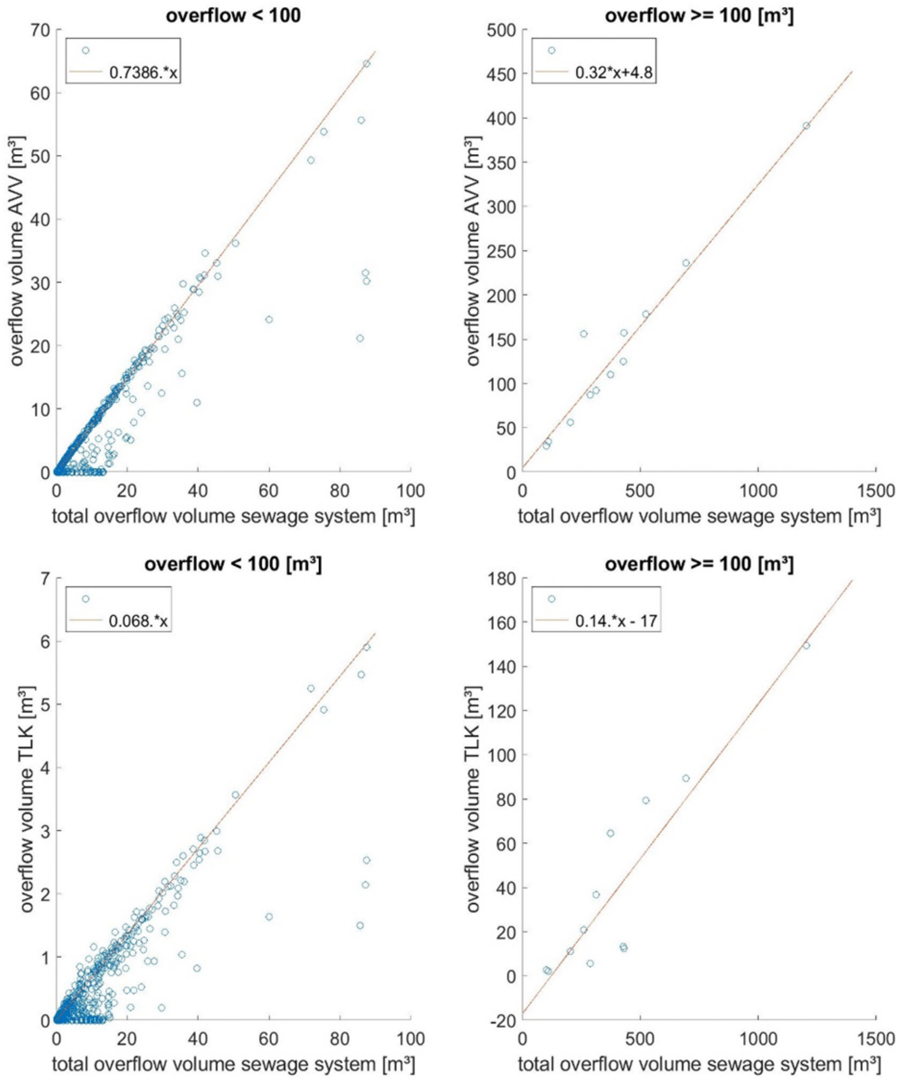


Figure 29: Linear relation between the total overflow volume of WWTP Evergem and the overflow volume in AVV and TLK according to the results from the test events in InfoWorks CS. The Pearson correlation coefficient [r] for AVV is 0.92 and 0.97 for the left and right figure, respectively. For TLK, the Pearson correlation coefficient [r] is 0.89 and 0.92 for the left and right figure, respectively.

These relations were applied to the results of the total overflow volume obtained from InfoWorks CS. In both cases, the overflow volume is overestimated, the WBF is about 22 % for AVV and 18 % for TLK (see Figure 30).

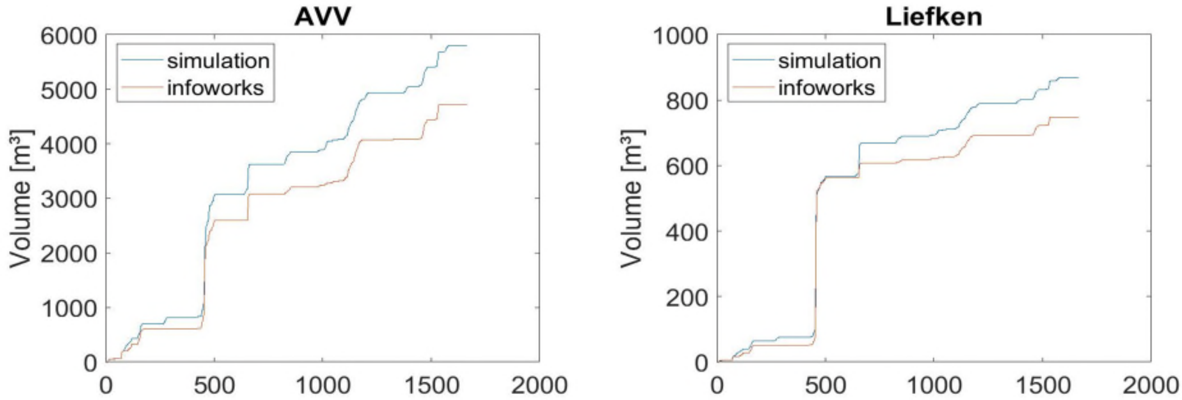


Figure 30: The cumulative results for the different test events after applying the relation between the total overflow volume and overflow volumes in each catchment area on the total volume obtained from Infoworks CS. For the overflows of WWTP Evergem in AVV and TLK.

InfoWorks CS vs CM1b vs Observations

For the several test events the results from the hydraulic model, CM1b and the observations from DIVA were compared. Both the results at the WWTP outlet and the total overflow volumes of the system are analysed (see Figure 31). Left on Figure 31, it can be noted that the daily effluent volume at the outlet of the WWTP is correctly estimated by CM1b and slightly overestimated by InfoWorks CS. On the right part of Figure 31, it can be noticed that CM1b has higher values for the overflow volume compared to InfoWorks CS, especially for more intense rainfall events. According to Figure 31, there is a definite difference between the overflow volume obtained through CM1b and InfoWorks CM. It seems that more water enters the system at CM1b compared to InfoWorks CS, this can be due to a difference in contributing area. InfoWorks CS has a contributing area of 1.56 km² for Evergem and in CM1b 2km² was retrieved after calibration. When a smaller area is used in the CM it seems that the overflow volume gives a better match, but when looking at the daily discharge at the outlet of the WWTP, it is clear that the current area of 2 km² shows better results. Also for Evergem a relation was sought between the rainfall intensity and the total overflow volume of the sewage system (see Figure 32). Also here it can be noticed that CM1b has higher values than InfoWorks CS, especially at higher rainfall intensities.

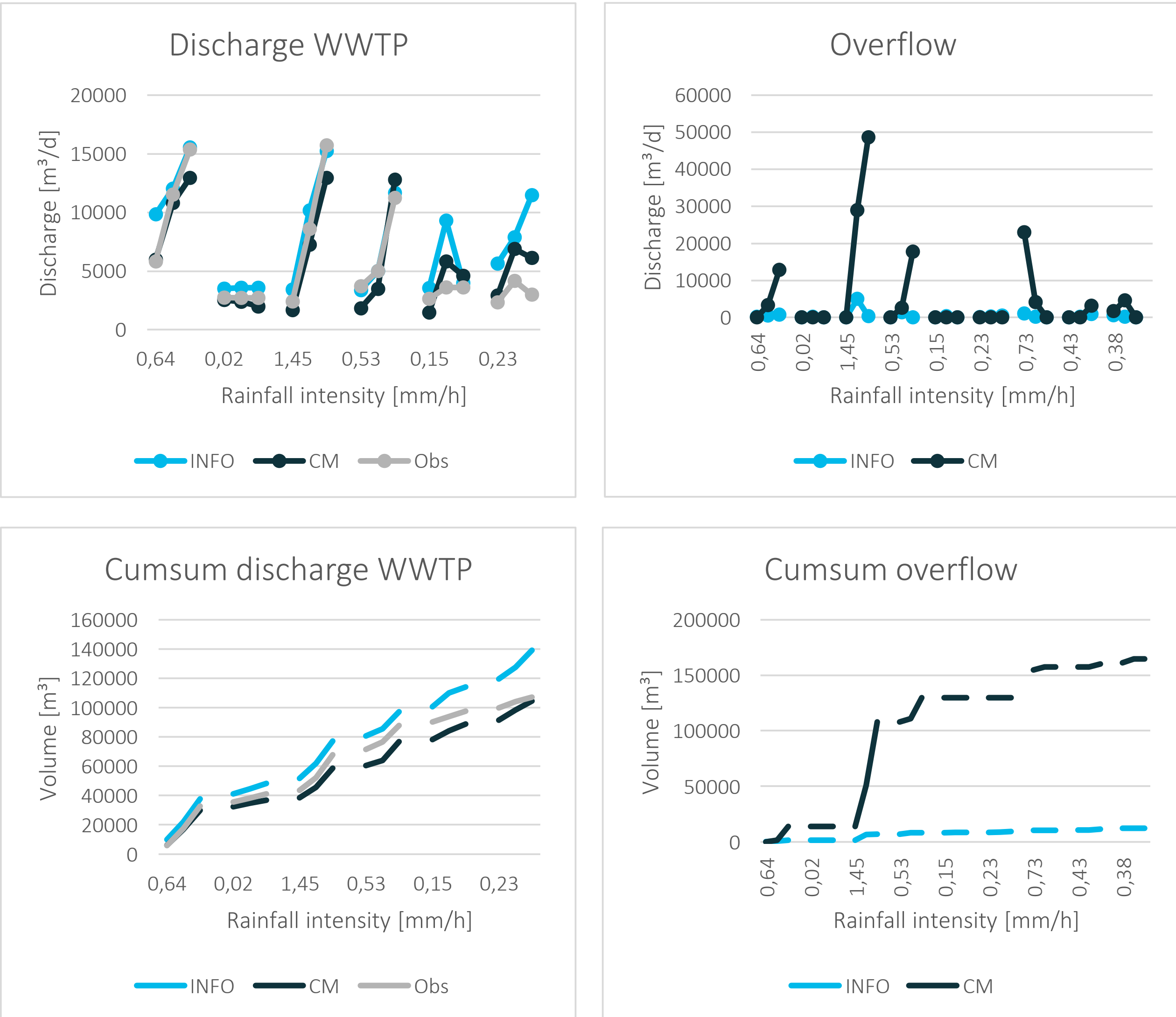


Figure 31: The results from the Infoworks CS model, the CM1b and the observations from the DIVA dataset are compared for the used test events. Left – the discharge at the outlet of the WWTP in Evergem is looked at, as well at the discharges for each event as the cumulative volumes. Right – the overflow volumes are examined. Here also both the time series, and the cumulative volumes are looked at. Since there are no observations of the overflow volumes only the results from the Infoworks CS model and CM1b are examined.

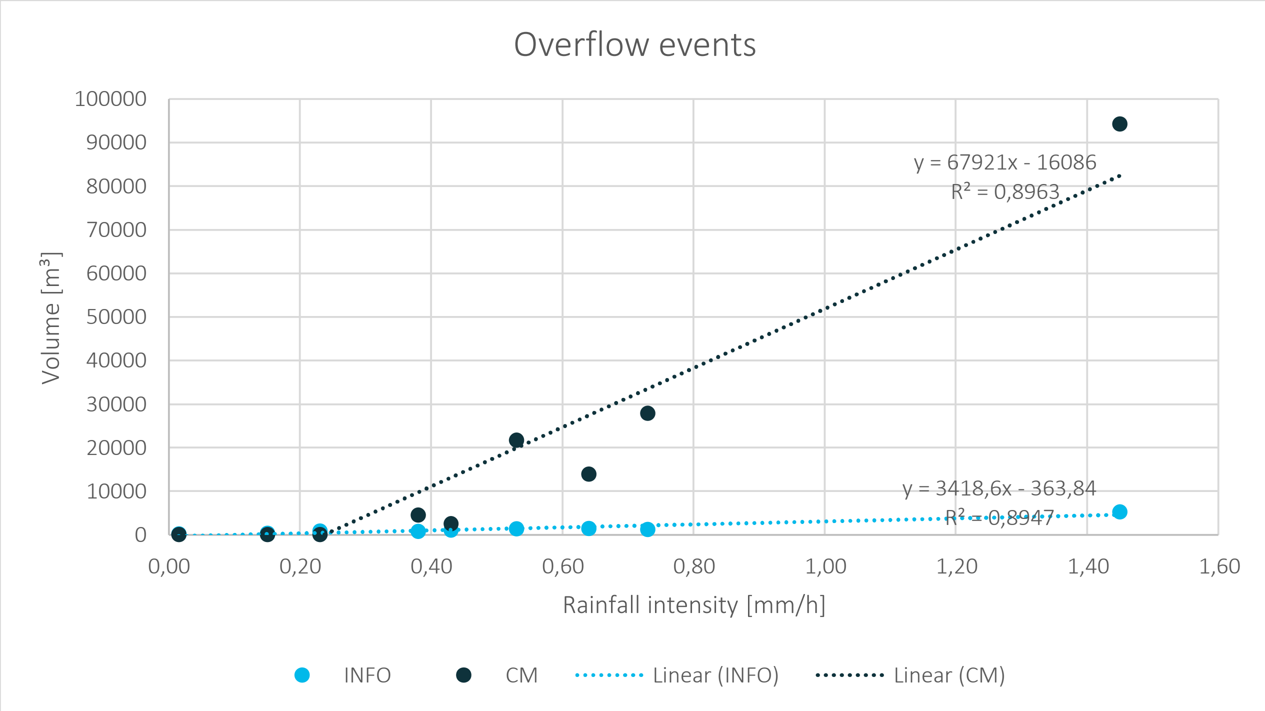


Figure 32: The different rainfall test events are ranked according to their intensity and the results from the Infoworks CS model and CM1b for WWTP Evergem are plotted to indicate the linear trend between the overflow volumes and the rainfall intensities.

Contribution to TLK & AVV

Table 5, Figure 33 and Figure 34 give more insights in the percentage contribution of the overflows from the sewage system of Evergem towards the river discharges at the outlets of catchment areas TLK and AVV. It can be noticed that the contribution of the permanent flows is low in AVV and non-existing in TLK. The percentage contribution, looking at overflow volumes, from Evergem to TLK rises to 48%, but is on average 0.8%. When looking at AVV the maximal contribution over the period 2006-2019 is larger than 100 and on average the contribution is 6.7%. A contribution larger than 100% isn't possible, probably this is due to the overestimation of overflow volumes at higher rainfall intensities compared to InfoWorks CS and the uncertainty of the previous made hydrological-hydraulic model (De Meester, 2021) . When the results of the hydrological-hydraulic model are compared to the results of the model PEGASE, it seems that the used model has lower values than PEGASE, especially at low river discharges (see Appendix I.I (Comparison with PEGASE)).

It can also be noticed that the inconsistencies happen during summer months, which often has lower water discharges. When looking at TLK, the maximum percentage contribution, over the period 2006-2019, is about 47%, while on average it is about 0.8%, which is rather low. Although a maximum contribution of 47% and an average contribution of 0.8% is rather low, some overflow events of WWTP Evergem in TLK might have a significant impact on the water quality at the intake of WPC Kluizen due to its proximity. The contribution of overflows in AVV is higher, up to 100% and on average 6%, in combination with its proximity to the inlet of WPC Kluizen these can be of high relevance.

Table 5: Results of the percentage contribution of WWTP Evergem towards the discharges at the outlet of the catchment areas AVV and TLK. Both the percentage contribution of the permanent, untreated flows, are given and the percentage contribution of the overflow volumes. For the years 2017 and over the period 2006-2019, the maximum percentage contribution and the average percentage contribution is given. The two values given by the average contribution of overflow indicate the average when all the time steps are included/ average when only the time steps where an overflow occur are included. For the average, the days where the percentage contribution exceed 100% the value is set to 100%. Last also the amount of days where the percentage contribution is higher than 100% is given, since these are not realistic values

AVV	2017	2006-2019

	Max	Average	Max	Average
permanent	2.50	0.60	5.07	0.45
overflow	134.44	0.99/12.96	327.70	0.59/6.67
total	136.62	1.59/13.56	136.62	1.04/7.12
> 100 %	2.00		7.00	
TLK	**2017**		**2006-2019**	
	Max	Average	Max	Average
permanent	0.00	0.00	0.00	0.00
overflow	9.82	0.07/0.87	47.74	0.07/0.80
total	9.82	0.07/0.87	47.74	0.07/0.80
> 100 %	0.00		0.00	

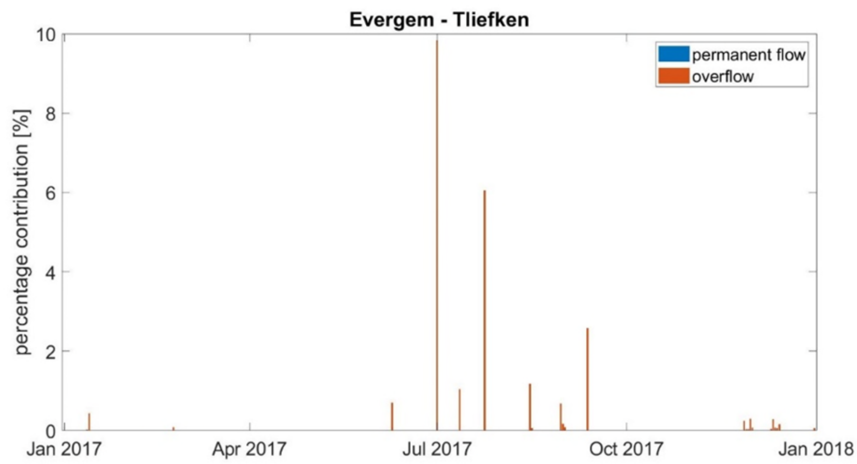


Figure 33: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Evergem to TLK for 2017

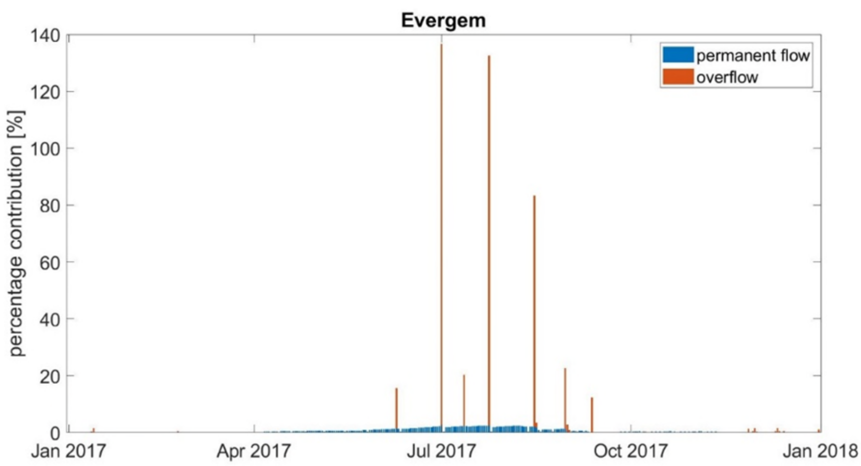


Figure 34: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Evergem to AVV for 2017

3.1.3 Tielt

Results CM

Figure 35 shows the daily discharge at the outlet of the WWTP. It can be noticed that during the summer months the simulations, underestimate the low values and the peaks compared to the observations. When looking at the frequency and moment of overflow (Figure 36), it can be seen that there is quite some resemblance between the simulations and the observations from MOS.

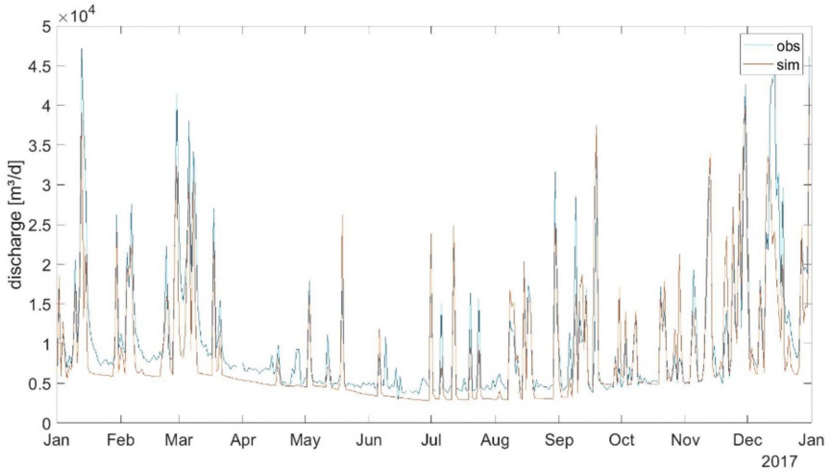


Figure 35: Daily discharge [m³/d] at WWTP Tielt in 2017. The blue line represents the observations, from the DIVA dataset and the orange line represents the results from CM1b.

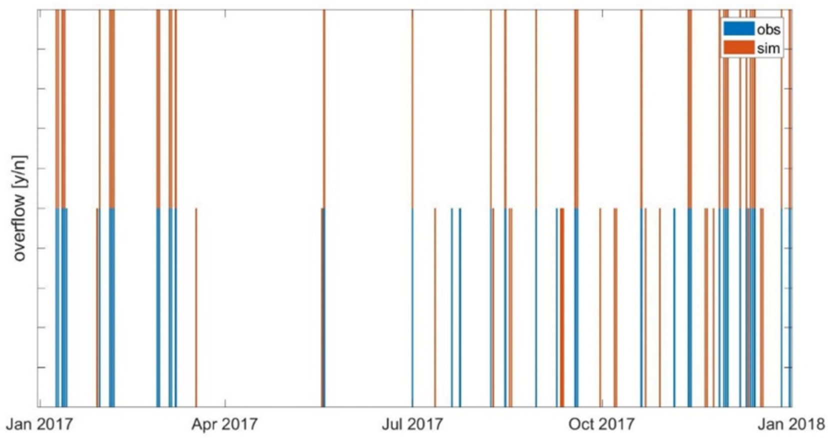


Figure 36: Representation of the moments of overflow using a categorical approach on a daily scale for WWTP Tielt in 2017. A day is categorized as one if during that day one or more overflows occurred, otherwise it is categorized as zero (so no bar visible). Both the observations (MOS dataset) and the simulations using CM1b are shown.

Results InfoWorks CS

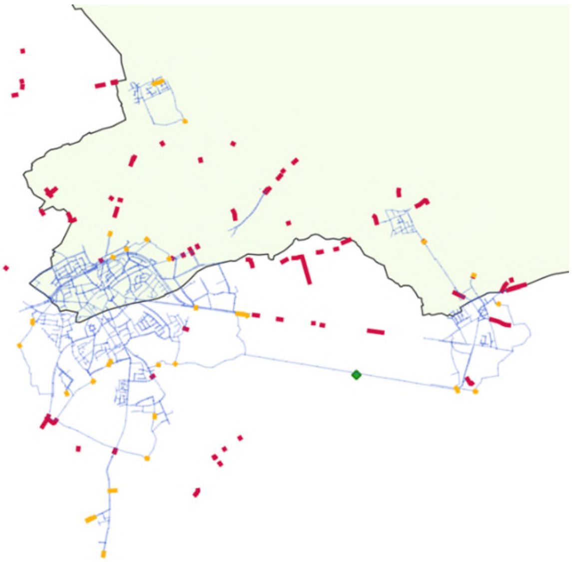


Figure 37: blue represent the pipes connected to the WWTP from State A, InfoWorks CS. Red rectangles are the permanent flows and the orange rectangles are the locations of overflow. The green rhombus is the location of the WWTP.

Figure 37 gives the locations of the permanent discharges and overflows [10]. It seems that there are quite some permanent flows located in the catchment area of Poekebeek.

Overflow Poekebeek

Tielt only has an influence on the catchment area of Poekebeek. Figure 38 gives the correlation between the total overflow volume of the sewage system and the overflow volume in Poekebeek. This relation is applied on the results from the hydraulic model and the cumulative volume can be seen on the right part of Figure 38. It looks like this relation represents the division well and can be used in further analysis.

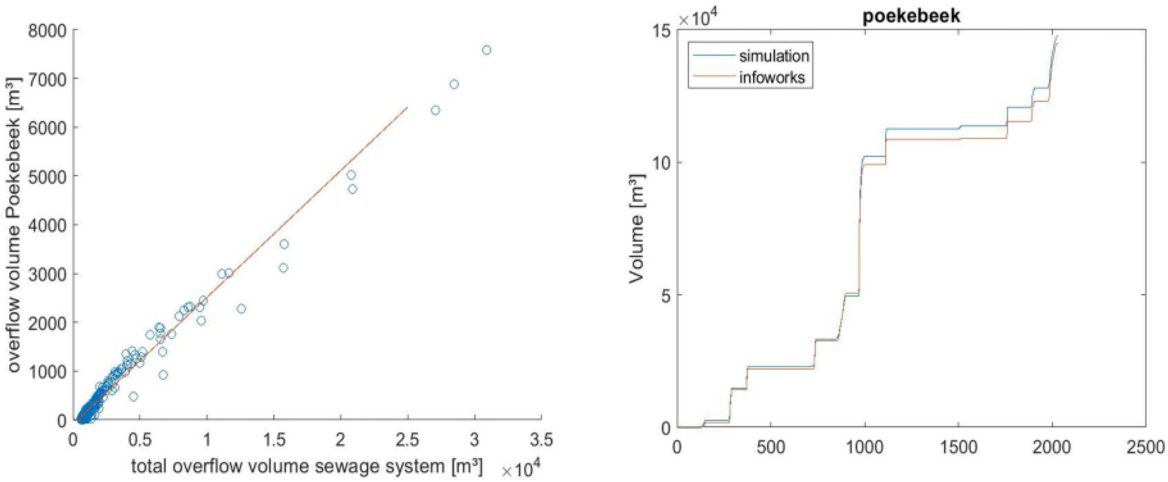


Figure 38: Left – linear relation between total overflow volume of WWTP Tielt and the overflow volume in Poekebeek according to the results from the test events in Infoworks CS, the pearson correlation coefficient is 0.9796. Right – The cumulative results for the different test events after applying the relation between the total overflow volume and overflow volumes in each catchment area on the total volume obtained from Infoworks CS. For the overflows of WWTP Tielt Poekebeek.

/

InfoWorks CS vs CM1b vs Observations

For the several test events the results from the hydraulic model, CM1b and the observations from DIVA were compared. Both the results at the WWTP outlet and the total overflow volumes of the system are analysed (seeFigure 39).

Looking at the left column of Figure 39, it can be noticed that both CM1b and Infoworks CS are able to estimate the discharge at the WWTP outlet. When looking at the overflow volumes (right part of Figure 39), InfoWorks CS has slightly higher values than CM1b. Figure 40 gives the relation between the rainfall intensity and the total overflow volume for results obtained from CM1b and the hydraulic model. There is quite some scatter, and also here InfoWorks CS has continuously higher overflow volumes.

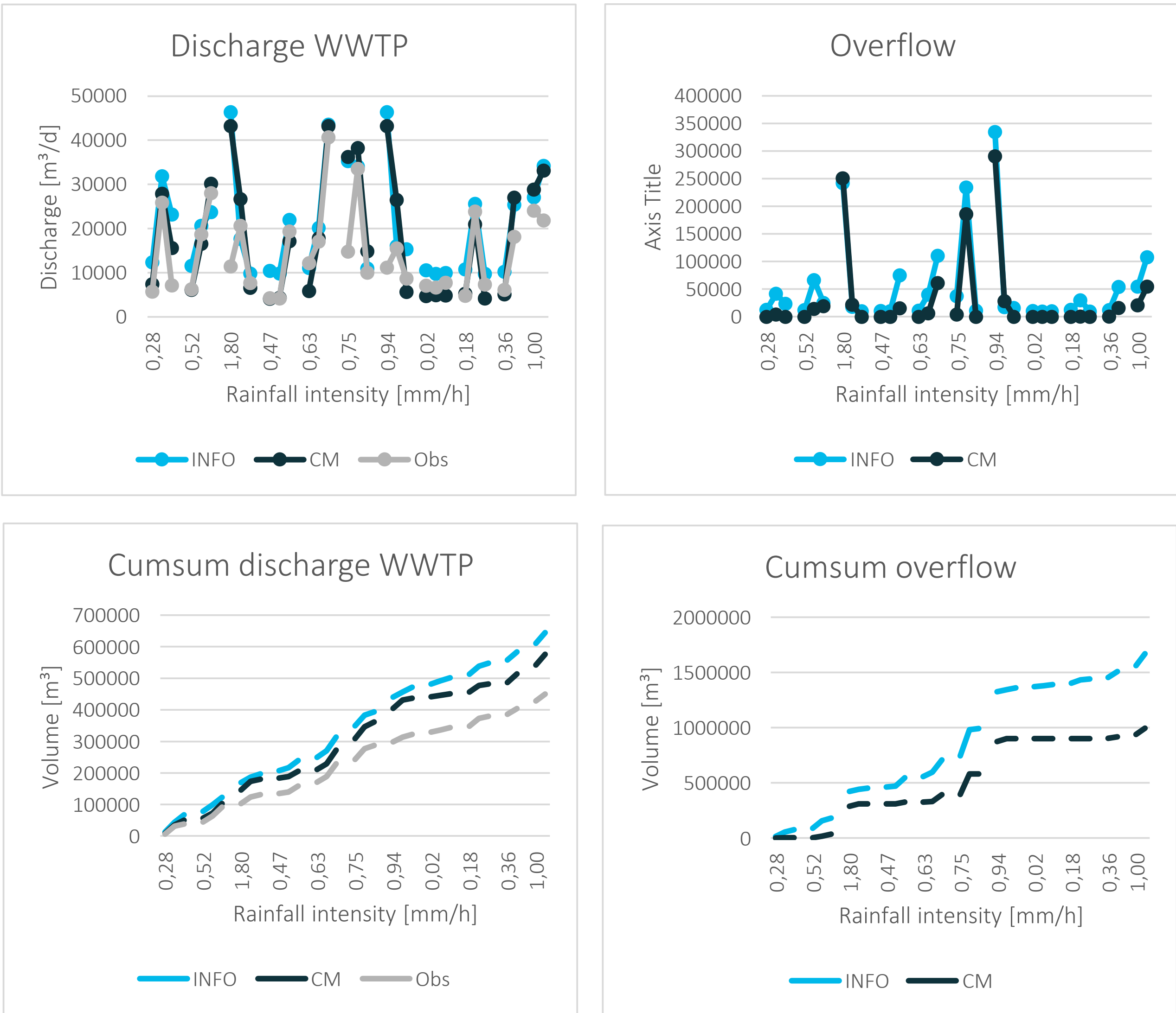


Figure 39: The results from the InfoWorks CS model, the CM1b and the observations from the DIVA dataset are compared for the used test events. Left – the discharge at the outlet of the WWTP in Tielt is looked at, as well at the discharges for each event as the cumulative volumes. Right – the overflow volumes are examined. Here also both the time series and the cumulative volumes are looked at. Since there are no observations of the overflow volumes only the results from the InfoWorks CS model and CM1b are examined.

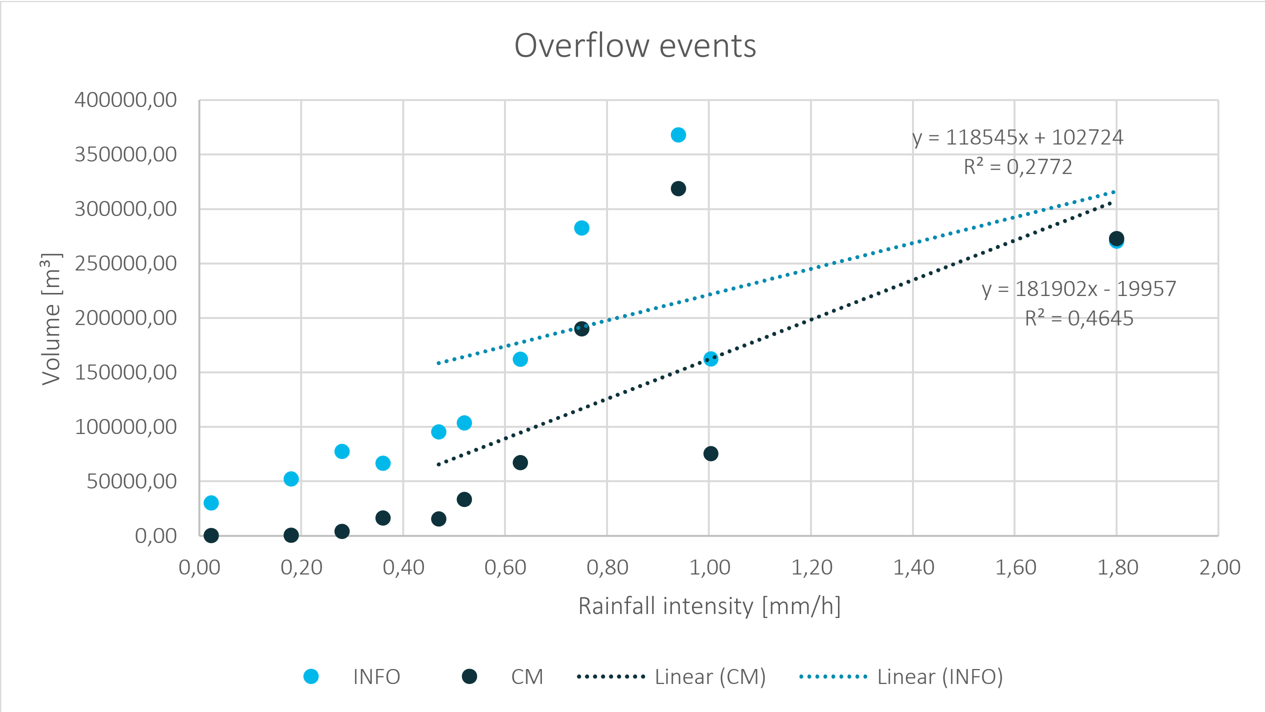


Figure 40: The different rainfall test events are ranked according to their intensity and the results from the InfoWorks CS model and CM1b for WWTP Tielt are plotted to indicate the linear trend between the overflow volumes and the rainfall intensities.

Contribution to Poekebeek

Table 6 and Figure 41 give more insights in the percentage contribution of the overflows from the sewage system of Tielt towards the river discharges at the outlets of catchment area Poekebeek. The average percentage contribution of overflow, over the period 2006-2019, is about 16.64%. Here again, at some moments the total contribution exceeds 100%. The average contribution of permanent discharges is rather low. A contribution of overflows up to 100% can be of relevance, but regarding the purpose of this study, Poekebeek is of less importance.

Table 6: Results of the percentage contribution of WWTP Tielt towards the discharges at the outlet of the catchment area Poekebeek. Both the percentage contribution of the permanent, untreated flows, are given and the percentage contribution of the overflow volumes. For the years 2017 and over the period 2006-2019, the maximum percentage contribution and the average percentage contribution is given. The two values given by the average contribution of overflow indicates the average when all the time steps are included/ average when only the time steps where an overflow occur are included. For the average, the days where the percentage contribution exceed 100% the value is set to 100%. Last also the amount of days where the percentage contribution is higher than 100% is given, since these are not realistic values

Poekebeek	**2017**		**2006-2019**	
	Max	Average	Max	Average
permanent	5.84	1.40	8.83	0.98
overflow	28.85	0.14/3.3	753.25	0.63/16.64
total	30.80	1.53/4.7	759.98	1.61/17.62
> 100 %	0		15	

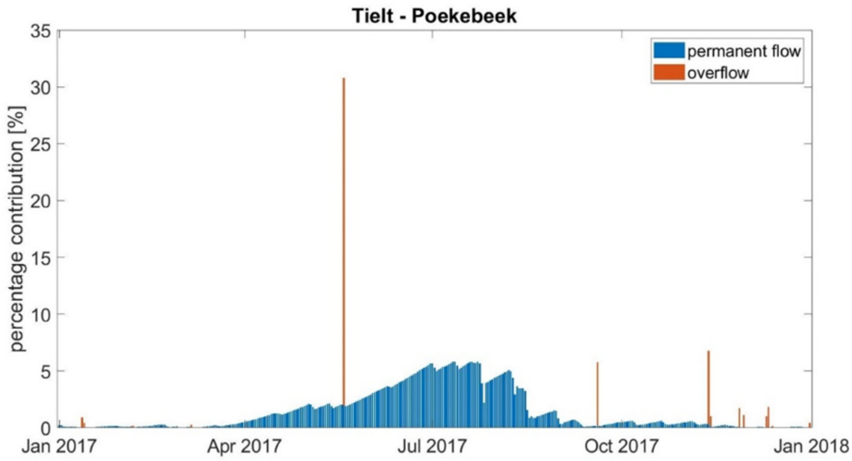


Figure 41: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Tielt to Poekebeek for 2017

3.1.4 Aalter

Results CM

Figure 42 shows the daily discharge at the outlet of the WWTP. It can be noticed that the simulations of the CM1b overestimate the low values in summer and underestimate the high values in winter. The frequency and moment of overflow coincide between the simulations of CM1b and the observations from MOS (see Figure 43).

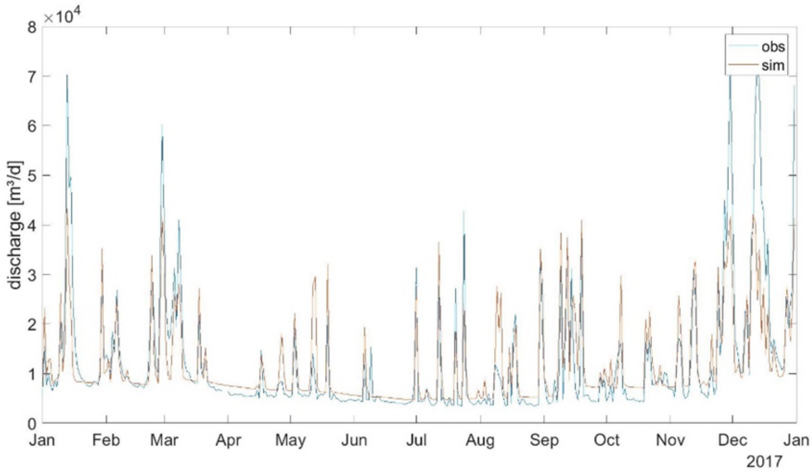


Figure 42: Daily discharge [m³/d] at WWTP Aalter in 2017. The blue line represents the observations, from the DIVA dataset and the orange line represents the results from CM1b.

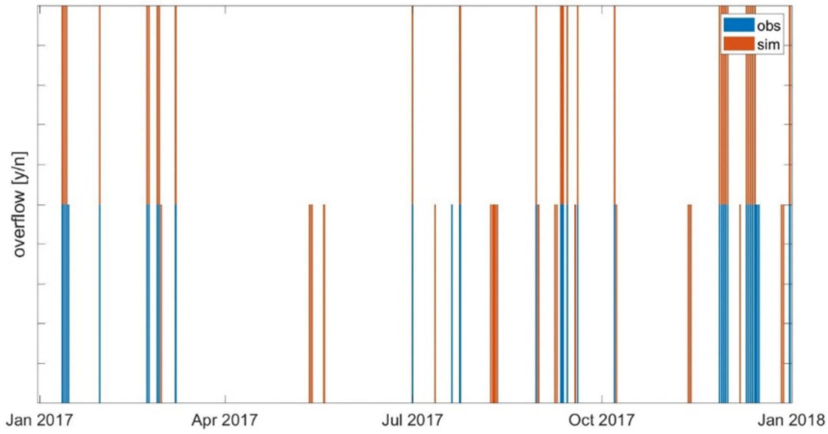


Figure 43: Representation of the moments of overflow using a categorical approach on a daily scale for WWTP Aalter in 2017. A day is categorized as one if during that day one or more overflows occurred, otherwise it is categorized as zero (so no bar visible). Both the observations (MOS dataset) and the simulations using CM1b are shown.

Results InfoWorks CS

Figure 44 shows the locations of permanent discharges and overflows [7 in Poekebeek]. It seems that there are quite some permanent flows located in the catchment area of Poekebeek.

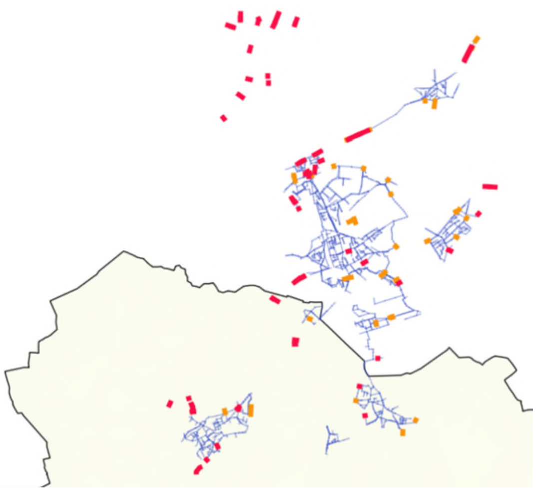


Figure 44: Blue represents the sewage network according to Infoworks CS. The red rectangles are the locations of permanent flows and the orange rectangles represent the locations of overflow

Overflow Poekebeek

Aalter only has an influence on the catchment area of Poekebeek. Figure 45 gives the correlation between the total overflow volume of the sewage system and the overflow volume in Poekebeek. It can be noticed that there is a lot of scattering at low values. This relation is applied on the results from the hydraulic model and the cumulative volume can be seen on the right part of Figure 45. It looks like this relation results in a small overestimation. One reason could be the selection of the correct outfall nodes in InfoWorks CS. Several outlets had a permanent discharge in combination with an overflow, as a result these can't be analysed, so probably the overflow volume of InfoWorks CS is a bit higher.

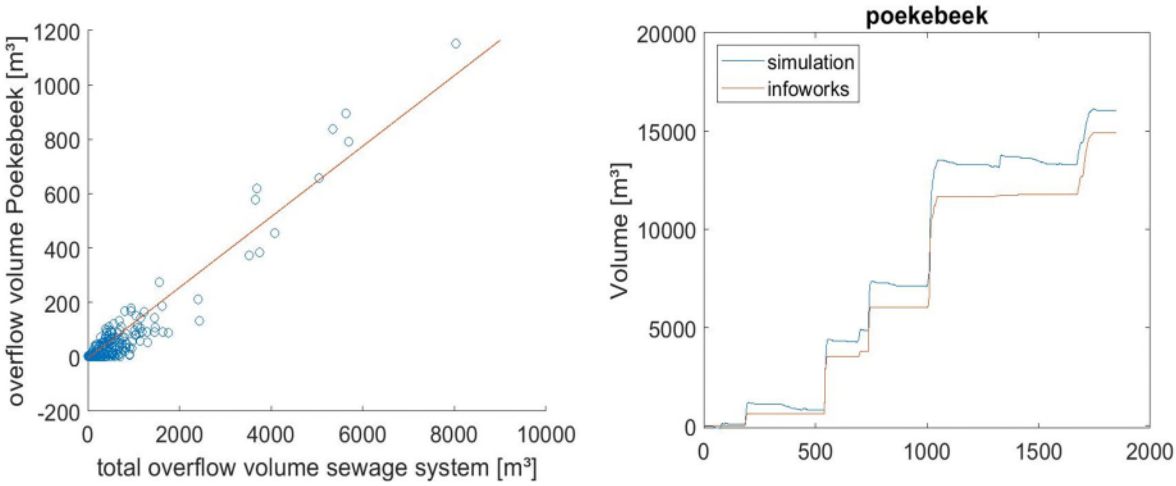


Figure 45:Left – linear relation between total overflow volume of WWTP Aalter and the overflow volume in Poekebeek according to the results from the test events in Infoworks CS. The Pearson correlation coefficient [r] is 0.95. Right – The cumulative results for the different test events after applying the relation between the total overflow volume and overflow volumes in each catchment area on the total volume obtained from Infoworks CS. For the overflows of WWTP Aalter Poekebeek.

InfoWorks CS vs CM1b vs Observations

For the several test events the results from the hydraulic model, CM1b and the observations from DIVA were compared. Both the results at the WWTP outlet and the total overflow volumes of the system are analysed (see Figure 46). Looking at the left column of Figure 46, it can be noticed that InfoWorks CS overestimate the daily discharge at the outlet of the WWTP. On the contrary, the results of CM1b are in line with the observations. When looking at the overflow volumes (right part of Figure 46), the results of InfoWorks CS and CM1b are similar.

Figure 47 gives the relation between the rainfall intensity and the total overflow volume for results obtained from CM1b and the hydraulic model. There is quite some scatter, but at higher rainfall intensities it seems that CM1b has higher overflow volumes than InfoWorks CS.

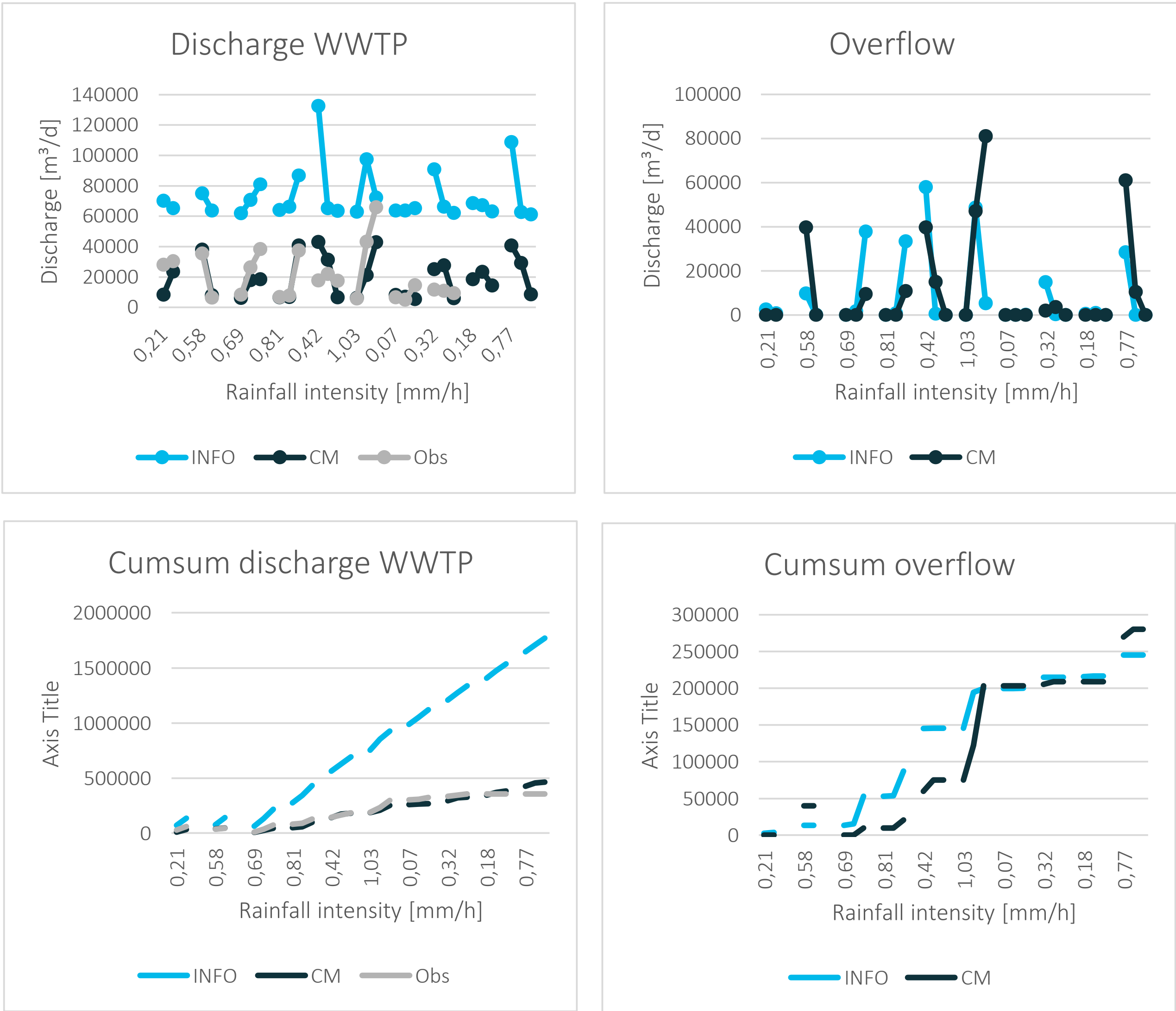


Figure 46: The results from the InfoWorks CS model, the CM1b and the observations from the DIVA dataset are compared for the used test events. Left – the discharge at the outlet of the WWTP in Aalter is looked at, as well at the discharges for each event as the cumulative volumes. Right – the overflow volumes are examined. Here also both the time series and the cumulative volumes are looked at. Since there are no observations of the overflow volumes only the results from the InfoWorks CS model and CM1b are examined.

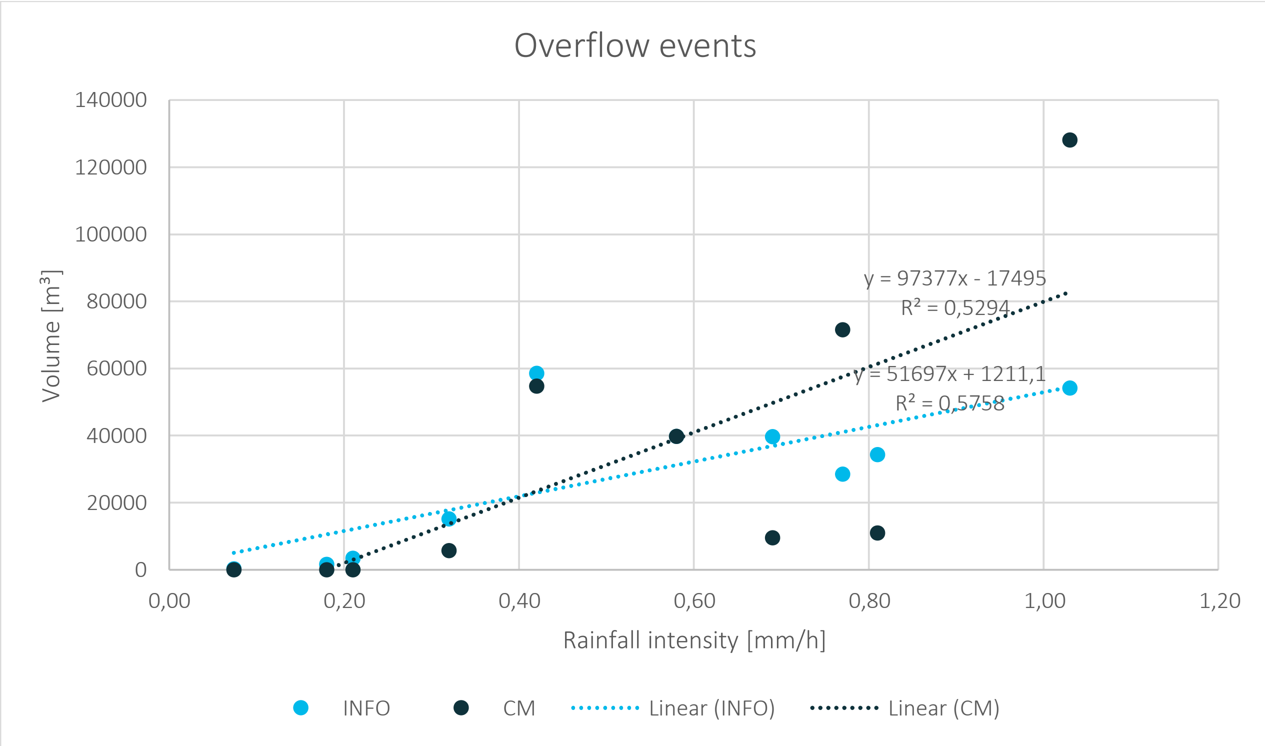


Figure 47: The different rainfall test events are ranked according to their intensity and the results from the Infoworks CS model and CM1b for WWTP Aalter are plotted to indicate the linear trend between the overflow volumes and the rainfall intensities.

Contribution to Poekebeek

Figure 48 and Table 7 give more insights in the percentage contribution of the overflows from the sewage system of Aalter towards the river discharges at the outlet of catchment area Poekebeek. The average percentage contribution of overflow, over the period 2006-2019, is about 6.5%. Here again, at some moments the total contribution exceeds 100%. The average contribution of permanent discharges is rather low. A contribution of overflows up to 100% can be of relevance, but regarding the purpose of this study, Poekebeek is of less importance.

Table 7: Results of the percentage contribution of WWTP Aalter towards the discharges at the outlet of the catchment area Poekebeek. Both as the percentage contribution of the permanent, untreated flows, are given and the percentage contribution of the overflow volumes. For the years 2017 and over the period 2006-2019, the maximum percentage contribution and the average percentage contribution is given. The two values given by the average contribution of overflow indicates the average when all the time steps are included/ average when only the time steps where an overflow occur are included. For the average, the days where the percentage contribution exceed 100% the value is set to 100%. Last also the amount of days where the percentage contribution is higher than 100% is given, since these are not realistic values

Poekebeek	**2017**		**2006-2019**	
	Max	Average	Max	Average
permanent	3.88	0.98	6.18	0.69
overflow	98.03	0.71/6.62	285.44	0.75/6.5
total	101.90	1.68/7.6	286.76	1.44/7.19
# > 100%	1		11	

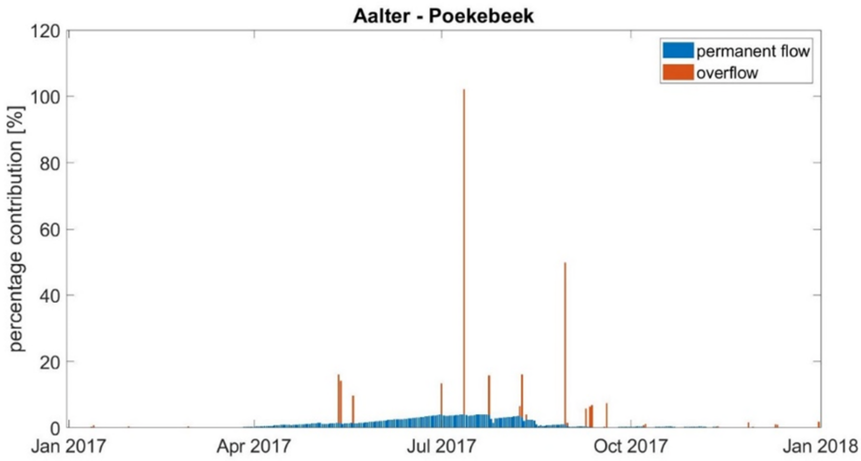


Figure 48: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Aalter to Poekebeek for 2017

3.1.5 Ghent

There is no InfoWorks CS model available for Ghent, therefore the division of the total overflow volumes over the different catchment areas can't be done in detail, assumptions have to be made based on the available datasets. To reduce the uncertainty, the decision was made to use the more physical based CM3 model. Since this model has a limited amount of parameters and it's parameters are physical interpretable, a subset of the sewage system can be selected to simulate. Only the pipes of the sewage system of Ghent that are located in the water abstraction area of WPC Kluizen were taken into account. A sensitivity analysis was done, based on all the available stations, to gain more insight in the parameters (see Appendix V (Sensitivity analysis CM3)).

When looking more into detail to Ghent, it seemed that the overflow frequency, validated against the MOS dataset on a daily scale, is about 20 times a year, implying that the sewage system of Ghent has less overflows than the other used stations. As a result, in further analysis the overflow frequency is set to 20 times a year, two overflows are considered independent if there are at least 2days in-between. The contributing area is obtained from the DIVA dataset and the recession constant is set to 2000 seconds.

The domestic wastewater flow was estimated using the amount of residents which are linked to the pipes. The parasitic water is estimated based on the relation with the groundwater (see Appendix III (Parasitic water flow)), a factor of 0.22 was applied to only include the PWFF in the selected sewage system. As a result the assumption is made that the parasitic water is equal at every pipe. Figure 49 gives the moments of overflow in 2010 for the CM3 and the MOS dataset. It can be seen that there are slightly more overflows according to the model than recorded by MOS.

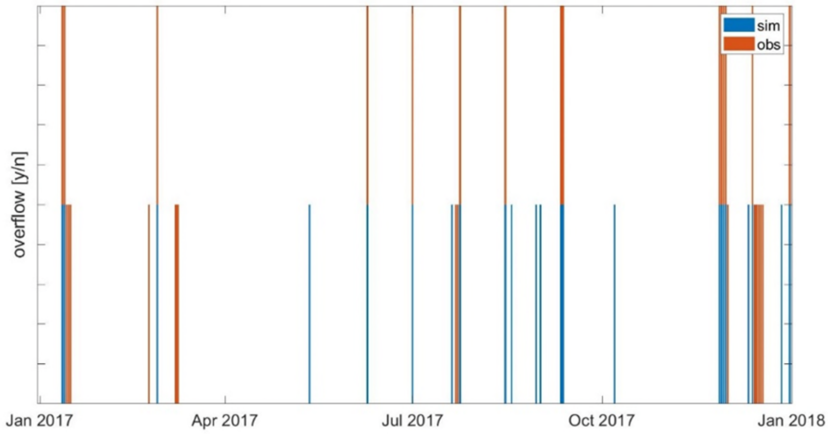


Figure 49: Representation of the moments of overflow using a categorical approach on a daily scale for WWTP Ghent in 2017. A day is categorized as one if during that day one or more overflows occurred, otherwise it is categorized as zero (so no bar visible). Both the observations (MOS dataset) and the simulations using CM1b are shown.

Results InfoWorks CS

Figure 50 shows the subset of the network which is located in the water abstraction area. Together with the estimated locations of the permanent flows (coloured dots) and the overflows (yellow dots). The location of the permanent flows and overflows are based on the AWIS dataset (more information see Appendix VII (InfoWorks CS vs AWIS – overflow)). The permanent overflows will be estimated using only the DWF, so the number of residents. Hereby only the people directly connected to these outlets will be taken into account, this is probably an underestimation. At the moment all the overflows of Figure 50 are taken into account. But probably some outlets should be ignored since it seems they flow into a channel. The assumption is made that the division of the total overflow volume of the sewage system over the different catchment areas can be done by taking into account the length of the connected pipes. Using this assumption the dataset can be split in % overflow for each zone, depending on the length of the pipes. The assumption is made that the pipes and outflows which are not located in the water abstraction area do not influence the water abstraction area.

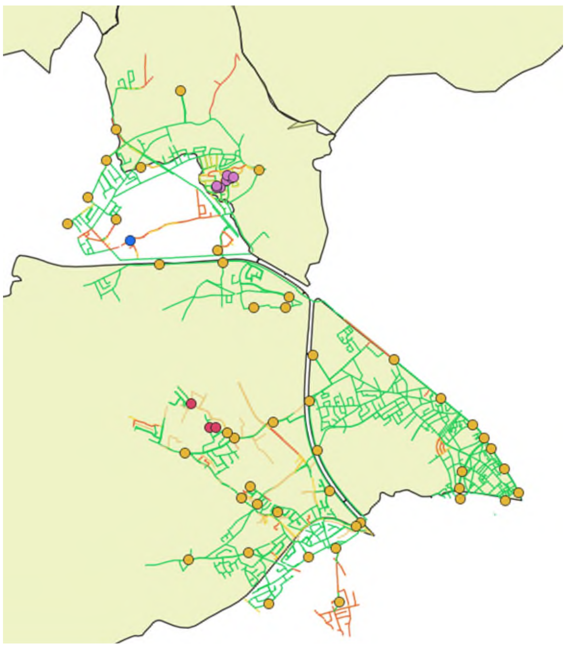


Figure 50: Part of the sewage system Gent located in the water abstraction area according to the AWIS dataset. Green is mixed pipes, orange DWF and yellow is WWF. the yellow dots are locations of overflow. the colored dots are (probably) permanent discharges which contain contaminated water.

Contribution to TLK and OKM

Table 8, Error! Reference source not found. and Figure 52 give more insights in the percentage contribution of the overflows from the sewage system of Ghent towards the river discharges at the outlets of catchment area OKM and TLK. It can be noticed that the permanent discharges are negligible, only the overflows have an important contribution. The average percentage contribution of overflow is 5.07% towards TLK, with peaks higher than 100%. While the average contribution of overflow towards AVV equal is to 15.6% with also peaks higher than 100%. A percentage contribution higher than 100% can't occur in reality but it should be kept in mind that both the estimation of the river discharge and the moment and the overflow volumes are estimations. When we compared the results of the river discharges from the previous made hydrological –hydraulic model with the results of PEGASE (see Appendix I.I (Comparison with PEGASE)), it could be concluded that for both areas the used hydrological-hydraulic model has lower Q10 values than PEGASE. Due to the close location of OKM and TLK towards the inlet of WPC Kluizen and an average contribution of 5% and 15%, with peaks up to 100%, Ghent can negatively impact the water quality at the inlet of WPC Kluizen.

Table 8: Results of the percentage contribution of WWTP Gent towards the discharges at the outlet of the catchment areas OKM and TLK. Both the percentage contribution of the permanent, untreated flows are given as the percentage contribution of the overflow volumes. For the years 2017 and over the period 2006-2019, the maximum percentage contribution and the average percentage contribution is given. The two values given by the average overflow indicates the average when all the time steps are included/ average when only the time steps where an overflow occur are included. or the average, the days where the percentage contribution exceed 100% the value is set to 100%. Last also the amount of days where the percentage contribution is higher than 100% is given, since these are not realistic values

TLK	**2017**		**2006-2019**	
	Max	Average	Max	Average
permanent	0.00	0.00	0.00	0.00
overflow	22.82	0.29/4.63	310.98	0.31/5.07
total	22.82	0.29/4.63	310.98	0.31/5.07
> 100 %	0.00		2.00	
OKM	**2017**		**2006-2019**	
	Max	Average	Max	Average
permanent	0.83	0.24	2.01	0.22
overflow	98.79	1.24/19.6	472.79	0.96/15.55
total	98.92	1.48/19.84	474.19	1.18/15.77
> 100 %	0.00		14.00	

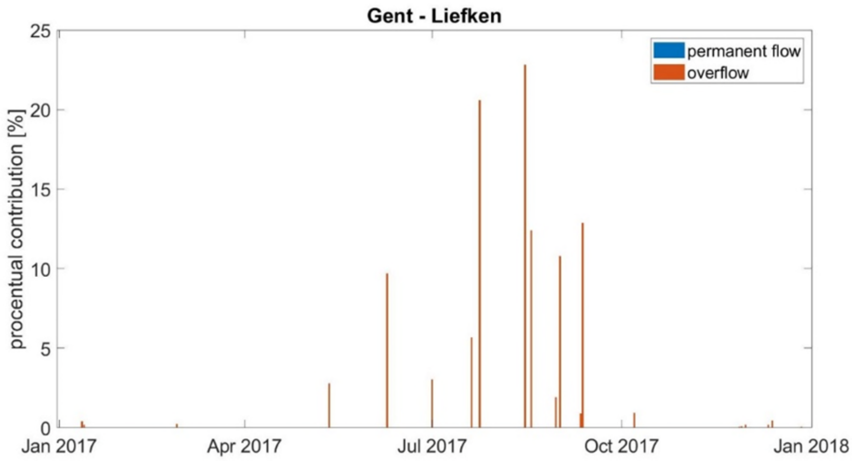


Figure 51: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Gent to TLK for 2017

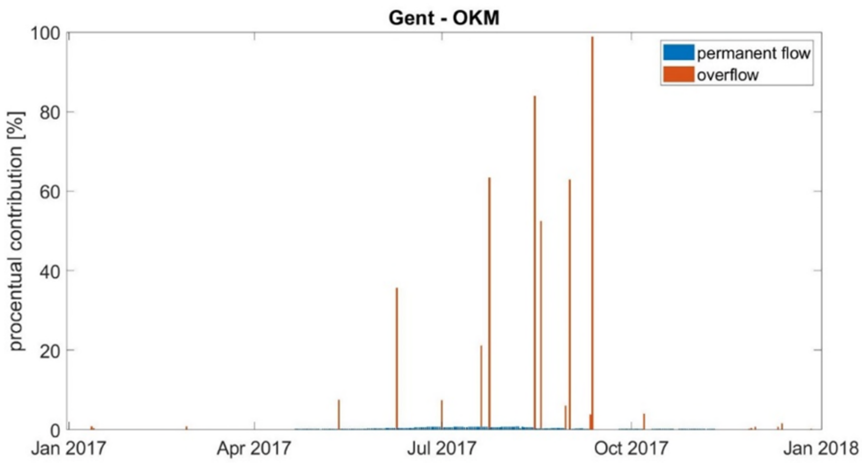


Figure 52: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Gent to OKM for 2017

3.2 Total contribution to each catchment area

In this paragraph the combined impact of the different sewage stations: Nevele, Tielt, Aalter, Evergem and Gent will be analysed on the different catchments areas: Poekebeek, OKM and TLK. AVV is not discussed in this paragraph since only Evergem has an influence on this catchment area, therefore the results can be found in paragraph 3.1.2 (Evergem).

3.2.1 Poekebeek

Three WWTPs have overflows and permanent discharges into the catchment area of Poekebeek: Nevele, Aalter and Tielt. The combination of their contribution can be found in Figure 53 and Table 9. The average contribution, over the period 2006-2019, of the three WWTPs together is about 28%, with a maximum higher than 100%. The largest contribution comes from the WWTP of Tielt. On average, there are 45 days in a year when an overflow occurs. Due to the quite high average contribution, and high maximum contribution, the overflow events can be of relevance regarding the water quality in Poekebeek. But when looking at the inlet of WPC Kluizen, it seems unlikely that this will be of importance. Since during the summer months Poekebeek flows entirely towards AKL. The contribution of the permanent discharges is rather low, on average 2%, whereby all WWTP are similar. On one year, an overflow occurs on an average of 45 days in the catchment area of Poekebeek.

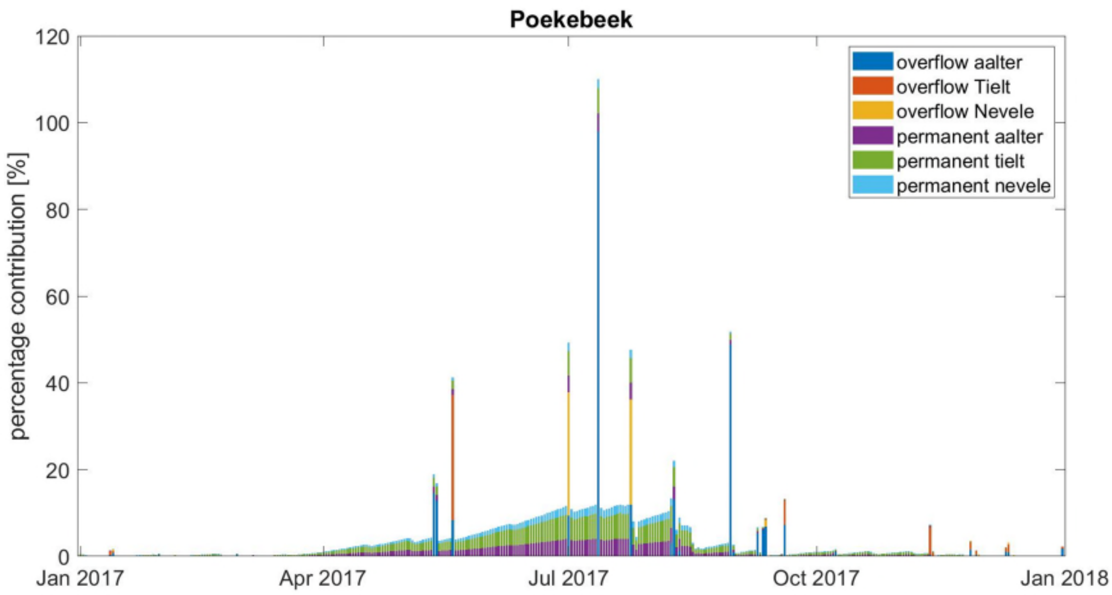


Figure 53: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Aalter, Tielt and Nevele to Poekebeek in 2017

Table 9: Results of the percentage contribution of WWTP Tielt, Aalter and Nevele towards the discharges at the outlet of the catchment area Poekebeek. Both the percentage contribution of the permanent, untreated flows are given and the percentage contribution of the overflow volumes. Over the period 2006-2019, the maximum percentage contribution and the average percentage contribution is given. The value given by the average overflow indicates the average when only the time steps where an overflow occur are included, hereby the values that exceed 100 are set to 100%. Last also the amount of days where the percentage contribution is higher than 100% is given, since these are not realistic values.

2006-2019	max	average		max	average
Aalter	285.45	6.50	**PERM**	6.18	0.69
Tielt	753.25	16.64	**PERM**	8.83	0.98
Nevele	54.03	5.38	**PERM**	3.07	0.34
Total	1092.73	28.52		18.08	2.01
# > 100%		28			

3.2.2 OKM

Two WWTPs have overflows and permanent discharges located in OKM: Nevele and Gent. The combination of their contribution can be found in Figure 53 and Table 10. The combination of their contribution is on average, over the period 2006-2019, about 16% in which Ghent is the largest contributor. Peaks up to minimum 100% contribution of overflow occur about 10-20 times a year. Due to the location of OKM relative to the inlet of WPC Kluizen, these overflows can play an important role regarding the water quality. On average, there are 57.2 days in a year when an overflow occurs. The permanent discharges are low for Ghent and Nevele, with a total average of 0.32%.

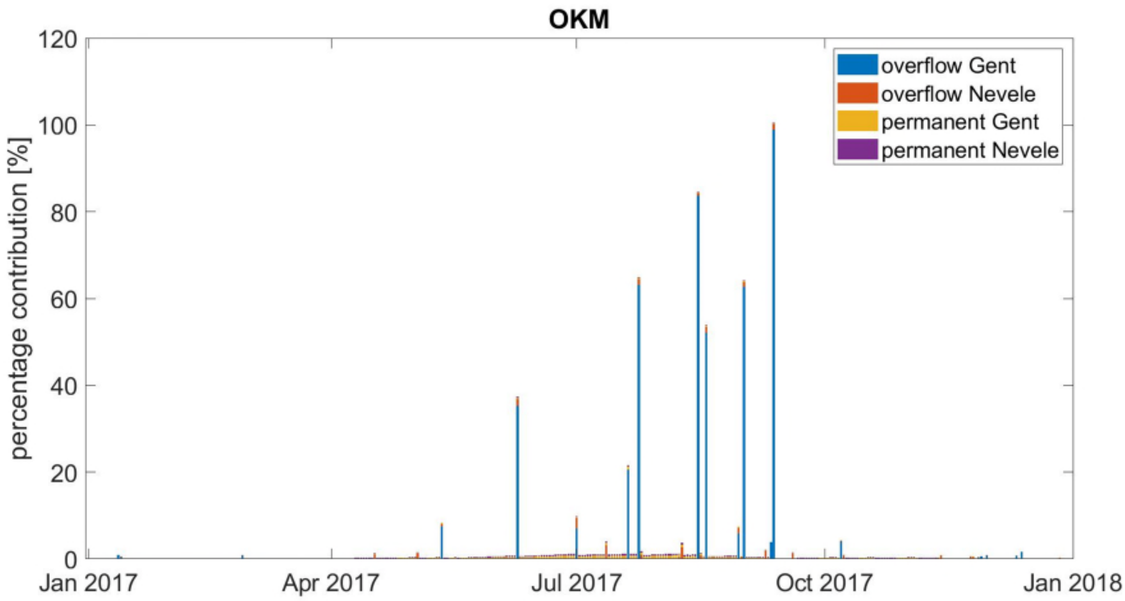


Figure 54: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Gent and Nevele to OKM in 2017

Table 10: Results of the percentage contribution of WWTP Gent and Nevele towards the discharges at the outlet of the catchment area OKM. Both the percentage contribution of the permanent, untreated flows are given and the percentage contribution of the overflow volumes. Over the period 2006-2019, the maximum percentage contribution and the average percentage contribution is given. The value given by the average overflow indicates the average when only the time steps where an overflow occur are included, hereby the values that exceed 100 are set to 100%. Last also the amount of days where the percentage contribution is higher than 100% is given, since these are not realistic values.

2006-2019	max	average		max	average
Gent	472.79	15.55	**PERM**	2.01	0.22
Nevele	8.78	0.47	**PERM**	0.95	0.10
Total	481.57	16.02	**PERM**	2.96	0.32
# > 100%		15			

3.2.3 TLK

Two WWTPs have overflows and permanent discharges located in TLK: Gent and Evergem. The combination of their contribution can be found see Figure 55 and Table 11. The combination of their contribution is on average, over the 2006-2019, about 6% in which Ghent is the largest contributor. Peaks up to minimum 100% contribution of overflow occur about 3 times a year. Due to the location of TLK relative to the inlet of WPC Kluizen, these overflows can play an important role regarding the water quality. On average, there are 38.21 days in a year when an overflow occurs. In TLK there is no influence of permanent discharges.

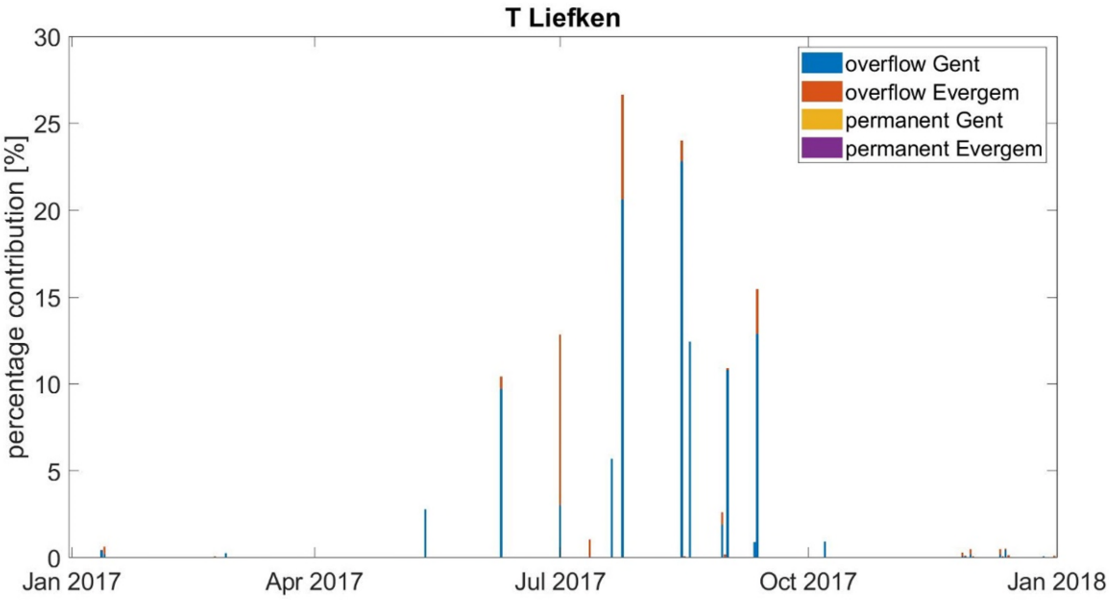


Figure 55: Percentage contribution [%] of the overflows and permanent untreated discharges from WWTP Gent and Evergem to TLK in 2017

Table 11: Results of the percentage contribution of WWTP Gent and Evergem towards the discharges at the outlet of the catchment area TLK. Both the percentage contribution of the permanent, untreated flows are given and the percentage contribution of the overflow volumes. Over the period 2006-2019, the maximum percentage contribution and the average percentage contribution is given. The value given by the average overflow indicates the average when only the time steps where an overflow occur are included, hereby the values that exceed 100 are set to 100%. Last also the amount of days where the percentage contribution is higher than 100% is given, since these are not realistic values.

2006-2019	max	average		max	average
Gent	310.98	5.07	**PERM**	0	0
Evergem	47.74	0.80	**PERM**	0	0
Total	358.72	5.87	**PERM**		
# > 100%		3			

4 Conclusion

Since the drinking water protection area of WPC Kluizen is located in a rural area, an urban module was created. This urban module calculates the percentage contribution of overflow and permanent discharges from each considered WWTP (Nevele, Evergem, Tielt, Aalter and Ghent) towards each catchment area (Poekebeek, OKM, TLK and AVV), based on precipitation and evaporation data. The urban module uses conceptual models (CM) to estimate the total overflow volumes of the sewage systems. In addition, it uses information from hydraulic models to distribute the total overflow volume among the different catchments.

When looking at the results of the urban module, the overflow volumes are often overestimated in comparison to the results from the hydraulic models available in InfoWorks CS. But since the total discharge at the outlet of the WWTP is well estimated, we assumed that the overflow volume is acceptable to give an indication of the contribution towards the river discharge. When the relation between rainfall intensity and overflow volumes is further analysed, it seems that in most cases the CM give steeper slopes than InfoWorks CS, which is in line with previous conclusions.

In this report, the worst case scenario regarding the quantitative contribution of the sewage system towards the river discharge is analysed since (1) the used CMs give an overestimation of the overflow volumes at high rainfall intensities, (2) the assumed value of 150 l/(capita*d) for permanent discharges is high and (3) the used river discharges are low in comparison to other models.

Based on our results, we can conclude that for the permanent discharges, where only domestic wastewater was taken into account, the average percentage contribution over the period 2005-2019 increases from 0 – 2% where TLK < OKM < AVV < Poekebeek. This already indicates the impact of the resource protection program that is in place for the drinking water protection area of the WPC with the catchments nearest to the inlet having the least amount of permanent discharges to the waterways and the catchment that is the furthest and least employed, the highest contribution.

When looking at the average overflow contribution, which includes WWF and DWF, this increases from 1.77-28% where AVV < TLK < OKM < Poekebeek, hereby WWTP Tielt and Ghent have the highest contribution. The yearly average number of days where an overflow occur range from 32.2 to 52.2 days, where AVV < TLK < Poekebeek < OKM. Combining the information regarding the contribution of overflow, permanent discharges and amount of days, one could conclude that Poekebeek is affected the most by the sewage systems. But when taking into account the scope of the study, namely the impact on the intake of WPC Kluizen, Poekebeek is of less relevance. Often the water will flow entirely towards AKL and even if it flows towards OKM, the water needs to travel a while before it enters WPC Kluizen. Therefore the catchment areas closely located to the intake of WPC Kluizen are more relevant, namely TLK, OKM and AVV. OKM has an average overflow contribution of 16% and the highest number of days where an overflow occur, therefore this region can have an important impact on the water quality at the intake of WPC Kluizen. For TLK and AVV, the average percentage contribution is rather low (<7%) and the number of days where an overflow occur in one year is below 40. But both WWTPs have peaks in overflow contribution reaching up to 100%. Due to the location of AVV and TLK, these peaks can be, temporal, of high relevance regarding the water quality at the inlet of WPC Kluizen. In general, the highest percentage contributions occur, logically, in the summer months. In general there is less intake by WPC Kluizen during the summer months, but when WPC Kluizen decides to have longer periods of intake in the summer months, the impact of overflows must be considered.

5 Recommendations

Since WWTP Evergem and Ertvelde are located upstream of the inlet at WPC Kluizen these weren't considered so far. But when WPC Kluizen abstract water from the drinking water protection area the direction can change, as a result these stations can be of high relevance regarding the water quality and should be added to the urban module.

In this report, the resulting time series have a time step of 15 minutes, but the calibration and the validation are done on a daily scale, due to available data. Therefore a sensitivity analysis can be useful to gain more insights in the potential extra uncertainty added due to the aggregation on a daily scale. Beside this, the sewage systems are considered in isolation. While they are in general influenced by external factors such as the water level heights. Therefore adding a river model can improve the estimations, especially regarding the overflow frequency.

The used Infoworks CS models were not updated to the current situation. Therefore an in-depth comparison with the AWIS dataset can improve the results. Since over the past years some permanent discharges have been removed and/or more pipes and overflows have been added. Next to this the, an exploration of potential external factors that can explain the difference in overflow frequency over different years could help gain insight in the results.

Regarding the estimation of the parasitic water flow based on the groundwater levels, WWTP Aalter and Evergem showed a less clear correlation than the other stations. Therefore an in-depth analysis for WWTP Aalter and Evergem regarding the estimation of the parasitic water flow can be an improvement.

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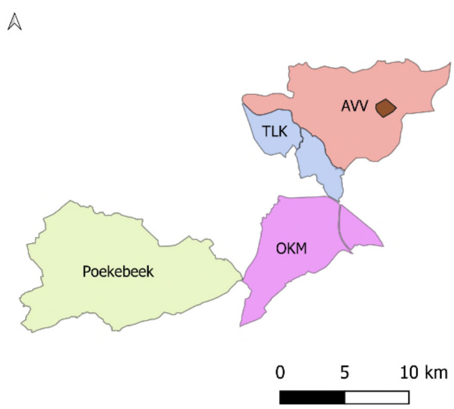
I Conceptual hydrological – hydraulic water balance model

We are interested in the contribution of the overflow towards the surface water discharge. During the previous part of this study (De Meester, 2021) a conceptual hydrological-hydraulic water balance was made. This model delivers the water uptake at WPC Kluizen, by estimating the river discharge for each of the catchment areas (see Figure 56). These results are used as reference to estimate the influence of overflows on the surface water.

Table 12 gives an overview of the parameters which are used to estimate the surface water discharges at the different uptake zones. (The results were obtained using version - Massabalans_V11_DB_orig_lokaleData , run = long; settings_simulation_localeData_NEW, Massabalans_V11_simulatie, results are in m³/s and are available every



5 minutes).

Figure 56: overview different catchment areas

Table 12: Overview of model results used from the hydrologic-hydraulic model to estimate the river discharges at the different catchment areas

Catchment area	Results from Model
OKM (Oude Kale-Merebeek)	Q_IN_OKM – results from GR4J model without extra input of Poekebeek
Poekebeek	Results directly from GR4J model
Liefken	Q_UIT_OKM * Q_OKM_naar_TLK + Q_RR_TLK
AVV (Avrijevaart)	Q_IN_AVV (this includes input from 'T Liefken)

I.I Comparison with PEGASE

A comparison between PEGASE (VMM, n.d.) and the conceptual hydrological – hydraulic water balance made in the previous study (De Meester, 2021) was done to gain more insight in the reliability of the results from the conceptual hydrological – hydraulic water balance, since these results will serve as reference level for the river discharges in each catchment zone.

PEGASE is a surface water quality model which is developed by Aquapôle (Deliège et al., 2009). The model consist of three parts: first the discharges are calculated based on the available discharge measurement stations at Waterinfo. The second and third part regard the water quality. Since here we are only interested in the water quantity we will focus on part 1. PEGASE has a minimal time step of one day and the network has a detailed discretization, where each node is located at a maximum distance of 200m (Deliège et al., 2009). In Table 13 the comparison is made between our hydrological-hydrodynamic model and the river discharge used in PEGASE. The quality of the river discharges in PEGASE are categorized as mediocre. This comparison can give us more insights in our model performance. The comparison is done using the average discharge of one year and the 10th percentile of that same year. The model comparison is done in a schematic way since the two models can differ in in-/excluding rivers (e.g. Poekebeek is partly flowing into the OKM at PEGASE, while this is not the case in our model – or at least not after 2012). The specific locations that are compared can be found further on.

When looking at the results for Poekebeek it seems that the average discharge is overestimated in our model and the 10th percentile is underestimated in our model. Looking at the results from OKM it seems that when Poekebeek is not taken into account the 10th percentile are of the same order but the average discharge is overestimated in our model. But when the actual value from PEGASE is used, so Poekebeek is allowed to flow partly into OKM, the average discharges are more coinciding between the two models and our model underestimates the lower discharges. When looking at the results for ‘T Liefken, it seems that both the average and the 10th percentile discharges from PEGASE are higher. When looking more into detail at the results from PEGASE it doesn’t seem that there is an external discharge added, the discharge seems to rise with 0.03 m^3/s on average over the catchment. The last comparison is done for AVV, here our model underestimates the results, both the average discharges and the 10th percentiles.

It can be concluded that there are some differences between the two models. When looking at the average discharge our hydrological-hydrodynamic conceptual model has higher values in OKM and Poekebeek, but lower values in AVV and ‘T Liefken. When looking at the 10^{th} percentiles our model has lower values in Poekebeek, ‘T Liefken and AVV, than compared to the values from PEGASE. These differences should be kept in mind during further analysis but with the side note that the comparison is done between two models. Each model is a simplification of reality and not many observations are available in this region to validate the models.

Table 13: PEGASE results for the different uptake zones

		PEGASE		GR4J	
		Q10 [m^3/s]	$Q_{average}$ [m^3/s]	Q10 [m^3/s]	$Q_{average}$ [m^3/s]
OKM [2017]	input Poekebeek	0.076	0.44	0.00	0.00
	Outflow OKM (before pump)	0.11	0.63	0.03	0.54
	Only OKM	0.03	0.18	0.03	0.54
Poekebeek [2017]	outflow	0.08	0.44	0.03	1.13
T Liefken [2015]	zomergem + klein brakeleike + sleidingsvaardeken vs input duivelsputgemaal and GR4J	0.43	2.82	0.04	0.48
AVV [2015]	outfall Ertvelde	0.36	1.42		
	GR4J + TLK			0.03	0.90

II Test events

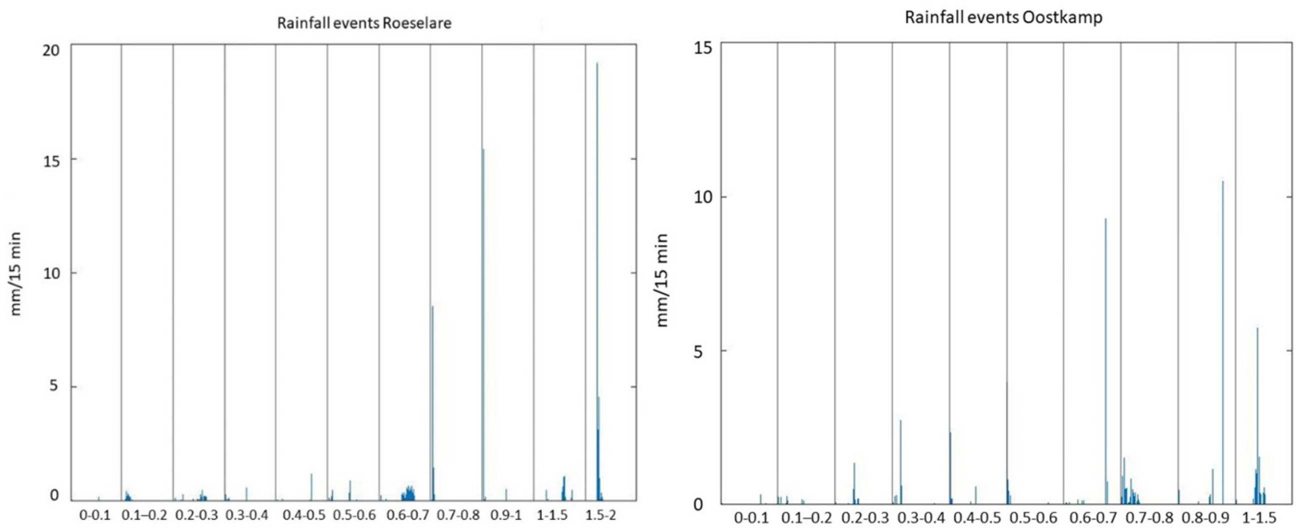


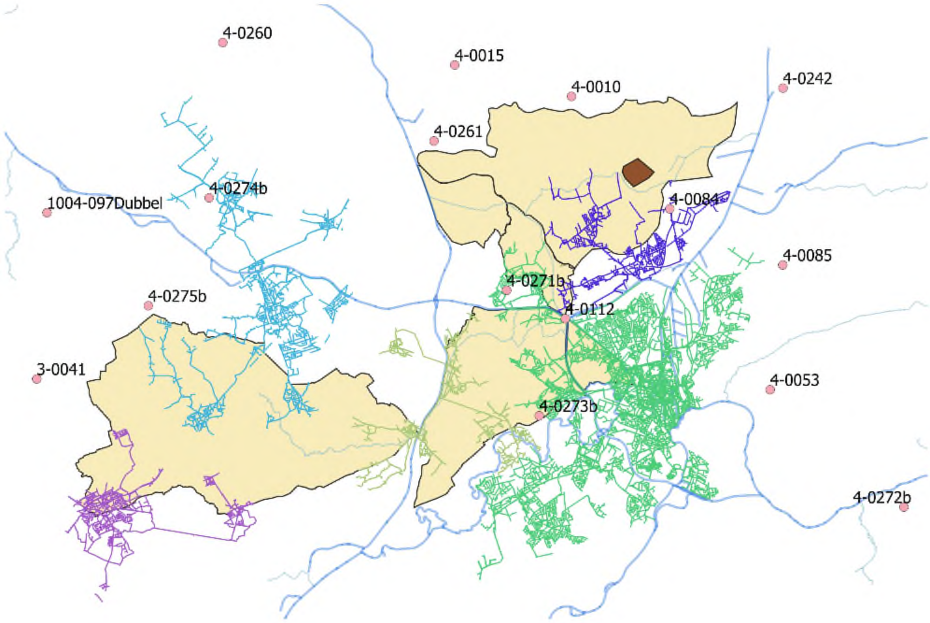
Figure 57: the used test events of Roeselare and Oostkamp

III Parasitic water flow

Since one of the sources for PWF is infiltration of groundwater through leakages (Dirckx et al., 2009) a linear relation is tried to be found between the closest located groundwater level observation and the PWF. Figure 58 gives an overview of the locations where groundwater level data is available. The groundwater level data is obtained through *Databank Ondergrond Vlaanderen* (DOV) and represents the simulated groundwater levels using SWAT models, which are calibrated against monthly measures (DOV, n.d.). The PWF was calculated using the DIVA dataset from Aquafin, since after 2017 data of the PWF isn't available anymore. When calculating the PWF, sometimes negative values were obtained; these were set to zeros since this is in reality not possible. These negative values occur when the domestic wastewater values are higher than the DWF.

Table 14 gives for each WWTP station the used equation to calculate the PWF and the used groundwater level data station. Column WBD [2017] gives the water balance discrepancies between the observations and the simulations of PWF for the validation period 2017. In some stations e.g. Nevele and Ghent these are good but in other stations such as Aalter and Evergem the simulations overestimate the observations in 2017. Figure 59 gives the time series of the groundwater levels and PWF for each station. It can be noticed that in general the trends for the different stations is as expected. Higher groundwater levels result in higher flow of PWF. This trend is less pronounced at Evergem. Next to this, it seems that the PWF values of Aalter decrease over time, this can explain the high WBD value for 2017. Figure 60 gives the correlation between the available groundwater data and the PWF for each

WWTP station; all stations show the expected trend of a positive correlation between PWF and groundwater level. But it is noticeable that for Evergem, the correlation is not good and that there is quite some scattering at Aalter.



Since the PWF depends on the amount of leakages, which can change over time (some will be formed other will be repaired), and the groundwater levels, which can differ locally, the estimation of the PWF should be seen as coarse.

Figure 58: Overview available groundwater data stations

Table 14: For each WWTP station the used groundwater level station is shown, and the applied linear equation to calculate PWF [m³/d] from the groundwater level (GW, [cm-ss]). Beside this, also the Water Balance Discrepancies (WBD, (observations – simulations)) value of PWF for the validation period 2017 is given. As a result represents a negative WBD in an overestimation of the simulations and a positive value in an underestimation of the simulations.

Name	Groundwater	Equation	WBD [%] [2017]
Nevele	x4_0273b	PWF = exp(-9.4*10^(-5).*gw.^2+7.3);	-15.09
Tielt	x3_0041	PWF = exp(-0.00011.*gw.^2 + 8.3);	26.32
Aalter	x4_0274b	PWF = 40.*gw + 7.7*10^3;	-69.02
Gent	x4_0273b	PWF = 1.3*10^2 .* gw + 3.4.*10^4;	1.42
Evergem	x4_0084	PWF = exp(-9.*10^(-5).*gw.^2 + 9.1);	-51.14

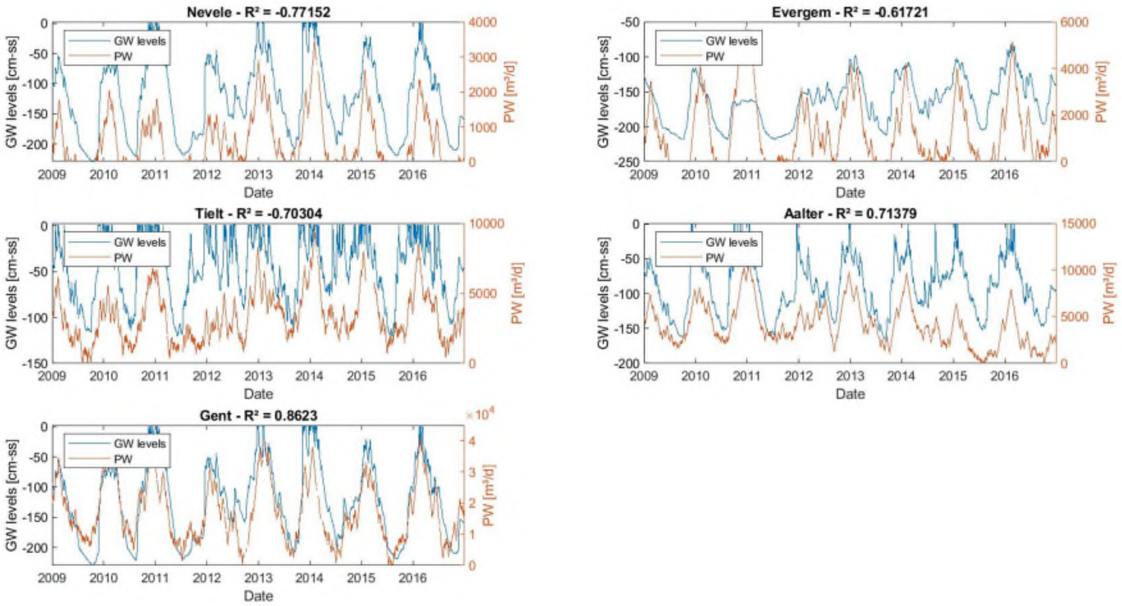


Figure 59: Time series over period 2009-2016 of the groundwater levels and parasitic water (calculated based on the DIVA dataset [DWA – H])

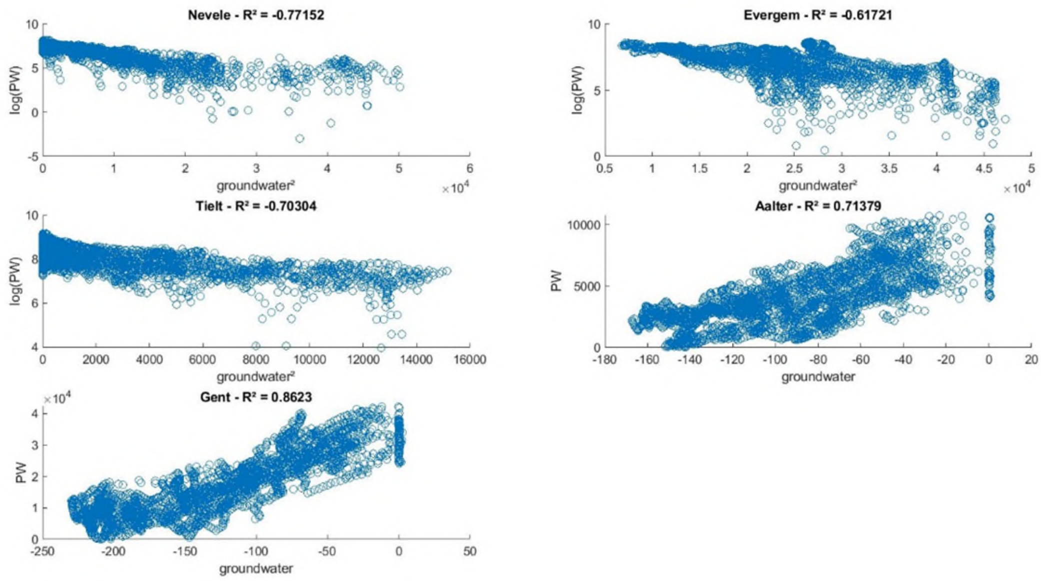


Figure 60: Correlation between the used measured groundwater levels and calculated PWF for each WWTP station

IV Estimation contributing area

To get insight in the rainfall runoff the contributing area should be estimated. Several datasets are available which can give an indication of the contributing area: area included in InfoWorks CS, the DIVA dataset from Aquafin, the zoning dataset from VMM (VMM, n.d.) the AWIS shape file – more specifically 'riolering aanwezig' and applying a buffer zone around the 'streng' dataset from AWIS. To get better insight in the differences between the datasets and to estimate which dataset is more reliable, these are compared in this paragraph and a sensitivity analyses was done in Appendix V (Sensitivity analysis CM3). When these datasets are compared (see Figure 61), it can be noticed that they deliver different areas. Therefore each source is discussed in detail below.

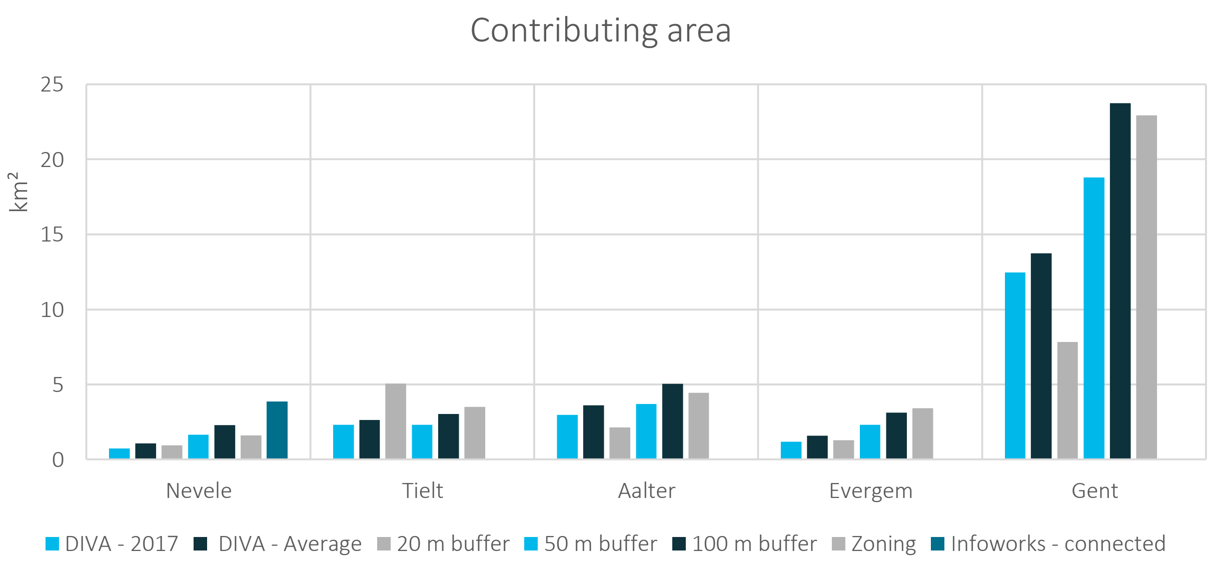


Figure 61: Contributing area for each WWTP according to different sources.

IV.I VMM/DIVA dataset

The water abstraction area in the DIVA dataset is estimated based on the rainfall runoff. First the rainfall runoff is calculated, probably based on a sub flow filtering of the incoming discharges. In combination with the closest rainfall measurement stations the connected area is estimated by dividing the precipitation volume of the runoff by the observed precipitation volume multiplied by a runoff coefficient of 0.8. As a result the surface storage and the overflow volumes are not taken into account. Since the results depend on the rainfall variability and the applied filter method, they will differ for each year (see Figure 62).

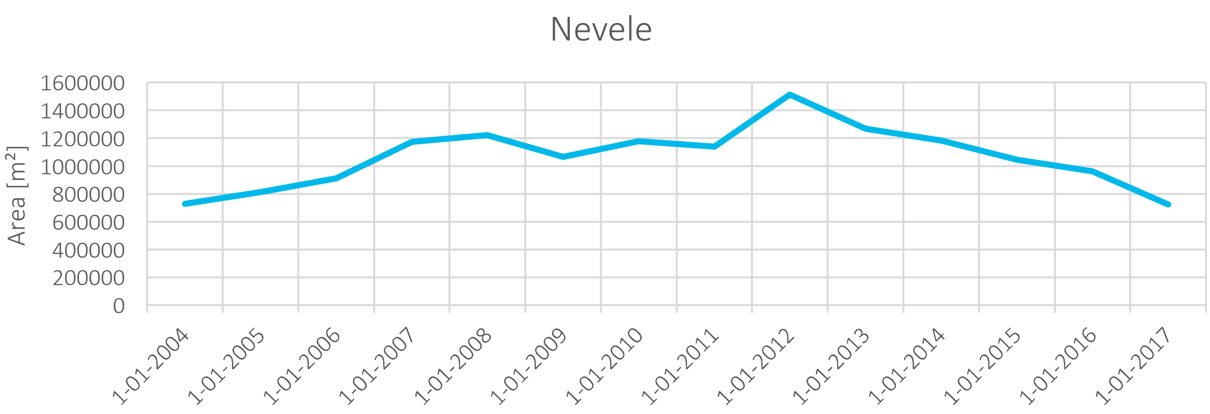


Figure 62: Contributing area for Nevele according to the DIVA dataset

IV.II Zoning database VMM + soil coverage map (BBK - *bodembedekkingskaart*)

From Geoloket a database of the zoning can be downloaded (VMM, n.d.). Here there are several categories: central area – this area is connected to a WWTP and pipes are present. Collective optimized outside area –recently pipes are added and these are connected to the WWTP. Collective outside area to optimize - pipes are planned, or are present but not yet connected. And individual optimizing outside area - no pipes are present, the wastewater has to cleaned using a IBA (individual waste water treatment plant). The assumption is made that the central area and the collective optimize outside area is connected and that the impermeable surfaces act as contributing area. As a result this GIS file can be combined with the BBK layer (source: BBK - *bodembedekkingskaart*, Geopunt) to obtain an estimation of the contributing area. From the BBK layer, only building and streets are taken into account. The other impermeable surfaces are not taken into account because otherwise non connected private impermeable surfaces such as terraces, parking spots etc. are included.

IV.III Buffering zone AWIS + soil coverage map (BBK)

A last method to obtain an estimation of the contributing area is to use the AWIS ‘streng’ dataset with a buffer in combination with the BBK layer to get an estimation of the contributing area. Here again only the buildings and streets are taken into account from the BBK dataset. A buffer of 20, 50 and 100 m is used. From the AWIS dataset only water from DWA, RWA, GEM and overflows are taken into account, as a result the rainwater which is flowing to a ditch is not considered.

V Sensitivity analysis CM3

To obtain better insight in the interpretation and usage of the parameters in CM3 a sensitivity analysis was done. First the area was analysed, as mentioned before there are several sources of contributing area, these are set opposite to each other to see what the effect is on the daily discharge. Hereby the period 2006-2017 is used for the calculation of the metrics, since 2005 is used as a spin up period. A recession constant K equal to 2.22 is used, which represents 2000 seconds and two overflows are seen as independent if there are at least 2 days in between the peaks, this value is chosen since it is in resemblance with the independent storms. Here also a surface storage of 2 mm and a runoff coefficient of 0.8 was taken along. Figure 63 shows the results for the sensitive analyses Regarding the contributing area. It can be concluded that DIVA shows the best results, looking at NSE values and the spreading of the results. The negative NSE values are due to Evergem, the course of the daily discharge can’t be well predicted by a CM for this case.

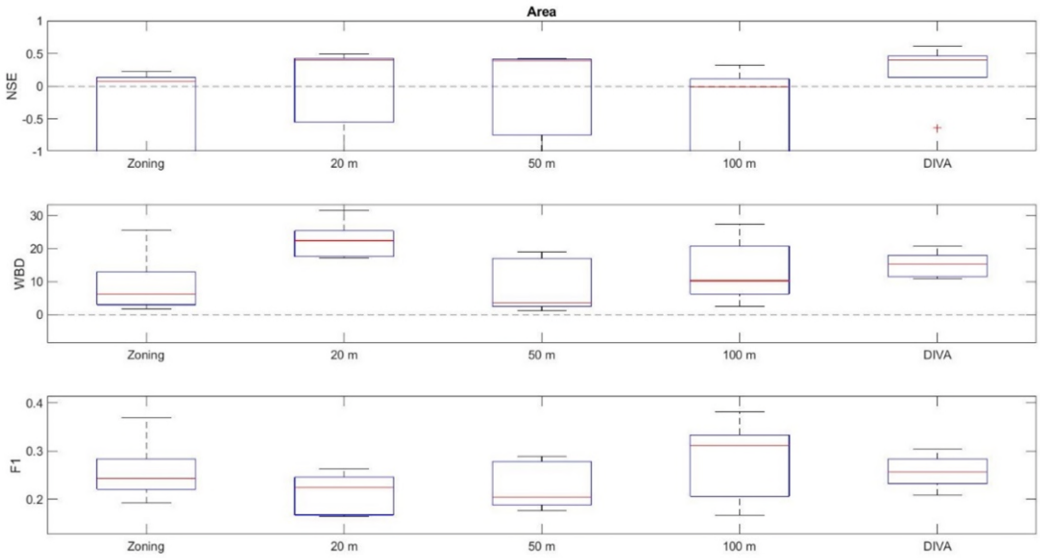


Figure 63: Sensitivity analysis of CM3 for the variable contributing area

Afterwards the sensitivity of the overflow frequency was analysed, using the area of DIVA, results can be found in Figure 64. It seems that an overflow frequency of 30/40 times each year delivers the best results. But when looking at Ghent individually, it seems that a frequency of 20/25 each year is a better approach. Otherwise the frequency of overflow is clearly overestimated (see Figure 65). This implies that Ghent has less overflows than the other stations.

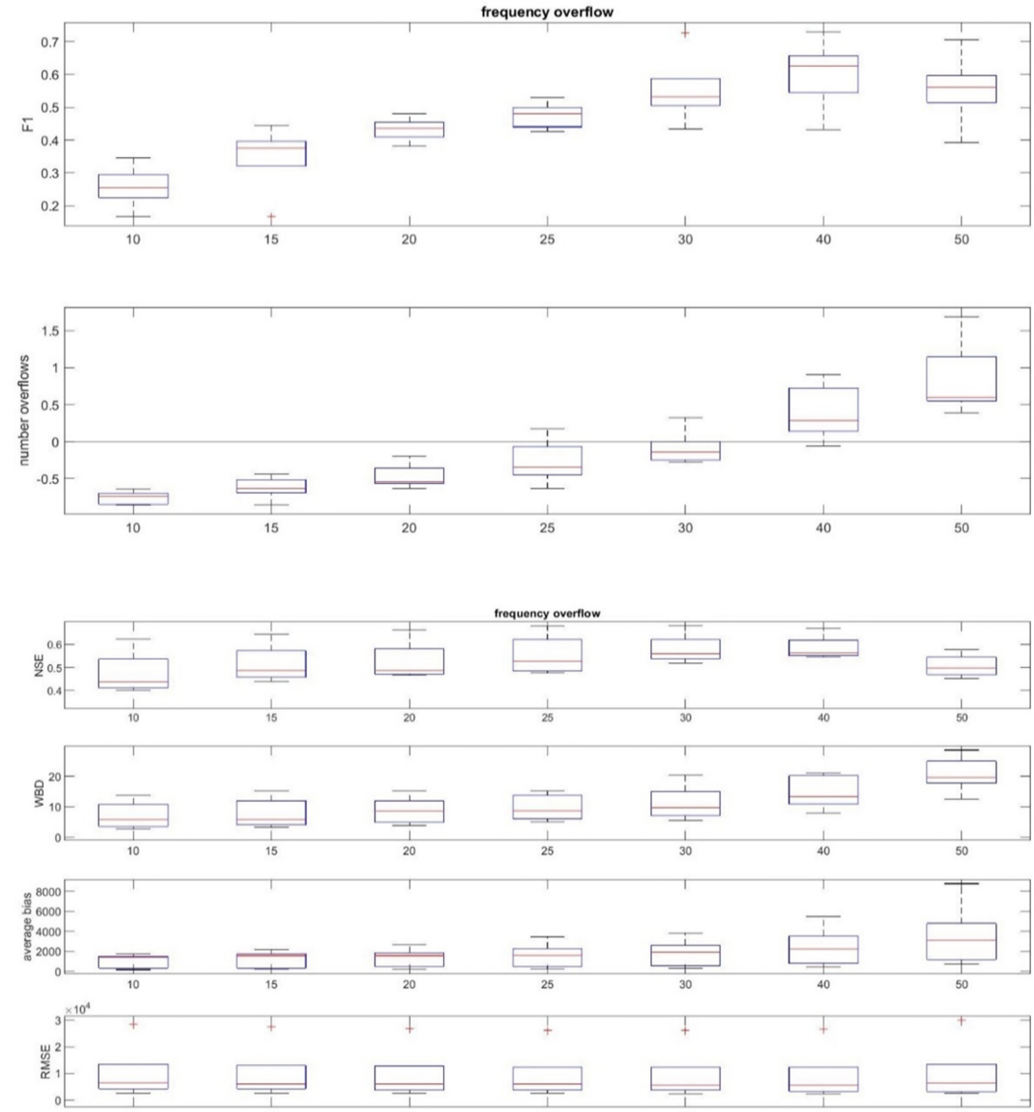


Figure 64: Results sensitivity analysis frequency overflow for CM3. The number of overflows represents [abs(#sim - #obs)/#obs]

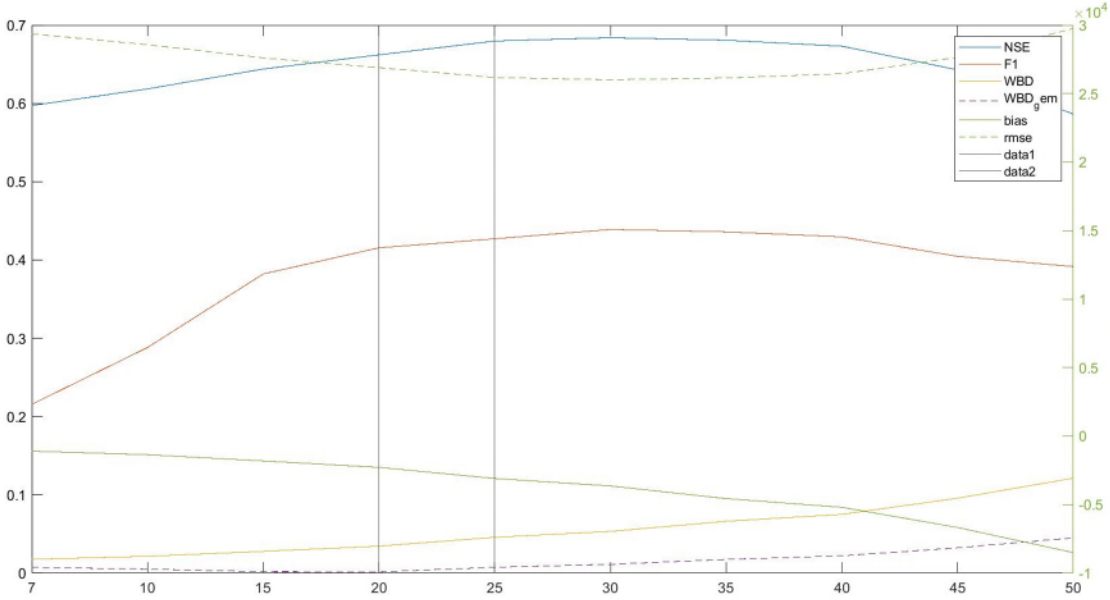


Figure 65: Results applying several overflow frequencies for Gent. The two black lines indicate the region where the amount of overflows is of the same range as the observations. X-axis represent the number of overflows in one year.

Also a sensitive analysis was done to gain better insight in the effect of population size, since here as well different sources are available. For these analyses the area of the DIVA dataset is used and an overflow frequency of 30. But according to Error! Reference source not found., it seems that the source of population doesn't make a big

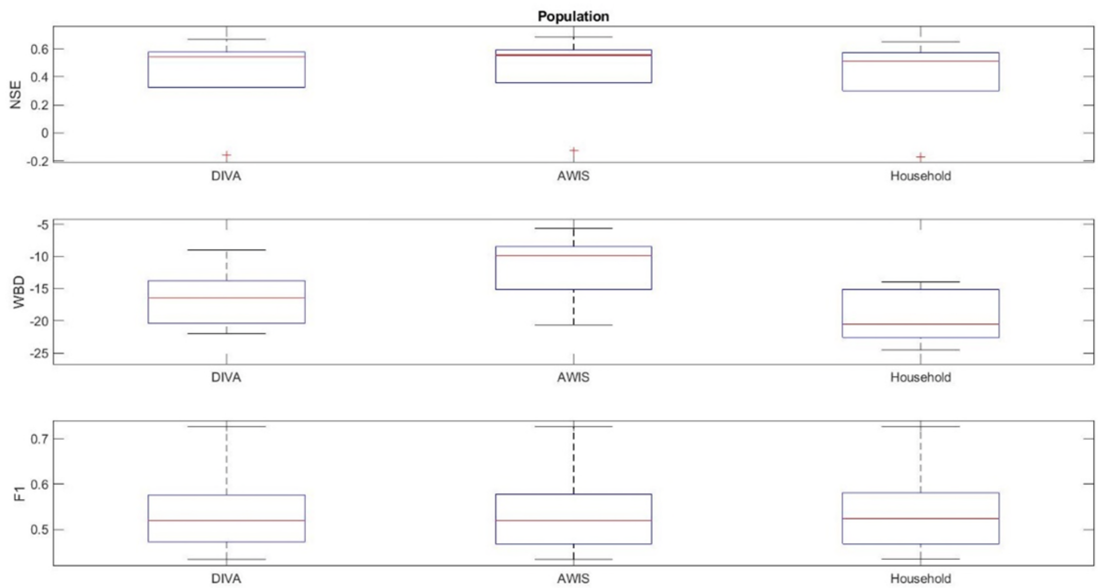


Figure 66: Sensitivity analysis CM3 for the population.

difference.

VI Modeling results

In the following paragraphs for each WWTP the validation results will be discussed, the comparison between the sewage system in 2018 and the one considered in InfoWorks CS is shown and the moment of overflows is compared between results from Infoworks CS and observations from the MOS dataset.

VI.I Nevele

Validation CM

Table 15: Results of the validation for WWTP Nevele. #sim indicate the number of days where an overflow occurs according to the CM and #obs represents the amount of days an overflow occurs according to the MOS dataset.

Validation 2017								
Model	**NSE**	**RMSE**	**Corr**	**Bias**	**WBD**	**F1**	**#sim**	**#obs**
CM1	0.72	599.97	0.89	-599.97	20.08	0.60	66.00	55.00
CM1b	0.77	286.88	0.89	-286.88	9.64	0.61	57.00	55.00
CM1c	0.80	216.65	0.91	216.65	-7.15	0.62	48.00	55.00
CM2	0.76	99.72	0.87	-99.72	3.39	0.51	99.00	55.00
CM3	0.58	356.88	0.84	-356.88	11.96	0.51	89.00	55.00

Based on the calibration and validation results, CM1b was chosen as final model for Nevele (see Table 15). It can be noticed that CM1c performs slightly better on most parameters, but the decision was made to work with CM1b since this model performs better looking at the number of days an overflow occur. The resulting parameters can be found in Table 16. Figure 67 gives the cumulative volumes at the outlet of WWTP Nevele in 2017, when CM1b is used.

Table 16: Obtained parameters CM1b Nevele

CM1b			
K	Recession constant 1	1/s	6.67E-05
Z	Threshold overflow	m³/s	0.15
Area	Area	km²	1.5
K2	Recession constant 2	1/s	4.44E-05

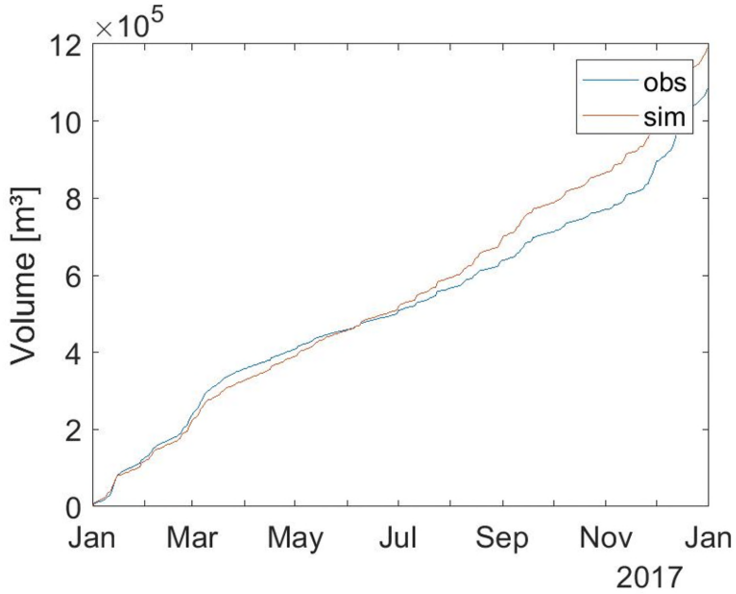


Figure 67: Cumulative volumes of daily effluent discharges from WWTP Nevele in 2017, when CM1b is used.

Comparison InfoWorks CS vs AWIS

Figure 68 shows the network of Nevele as represented in InfoWorks CS (State A), hereby some pipes are connected to the WWTP (dark blue lines) and some are not (light blue lines). The non-connected pipes will result in permanent flows. The black rectangles indicate the locations where an overflow can occur. It can be noticed that not every overflow is relevant for this study, since some locations are outside the water abstraction area of WPC Kluizen.

The model in InfoWorks CS is made in 2016, therefore a comparison was done with the sewage systems in 2018 from the AWIS dataset. It can be noticed that some permanent flows are now connected to the sewage station, as a result these permanent flows probably don’t exist anymore. In this report, the sewage system as represented in InfoWorks CS is used but in a later stage this could be adjusted.

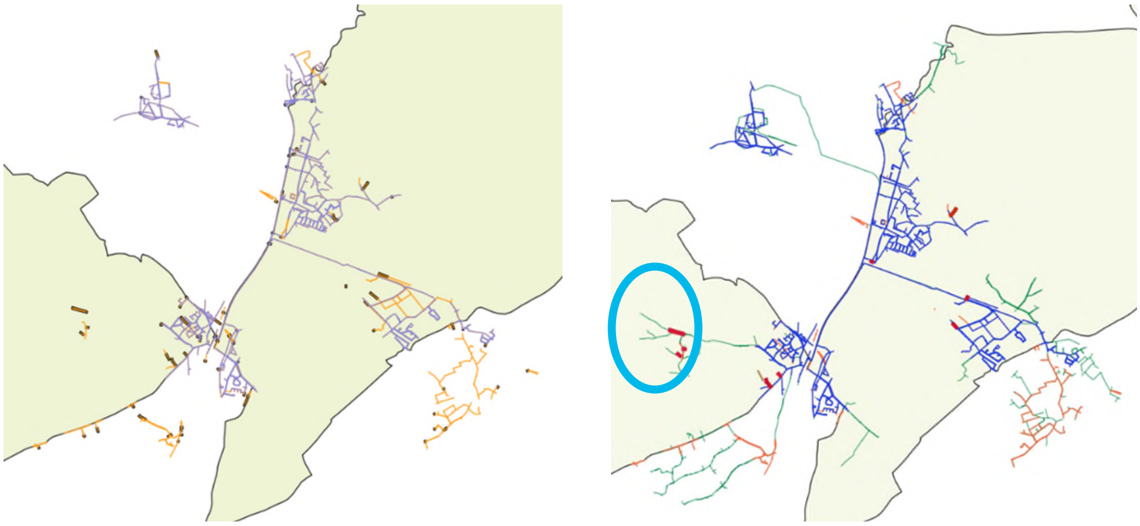


Figure 68: Left – orange represents 'State A', purple represents the pipes which are connected to the WWTP. The black rectangles are the locations where an overflow can occur. Right – the blue lines indicate the connected pipes according to InfoWorks CS [2016], while the green lines represent the connected pipes displays according to the AWIS dataset [2018], orange is 'State A'.

Moment of overflow

The MOS dataset has one observation from the sewage system of Nevele (see Figure 69). At this location, the moment of overflows were compared between the results of InfoWorks CS and the observations from the MOS dataset. Apart from the event in 2017, which has an intensity of 0.15mm/h, the timing between the two datasets coincides (see Figure 70).

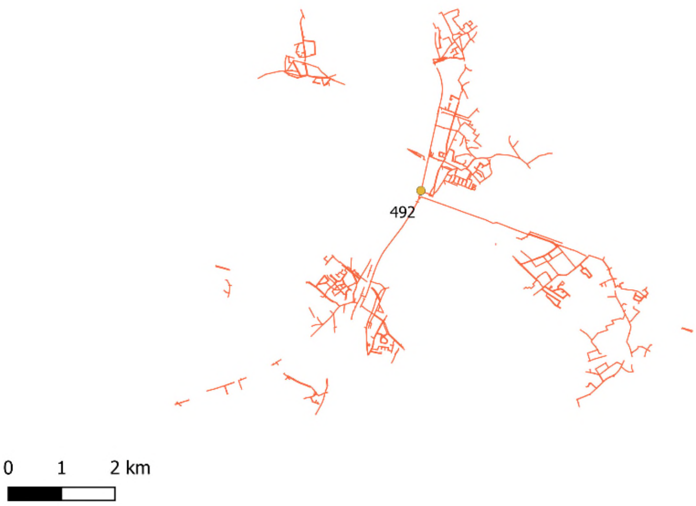


Figure 69: The yellow dot shows the location of the available observation from the MOS dataset and its ID. The orange lines show the sewage system as represented in 'State A' from InfoWorks CS.

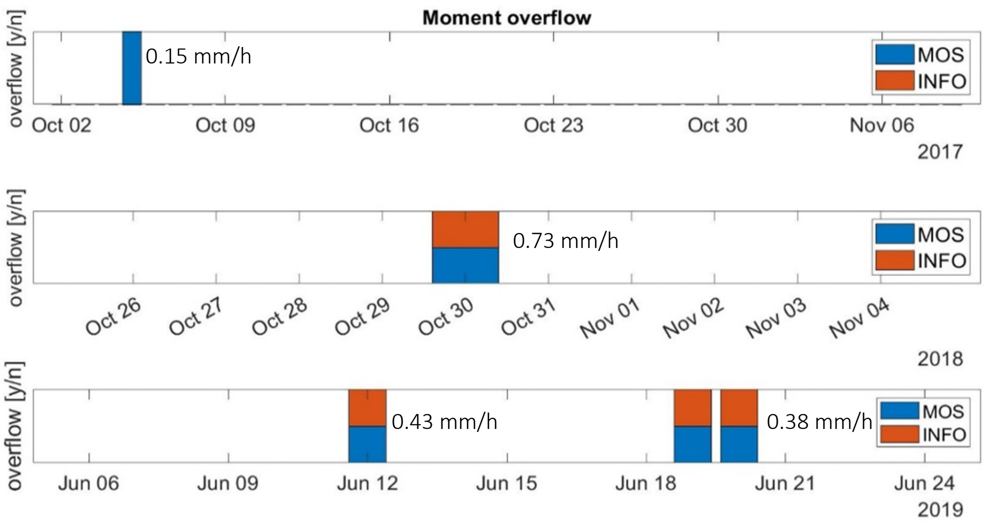


Figure 70: Comparison between the results from the hydraulic model and the MOS dataset for the used test events in Nevele.

VI.II Evergem

Validation CM

Table 17: Results of the validation for Evergem. #sim indicate the number of days where an overflow occurs according to the CM and #obs represents the amount of days an overflow occurs according to the MOS dataset.

Validation 2017								
Model	**NSE**	**RMSE**	**Corr [r]**	**Bias**	**WBD**	**F1**	**#sim**	**#obs**
CM1	0.37	134.13	0.73	-134.13	2.16	0.47	86.00	33.00
CM1b	0.35	422.13	0.78	-422.13	6.82	0.69	28.00	33.00
CM1c	0.44	1268.55	0.84	1268.55	-20.56	0.38	116.00	33.00
CM2	-0.06	86.47	0.60	86.47	-1.41	0.50	39.00	33.00
CM3	-1.23	985.89	0.59	-985.89	15.96	0.47	51.00	33.00

Based on the calibration and validation results, CM1b was chosen as final model for Evergem (see Table 17). The resulting parameters can be found in Table 18. Figure 71 gives the cumulative volumes at the outlet of WWTP Evergem in 2017, when CM1b is used.

Table 18: Obtained parameters CM1b Evergem

CM1b			
K	Recession constant 1	1/s	5.56E-05
Z	Threshold overflow	m^3/s	0.3
Area	Area	km^2	2
K2	Recession constant 2	1/s	5.56E-05

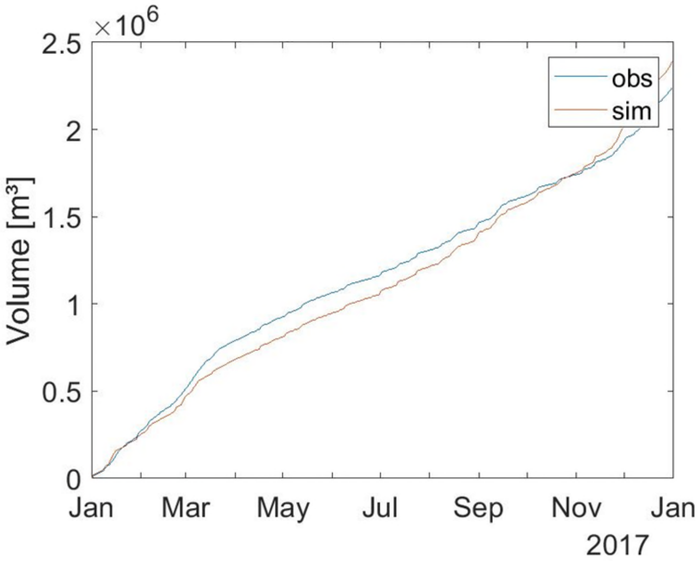


Figure 71: Cumulative volumes of daily effluent discharges from WWTP Evergem in 2017, when CM1b is used.

Comparison InfoWorks CS vs AWIS

Figure 72 shows the network of Evergem as represented in InfoWorks CS (State A), hereby some pipes are connected to the WWTP (dark blue lines) and some are not (light blue lines). The non-connected pipes will result in permanent flows. The black rectangles indicate the locations where an overflow can occur. It can be noticed that not every overflow is relevant for this study, since some locations are outside the water abstraction area of WPC Kluizen.

The model in InfoWorks CS is made in 2015, therefore a comparison was done with the sewage systems in 2018 from the AWIS dataset. In this case the both sewage systems are similar.

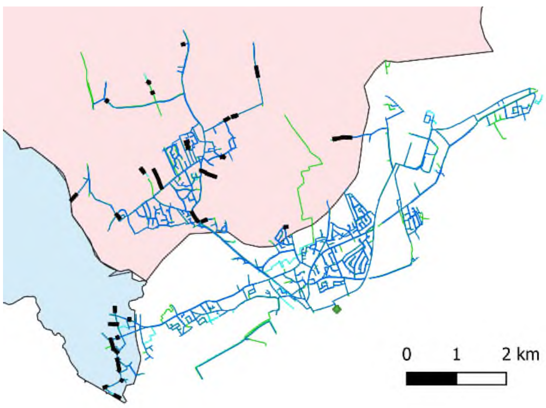


Figure 72: light blue represents 'State A', dark blue are the pipes which are connected to the WWTP according to InfoWorks CS [2015]. The green lines represent the pipes according to the AWIS dataset [2018]. The black rectangles are the locations where an overflow can occur. The green dot is the location of the WWTP.

Moment of overflow

The location of the MOS observation (see Figure 73) at Evergem couldn't be found in InfoWorks CS, there is no outfall in that region except fort he WWTP. Therefore a comparison of the moment of overflows between results from InfoWorks CS and the MOS dataset couldn't be done.

Figure 73: The orange dot shows the location of the available observation from the MOS dataset and its ID. The grey lines gives the sewage system as represented in 'State A' from InfoWorks CS.

VI.III Tielt

Validation CM

Table 19: Results of the validation for Tielt. #sim indicate the number of days where an overflow occurs according to the CM and #obs represents the amount of days an overflow occurs according to the MOS dataset.

Validation 2017								
Model	**NSE**	**RMSE**	**Corr [r]**	**Bias**	**WBD**	**F1**	**#sim**	**#obs**
CM1	0.76	925.30	0.88	925.30	-9.26	0.67	69.00	39.00
CM1b	0.75	1487.45	0.89	1487.45	-14.79	0.73	54.00	39.00
CM1c	0.17	4168.47	0.82	4168.47	-41.19	0.49	115.00	39.00
CM2	0.74	1137.32	0.88	1137.32	-11.35	0.69	62.00	39.00
CM3	0.49	2803.88	0.78	2803.88	-27.75	0.64	74.00	39.00

Based on the calibration and validation results, CM1b was chosen as final model for Tielt (see Table 19). It can be noticed that CM1 performs slightly better on most parameters, but the decision was made to work with CM1b, since CM1b performs better looking at the number of days an overflow occur. The resulting parameters can be found in Table 20. Figure 74 gives the cumulative volumes at the outlet of WWTP Tielt in 2017, when CM1b is used.

Table 20: Obtained parameters CM1b Tielt

CM1b			
K	Recession constant 1	1/s	0.00044
Z	Threshold overflow	m^3/s	0.5
Area	Area	km^2	3.5
K2	Recession constant 2	1/s	5.65E-05

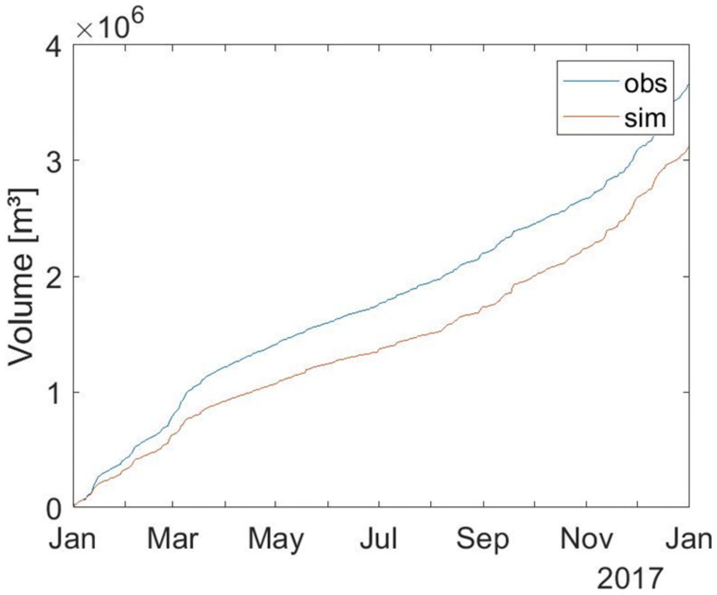


Figure 74: Cumulative volumes of daily effluent discharges from WWTP Tielt in 2017, when CM1b is used.

Infoworks CS vs AWIS

Figure 75 shows the network of Tielt as represented in InfoWorks CS (State A), hereby some pipes are connected to the WWTP (dark blue lines) and some are not (light blue lines). The non-connected pipes will result in permanent flows. The black rectangles indicate the locations where an overflow can occur. It can be noticed that not every overflow is relevant for this study, since some locations are outside the water abstraction area of WPC Kluizen.

The model in InfoWorks CS is made in 2011, therefore a comparison was done with the sewage systems in 2018 from the AWIS dataset. It can be noticed that some permanent flows are now connected to the sewage station, as a result these permanent flows probably don't exist anymore. In this report, the sewage system as represented in InfoWorks CS is used but in a later stage this could be adjusted.

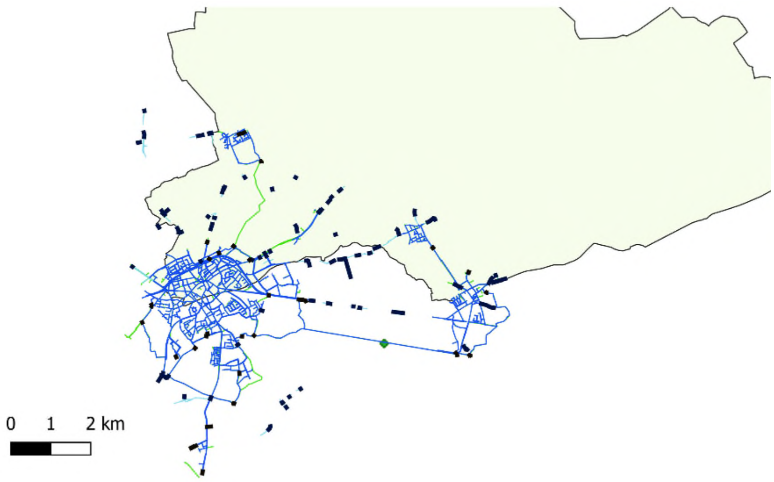


Figure 75: light blue represents 'State A', dark blue are the pipes which are connected to the WWTP according to InfoWorks CS [2011]. The green lines represent the pipes according to the AWIS dataset [2018]. The black rectangles are the locations where an overflow can occur. The green dot is the location of the WWTP.

Moment of overflow

The MOS dataset has four observations at the sewage system of Tielt (see Figure 76). At these locations, the moment of overflows were compared between the results of InfoWorks CS and the observations from the MOS dataset (see Figure 77Error! Reference source not found.). It can be noticed that the moments coincide between the two datasets.

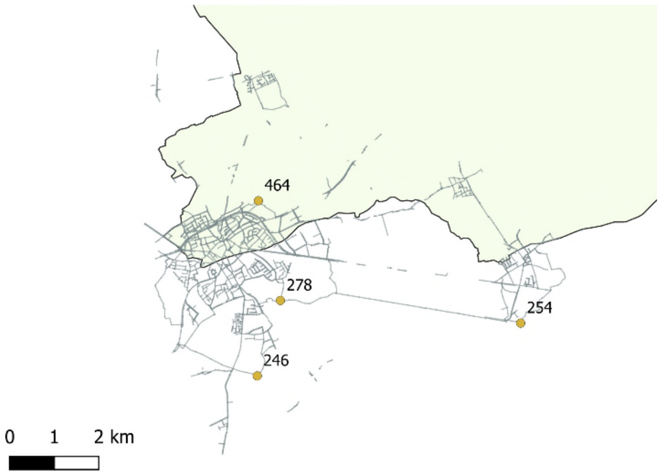


Figure 76: The yellow dots show the location of the available observation from the MOS dataset and their IDs. The grey lines gives the sewage system as represented in 'State A' from InfoWorks CS.

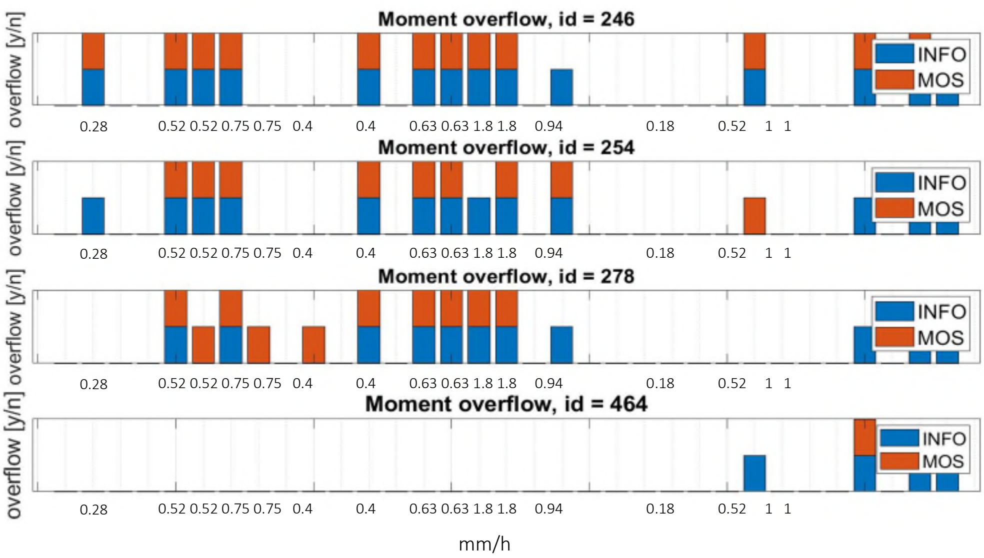


Figure 77: Comparison between the results from the hydraulic model and the MOS dataset fort he used test events in Tielt.

VI.IV Aalter

Validation CM

Table 21: Results of the validation for Aalter. #sim indicate the number of days where an overflow occurs according to the CM and #obs represents the amount of days an overflow occurs according to the MOS dataset.

Validation 2017								
Model	**NSE**	**RMSE**	**Corr [r]**	**Bias**	**WBD**	**F1**	**#sim**	**#obs**
CM1	0.73	729.56	0.86	-729.56	6.15	0.57	69.00	32.00

CM1b	0.70	171.01	0.85	171.0118	-1.37	0.71	47.00	32.00
CM1c	0.67	485.25	0.84	485.25	-4.00	0.93	1.00	32.00
CM2	0.58	11.13	0.77	11.13	-0.04	0.60	62.00	32.00
CM3	0.57	159.82	0.77	-159.82	1.39	0.57	71.00	32.00

Based on the calibration and validation results CM1b was chosen as final model for Aalter (see Table 21). The resulting parameters can be found in Table 22. Figure 78 gives the cumulative volumes at the outlet of WWTP Aalter in 2017, when CM1b is used.

Table 22: Obtained parameters CM1b Aalter

CM1b			
K	Recession constant 1	1/s	5.56E-05
Z	Threshold overflow	m^3/s	0.5
Area	Area	km^2	4
K2	Recession constant 2	1/s	5.56E-05

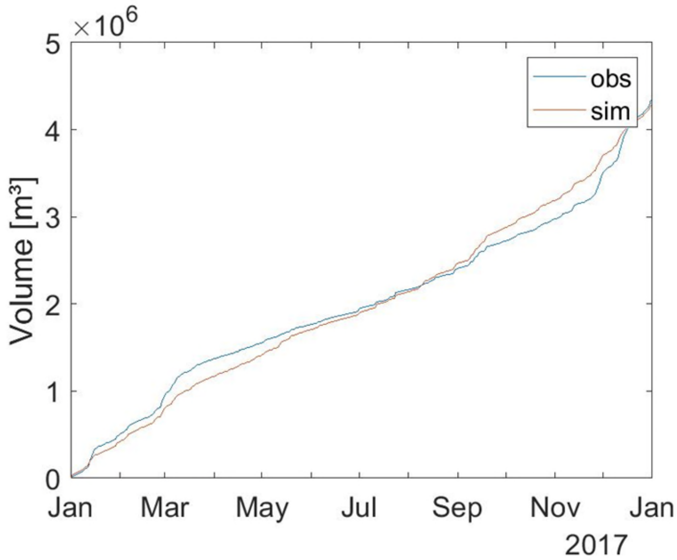


Figure 78: Cumulative volumes of daily effluent discharges from WWTP Aalter in 2017, when CM1b is used.

Infoworks CS vs AWIS

Figure 79 shows the network of Aalter as represented in InfoWorks CS (State A), hereby some pipes are connected to the WWTP (dark blue lines) and some are not (light blue lines). The non-connected pipes will result in permanent flows. The black rectangles indicate the locations where an overflow can occur. It can be noticed that not every overflow is relevant for this study, since some locations are outside the water abstraction area of WPC Kluizen.

The model in InfoWorks CS is made in 2006, therefore a comparison was done with the sewage systems in 2018 from the AWIS dataset. It can be noticed that some permanent flows are now connected to the sewage station, as a result these permanent flows probably don’t exist anymore. In this report, the sewage system as represented in InfoWorks CS is used but in a later stage this could be adjusted.

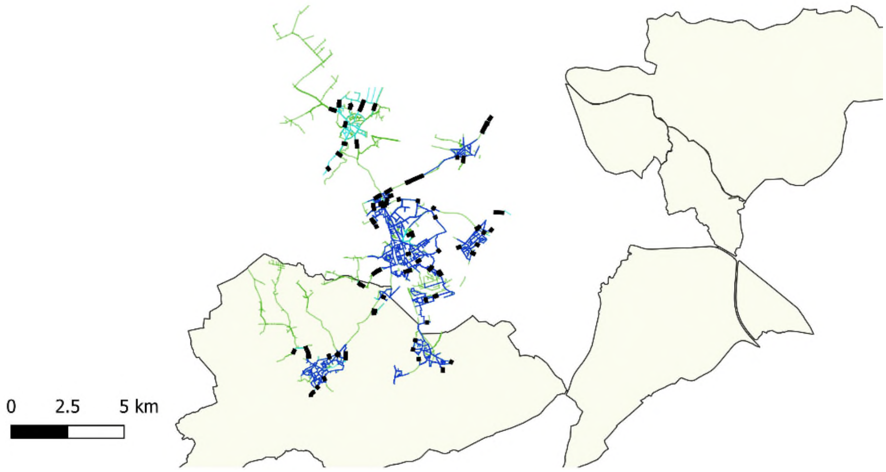


Figure 79: light blue represents 'State A', dark blue are the pipes which are connected to the WWTP according to InfoWorks CS [2006]. The green lines represent the pipes according to the AWIS dataset [2018]. The black rectangles are the locations where an overflow can occur.

Moment of overflow

The MOS dataset has four observations at the sewage system of Aalter (see Figure 80). At these locations, the moment of overflows were compared between the results of InfoWorks CS and the observations from the MOS dataset (see Error! Reference source not found.). MOS ID 452 couldn't be compared since it is a permanent flow in InfoWorks CS. Looking at Figure 81, it seems that that MOS dataset and the results from InfoWorks CS correspond quite well, in a few cases InfoWorks CS has an overflow while this is not reported in the MOS data, but when this occurs the overflow volumes are rather small

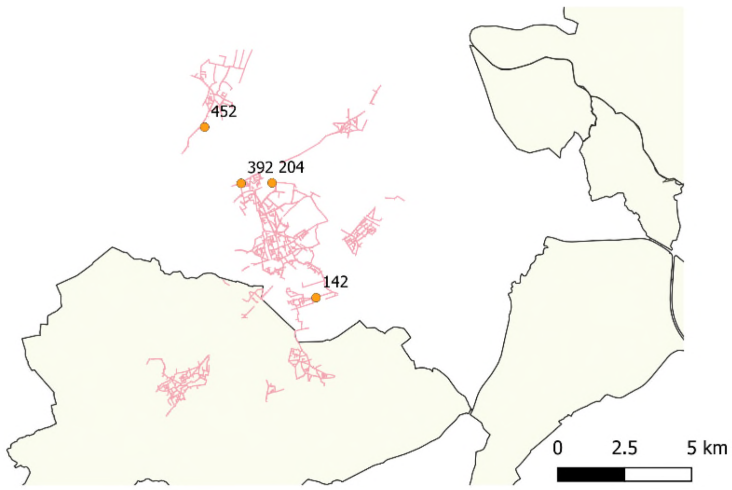


Figure 80: The orange dots shows the location of the available observation from the MOS dataset and their IDs. The pink lines gives the sewage system as represented in 'State A' from InfoWorks CS.

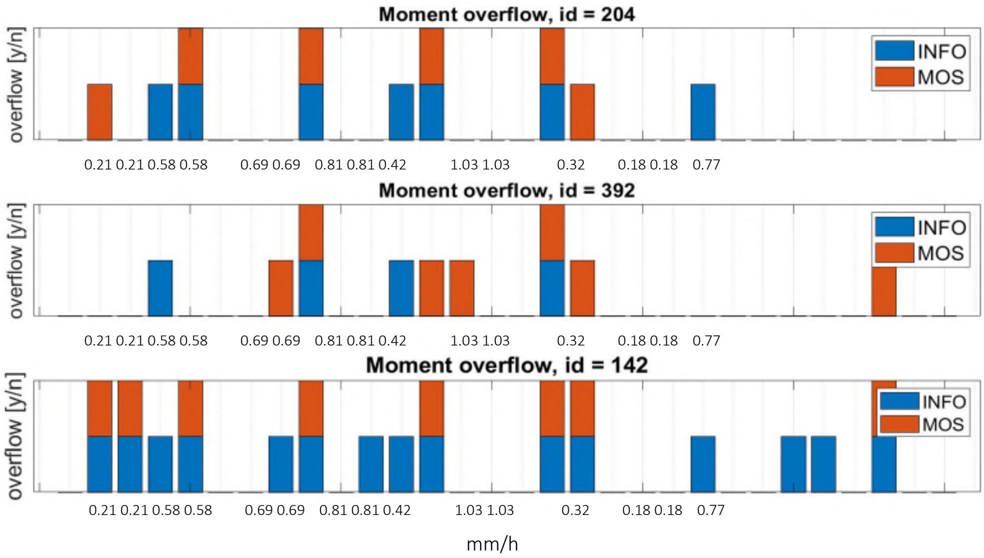


Figure 81: Comparison between the results from the hydraulic model and the MOS dataset for the used test events in Aalter

VII InfoWorks CS vs AWIS – overflow

VII.I Nevele

Since it was unclear where the locations of overflows are, the several available datasets were compared. Here the comparison is made between the hydro points of the AWIS dataset and the outfalls from InfoWorks CS (see Error! Reference source not found.). For Nevele, 31 hydro points are categorized as overflow and [29-6] locations in InfoWorks CS are categorized as outfalls, -6 are the outfalls which have a permanent flow. When looking at the pipes which are categorized as overflow (9 in total) these are all located in a hydro point of category *overflow*. When looking at the outfalls, see Error! Reference source not found., it can be noticed that at 16 locations both hydro point and an outfall can be found. When points are selected from the AWIS dataset based on lblvstelling

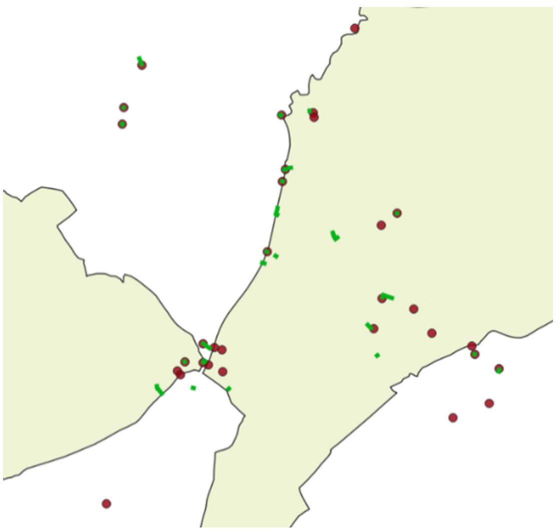


Figure 82: Red are the hydro points of overflow (AWIS) and green are the locations of overflow according to InfoWorks CS, connected to the WWTP and which don't have a permanent flow.

overstortwater, 63 points are selected, but it doesn't seem that this has an added value. Since the locations are the same as before. The additional locations seem to be permanent flows. As a result it can be concluded that there are some differences between the AWIS dataset and InfoWorks CS, but we can assume that the general trend is the same.

VII.II Evergem

When looking at Evergem (see Figure 83), the same conclusion can be drawn as for Nevele. The pipes of overflow coincide with the hydro points (lbltype ovst). When looking at the category of water *overstortwater* too much points are selected, it seems that also the locations with a permanent flow are taken into account here (as was the case for Nevele). In total 21 outfalls, that are connected to the WWTP can be found in InfoWorks CS and according to the AWIS dataset, namely hydro points of type *overflow*, 32 locations have an overflow.

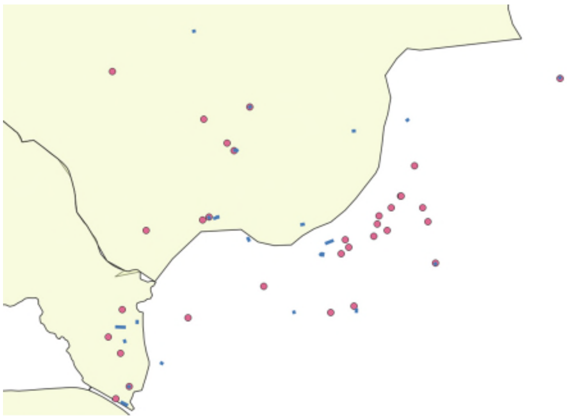


Figure 83: Locations of overflow according to the AWIS dataset (pink dots) and InfoWorks CS (blue pipes) for Evergem

The decision was made to take as overflow locations, the hydro points which have a label OVST according to the AWIS dataset. The permanent flows are the hydro points which have a label UITL as type, together with the label VUIL as UITLWAT.