Universidad del País Vasco Euskal Herriko Unibertsitatea
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UNIVERSITY OF THE BASQUE COUNTRY

GRADE IN MECHANICAL ENGINEERING

FINAL DEGREE PROJECT

PRESENT AND FUTURE ANALYSIS OF THE SEWER SYSTEM AND WASTEWATER TREATMENT PLANT IN HØRNING

Student: Arnedo, Morillas, Borja

Director: Juanes, Garcia, Francisco Javier

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Abstract

An increase in sewage, due to population growth and climate change, can cause an overflow of the combined sewer system and malfunctioning of the wastewater treatment plant in Hørning. To comprehend the current situation, an analysis of the transport and treatment of the sewage can be accomplished.

The aim of this report is to show how to make the sewer system and wastewater treatment plant of Hørning future-proof in relation to climate change, population growth and pollution.

A Mike Urban model has been run to evaluate the current state of the sewer system. To estimate the capacity of the sewer system in the future the model has been run with climate factors, resulting in pipe sections that could not cope with the future increase in runoff. It is proposed to separate the sewer system or to upgrade the actual system.

The key process parameters of the wastewater treatment plant have been calculated and analysed to verify its performance. To get an understanding of the denitrification process in the OCO tank, an experiment has been conducted. The prediction for the future is calculated based on assumptions. The current state of the wastewater treatment plant is adequate, but problems in the future are expected regarding sludge age and nitrification, which will result in a smaller volume for denitrification. This issue can be solved by alternating the aerobic, anoxic and anaerobic volumes of the process tank or construct a larger OCO tank.

The receiving body will get polluted if the requisites are not fulfilled or during long rain events, when the combined sewer overflow activates. To evaluate the status of the stream, a closer look is taken to the invertebrates through a macro index. The analysis of the samples displays a moderate condition of the stream. To improve the ecological condition of the stream, a separate sewer system or a larger basin, with a possibility of reintroduction to the transport process to the wastewater treatment plant, is proposed.

Laburpena

Hondakin-uren igoera batek, populazioaren hazkundeak eta klima-aldaketak piztuta, Hørning-eko estolderia konbinatuko sistemaren gainezkatze bat eta hondakin-uretako tratamendu-instalazioaren funtzionamendu txarra eragin ditzake. Gaurko egoera ulertzeko, hondakin-uren garraio eta tratamenduaren analisi bat egiten da.

Txosten honen helburua Hørning-eko estolderia-sistema eta hondakin-uren araztegia etorkizunerako nola prestatu daitezke erakustea da, klima-aldaketari, populazioaren hazkundeari eta poluzioari dagozkionez.

Estolderia-sistemaren gaurko egoera ebaluatzeko Mike Urban-ekin simulazio modelo bat sortu da. Etorkizunean estolderia-sistemaren ahalmena estimatzeko, modeloa zenbait faktore klimatiko kontuan hartuz exekutatu da, etorkizuneko isurtzearen handiagotzeari kontra egin ezin izango luketen hodi sekzioak emaitza bezala emanez. Estolderia-sistema banatzea edo sistema erreala eguneratzea proposatzen da.

Hondakin-uretako tratamendu plantaren prozesuaren parametro gakoak kalkulatu eta analizatu egin dira bere errendimendua egiaztatzeko. OCO-tankearen desnitrifikazio-prozesua ulertzeko, esperimentu bat egin da. Etorkizunerako aurresana usteak erabiliz egin da. Araztegiaren gaurko egoera egokia da, baina lohien eta nitrifikazioaren adinari dagokionez arazoak espero dira, emaitza bezala desnitrifikaziorako bolumen txikiagoa bat izanez. Arazo hau ebatz daiteke prozesu-tankearen bolumen aerobiko, anoxiko eta anaerobikoak aldizkatuz edo OCO tanke handiago bat eraikiz.

Uren gorputz hartzailea kutsatuko da araztegiaren irteeran gutxieneko baldintzak betetzen ez badira edo luzatutako euri ekitaldietan, estolderia konbinatuko gainezkatze sistema aktibatzen denean. Errekaren egoera ebaluatzeko, ornogabeen azterketa egiten da, makroa index bat eginez. Laginen analisiak erakusten dute errekaren situazioa moderatua dela. Baldintza ekologikoa hobetzeko, banandutako estolderia sistema eraikitzea edo arro handiago bat egitea, tratamendu plantaren garraio prozesura birsartzeko aukera izango duena, proposatzen da.

Resumen

Un aumento en las aguas residuales, debido al crecimiento de la población y al cambio climático, puede causar un desbordamiento del sistema de alcantarillado combinado y un mal funcionamiento de la planta de tratamiento de aguas residuales en Hørning. Para comprender la situación actual, se realiza un análisis del transporte y tratamiento de las aguas residuales.

El objetivo de este informe es mostrar cómo hacer que el sistema de alcantarillado y la planta de tratamiento de aguas residuales de Hørning están preparadas para los años venideros en relación al cambio climático, el crecimiento de la población y la contaminación.

Para evaluar el estado actual del sistema de alcantarillado se ha creado un modelo de simulación con Mike Urban. Para estimar la capacidad del sistema de alcantarillado en el futuro, el modelo se ha ejecutado teniendo en cuenta factores climáticos, dando como resultado secciones de tubería que no podrían hacer frente al aumento futuro de la escorrentía. Se propone separar el sistema de alcantarillado o actualizar el sistema real.

Los parámetros clave del proceso de la planta de tratamiento de aguas residuales se han calculado y analizado para verificar su rendimiento. Para comprender el proceso de desnitrificación en el tanque de OCO, se realizó un experimento. La predicción para el futuro se ha hecho en base a suposiciones. El estado actual de la planta de tratamiento de aguas residuales es adecuado, pero se esperan problemas en el futuro con respecto a la edad de los lodos y la nitrificación, lo que dará como resultado un volumen menor para la desnitrificación. Este problema se puede resolver alternando los volúmenes aeróbicos, anóxicos y anaeróbicos del tanque de proceso o construyendo un tanque OCO más grande.

El cuerpo receptor del agua se contaminará si no se cumplen los requisitos mínimos a la salida de la planta o durante eventos de lluvia prolongada, cuando se activa el sistema de desbordamiento de alcantarillado combinado. Para evaluar el estado del arroyo, se examina más detenidamente a los invertebrados a través de un macro index. El análisis de las muestras indica una condición moderada del arroyo. Para mejorar la condición ecológica, se propone un sistema de alcantarillado separado o una cuenca más grande, con una posibilidad de reintroducción al proceso de transporte a la planta de tratamiento de aguas residuales.

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AS	Activated sludge
BOD	Biological Oxygen Demand
BOD,i	Inlet Biological Oxygen Demand
BOD,o	Outlet Biological Oxygen Demand
Ci	Inlet concentration
CCTV	Close Circuit Television
CDS	Chicago Design Storm
C_L	Operating oxygen concentration
Co	Outlet concentration
COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflow
C_{walt}	Dissolved oxygen concentration
DM	Dry matter
DP	Degree of Purification
DW	Dry weather
EBPR	Enhanced Biological Phosphorus Removal
ESP	Excess Sludge Production
EU	European Union
Fe	Iron
F/M ratio	Food to microorganism ratio
H_{eff}	Effective depth
HRT	Hydraulic Retention Time
H_{tot}	Total depth
L_{BOD}	Oxygen used for the decomposition of organic matter
L_{DN}	Reduction in oxygen consumption due to denitrification
L_N	Oxygen used for nitrification

LTS	Long Term Statistic
m,Fe	Mass of iron
mN,DN	Denitrified mass of nitrogen
mN,i	Mass of nitrogen in the inlet
mN,o	Mass of nitrogen in the outlet
mN,SP	Mass of nitrogen in the excess sludge production
N,out	Nitrogen in the outlet
OC_a	Oxygen consumption under actual conditions
OC_{std}	Oxygen consumption under standard conditions
OR	Overflow rate
P	Phosphorus
PAO	Phosphate Accumulating Organisms
PE	Person Equivalent
Q	Flow
Qi	Inlet flow
Qo	Outlet flow
Qr	Return flow
R	Return sludge rate
rDN	Denitrification rate
RWW	Raw Wastewater
SA	Sludge Age
SLR	Solids Loading Rate
Sol	Solution
SP,bio	Biological Sludge Production
SP,chem	Chemical Sludge Production
SP,tot	Total Sludge Production
SS	Suspended Solids
SUDS	Sustainable Urban Drainage System

SVI	Sludge Volume Index
T	Temperature
TN	Total Nitrogen
Tot Fe	Total Iron
TP	Total Phosphorus
V_A	Aerobic volume
V_{AN}	Anaerobic volume
V_{DN}	Denitrificated volume
V_{N+DN}	Anoxic volume
$V_{tot,15d}$	Total volume needed for a 15-day sludge age
$V_{tot\ act}$	Actual total volume
WWTP	Waste Water Treatment Plant
X_A	Sludge concentration
X_R	Return sludge concentration
Y tot	Yield constant
α	Oxygen transfer correction factor
β	Surface tension correction factor

1. INTRODUCTION

Hørning is a town located in Skanderborg municipality, just south of the city Aarhus, in the Eastern part of Jutland. The population of Hørning has nearly doubled during the last 40 years to a population of 7,881 inhabitants. In 2015, 632 people moved to Hørning. 32 % of the people that moved from Aarhus to Skanderborg municipality moved to Hørning. (Skanderborg kommune, 2016)

The population growth of Hørning is causing an increase in the quantity of wastewater. The quantity of stormwater will increase as well, due to heavy precipitation, related to climate change. In the older parts of Hørning combined sewer systems are still in use. An increase in water can cause an overflow of the system and the untreated water discharges directly to the receiving water, which can cause pollution.

Investigating the water management of Hørning is of interest because of the rapid changes in the weather and the households connected to the system. The vacant capacity of the wastewater treatment plant (WWTP) nowadays and the acceptable plant inlet in the future, should be analysed to maintain the requirements for the outlet and the performance of the plant.

The report attempts to show how to make the sewer system and wastewater treatment plant of Hørning future-proof in relation to climate change, population growth and pollution.

At first, the physical and hydraulic conditions of the current sewer system will be discussed and modelled in Mike Urban. Problems of the sewer system will be analysed and one solution will be modelled in Mike Urban.

Secondly, the wastewater treatment plant will be described and the key data will be calculated. This key data will be used for calculating the vacant capacity of the plant; in addition, future problems for the wastewater treatment plant will be discussed and a possible solution will be given. Furthermore, the denitrification rate will be estimated from analysing sludge samples of the wastewater treatment plant of Hørning, which will give a more accurate estimation of the vacant capacity.

At last, the impact on the receiving body will be discussed. It will be shown by a macro index, formed by analysing samples of the Aarhus Å stream.

This report was made in Aarhus University in the city of Aarhus (Denmark), during the months of September, October, November and December of 2018 (starting on the 23rd October and ending on 16th December) while I was there taking part in the Erasmus program. The project was offered as a part of the fall international semester in Urban Water/ Wastewater Engineering at the previously mentioned university.

2. SEWER SYSTEM

For more information about this section of the report, see Appendix I. In here the analyses will be further explained and more figures will be presented.

The objective of section two of this report is to give a detailed overview of the status of the sewer system in Blegind. A Mike Urban model, which is a flexible GIS-based system for modeling and design of water distribution networks and collection systems for waste water and storm water, is made to examine the present hydraulic capacity of the system. If the system is found to be inadequate to handle current and future rain events, solutions will be put forth to manage the problems. The load of the system is expected to increase in the future as a result of climate change and population increase. The focus of this report will be on Blegind, the south part of Hørning, but the transport pipes to Hørning will be analysed as well.

For the creation of the Mike Urban model, first of all, the map of Blegind was imported. Secondly, the actual sewer system with its manholes, pipe sections and overflow structures was modelled, using the tools of the simulation programme; the data used, which was provided by Skanderborg Forsyning, will be presented during this section of the report. Finally, the whole parcel was divided into smaller catchment areas as a way to have more accurate results.

Simulations have been run with a 10-year Chicago Design Storm (CDS) rain to evaluate the status of the system. To estimate the capacity of the system in the future, a climate factor with a 100-year time horizon is used, combined with a 10-year CDS rain. Lastly, to evaluate possible solutions involving a separate sewer system a 5-year CDS rain is used.

The Mike Urban version used is the MIKE 2016.

2.1 Description of the sewer system

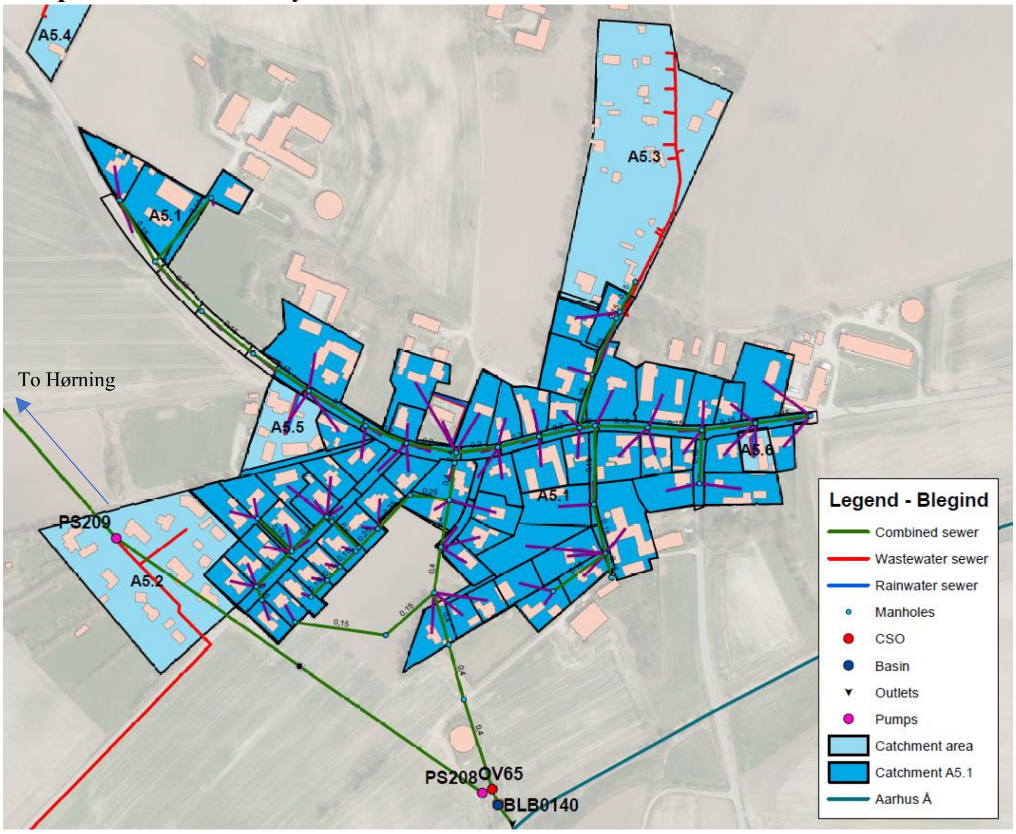


Figure 1. Map of Blegind showing the sewer system and catchments. The map can be found full size as Appendix IV.3

In Figure 1 a layout of Blegind is shown. The main part of the sewer system in Blegind (Area A5.1) is a combined system constructed in 1940. Smaller areas of the town were constructed past 1998 and these parts only have a wastewater sewer. It is unclear how the rainwater from these areas is drained off. The sewage gravitates towards a pumping station (PS208) south of the town. A Combined Sewer Overflow (CSO), OV65 is located just before the pumping station to protect it from overflowing in case of heavy rainfall. The discharged water from the CSO flows into a basin and from there into Aarhus Å.

The sewage is pumped from PS208 to another pumping station (PS209) located in the southwestern part of town. From here the water is pumped to the manhole Y3F0160 and from this point it gravitates towards Hørning. During the transport to Hørning WWTP three additional pipes are connected to the transport pipe, significantly increasing the amount of water and the dimensions of the pipe. For a complete overview of the sewer system see Appendix IV.1.

2.1.1 Physical condition of the sewer system

The physical condition of the sewer system in Blegind is unknown, since there are no available CCTV inspections. To estimate the physical condition, CCTV inspections of the sewer system in Hørning are used.

The pipes inspected in Hørning were constructed in 1950, ten years later than the pipes in Blegind (Skanderborg Kommune, 2018), but the CCTV inspections already show several critical failures of the pipes (Appendix I.1) There are many variables that can influence the wear of the sewer pipes: the composition of the sewage, construction quality, traffic load, concrete quality among others. Thus, it is difficult to draw a conclusion on the physical condition of the sewer system in Blegind, on basis of the CCTV inspections of Hørning. Modern concrete pipes have a life expectancy between 75-150 years (Miljøstyrelsen, 2006); it is unlikely that pipes from 1940 will last this long. It can be concluded that the pipes are probably at the end of their service life and in need of repair or replacement.

2.1.2. Catchments

The town of Blegind is divided into one main catchment area and several smaller areas, as observed in Figure 1. The main area is A5.1, which consists of a combined sewer system dating from the 1940s. The other areas are updated with a separate sewer system and new developments are constructed with a separated sewer system.

The areas A5.5 and A5.6 have a separated sewer system, but the rainwater and the wastewater still flow into the combined system of area A5.1. Therefore, these two areas are treated as part of area A5.1, since currently there are no plans of separating area A5.1. The remaining areas of Blegind only contribute with wastewater to the combined sewer system. The quantities are so low that they are excluded from the model. (Skanderborg Kommune, 2015)

To increase the accuracy of the model, area A5.1 is divided into smaller catchments, so that every plot has its own catchment.

Imperviousness

The imperviousness is determined via a GIS analysis, where the area constructed of impervious materials is calculated as a percentage of the catchment (calculation in Appendix V.1). Catchments that solely consists of roads or green areas have a set value, see Table 4.1.

Table 1. The imperviousness used in the model.

Type of area	Imperviousness (%)
Standard catchment in Blegind [avg.]	33
Impermeable – Roads, sidewalks	100
Semi impermeable – Gravel roads, grass reinforcement tiles, etc.	50
Permeable – Green areas	10

If areas in the model only contain one of the above-mentioned types, the imperviousness from the table is used. Otherwise, the imperviousness from the GIS analysis is used.

The imperviousness stated in the wastewater plan for Blegind is 31 % (Skanderborg Kommune, 2015). The result of the GIS analysis is a bit higher, with an average imperviousness of 33 %. For further explanation see Appendix I.2.

Concentration time

The concentration time is the time the water takes to get from the farthest corner of the catchment to the manhole where it enters the sewer system. The default setting in Mike Urban is seven minutes. This concentration time is used for all the catchments in Blegind, because they are relatively small and homogenous in size. The concentration time of the major catchment areas of Hørning is calculated based on an assumption that the water travels with a speed of 1 m/s. Furthermore, a base time of seven minutes is added to the concentration time.

Table 2. The concentration time for the catchments located in Hørning. These catchments are much larger than the ones in Blegind; therefor a longer concentration time is used.

Name	Longest distance(m)	Velocity (m/s)	Base value (min)	Concentration time (min)	Imperviousness from wastewater plan (%)
A1.1	190	1	7	10	45
A1.2	670	1	7	18	40
A1.5.1	400	1	7	14	32
A1.6	235	1	7	11	34
A1.7	875	1	7	22	30
A1.7.2	200	1	7	10	42
A1.7D	185	1	7	10	30

2.1.3. CSOs

In the model there are four CSOs, one of them (OV65) is a manhole registered as a CSO and operates as one. This manhole is constructed with an overflow pipe (ø400) located 10 cm above the top of the inflow pipe going to PS208.

Overflow OV69, OV70 and OV73 are part of the combined sewer system in Hørning. They are necessary to have in the model because they greatly affect the amount of sewage going into the transport pipe coming from Blegind.

Table 3. Overview of the CSOs in the model. OV65 is only a manhole, therefor it has no crest. The discharge is calculated by Mike Urban.

Name	Placement	Crest width (m)	Ground level (m)	Crest level (m)	Bottom level (m)	Discharge (m^3) Status (10-year rain)
OV65	Damvej	N/A	52.32	N/A	48.32	469
OV69	Bakkedraget	5.5	53.44	51.16	50.94	1179
OV70	Blegindvej	3.8	49.84	48.37	47.84	668
OV73	Nydamshuse	2.7	49.14	47.22	46.94	120
Total						2436

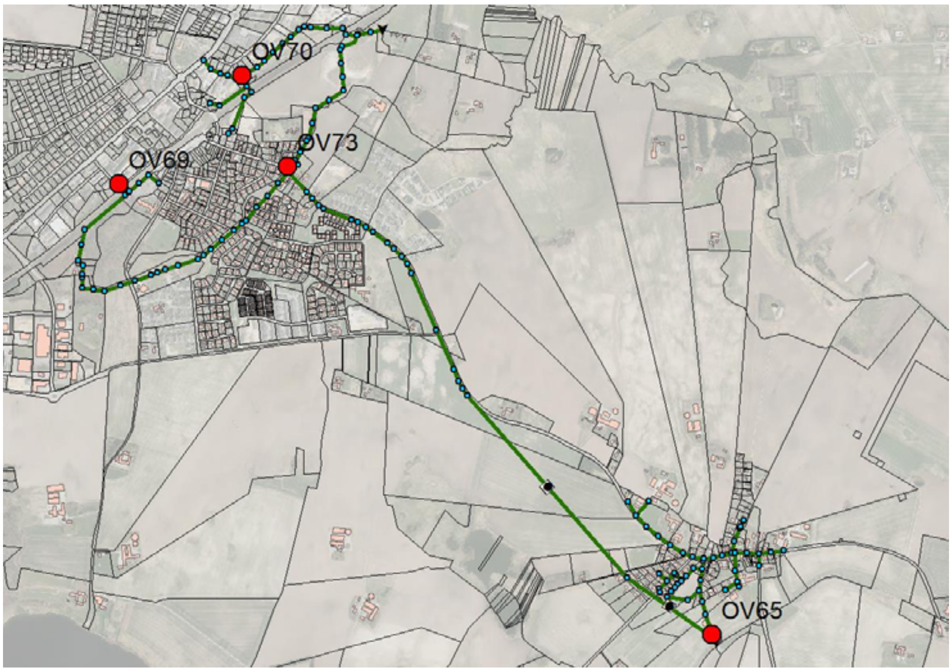


Figure 2. Map of CSOs in the model

2.1.4. Basins

There is one basin connected to the sewer system in Blegind called BLB0140; it is located just after the overflow structure OV65 and pumping station PS208. The outlet from the basin flows into the stream Aarhus Å. The inflow pipe is at the beginning of the left side of the basin and the outflow pipe at the end of the right (Appendix I.3), ensuring maximum settling capabilities of the basin by making the effective route the water must travel the longest possible. The inlet pipe is ø400 and the outflow pipe is ø110. It is not known whether the basin is constructed with a permanent water level. The basin has been observed two times and in both occasions the basin had water in it. To be on the safe side, it is assumed that there is a permanent water level at level 49.00; 0.78 m from the bottom of the basin. The basin has a large crack in the wall effectively reducing the depth of the basin with approximately 0.4 m. This only becomes an issue in case of high-water levels.

Table 4. Data of the basin

Name	Placement	Edge level (m)	Bottom level (m)	Volume (m^3)	Outflow Q (l/s)
BLB0140	Damvej	51.92 (52.32)	49.00 (48.22)	950	25

The numbers in parenthesis are the levels from Skanderborg forsyning webgis. The edge level of 51.92 is 0.4 m lower than the edge level found in the webgis, beacuase of the crack in the side. The bottom level has been raised 0.78 to account for a possible permanen water level. The outflow is calculated by Mike Urban.

2.1.5. Pumping stations

Table 5. Overview of the pumping stations. The information is provided by courtesy of Skanderborg Forsyning. For more information about the functioning of the pumping stations see Appendix I.4.

Name	Placement	Size	Pump capacity		Levels	
		(mm)	(m^3/h)	(l/s)	Start (cm)	Stop (cm)
PS208	Damvej	Ø1500	36	10	70	30
PS209	Søtoften	Ø1500	46.8	13	70	30

2.1.6. Separated areas connected to the combined system

The wastewater from the separated sewer systems in Blegind and Hørning, besides areas A5.5 and A5.6 as mentioned in the chapter above, are excluded from the model. This is done on the basis that these areas contribute very little to the sewer system in times of maximum discharge. To illustrate this, the largest separated system in Hørning, area A1.24, can be examined. The amount of wastewater discharged from this catchment into the combined sewer at peak load is 6.4 l/s (Calculation in Appendix V.3); this value is a worst-case scenario. The flow of sewage in the combined sewer at peak load in the status model with a 10-year-rain event is 75 l/s (Mike Urban network file). The wastewater amounts to 8.5 % of the discharge in the combined sewer, making it insignificant.

2.2. Setup of the model

2.2.1. Missing data

The database from Skanderborg Forsyning provided solid data on the sewer system, thus few assumptions about the sewer system are necessary. The data has been thoroughly checked for mistakes and missing elements to make sure that the model describes the real-world conditions accurately.

In the case of missing bottom levels in a manhole, linear interpolation is used to estimate the level. If terrain levels are missing, Scalgo-Live is used to find the level (Scalgo, 2017). Manholes with bottom levels that are deemed incorrect are also changed by using linear interpolation, taking into account the general slope of the system and of the terrain. In the event of missing diameters of the manholes it is assumed that the diameter is ø1000. If the pipe diameter is missing, the surrounding pipes are used as a guideline.

2.2.2. Accuracy of the model

To adjust the model and accurately reflecting the sewer system, several sensitivity analyses on different parameters have been made using a 10-year CDS rain; no scaling factors are used in any of these simulations. The analyses are in Appendix I.5.

The status model is simulated with a 10-year CDS rain and it is considered accurate when a limited number of manholes is flooding to terrain, since the risk of under dimensioning of the pipes is taken into account.

2.3. Status and plan

2.3.1. Status (No scaling factor used)

The status model shows problems with flooding in the upper parts of the sewer system (Figure 3). The problem is caused by a combination of small pipes and inadequate dimension changes of the pipes (Figure 4). This can be seen by the rapid drop in energy level (marked by blue circles on the length profile).

The basin has vacant capacity with a maximum water level in the status model of 50.20 m, with the edge of the basin being located at level 51.92. If the capacity of the pipes is increased, the result will be a faster discharge to the basin. No problems are found in the sector from Blegind to Hørning, because the three CSOs in Hørning are working as expected and keeping the pipes at capacity.

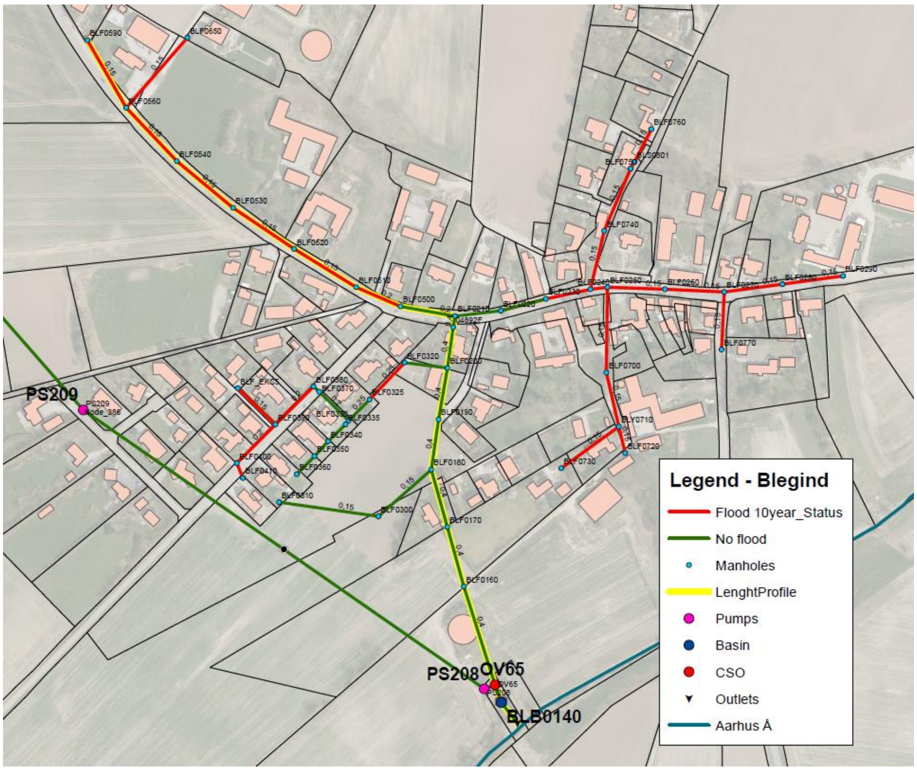


Figure 3. Flood map of Blegind during a 10-year CDS rain with no scaling factor. See full size in Appendix IV.4.

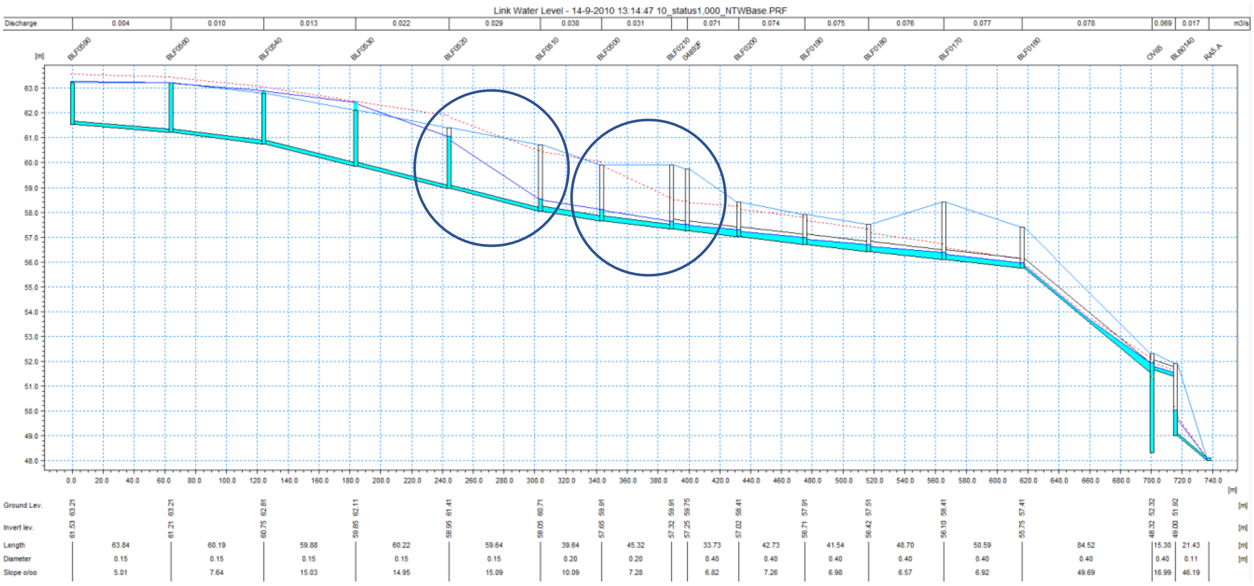


Figure 4. Length profile of BL0590 to RA5.A (outlet) in the status simulation.

The blue circles indicates the choke points of the system. The length profile is shown full size in Appendix IV.7.

2.3.2. Plan (scaling factor 1.716)

The plan model is run with a scaling factor to take future development, uncertainties in the model and changing climate into account. To calculate the scaling factor, each of the uncertainty factors are multiplied.

Table 6. Uncertainty factors used in the plan model.

Uncertainty	**Recommended factor of safety**	**Chosen factor of safety**	**References**
Statistical	1.2	1.2	SVK Skrift 27
Climate factor	1.2-1.4	1.3	SVK Skrift 30
Future development	1.1	1.1	
Total scaling factor		**1.716**	

Requirements

The combined sewer system must be able to handle a 10-year rain event to fulfil the requirements

Table 7. Service requiremnts. (SVK, 2006)

Type of sewer system	**Allowable return period for water at terrain level**
Combined	10 year
Separated	5 year

The picture in the plan analysis is the same as in the status, but the extend of the flooding is greater. Now, flooding problems have moved further downstream and a section of the larger pipes are also flooded. Larger pipes are needed, or the water will need to be delayed, to manage the capacity problems at the choke points. These points are marked with blue circles on Figure 5.

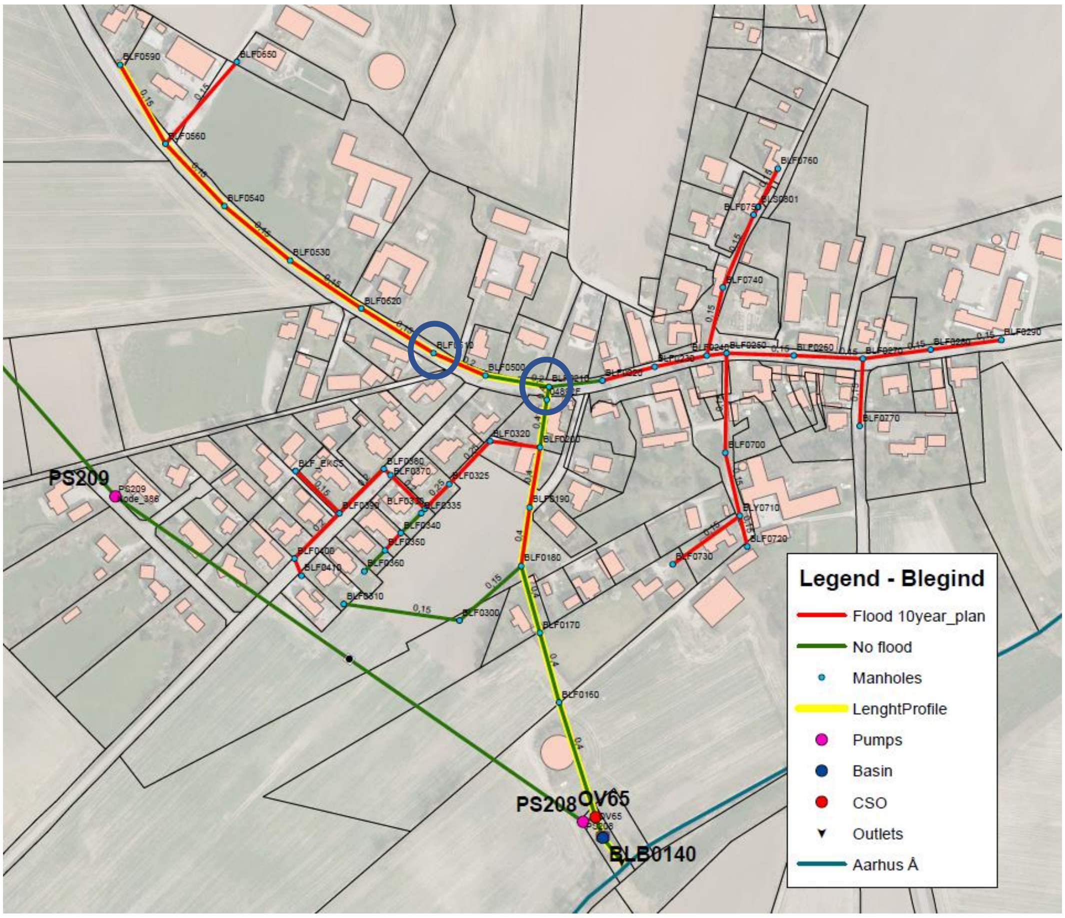


Figure 5. Flood map of Blegind during a 10-year CDS rain with a scaling factor of 1.716.

The blue circles indicate the chokepoints of the system. See full size in Appendix IV.5.

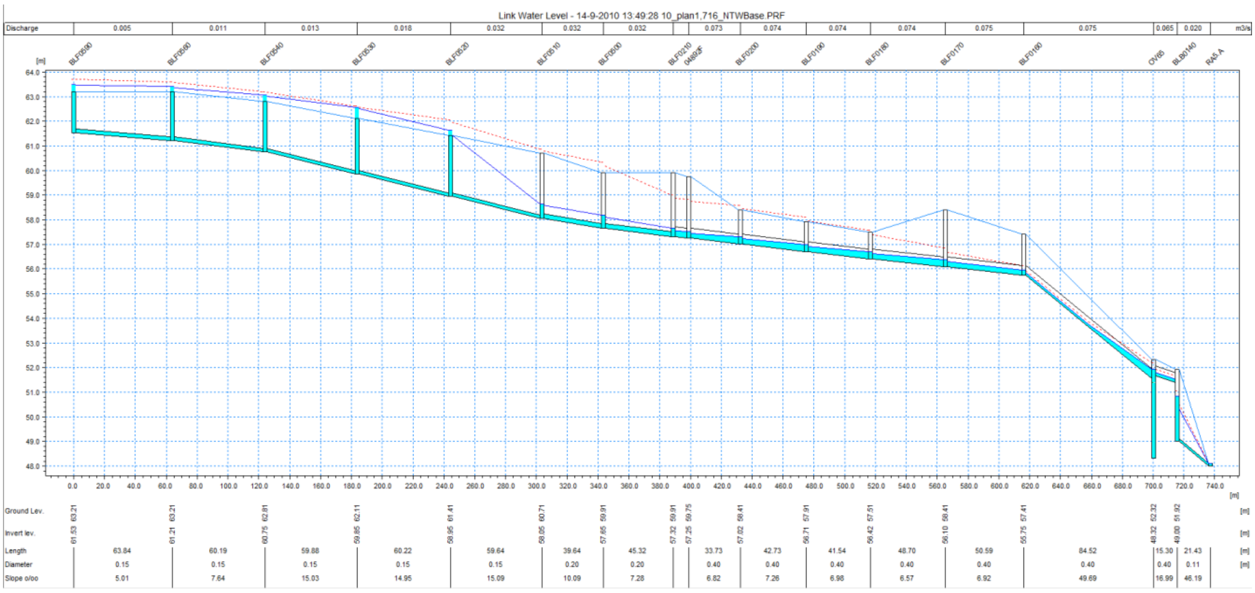


Figure 6. Length profile from BL0590 to RA5.A (outlet) in the plan simulation. The length profile can be seen full size in Appendix IV.8.

2.4. Possible solutions

In the future the extend of the flooding will be greater. The current state of the transport system to Hørning is adequate to handle the future predictions, as long as the CSOs in Hørning continues to operate. The flow from Blegind will only increase if the capacity of the pumping stations in Blegind is increased.

The future predictions indicate major capacity problems in the sewer system of Blegind. In this chapter, three solutions are presented that can solve the issues.

2.4.1. Solution 1: Separate sewer system (classic)

- Two string system - One for rainwater and one for wastewater.
- New basin constructed instead of BLB0140 at Damvej to handle increase in rainwater.
- Existing pumping station PS208 & PS209 will only handle wastewater

New sewer system

A two-string system is constructed, one pipe to handle rainwater and another pipe to handle wastewater.

The rainwater pipes are dimensioned preliminary using the rational method to get an estimation of the required sizes. Subsequently, the pipes are modelled in Mike Urban to make sure that they fulfil the service requirements. A scaling factor of 1.65 is used, because the system will be designed for a 5-year-rain event. As can be seen in Appendix I.6., the new pipes solve the problems of flooding.

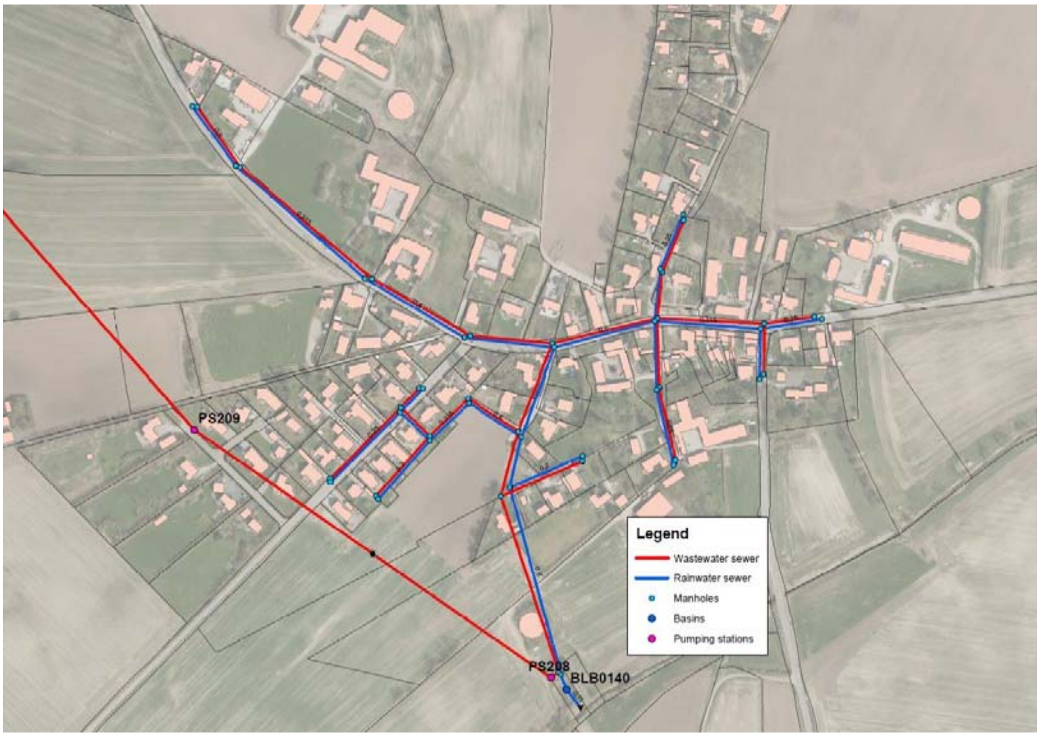


Figure 7. Solution 1- Separated sewer system. See full size in Appendix IV.9.

Table 8. Uncertainty factors used in 5-year CDS rain simulation. Note the difference in climate factor from 1.3 in the plan model to 1.25 in this simulation.

Uncertainty	Chosen factor of safety (5-year-rain)
Statistical	1.2
Climate factor	1.25
Future development	1.1
Total scaling factor	1.65

The wastewater pipes are dimensioned by estimating the amount of wastewater produced per household in the peak hour. The self-cleaning of the pipe is calculated using a minimum flow of 1 l/s. The calculations can be seen in Appendix V.4.

The transport pipe of the new system from Blegind to Hørning will not experience any significant increase in the flow, because the present flow is limited by the pumps. The separated system contributes less to the pumps than the old combined system.

Pumps

The existing pumps will be able to cope with the wastewater transported from Blegind. However, there can be a problem with hydrogen sulphide, because of the long retention time in the pipes and pumping stations. The new wastewater pipes are made of polyethylene, which are more resistant to hydrogen sulphide than concrete pipes, so the main problem is the pumping station (Vollertsen, 2017). It is unknown whether the pumping stations are made of polyethylene or concrete. If they are made of concrete, which is highly susceptible to corrosion, actions will need to be taken to ensure the longevity of the pumping stations. One solution could be to line the walls of the pumping stations with polyethylene to make them more resistant to corrosion (AltomTeknik, 2017). If possible, it might be necessary to operate the pumping stations in a different way to ensure a smaller retention time.

Basin

The increase in rainwater will require a new basin. The old basin is nearly large enough, but as it is in very poor conditions a new one is dimensioned using SVK-spreadsheet (Appendix I.6.1.). To validate that the basin is correctly dimensioned, a Long Term Statistic (LTS) analysis needs to be run in Mike Urban, because of linked rain events.

2.4.2. Solution 2: Separate sewer system (SUDS)

- New wastewater pipes are constructed or old pipes are relined and used.
- Households handle rainwater on their own plot.
- Existing pumping stations will only handle wastewater.

Wastewater

If it is cost-effective to reline the old pipes and keep the old system in use to handle wastewater, this is the preferred method. This will be determined by a CCTV inspection. Calculations should be made to ensure that the pipes are self-cleaning. If this is not the case and the utility company does not want to flush the pipes regularly, new pipes should be constructed. The new pipes will follow the same path as the existing pipes because of the terrain, and because the existing infrastructure to pump the water to Hørning is already in place south of the town.

If new pipes are constructed, the same problems with hydrogen sulphide as described in 'Solution 1' can arise. If the old pipes are used, the effects of hydrogen sulphide might be mitigated. Their diameter is bigger than the one of the new pipes, and a bigger diameter equals less hydrogen sulphide (Vollertsen, 2017). The concrete will be protected by the polyester used in the relining process.

Sustainable Urban Drainage System (SUDS)

Rainwater can be split into two categories: rainwater from road surfaces and rainwater from households.

To handle the water from the roads, it is proposed to construct a wadi along the roads of Blegind. This wadi will be able to store water and let it trickle down into the soil. Furthermore, it will transport the water to the lowest points, where soakaways will be constructed. The alternative solution to this is to have a separate pipe for collecting the water from the road. This solution is not ideal since it defeats the point of SUDS, but it may be more economical.

The rainwater from the households, i.e. roofs, driveways and other impervious areas, can be handled by one of the following structures: soakaways, dry & wet basins, green roofs & walls or storage tanks. All these structures have their advantages and disadvantages; thus, an individual approach must be taken to ensure that the correct solution for each household is chosen. It depends on the amount of space available, aesthetics, condition of the soil and economy.

For the SUDS solution to work, it is paramount that the soil in Blegind can handle the increased amount of water. If the soil is too impermeable, the SUDS solution will not work and one of the other solutions must be chosen. It is possible to offset the effect of a semi impermeable soil by constructing larger storage volumes, delaying the water.

Conclusion

This method has the potential to be very cost effective, but there are many unknowns, for instance the state of the pipes. If the old pipes can be used to handle wastewater, there is no need for digging up the road. If the old pipes are worn down, new pipes will have to be constructed. This will increase costs but futureproof the system. For the wadis to work, the road surfaces need to have the correct gradient to lead the water in the right direction. The modification of the road surface gradient will also increase the cost.

When taking initial costs and future cost into consideration, a detailed calculation will have to be made to determine which solution is the most favourable.

The risk of this project is the unknown condition of the soil. Additionally, there is a risk that citizens do not accept the proposal to handle their own drainage; in that case there is nothing the utility company can do. The utility company must fulfil the service criteria. To persuade the citizens to accept the deal, it is advisable to offer them money amounting to what they would normally have had to pay in connection fee.

2.4.3. Solution 3: Enhancement of existing system

- Bursting to increase hydraulic capacity of pipes (Munck Forsyning, 2019)
- Relining of existing pipes in poor condition
- Decreasing the catchment area

This solution retains the combined sewer system, but upgrades are made to increase the capacity and longevity of the system. Like ‘Solution 2’, a CCTV inspection is needed to outline the state of the sewer system and see if it is feasible to upgrade it. Pipe bursting is used to increase the capacity of the pipe where it is needed. If the pipes have a sufficient size but are in a poor condition, they will be relined. Furthermore, it can be necessary to decrease the amount of rainwater going into the system.

One way to achieve this is to make a deal with some of the citizens to handle the rainwater internally on their own plot. Another possibility is to construct soakaways to manage the water from the roads.

Conclusion

The great advantage of the No-Dig methods is the price. It is cheaper and less disturbing for the citizens than conventional digging. The downside is that the service life is shorter than that of a new system; it will need to be replaced sometime in the future. Furthermore, it does not solve the issue of sewage flowing into Aarhus Å when there are heavy rains.

2.5. Conclusion

In its present state the sewer system does not fullfil the service requirements. It is also clear that a further increase in capacity is needed to deal with climate change. The plan calculation of the hydraulic capacity shows that few pipe sections are able to cope with the future increase in runoff.

Although the status calculation do not live up to the service requirements, it is not demanded to upgrade the system. It is only in the event of major upgrades to the system that the requirements must be met. Nonetheless, the future predictions do raise cause for concern, and actions ought to be taken within the near future.

It is strongly reccomended to perform a CCTV inspection of the sewer system to outline the condition of the system. Then it is possible to outline the urgency with which a future plan must be made. If the condition of the sewer system is poor, it is recommended to initiate ‘Solution 1’ as soon as poosible.

‘Solution 1’ is the plan to construct a separate sewer system in Hørning, utilising the existing pumping station and upgrading the existing basin to handle more rainwater. The new separated sewer system will futureproof Blegind and will make it able to withstand climate change.

3. WASTEWATER TREATMENT PLANT

For more information about this section of the report, see Appendix II. In here calculations will be presented.

The Wastewater Treatment Plant (WWTP) is located in the North-Eastern part of Hørning. The WWTP purifies the wastewater and stormwater of Hørning and surroundings and operates according to the OCO method. The OCO method means that the process tank is divided in three zones, under different conditions (anaerobic, anoxic and aerobic), in order to remove nitrogen. The WWTP has received updates throughout the years, most notably in 2016, when a new clarifier was installed.

In this chapter a description of the WWTP of Hørning will be given. At first, an overview of the plant will be given and the elements of the plant will be explained. Second, a technical description will provide the data to calculate the key process parameters. Third, the vacant capacity will be calculated using the key process parameters and the denitrification rate obtained by laboratory work. At last, a suggestion will be given for the improvement of the WWTP, taken in account the future predictions.

3.1. Plant Description

A brief description of the WWTP and the parts that form the plant is shown.

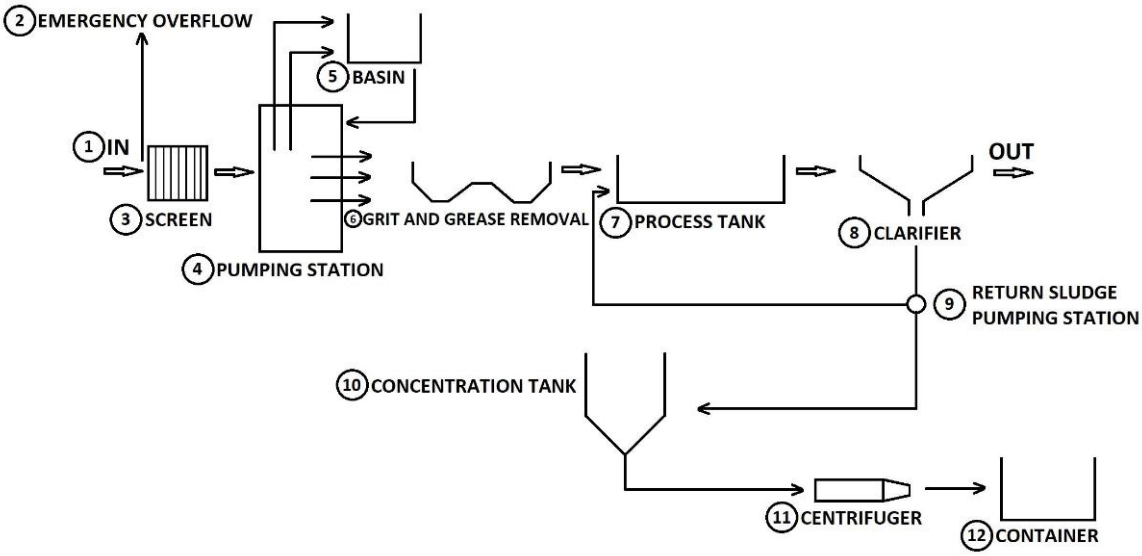


Figure 8. Diagram of the Wastewater Treatment Plant

3.1.1. Inlet flow

The inlet flow to Hørning's WWTP runs through a gravitational pipe running from the southern to the northern part of the town. In the dry season (April to September) the minimum inlet flow is 1146

m^3/d, while in wet season (October to March) the minimum inlet flow is 1224 m^3/d. The average dry weather flow is estimated to be 1725 m^3/d.[1]

3.1.2. Emergency Overflow

The emergency overflow is a structure used to protect the plant in case of large rainfall events. The emergency overflow activates when the capacity of the basin is reached.

3.1.3. Screen

The screen ensures mechanical removal of large physical objects that can cause damage to the following elements of the WWTP.

3.1.4. Pumping Station

The pumping station is a rectangular structure including five pumps. Three of them pump the water to the grit and grease removal chamber. The other two are used during large rainfall events to pump the storm water to the basin, where the water is stored until there is vacant capacity to reintroduce it to the wastewater treatment process.

Prior to October 2016 the capacity of the pumping station was 200 m^3/h. In October 2016 the new clarifier started operating and the capacity of the pumping station was increased to 380 m^3/h.

3.1.5. Basin

The storm water storage tank or basin is located just before the start of all the process, and it is used to store the excess of water in case of large storm and rainfall events. The data of the basin is shown in Table 9. (Maribo, Basin Data, 2017)

Table 9. Basin dimensions of Hørning WWTP

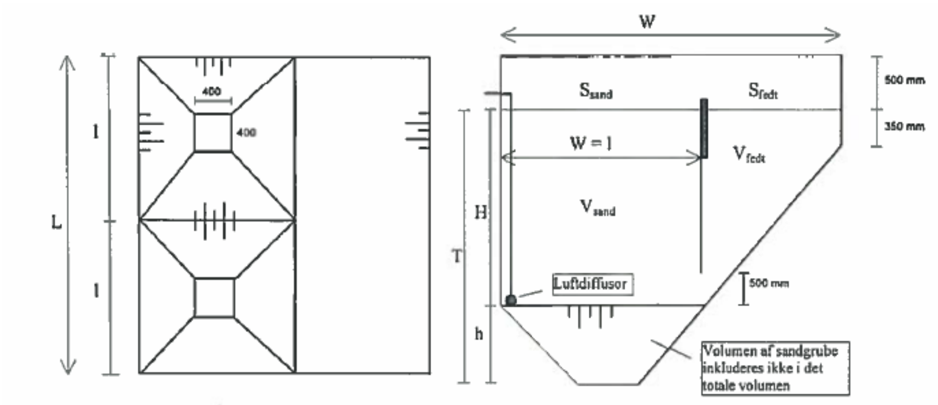
Inner diameter of outer wall	$Ø_{SHT}$ = 18.06 m
Total tank depth	$H_{SHT,tot}$ = 5.00 m
Effective tank depth	H_{eff} = 4.70 m
Tank volume	V_{SHT} = 1200 m

3.1.6. Grit and Grease Removal Chamber

The grit and grease removal chamber ensures mechanical removal of stones, grit and sand, which can form permanent deposits at the bottom of the process tank. The removal is carried out by airlift pumps.

[1] Values obtained using the given data from 2012-2015.

The structure is designed for a removal of 95 % of the sand particles larger than 0.2 mm during a flow of 150 l/s. The applied structure is shown in Figure 9.



Type	l m	L m	W m	H m	h m	S_{sand} m^2	S_{fedt} m^2	V_{sand} m^3	V_{fedt} m^3
44	3,10	6,20	5,05	2,30	1,35	19,20	12,10	44,20	16,00

Figure 9. Grit and grease removal structure of Hørning WWTP

3.1.7. Process Tank (OCO Tank)

The process tank is where the biological removal takes place. The tank is divided into three different zones:

Zone 1, anaerobic zone: an agitator mixes the water with activated sludge and the microbes contained in the sludge create easy degradable matter (complex organic matter is broken down into smaller organic compounds) needed for the nitrification that will happen later.

Zone 2, anoxic zone: in this zone denitrification takes place. The level of oxygen is low; therefore, micro-organisms use nitrate as an oxidizing agent to decompose organic matter. An agitator will make the water run in circles, moving the water from this zone to zone 3.

Zone 3, aerobic zone: in this zone nitrification takes place. Ammonia and organic nitrogen are transformed into nitrate. Another agitator will move the water in this zone.

The air to the OCO tank is supplied by three blowers with the following characteristics

- *First blower:* It has a motor of 11 kW that supplies 540 N·m^3/h.
- *Second blower:* Consists in a two-step motor of 23/34 kW supplying 540/900 N·m^3/h.
- *Third blower:* 22 kW motor supplying 1140 N·m^3/h.

The dimensions and a layout are shown in Table 10 and Figure 10. (Maribo, Basin Data, 2017)

Table 10. OCO tank dimensions of Hørning WWTP [2]

Inner diameter of the outer tank	Ø1 = 34.6 m
Inner diameter of C - wall	Ø2 = 25.5 m
Inner diameter of the anaerobic tank	Ø3 = 13.6 m
Total tank depth	$H_{tot,OCO}$ = 4.0 m
Effective tank depth	$H_{eff,OCO}$ = 3.60 m
Total Volume	V_{OCO} = 3385 m^3
Anaerobic volume	V_{AN} = 523 m^3
Aerobic volume + anoxic volume	V_{N+DN} = 2862 m^3

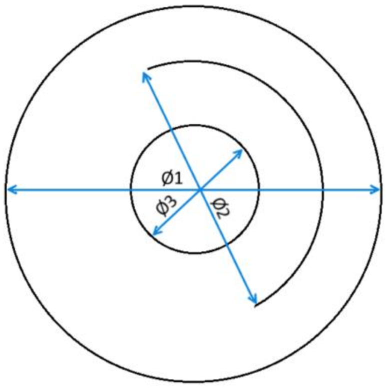


Figure 10. Layout of the OCO tank of Hørning WWTP

3.1.8. Clarifier

In the clarifier the sludge settles and the purified water is extracted. The dimensions of the new clarifier are shown in Table 11. (Maribo, Basin Data, 2017)

Table 11. Clarifier dimensions of Hørning WWTP

Inner diameter of outer wall	$Ø_{ET}$ = 28.3 m
Total tank depth	H_{tot} = 4.22 m
Effective tank depth	H_{eff} = 3.70 m
Tank area	629 m^2
Tank volume	2327 m^3

[2] As the calculated volumes using the diameter and the effective depth did not match the given values of the volumes, the calculated values were used.

3.1.9. Return Sludge Pumping Station

The return sludge pumping station consists of one pump that elevates the excess sludge from the clarifier to the process tank and to the concentration tank.

3.1.10. Concentration Tank

The concentration tank is used in the dewatering process of the excess sludge; separation of water and sludge is carried out by gravity.

3.1.11. Centrifuge

The centrifuge removes the remaining water content from sludge by rotating it at high speed. After the centrifuge has completed its process, dry sludge is placed in containers.

3.1.12. Container

Containers are used for storage of the excess sludge taken out from the clarifier. The sludge is collected and used as fertilizer on fields or taken to land fields. (Skandeborg forsyningsvirjsomhed, 2017)

3.2. Key Process Parameters

In this chapter, the actual performance of the WWTP is studied by calculating the most significant parameters. The determined values of the key process parameters of the WWTP are shown. The calculations can be found in Appendix II of the report.

3.2.1. Requirements and plant performance

In Table 12., the requirements for EU sensitive areas, Hørning's WWTP requirements and the calculated average outlet values can be observed. The values that did not fulfil the requisites are coloured in red.

Table 12. EU requirements to sensitive areas (c.f.EEC/91/1271). Danish requirements specified in statutory order 501/1999 (Maribo, WT 1 Introduction, 2018)

	EU requirements	Denmark requirements	Hørning requirements	2013	2014	2015	2016	2017
BOD (mg/l)	< 25	< 30	< 10	4.6	3.4	4.0	7.8	1.9
COD (mg/l)	< 125	< 75	< 75	29.8	24.5	28.0	27.2	20.4
SS (mg/l)	< 35	< 15	< 8	9.3	7.1	13.0	7.8	5.3
TN (mg/l)	< 15	< 8	<8	4.1	2.9	2.8	4.7	3.5
TP (mg/l)	< 2.0	< 1.5	< 0.4	0.4	0.2	0.3	0.3	0.1

3.2.2. Temperature

For 2012 Solbjerg's, suburb next to Hørning, temperature data is only available and it is represented in Figure 11 (Maribo, Wastewater temperatures, 2014). However, Hørning's data is accessible in 2017; it is shown in Figure 12. In both cases the average temperature is around 12 ºC.

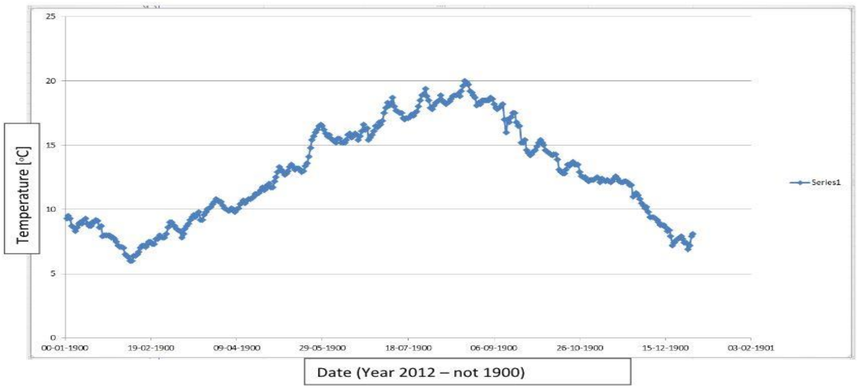


Figure 11. Temperature in Solbjerg in 2012

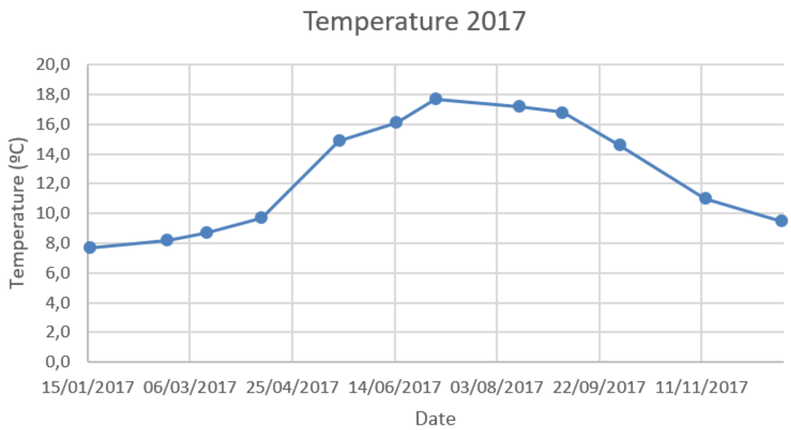


Figure 12. Temperature in Hørning in 2017

3.2.3. Clarifier

Solids loading rate

The relation between the suspended solids entering the clarifier, inlet flow and return flow, and the surface area of the clarifier is called solids loading rate (SLR).

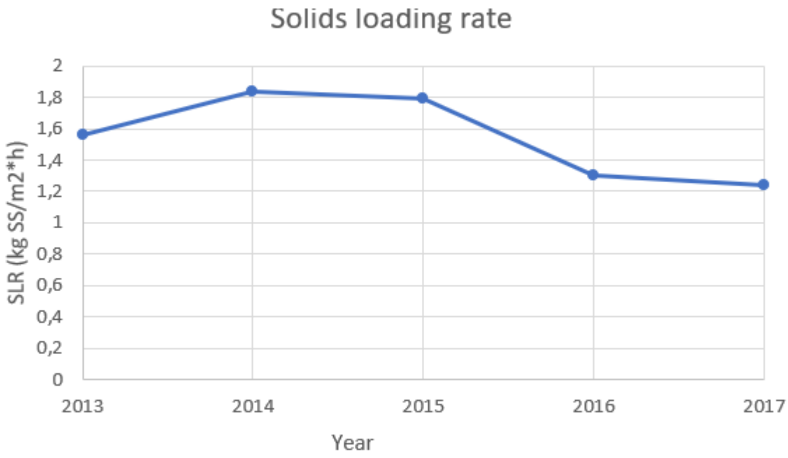


Figure 13. Solids Loading Rate evolution

The results are within the average typical values for a plant of this type. (Maribo, WWTP Chap 5.7-5.8 p61, 2018)

Overflow rate

The overflow rate (OR) describes the settling characteristics of solids in a specific wastewater. It does not depend on the return sludge flow.

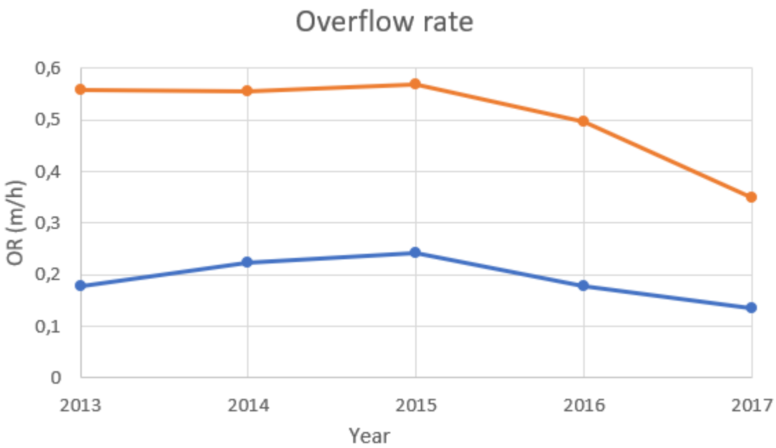


Figure 14. Comparison between average Overflow rate and maximum Overflow rate

The lower the rate, the smaller the particles can be settled out and removed from the plant. Figure 14. suggests that the values got lower since the new clarifier was installed (2016), which shows that the clarifier is well prepared for particle removal.

Hydraulic retention time

The hydraulic retention time is defined as a measurement of how much time the wastewater spends in the tank.

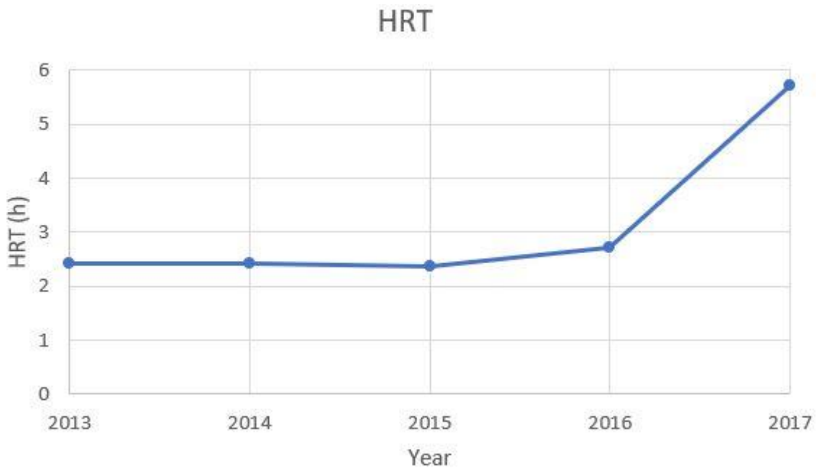


Figure 15. Development of the Hydraulic Retention Time

As it can be appreciated in Figure 15., the hydraulic retention time complies with the requirement of 1.4 hours (Maribo, Chap 5.1-5.3 Mechanical purification, 2018); it is around 2 hours to 5 hours. It should be mentioned that the huge increase in retention time of 2017 can be attributed to the installation of the new clarifier.

Sludge volume index

The sludge volume index (SVI) is used to describe the settling characteristics of the sludge in the aeration tank and it is a parameter to determine the recycling rate of the sludge.

The common range for an SVI at a conventional activated sludge plant should be between 100 ml/g and 120 ml/g, occasionally up to 150 ml/g, the optimum SVI has to be determined for each plant experimentally (Maribo, Chap 5.1-5.3 Mechanical purification, 2018) . Sludge with a low SVI has good settling characteristics.

Although all the years seem to have their biggest peaks during the wet season, when there is more precipitation, the levels tend to be under 150 ml/g, except for 2015, which has very high levels. The main explanation for this may be that due to the malfunctioning of the old clarifier, a new one was built in 2015, but it was not taken into operation until October 2016, where the values seem to be under control again. Finally, to calculate the SVI the average value of the X_A is used.

Variations of the sludge volume index during the years are shown in the following graphs, from 2012 to 2017. In the report some of the graphs are presented, the rest of them are in the Appendix II.

Figure 16. Sludge Volume Index from 2012-2013

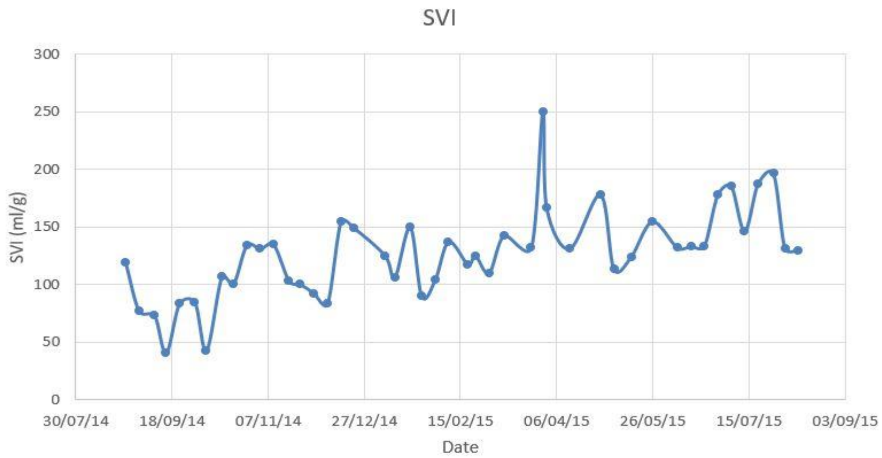


Figure 17. Sludge Volume Indez from 2014-2015

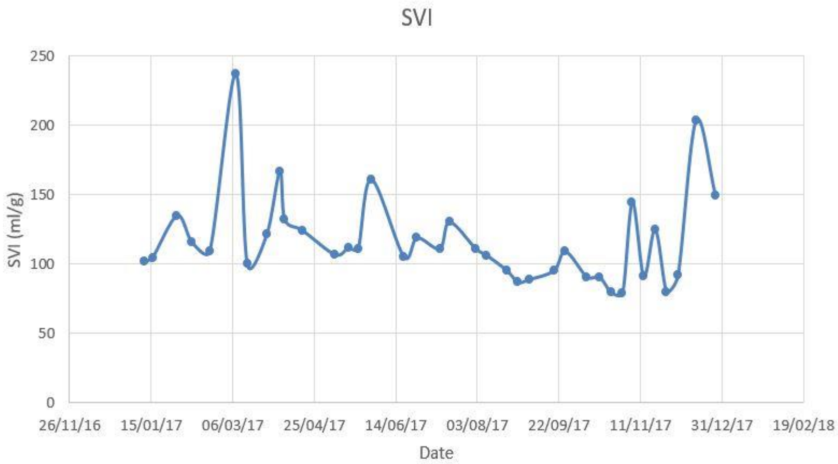


Figure 18. Sludge Volume Index from 2017

3.2.4. OCO tank

Purification efficiency

The degree of purification efficiency is expressed by the amount of compounds, chemicals, suspended solids and biological matter, removed from the wastewater entering the WWTP. The degree of purification for the BOD, COD, TN and TP can be observed in Figure 19.

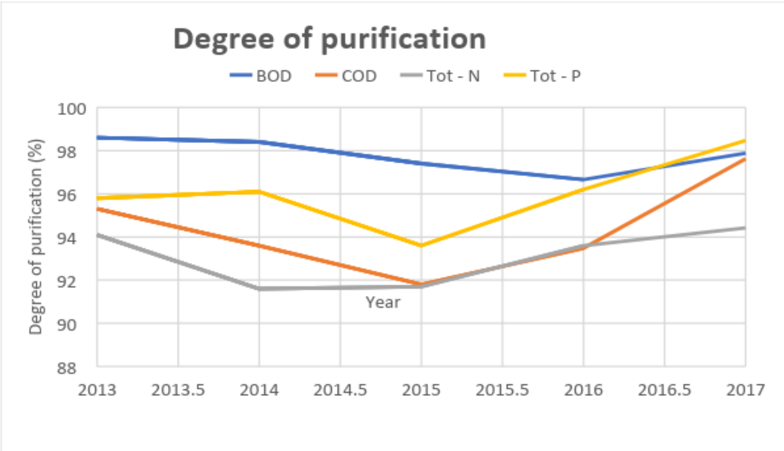


Figure 19. Representation of the Degree of Purification

As it can be appreciated, the purification efficiency is high, among 91 % to 99 %, this means a good removal capacity.

F/M ratio

The food to microorganism ratio, F/M ratio, is used to analyse if there are enough microorganisms in the aeration tank to remove the incoming organic matter and to control the activated sludge process. The F/M ratio and the degree of purification are inversely proportional, when the F/M ratio is high the degree of purification is low and vice versa.

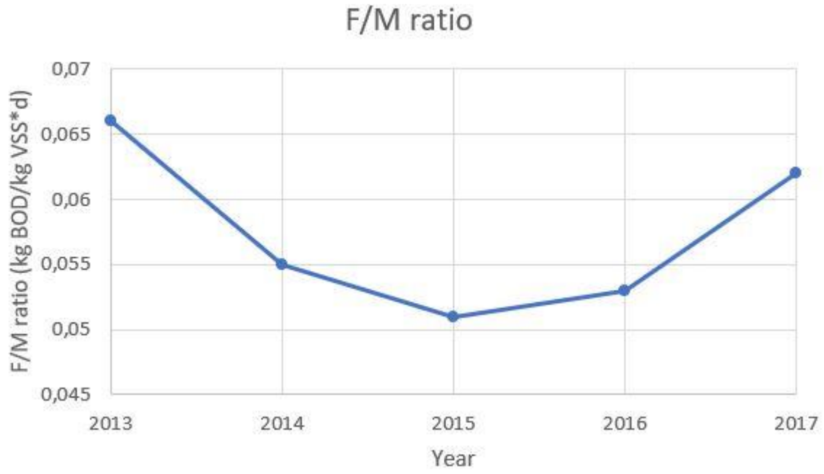


Figure 20. Variation of the average F/M ratio

In Figure 20., it can be observed that the F/M ratio is maintained in low loading, between 0.0-0.3 kg BOD/kg VSS*d, so large amounts of higher microorganisms will be present in the plant (Maribo, WWTP Chap 6. Biological purification processes, 2018). This also means that the sludge will contain small amounts of biodegradable organic matter.

COD/BOD ratio

The COD/BOD ratio is a good indicator of the biodegradability of the organic matter, because the higher the ratio the more difficult to degrade it. In this case, for 2013, 2014 and 2016 is in the low ratio, 1.5 – 2.0, while in 2015 is in the typical ratio, 2.0 – 2.5, and in 2017 is in the high ratio, 2.5 – 3.5. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

Table 13. Calculated COD/BOD ratios

Year	COD/BOD
2013	1.868
2014	1.797
2015	2.222
2016	1.799
2017	3.029

Even though last year's data reveals a high ratio, it can be assumed that the plant has a relatively low COD/BOD ratio; this means that it will be easy to degrade the organic matter of the plant.

Sludge production

Every day sludge is removed from the plant in order to maintain a constant sludge quantity. Some of the sludge leaves the plant with the purified wastewater and another part is removed as excess sludge.

Sludge production can be divided into two types, biological sludge production and chemical sludge production.

When nitrogen, phosphorus and organic matter are removed from the sludge by biological purification, it is called biological sludge production. While chemical sludge production involves the removal of sludge by the addition of chemical agents, in the case of the plant iron chloride or iron sulphate, often in combination with a purification process. (Maribo, WWTP Chap 7. Chemical Wastwater purification, 2008)

Figure 21. shows the relation between the total sludge production, the biological sludge production and the chemical sludge production.

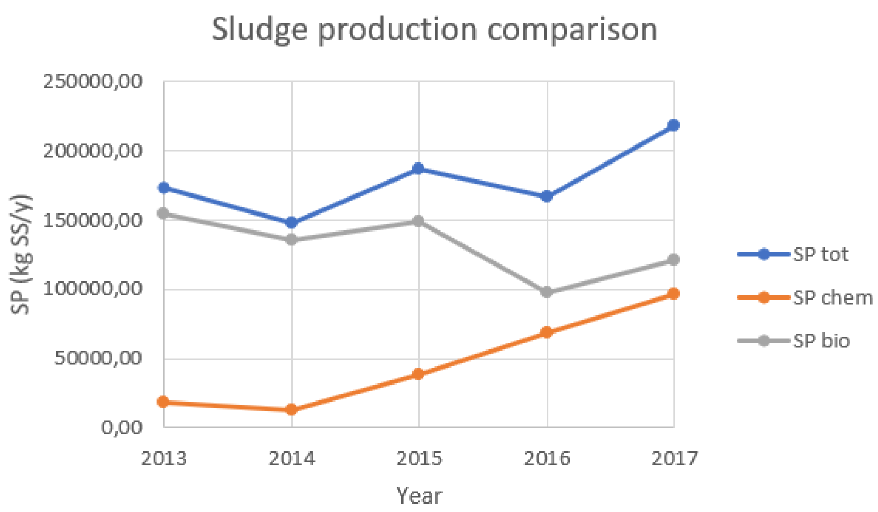


Figure 21. Comparison between the total SP, the biological SP and the chemicial SP

As it is observed, the tendency of the total amount of sludge production is getting bigger year by year, as the population has increased and more load is entering the plant.

Excess sludge production

The sludge quantity discharged by the pumps from the activated sludge plant, forming the base for the sludge treatment, is called excess sludge production (ESP).

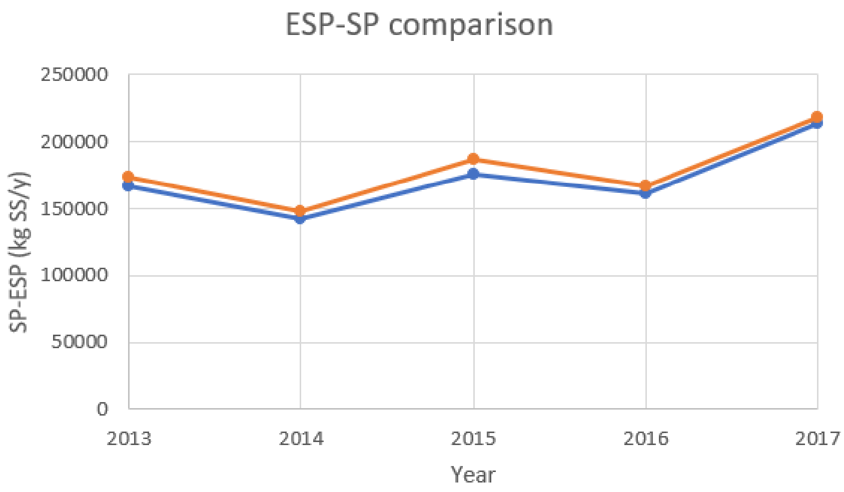


Figure 22. Comparison between the total Sludge Production and the Excess Sludge Production

In Figure 22., it can be perceived that the outlet quantity of sludge remains almost constant.

Yield constant

The total yield constant expresses the growth of microorganisms which result from the degradation of organic matter in wastewater.

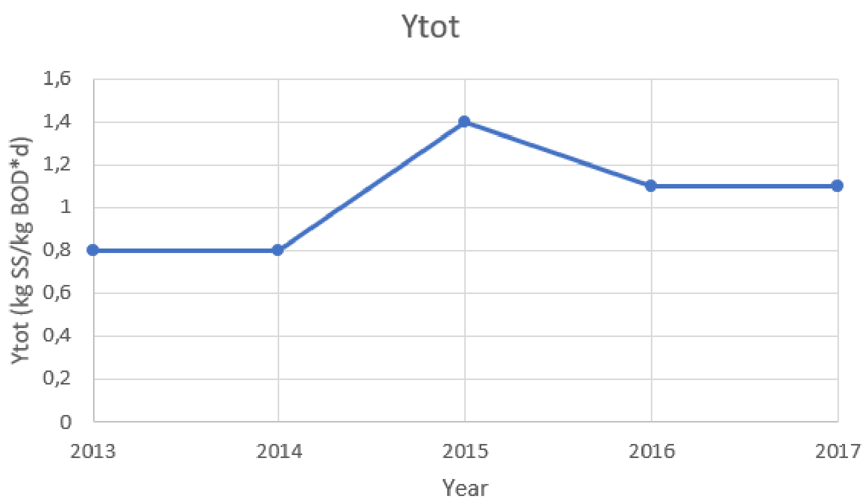


Figure 23. Calculated values for the Yield constant

If the values of the F/M ratio obtained before are compared to Table 14., a value of the yield constant between 0.6-1.1 kg DM/ kg BOD would be necessary. This makes sense with the obtained values for the yield constant.

Table 14. Connection between the F/M ratio, DP-or removal of organic matter- and the yield constant. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

F/M ratio [kg BOD·kg VSS^{-1}·d^{-1}]	Notation	DP for BOD [%]	Y_{tot} [kg DM/kg BOD]
0.0 – 0.3	Low loading	90 – 98	0.6 – 1.1
0.3 – 0.6	Intermediate loading	85 – 90	1.0 – 1.3
0.6 – 5	High loading (or: biosorption)	50 – 85	1.3 – 1.0

Sludge age

Sludge age is defined as the average time in days the suspended solids remain in the entire system.

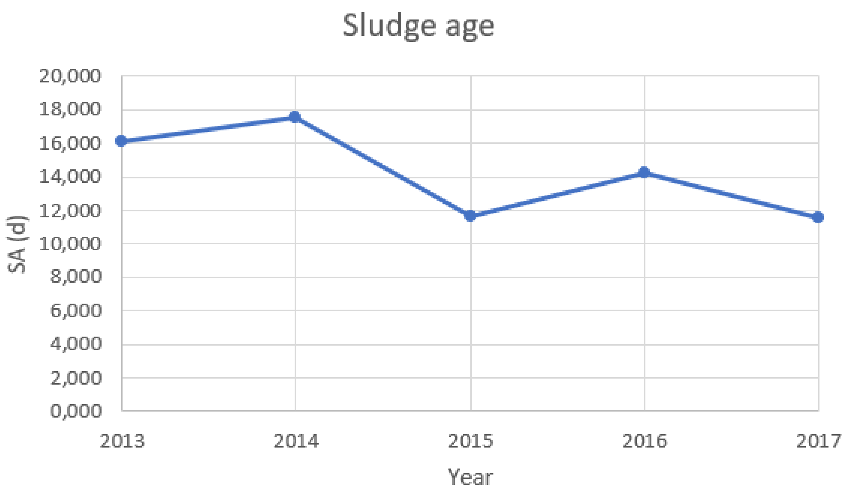


Figure 24. Evolution of the aerobic Sludge Age

If Figure 21. and Figure 24. are compared, it can be appreciated that the sludge production and the sludge age are inversely proportional, so when the sludge production grows the sludge age decreases and vice versa. The sludge age is kept between 10-14 days, which for the actual conditions will probably ensure nitrification. Nevertheless, some solutions could be found, such as making the aerobic volume bigger, to get a longer sludge age and make sure nitrification is going to take place.

Return sludge rate

The flow of sludge returned to the aeration tank from the settling tank is called return sludge rate (R).

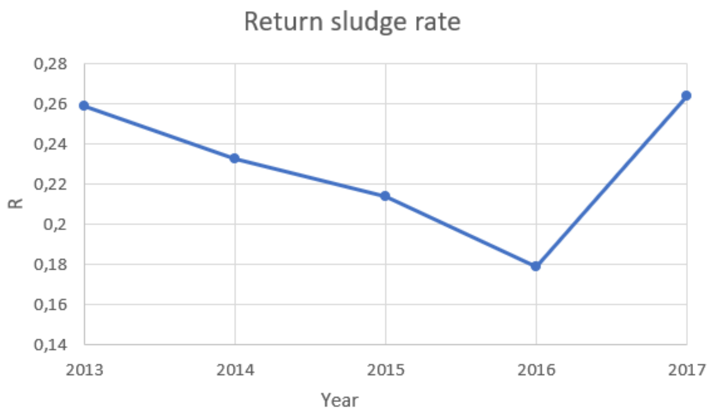


Figure 25. Variation of the return sludge age

Denitrification

During the denitrification the nitrate-nitrogen is converted into gaseous atmospheric nitrogen. When talking about denitrification the COD/TN ratio is important; if the ratio is high the denitrification process will be quick. However, a low ratio will mean a slow process and that it may be necessary to add external carbon sources.

Table 15. Calculated COD/TN ratios

Year	COD/TN
2013	10.000
2014	10.849
2015	9.444
2016	9.506
2017	15.053

In 2013, 2015 and 2016 the COD/TN ratio is in the low ratio range, 6 to 10 kg COD/kg TN, so the process will be slow and external carbon sources could be necessary. Nevertheless, in 2014 and 2017 the COD/TN ratio is in the high ratio range, 10 to 14 kg COD/kg TN, then a quick denitrification process by using the content of organic matter in the raw wastewater may take place. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

Denitrification rate

The denitrification rate is dependent on the organic matter that is included in the reaction. The obtained values for the denitrification rate are represented in Figure 26.

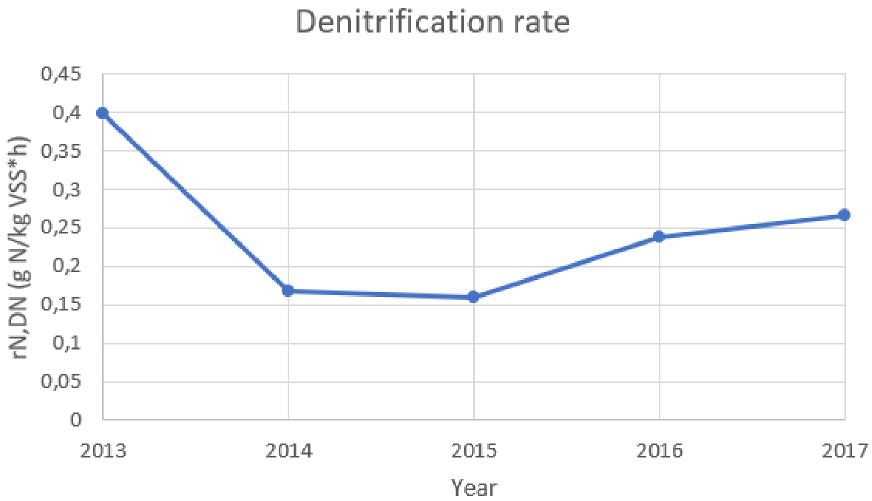


Figure 26. Evolution of the Denitrification rate

The WWTP of Hørning works using carbon from the raw wastewater. Comparing the results with Figure 27., such low rates suggest that the plant can work in very low temperatures. Therefore, the rate could be augmented in order to get more denitrification. Nevertheless, the plant fulfils the outlet requirements.

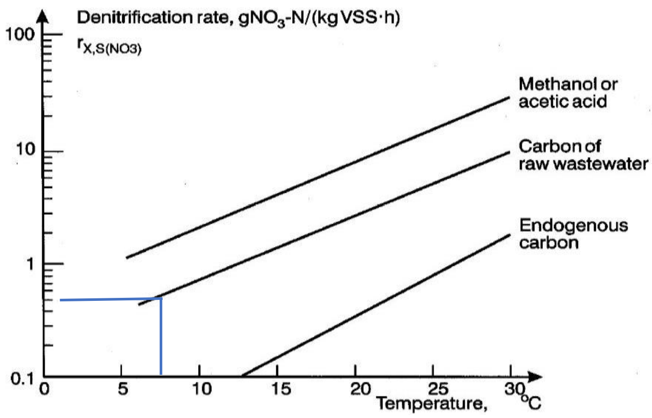


Figure 27. Relation between carbon source for denitrification, temperature and denitrification speed. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

Phosphorus removal

Phosphorus is one of the main components of the sludge, and the removal of it is important in order to avoid eutrophication. Eutrophication consists of the enrichment of bodies of water with minerals and nutrients that could provoke excessive growth of plants and algae. (Wikipedia, 2018)

The phosphorus can be removed from the WWTP in two different ways, chemically and biologically.

The enhanced biological phosphorus removal (EBPR) consists of the extraction of phosphorus by using a special group of bacteria called Phosphate Accumulating Organism (PAO).

Nonetheless, chemical precipitation of phosphorus lies in the addition of a chemical compound, in the case of Hørning iron chloride or iron sulfate, that reacts with the dissolved phosphate, usually found as PO_4^{-2}, to form highly insoluble salts.

To measure the probability for biological phosphorus removal the COD/P ratio is obtained.

Table 16. Calculated COD/P ratios

Year	COD/P
2013	63.821
2014	64.604
2015	68.004
2016	66.749
2017	114.788

Calculated values are over 40, so good chances for efficient biological removal of phosphorus are assumed. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

Figure 28. represents the total amounts of iron phosphorus and solution in the WWTP.

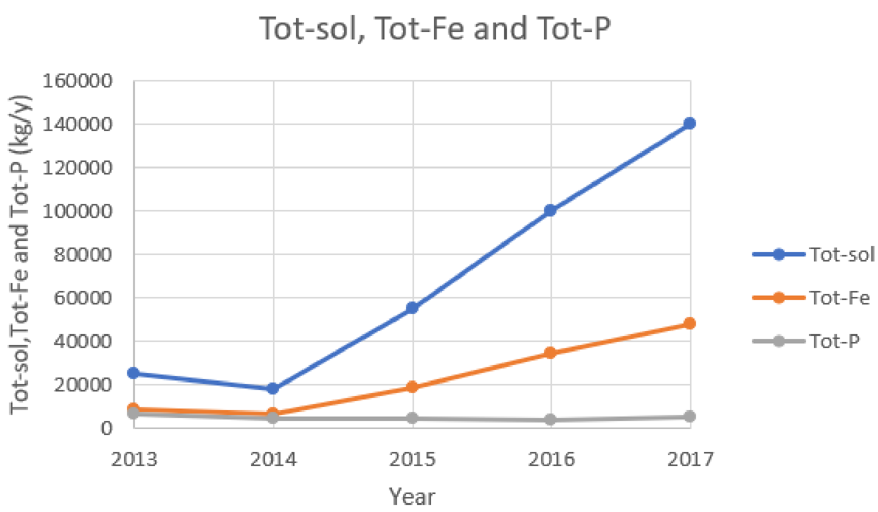


Figure 28. Comparison between total phosphorus, total solution and total iron

Oxygen requirements

Activated sludge plants usually have an oxygen requirement that can be divided into three main groups.

Table 17. Oxygen requirements definition

L_{BOD}	Oxygen used for the decomposition of organic matter
L_N	Oxygen used for nitrification
L_{DN}	Reduction in oxygen consumption due to denitrification

In a WWTP where nitrification takes place, the remaining part of nitrogen will be oxidized to nitrate in the nitrification process.

The denitrification process removes a part of the nitrate in water, as the nitrate acts as an oxidizing agent the oxygen requirement is reduced.

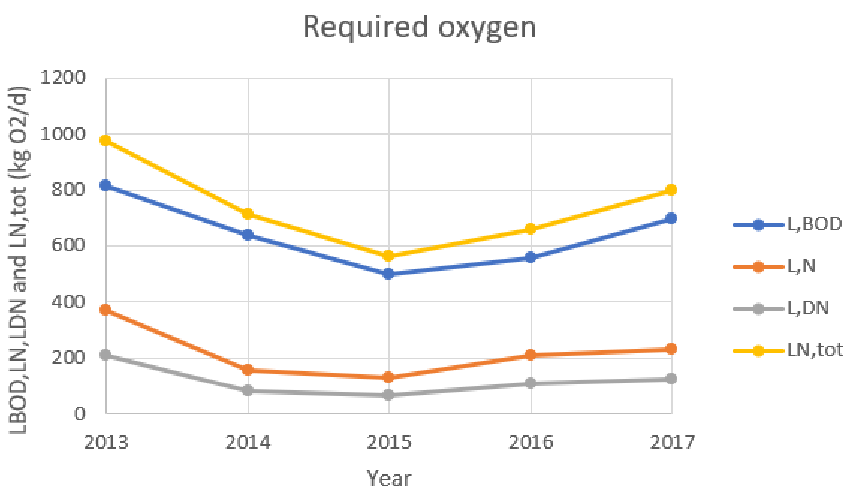


Figure 29. Comparison between LBOD, LN, LDN and LN,tot

Aeration system

The capacity of the aeration system is given by the manufacturer under standard conditions, but in the WWTP the conditions are different, so the capacity gets reduced.

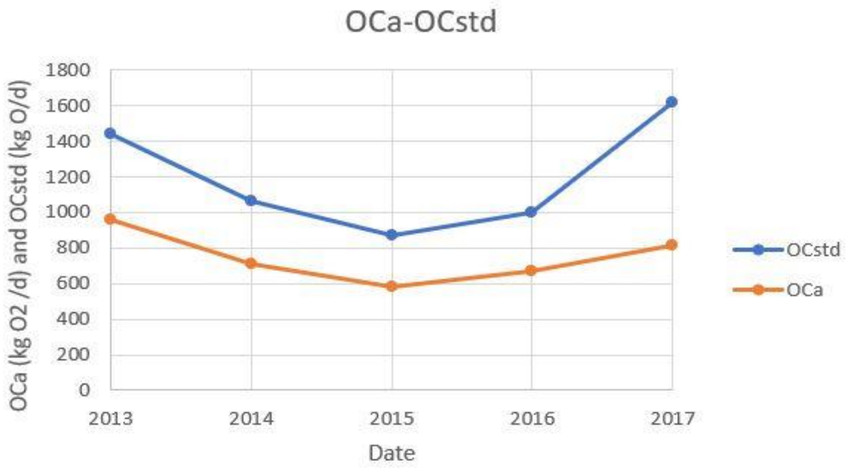


Figure 30. Comparison between OCstd and OCa

As it can be observed in Figure 30., the oxygenation capacity at actual conditions is lower than the oxygenation capacity at standard conditions, which means that the plant is working in a correct way.

3.3. Denitrification Rate

For more information about this section of the report, see Appendix II.5. In here the page used during the experiment to collect data will be presented. Moreover, the method step by step with pictures will be showed.

The objective for the experiment is to get an understanding of the denitrification process. Analysing the samples will give key parameters for calculating the denitrification rate. The denitrification rate is useful to determine the capacity of the wastewater treatment plant in Hørning.

It is assumed that the denitrification process of the wastewater treatment plant in Hørning will be fast. The average kg COD/kg TN ratio obtained from the years 2012 - 2017 is 11, which means a high ratio (10-14 kg COD/kg N). This offers good chances for a quick denitrification process by using the content of organic matter in the raw wastewater. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

If the assumption is correct, then the outcome of the experiment will give a quick denitrification process.

The experiment was carried out in the biology laboratory of the faculty of engineering of the Aarhus University during the month of November of 2018.

3.3.1. Materials and Methods

1. Equipment
    - Weigh and dryer unit, Kern D85

    - Spectrophotometer, GR-tech Instrument® model 752N

    - Vacuum filtration system

    - Measuring cylinder, 1000 ml

    - Volumetric flask, 100 ml

- Beaker, 100 ml

- Test tube, plastic

- Wash bottle, plastic

- Funnel

- Stirring device

- Thermometer

- Pipette, 1 ml and 0,2 ml

- Syringe, 10 ml

- Syringe filter

- Filter paper,syringe filter

- Filter paper

- Weighing dishes

- Forceps

- Digital scale

- Timer

2. Substances
    - Demineralised water

- Sodium Nitrate ($NaNO_3$)

- Nitrate-Nitrogen TNTplus vial test (0.23 - 13.2 mg/l N), HACH chemicals type LCK 339

3. Samples

Table 18. Samples taken at the WWTP

Sample	Description
RWW	Raw wastewater
AS	Activated sludge

Both samples were collected the 20th of November of 2018 at 8.35am.

4. Method [3]

One litre of the activated sludge sample (AS) was taken and put into a one-litre measuring cylinder. Sedimentation will occur and after approximately 20 minutes, when half of the total sludge volume was settled, the water was taken out and filled up with the raw wastewater sample (RWW) to one litre. It was slightly stirred and left under anoxic conditions. The temperature and PH of the one litre sample were measured.

A $NaNO_3$ solution of 100 ml was prepared by obtaining a concentration of approximately 1 g N/l. 10 ml of this solution was added to the one liter sample and slightly stirred. Directly after the 10 ml of the $NaNO_3$ solution was added, the first sample of 5-6 ml was taken. The sample was filtered and put into a test tube and numbered as C0. This sample was the starting concentration of NO_3-N in the one litre sample.

The amount of samples needed was estimated by using the calculated denitrification rate for the years 2012-2017, which resulted in seven samples with an interval of 5, 10 or 15 minutes. After the last sample the temperature was measured again.

The samples were analysed by using the Nitrate-Nitrogen TNTplus vial test (0.23 - 13.2 mg N/l). After 15 minutes, according the user manual, the sample was put into the spectrophotometer and an amount of mg N/l was given.

A control experiment had been done to obtain more accurate data. The method of this control experiment was similar to the method written above, yet a concentration of approximately 1.3 g N/l was used.

Simultaneously with analysing the samples for the denitrification rate the suspended solid concentration was measured. A sample of 50 ml of the AS sample was taken. With the use of a vacuum filtration system the sample was filtered and the suspended solids remained on the pre-dried filter paper. The filter paper was dried by a weigh and dryer unit and an amount of g SS/50 ml was given. This was repeated three times.

[3] For further information see Appendix II.5.2. and II.5.3.

3.3.2. Results

1. Temperature and pH value

The temperature measured before taking the samples was 18 degrees Celsius and after the sampling 20 degrees Celsius. The pH value of the one liter sample was 7, which means neutral acidity.

2. NO_3-N concentration

The measured NO_3-N concentrations are displayed in Table 19 and shown in Figure 31. Experiment started the 20th November of 2018 at 10.30am.

Table 19. Measured NO_3-N concentrations per time interval

Name	Time interval in hours	NO_3-N concentration (mg/l)
C0	00:00	9.92
C1	00:10	7.77
C2	00:25	3.84
C3	00:40	2.11
C4	00:55	0.48
C5	01:10	0.25
C6	01.25	0.38
C7	01:40	0.48

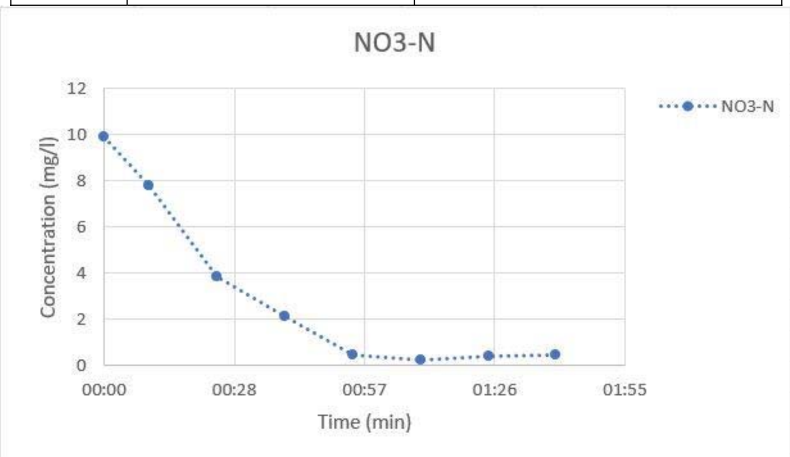


Figure 31. Representation of measured NO_3-N concentrations per time

The measured NO_3-N concentrations of the control-experiment are displayed in Table 20 and shown in Figure 32. Control-experiment started the 21st November of 2018 at 9.00am.

Table 20. Measured NO_3-N concentrations for the control-experiment per time interval

Name	Time interval in hours	NO_3-N concentration (mg/l)
C0	00:00	13.20
C1	00:10	10.90
C2	00:15	7.85
C3	00:20	6.18
C4	00:30	3.29
C5	00:40	1.41

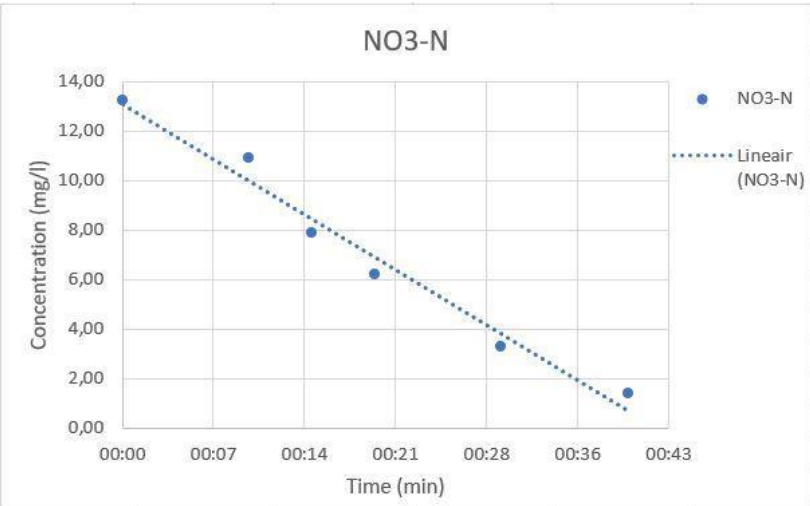


Figure 32. Representation of measured NO_3-N concentrations for the control-experiment over time

3. Suspended solids concentration

The measured suspended solids concentrations are displayed in Table 21.

Table 21. Measured SS concentration obtained from a 50 ml sludge sample at a temperature of 20 degrees Celsius

Sample	SS concentration (g/ml)	SS concentration (g/l)
1	0.00390	3.9
2	0.00436	4.36
3	0.00526	5.26
Average	0.00451	4.51

4. Denitrification rate

The denitrification rate was calculated with the data of the experiment and the control experiment. The temperature was approximately 20 degrees Celsius, since the sludge sample was stored at room temperature in the laboratory. It was taken into account that part of the measured suspended solids concentration was obtained from chemical sludge. The average percentage of chemical sludge in the sludge production is approximately 5 %; obtained from the years 2013-2017. (Appendix V.6)

Table 22. Estimated denitrification rate in Hørning WWTP in 2018

Denitrification rate (mg N/g SS*h)	Denitrification rate (mg N/g VSS*h)
3.941	4.926

3.3.3. Interpretation of the results

The pH value of domestic wastewater lies between 6.5 and 8.5; optimal acidity level is around 7 to 9 for denitrification. (Henze, 2000). The obtained result was a pH value of 7, which means optimal acidity level for denitrification.

The temperature of the one litre sample was in a range of 18 to 20 degrees Celsius. An assumption is made that the temperature of the one litre sample was approximately 20 degrees Celsius, since this temperature is more critical regarding the denitrification rate. At a temperature of 20 degrees Celsius, a denitrification rate of approximately 3 g N/VSS*h is necessary, as it can be appreciated in Figure 33.

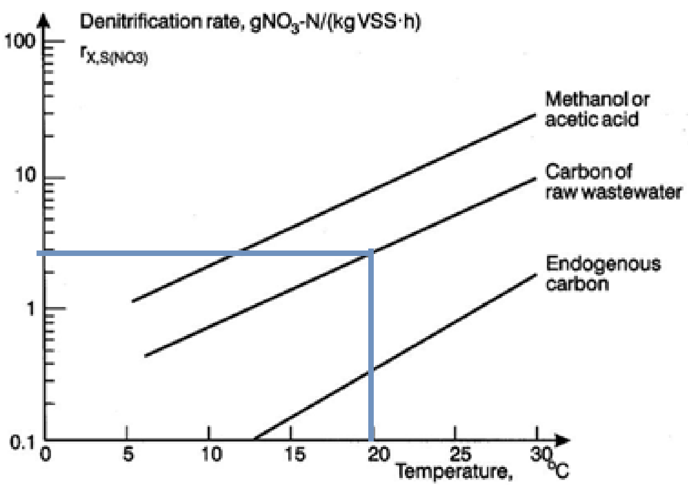


Figure 33. Relation between carbon source for denitrification, temperature and denitrification speed

The obtained denitrification rate was approximately 4.9 g N/VSS*h, which means that the denitrification is around 60 % better in the experiment.

The measured NO_3-N concentrations form a graph that is corresponding well to the theory. (Figure 33)

In theory the denitrification rate is formed by using this formula:

$$r_{DN} = \frac{\mu_{max}}{Y_{max}} * \boxed{\frac{S_{NO3}}{S_{NO3} + K_{S,NO3}}} * \frac{S}{S + K_S} * X_B \tag{1}$$

The fraction outlined in blue describes the effect of the nitrate concentration that can influence the denitrification rate, since the rest are constants. To simplify the equation the following formula is formed:

$$r_{DN} = k * \boxed{\frac{S_{NO3}}{S_{NO3} + K_{S,NO3}}} \tag{2}$$

- S_{NO3} is the concentration of nitrate in mg
- $K_{S,NO3}$ is the saturation constant for nitrate
- k is a constant factor

By assuming a constant (k), a graph can be formed similar to the graph obtained from the experiment.

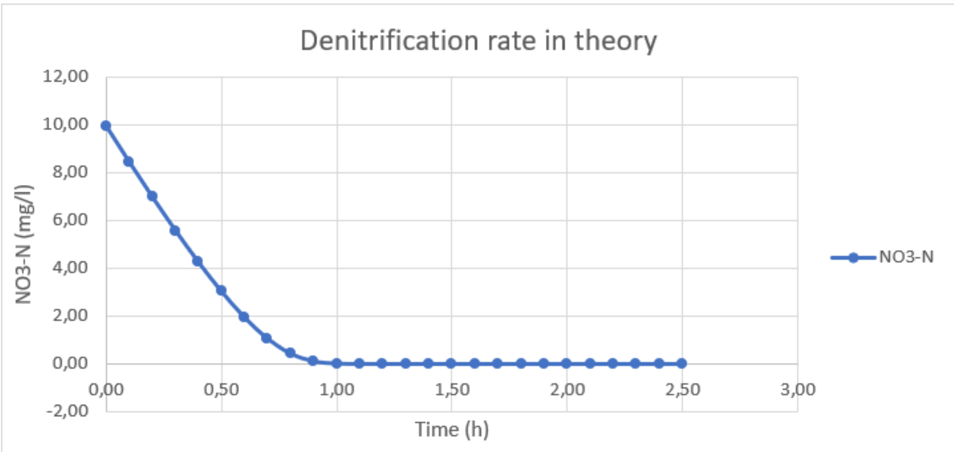


Figure 34. Denitrification rate obtained by equation 2 and assumed constant (k) of 18

The denitrification rate is a 0. order rate and then a 1. order at a low concentration of NO_3; at a concentration of around 2 mg/l and lower. (Appendix V.6)

3.3.4. Conclusion

The measured pH value, temperature and NO_3-N concentration over a time interval gave a result that corresponds to the theory. The measured denitrification rate is approximately 60 % better than necessary at the given temperature.

The hypothesis that the denitrification process of the wastewater treatment plant in Hørning will be fast is substantiated by the results of the experiment.

3.4. Estimation of Vacant Capacity and Future Predictions

The aim of this section is to analyse the possible changes in the area and how they could affect the WWTP. Firstly, the main future changes are described and estimated: the growth in population and the climate change. Then, some future calculations are done and analysed in order to verify the performance of the plant. Finally, solutions for the encountered problems are suggested. For more information about the calculus see Appendix II.6.

3.4.1. Factors to take into account for the future

Population

Hørning's population has experienced a huge increase during the last ten years, from 2006 to 2017, the increase has been 13.45 % (Wikipedia, 2018). The higher the population, the greater the dry weather flow (wastewater) is going to be and, in addition, the bigger the amount of nutrients the water is going to contain. If more nutrients are contained in the water, more oxygen consumption is demanded; even changing the aeration conditions to a non-suitable one for the removal of organic matter.

Figure 35. shows the possible evolution of the population until 2050. It was estimated following the tendency of the last years.

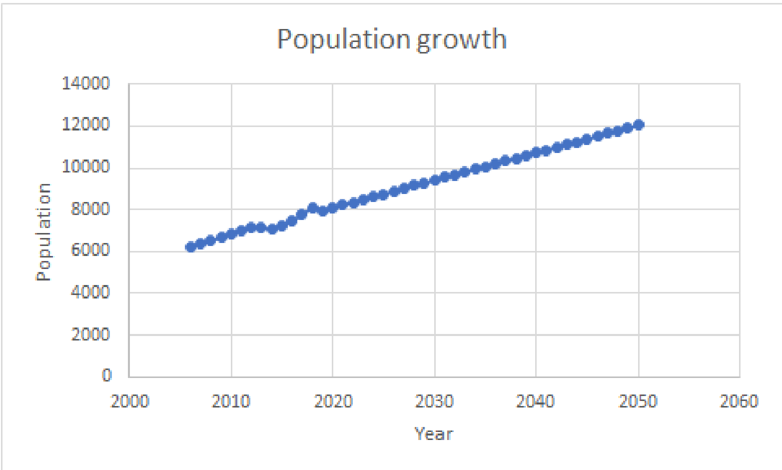


Figure 35. Population growth in future years

Climate change

It is well known that climate change is an issue concerning the planet nowadays; as a consequence of it, temperatures are increasing and extreme climate is taking place. In Denmark, the actual mean temperature is around 8.5 ºC and has increased around 1.5 ºC since the end of the 19th century. (ClimateChangePost, 2018)

Although average annual precipitation varies from year to year, in future years it is expected to have an increase in rain, as well as an increase in water level. (ClimateChangeAdaptation, 2015)

Table 23 and Table 24 show the expected variations in Denmark for the upcoming 32 years.

Table 23. Future variations in Denmark

Climate change in Denmark up to 2050 according to the A1B scenario	
Annual mean temperature	+ 1.2 °C (± 0.2 °C)
Winter	+ 1.5 °C (± 0.2 °C)
Summer	+ 0.9 °C (± 0,1 °C)
Annual mean precipitation	+ 7% (± 3%)
Winter	+ 11% (± 3%)
Summer	+ 4% (± 4%)
Sea	
Mean wind	+ 1%
Sea + land	
Mean wind	+ 3%

Table 24. Future variations in Denmark

Changes in extremes up to 2050 according to the A1B scenario	
Frosty days	-17 days
Growing season	+21 days
Heath wave	+2 days
Summer nights	+4% percentage points
Number of days with more than 10mm of precipitation	+7 days
5-day precipitation	+7mm
Mean intensity, precipitation	+0.5mm/d
Heavy precipitation events	+6% percentage points

3.4.2. Future performance of the WWTP

In this section the future performance of the WWTP is analysed. The calculations are shown in Appendix II.6.2.

The estimations made for the flow, BOD, COD, TN and TP for the coming years are presented in Figure 36., Figure 37. and Figure 38.

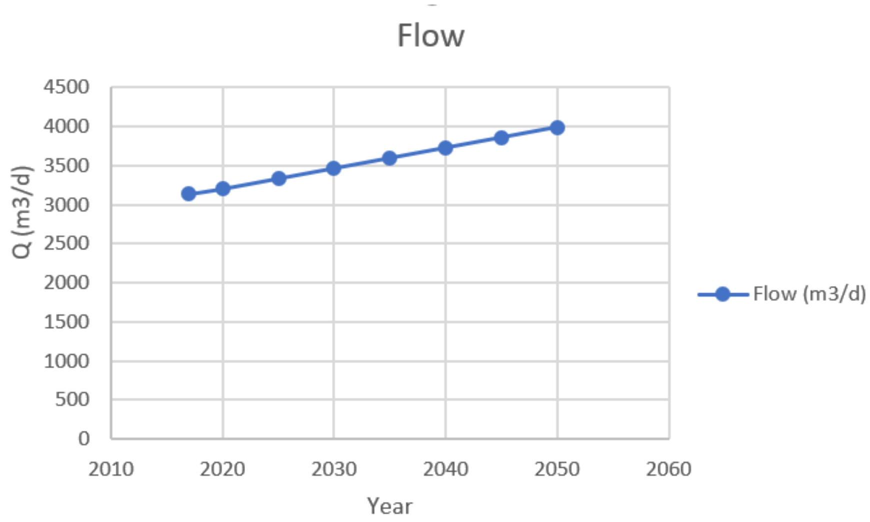


Figure 36. Expected inlet flow values

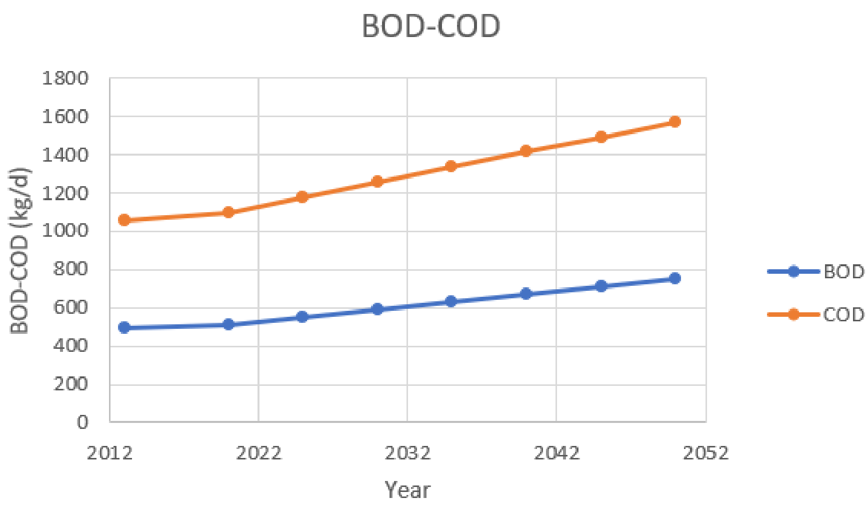


Figure 37. Expected BOD and COD inlet values

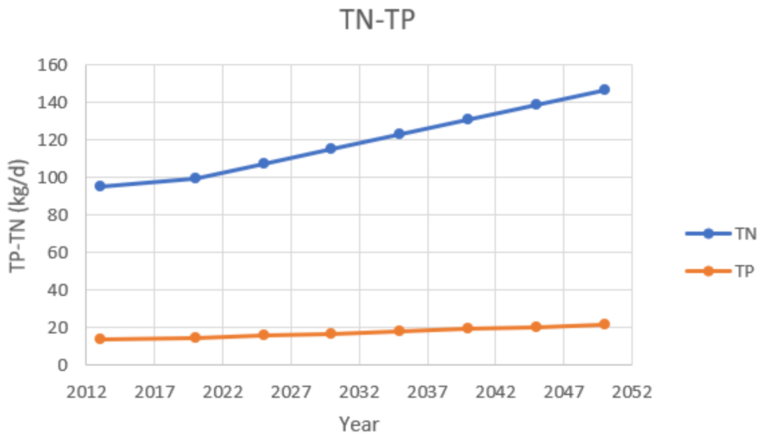


Figure 38. Expected TN and TP inlet values

In Figure 37. and Figure 38., it can be appreciated how the BOD and COD quantities in the inlet are supposed to grow in the future with an increase of 52.2 % and 48.7 % respectively. Besides, TN and TP are expected to rise as well with an increase of 55.1 % and 53.9 % respectively.

COD/BOD ratio is determined to study the degradability of the organic matter.

Table 25. Expected COD/BOD ratios

Year	COD/BOD
Avg 2013-2017	2.148
2020	2.142
2025	2.132
2030	2.123
2035	2.115
2040	2.109
2045	2.102
2050	2.097

As observed in Table 25, the COD/BOD will maintain in the typical ratio, between 2.0 and 2.5, which means that the organic matter would be easy to degrade. (Henze M. , 2000)

3.4.3. OCO tank

To know if the process tank is going to be able to perform well in the future, sludge age and F/M ratio are calculated assuming that the living conditions of the microorganisms are not going to change too much. Trying to work in a critical environment, the concentration of BOD in the outlet is supposed to be the maximum value of the requirements for Hørning, 10 mg/l.

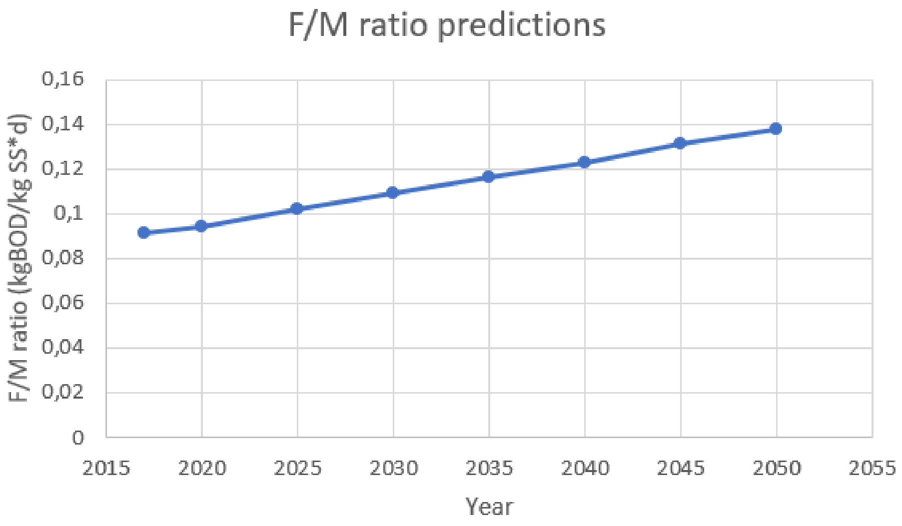


Figure 39. Future predictions for the F/M ratio

In Figure 39., it can be appreciated that the F/M ratio is awaited to grow in the upcoming years, following the tendency. Despite the increase, it will be maintained in the low loading range (0-0.3 kg BOD/kgVSS·d), which means an efficient degree of purification. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

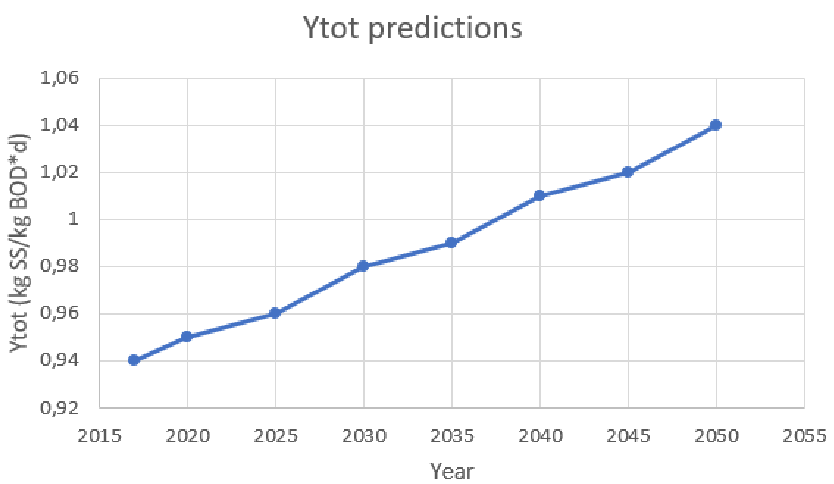


Figure 40. Future predictions of the Ytot

In Figure 40, it can be seen that the growth of the yield constant would not be so extreme; it goes from 0.94 kg SS/kg BOD*d to 1.04 kg SS/kg BOD*d. Therefore, it is confirmed that the living conditions of the microorganisms would not change in a severe way.

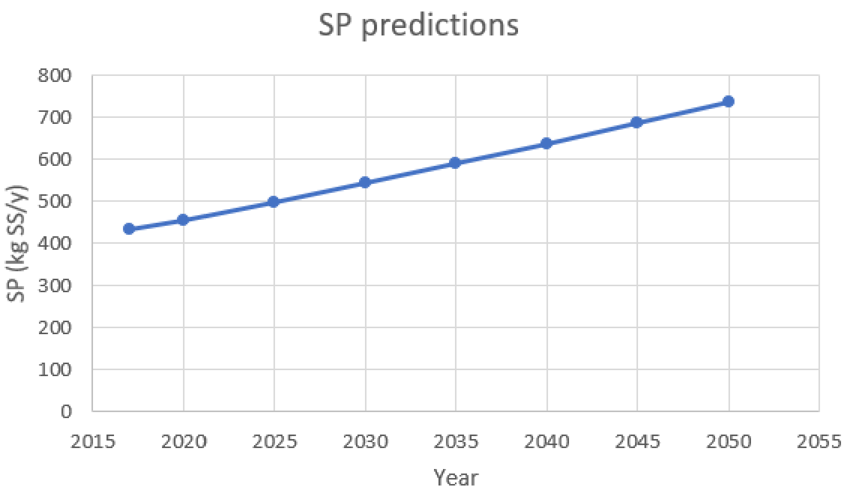


Figure 41. Future predictions of the Sludge Production

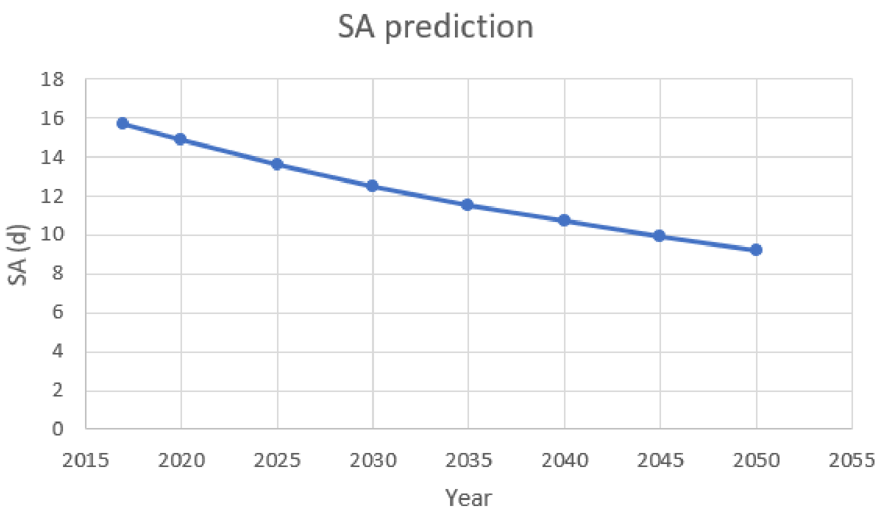


Figure 42. Future predictions of the Sludge Age

Figure 41. and Figure 42. represent the evolution of the sludge production and the sludge age. It is remarkable that in comparison with other analysed parameters, the growth of the sludge production has the sharpest rise (an increase of 70.08 %), which could provoke problems to the plant. In fact, this occurrence is reflected in the abrupt decrease of the sludge age, with a difference of 7 days in just 30 years. This means that the suspended solids will reside less time in the plant and that the micro-organisms will be less capable of surviving in the plant.

Minimum temperatures the plant has to bear are around 6 °C[4] as represented in Figure 43., at this temperature a sludge age around 15 days is needed in order to get nitrification. So, the main problem with the sludge age will be that the nitrification could not be guaranteed.

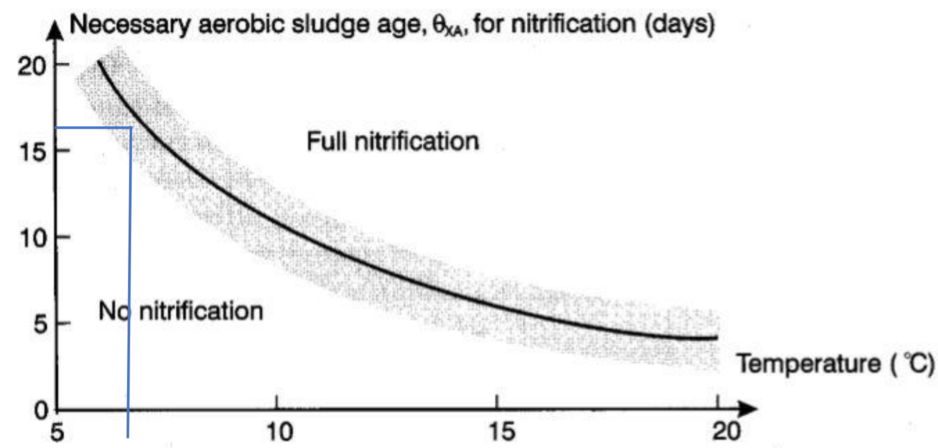


Figure 43. Conditions that need to be fullfiled in order nitrification takes place. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

Volume analysis

Now, another assumption is made. In this case, the total volume is calculated supposing that the required sludge age is a constant and has a value of 15 days, necessary for nitrification to happen; sludge concentration is also considered as a constant. For the sludge production, the calculated values for the upcoming years are taken into account.

Table 26. Future predictions of the volume

Year	$V_{tot,act}$ (m^3)	$V_{tot,15d}$ (m^3)
Avg 2013- 2017	3385	3314
2020	3385	3384
2025	3385	3540
2030	3385	3694
2035	3385	3852
2040	3385	4013
2045	3385	4179
2050	3385	4348

[4] It was estimated using the average sludge age of the past years.

The values coloured in red represent the years for which the total volume will not be sufficient.

Denitrification

The COD/TN ratio is calculated in order to verify in which ratio is going to work the plant when denitrification process takes place.

Table 27. Expected COD/TN ratios

Year	COD/TN
2017	11.088
2020	11.043
2025	10.967
2030	10.900
2035	10.843
2040	10.792
2045	10.747
2050	10.707

The obtained values will maintain between 10 to 14 kg COD/kg TN, so the plant will be in the high ratio range and the denitrification process will probably be fast. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

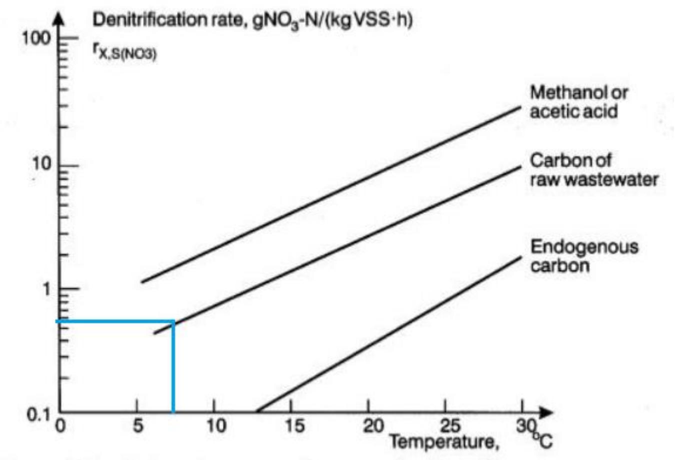


Figure 44. Relation between denitrification and temperature for different sources. Inblue, the rate for a temperature of 6ºC working with raw wastewater.

Knowing that the denitrification process will be fast and that at least 15 days are needed for nitrification, the aerobic and anaerobic volumes can be calculated. As an assumption, denitrification rate is kept constant with a value of 0.5 g N/kg VSS*h (0.4 kg N/kg SS*h).

Table 28. Expected denitrification

Year	N,out (mg/l)	mN,DN (kg/d)	V_{DN} (m^3)	V_A (m^3)
2013-2017	1.2	58.6	1386	1476
2020	2.9	55.3	1310	1552
2025	6.0	49.0	1160	1702
2030	9.0	42.5	1007	1855
2035	11.7	35.9	849	2013
2040	14.3	29.0	687	2175
2045	16.7	22.0	522	2340
2050	18.9	14.9	352	2510

The increase in population brings a high increase of sludge production, therefore, a bigger aerobic volume will be needed in the OCO tank. If more aerobic volume is needed, the anoxic volume is reduced and less denitrification will happen. This fact is reflected on the nitrogen concentration in the outlet, since 2030 it does not fulfil the requirements (8 mg/l).

Oxygen consumption

To analyse the oxygen consumption in the OCO tank, it is assumed that the three blowers are operating at their maximum load, 2580 Nm^3/h in total, and that the air flow is 8 $Nm^3/h*m$, between the standard values, 6 - 10 $Nm^3/h*m$. (Maribo, WT Chap 8. Aeration, 2018)

From Figure 45., it is estimated that the O_2 - input is around 20 g O_2/Nm^3*m. After calculating the oxygen consumption under standard conditions, a value of 4458.24 kg O_2/d is obtained.

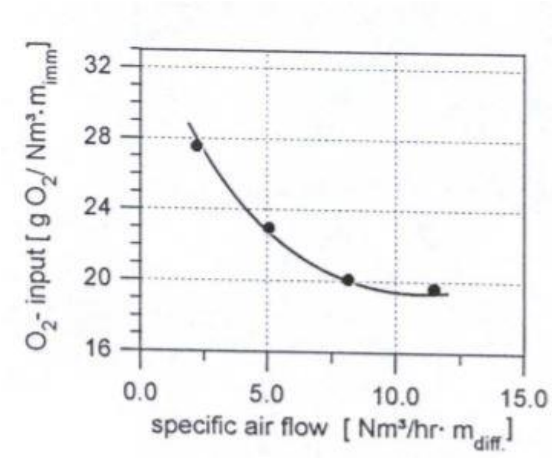


Figure 45. Relation between O_2 input and air flow.

Once the oxygen consumption under standard conditions is determined, the oxygen consumption under actual conditions is estimated.

A value of 2979.46 kg O_2/d is obtained, which is quite higher compared to the values of the previous years. Nevertheless, it is reasonable, because the blowers are operating at their maximum load; while in a normal situation they work below their maximum.

3.4.4 Clarifier

A study of the future performance of the clarifier is made. Taking into account the predicted values of the flow, calculated before, and that the sludge concentration is considered as a constant, the overflow rate, the hydraulic retention time and the solids loading rate are estimated.

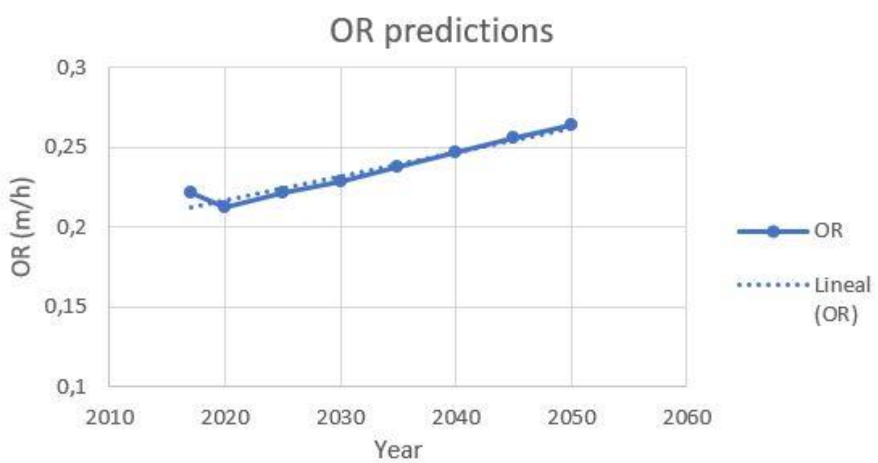


Figure 46. Predictions of the Overflow rate

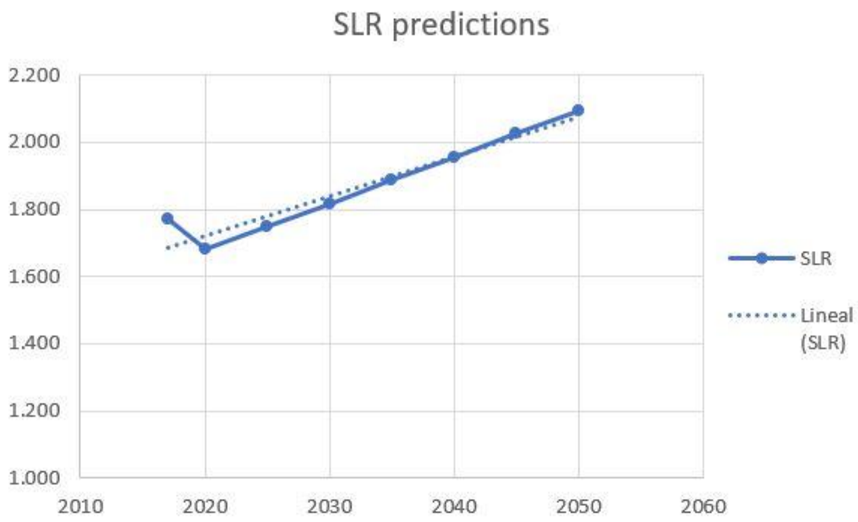


Figure 47. Predictions of the Solids Loadinf Rate

As it can be observed in Figure 46. and Figure 47., there is a showy increase of the OR and the SLR for future years due to the expected increase in the flow.

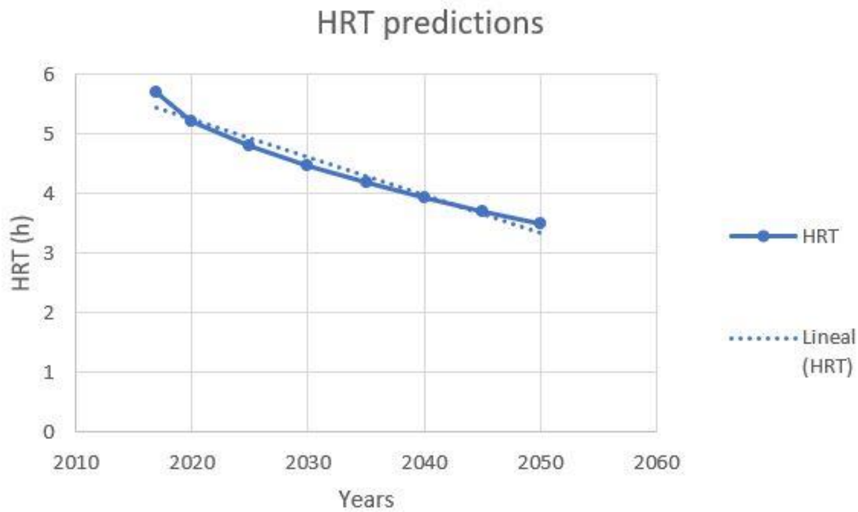


Figure 48. Predictions of the Hydraulic Retention Time

In Figure 48., it can be perceived how the hydraulic retention time is awaited to decrease in upcoming years. Despite the diminish of the HRT, the proper performance of the clarifier is assured, because the minimum value of the HRT is over the requirement of 1.4 h. (Maribo, WWTP Chap. 5 Mechanical Purification, 2017)

Dimensions

If the clarifier dimensions are valid for the future performance needs to be studied as well. Therefore, the overflow rate and the solids loading rate are calculated for the maximum possible inlet flow and will be compared to the requirements of the design criteria of clarifiers in Table 29. The required values for the clarifier of the WWTP are highlighted in yellow.

Table 29. Design criteria for circular settling tanks for activated sludge WWTP (Maribo, WWTP Chap. 5 Mechanical Purification, 2017)

Diameter [m]	Side water depth h_{eff} [m]	Overflow rate (OR) (= surface loading rate) [m/h]		Solids loading rate (SLR) [kg SS/(m^2·h)]	
< Ø25		Max*)	DW**)	Max*)	DW**)
	2.5	<1.0	<0.7	<9.2	<5.5
	2.7	<1.1	<0.8	<10.0	<5.7
	3.0	<1.2	<0.85	<10.5	<5.9
	>3.5	<1.3	<0.9	<11.0	<6.5
Ø25 – Ø35	3.0	1.1	<0.8	<10.0	<5.9
	>3.5	1.25	<0.9	<11.0	<6.5

*) *Max: $Q_{h,max,S}$: maximum flow [m^3/h] to the WWTP*

**) *DW: $Q_{h,max,DW}$ Dry weather flow [m^3/h], i.e. maximum flow to the plant in situations without rainwater. Often a 85 %-tile of the total flow statistics for the sewage area has been used. If $Q_{max,h}$ lasts longer than 3 -4 hours (dependant on an evaluation of how often this situation will occur) one should choose a lower load of the clarifiers (possibly by dimensioning the process tanks for a lover solids content X_L). If $Q_{max,h}$ can last for more than 10 – 15 hours and is expected to occur often (i.e. for large combined sewer systems with basins for accumulation of storm water) $Q_{max,h}$ should be used instead of $Q_{DW,h}$.*

First, it will be calculated for the minimum value of the return flow, 85 % of the inlet flow. After, a more critical situation will be analysed for the solids loading rate, supposing that the return flow is the 95 % of the inlet flow.

Table 30. Calculated maximum Overflow rate and maximum Solids Loading rate

OR max (m/h)	0.604
SLR max 85 % (kg SS/m^2*h)	4.918
SLR max 95 % (kg SS/m^2*h)	5.183

As all the values satisfy the conditions, the clarifier could be used in upcoming years.

To analyse if the clarifier will operate correctly in the future, estimations are made considering the maximum able flow for the inlet pumps and calculating the mass balance. The sludge concentration and the return sludge concentration values are supposed to remain constant, besides, the return flow is supposed to be the 85 % of Qmax,in.

Table 31. Calculated inlet and return flow, sludge concentration and return sludge concentration.

Qi (m^3/h)	380
Qr (m^3/h)	323
X_A (kg SS/m^3)	4.4
X_R (kg SS/m^3)	16.34

$$5277.82\ \frac{kg\ SS}{h} \geq 3093.20\ \frac{kg\ SS}{h}$$

Since the mass balance is fulfilled and the return sludge has to be > 85 % of Qmax,in, a good performance of the clarifier is guaranteed. (Maribo, WWTP Chap. 5 Mechanical Purification, 2017)

3.5. Suggestions for Improvement

After making the predictions for the future, two potential problems have been observed, related with the sludge age, which will go down to 10 days, and with the denitrification.

In order to obtain nitrification a sludge age of 15 days is needed. The needed aerobic volume has been calculated for a 15-day sludge age and added up to the anoxic (1316 m^3) and anaerobic (523 m^3) volumes to compare with the actual total volume (3385 m^3). As observed in Table 26., the calculations suggest that from 2025 a bigger aerobic volume is going to be needed in order to have full nitrification.

So as to keep denitrification working with an acceptable removal quality, the rate of denitrification could be increased or the sludge age reduced. Another option, could be to enlarge the concentration of sludge in the tank. However, the sludge production is still too high, so more extreme changes are needed.

As a solution, the distribution of the volumes could be changed, so that the actual tank is kept in operation for some more years. However, as a long-term solution constructing a new and bigger OCO tank would be the most viable option.

4. RECEIVING WATER BODY

For more information about this section of the report, see Appendix III. In here the Macro Index and figures of the invertebrates will be presented.

After having been treated, the water is discharged to the stream Aarhus Å which is 40 km long. It springs 54 metres above sea level in Astrup Mose (Solbjerg) southwest of the city of Aarhus and flows into Aarhus Harbour.

Until the 20th century there used to be a sizeable catch of eel and pike. Several families started to make a living from it and placed their houses and watermills in the rivers bank. It is for that reason, that through this century the river and its ecosystem went into serious ecological problems due to nutrient pollution from household wastewater and farmland runoff. Nowadays, after some costly efforts to restore the damaging effects of the eutrophication, the ecosystems and biodiversity of Aarhus Å are recovering.

Outlet concentration data has been calculated as an average and compiled in Table 12.

As it is observed, in most of the years all the requirements have been fulfilled, so an adequate treatment is assumed. But that is not all, the lowest values are the ones of 2017. This could be attributed to the development of new technologies and more strict requirements, to minimise the impact of the discharged water and recover an optimum stream quality.

With the purpose of knowing how well the status of the stream is, a closer look is taken to the living invertebrates by making a macro index.

4.1. Macro Index

4.1.1. The status of the stream

The last available report about Aarhus Å stream shows that the ecological condition before the CSO is moderate, at the CSO (OV65) the condition is poor and after it is good. “Good ecological condition” is the requirement set for the streams in Denmark.

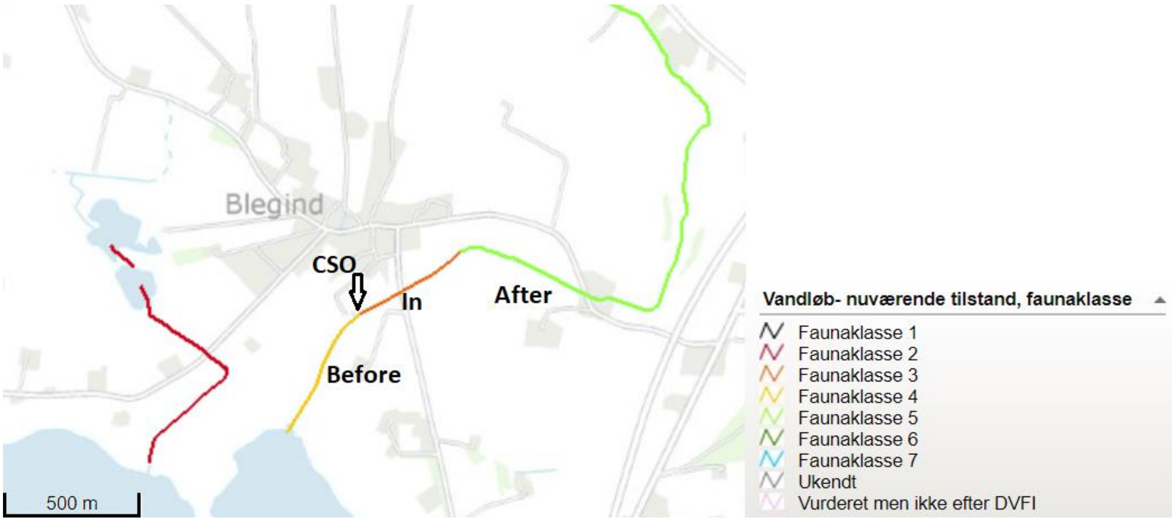


Figure 49. Map of the stream Aarhus Å showing the cological conditions

The stream's actual conditions are going to be evaluated by taking samples before the outlet of the CSO, right where the outlet is and after the outlet, in order to observe if the area has developed an improvement or a decrease in its conditions.

Figure 50. Aarhus Å stream before the CSO (picture of the left side)

Figure 51. Aarhus Å stream before the CSO (picture of the right side)

Figure 52. Aarhus Å stream right in the CSO (picture of the left side)

Figure 53. Aarhus Å stream right in the CSO (picture of the right side)

Figure 54. Aarhus Å stream after the CSO (picture of the left side)

Figure 55. Aarhus Å stream after the CSO (picture of the right side)

As the pictures display, Aarhus Å runs a quite straight path, which clearly shows that the stream is modified by humans. In one section after the CSO the bank has started to collapse, as the stream was trying to recover its natural path. Nonetheless, this specified area takes a very short length, nothing that could change the biological or ecological condition of the stream.

4.1.2. The method

The collecting of samples was carried out the 25th of November of 2018, between 9.00am-11.00am. Sampling of invertebrates is done at the three different locations mentioned in the text above. In every location samples are taken from under the water surface of the bank, the middle part and below stones to find a variety of species. In order to not disturb the living environment of the microorganisms, samples are taken starting downstream (after the CSO) and finishing upstream (before the CSO). Later on, obtained samples are analysed in the laboratory by the usage of a microscope (Kern Microscope. OBS101) and a book called "En oversigt over danske ferskvandsinvertebrater til brug ved bedømmelse af forureningen i søer og vandløb" (Københavns Universitet og Miljøkontoret, 1990) to find out which diversity-groups are present in the stream and determine the quality of it.

4.1.3. Results and discussion

Once all found insects and microorganisms are classified on their corresponding group, the data is used to determine the macro index value. Afterwards, the value is used to establish the water quality.

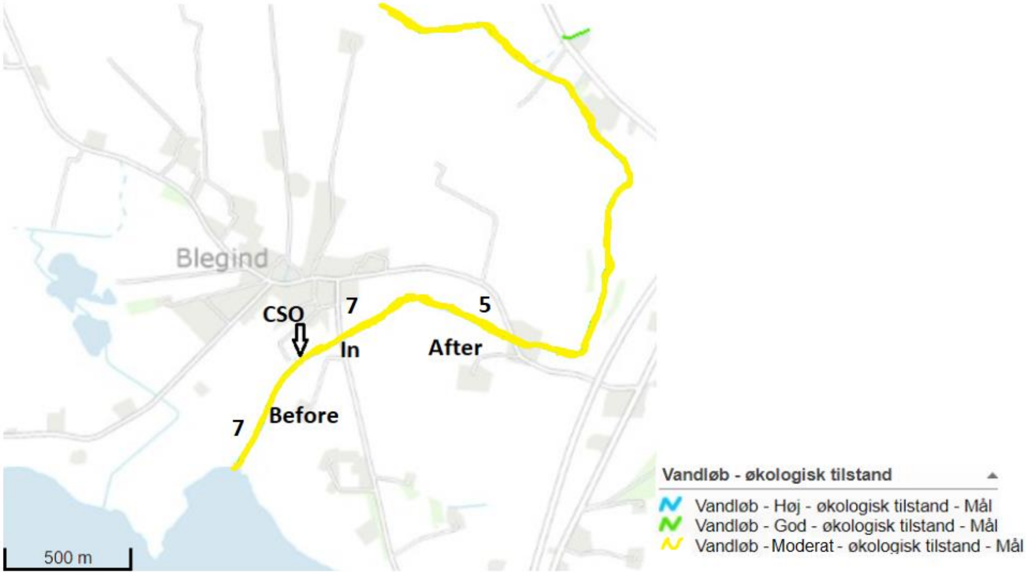


Figure 56. Map of the stream showing the results of the Macroindex for the actual ecological conditions

The variety of different living species is similar in the three areas; some of the insects were found in all of the three areas, which can make us assume that during the analysed length the stream maintains a moderate condition. Despite this, a comparison between the last report made by the Ministry of Environment and the results get by sampling has been done, because some of the species that were found in some of the areas were not supposed to be there. (For pictures of the found invertebrates see Appendix III.3)

- The Chironomus lives in a poor-quality environment; the appearance of this one after the CSO could be due to the activation of the CSO, when the water from the basin, which is highly likely to have poor quality, discharges in the stream taking and carrying with it all along the stream this kind of microorganism.
- Species from the Plecoptera family are found in good quality environments; in this case, they were found before the CSO, which is quite probable to happen, and right in the CSO area, where the level of pollution is usually high. This fact was confirmed after the visit to the zone; the smell in it was worse than in the other two areas. It is for this reason that finding a Plecoptera Isoptena is extraordinary. The main reason to the appearance of this microorganism in this area might have been the transport of it in strong currents during long rain events.
- A fish was found in the last section of the analysed stream length. It seemed to be dead, however, when analysing it in the lab, it was still breathing.

- Vegetation during the analysed length of the stream was not so varied (look Figures 50-55) There were plants on the banks of the stream, but none under the water. It is assumed that the living environment is quite similar in the three areas.

Taking into account these things, it is acceptable to say that the conditions of the stream are moderate.

4.1.4 Solutions/Possible actions

Even though the results show that the actual condition is moderate, some changes should be done to improve the ecological condition and fulfil the requirements. Some solutions are suggested.

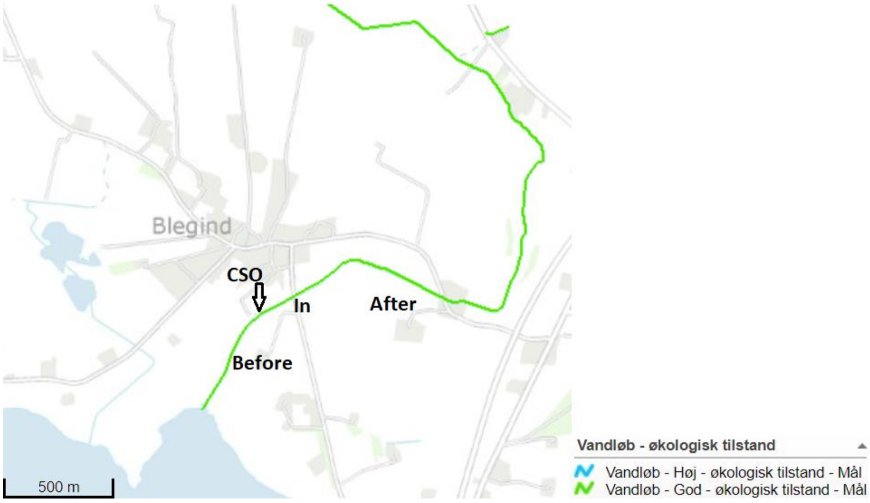


Figure 57. Map of the stream showing the required ecological conditions

1. *Make a larger basin:*
   Having a larger basin means having more capacity to retain water without overflowing. Even though the solution is easy and cheap to implement, it is a short-term solution, since it does not solve the problem with overflows. This effect can be reduced if the basin is constructed with a return pipe into the pumping station. This way, whenever there is vacant capacity in the pumping station, some of the wastewater from the basin can be transported to the WWTP in Hørning.

2. *Separating the sewer system:*
   The actual system is a combined system, which means that rainwater and wastewater flow through the same pipe. By separating both systems, one pipe system for the rainwater and another one for wastewater, pollution problems that happen during overflows would be decreased, since the only water that would be discharged to the stream would be the one coming from the rain. Wastewater would flow directly to the treatment plant, without passing through any overflow structure. Despite the implementation of this solution takes longer and is more expensive, the outcome is much more future-proof.

As a final conclusion, in spite of everything, the system needs a renewal with the purpose of avoiding flooding situations that could result in polluting the stream.

5. CONCLUSION

The report is divided in three main sections. First of all, the sewer system of the area of Blegind and the transport of the sewage to Hørning WWTP are analysed. A virtual model is created by Mike Urban using data from the wastewater plan and the GIS layers; the model is used to make a sensitivity analysis to identify the critical areas and parameters affecting the system. The plan calculation of the hydraulic capacity shows that very few strecthes of pipe are able to cope with the future increase in runoff.

To solve the water capacity problem, three solutions are given. The first one would be to separate the combined sewer system in two pipes, one for wastewater and another one for rainwater. This solution will need to line the walls of the pumping stations with PE, to make them more resistant to the possible corrosion that they will have to bear, and a new basin. The second one would include also the separation of the sewer system, but in this case, there will be only one pipe system for wastewater; rainwater will be handled locally, constructing a wadi along the roads and an optimal structure for each household. The third solution would be to upgrade the actual system by relining and bursting the pipes.

Secondly, WWTP in Hørning is investigated; the actual performance and the expected one for the future are scrutinised. The current execution of the plant is quite efficient in purification of water. To verify this, an experiment checking the denitrification rate is conducted; the denitrification process is working well. However, some problems are supposed to arise related to the sludge age, nitrification and denitrification. To keep an optimum nitrogen removal a 15-day sludge age is desired, so as a solution, a newer and bigger OCO tank will be needed.

Lastly, the status of the receiving water body is examined. The data of the outlet of the WWTP in Hørning is compared to the requirements of the plant. Besides, a macro index is led, in order to get further information about the status of the water near the CSO. After analysing the samples, the results are compared to the present condition and a moderate water quality is assumed. With the purpose of fulfilling the requirements two solutions are given. Firstly, making a larger basin so more water could be retained without overflowing. Then, as an improvement, a return pipe into the pumping station can be constructed. This way, whenever there is vacant capacity in the pumping station, some of the wastewater from the basin can be transported to the WWTP in Hørning. The second solution could be separating the sewer system; rainwater, less polluted than the wastewater, will be directly discharged into the stream and wastewater will flow straight to the WWTP.

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APPENDIX I. SEWER SYSTEM

I.1. Physical condition of the sewer system

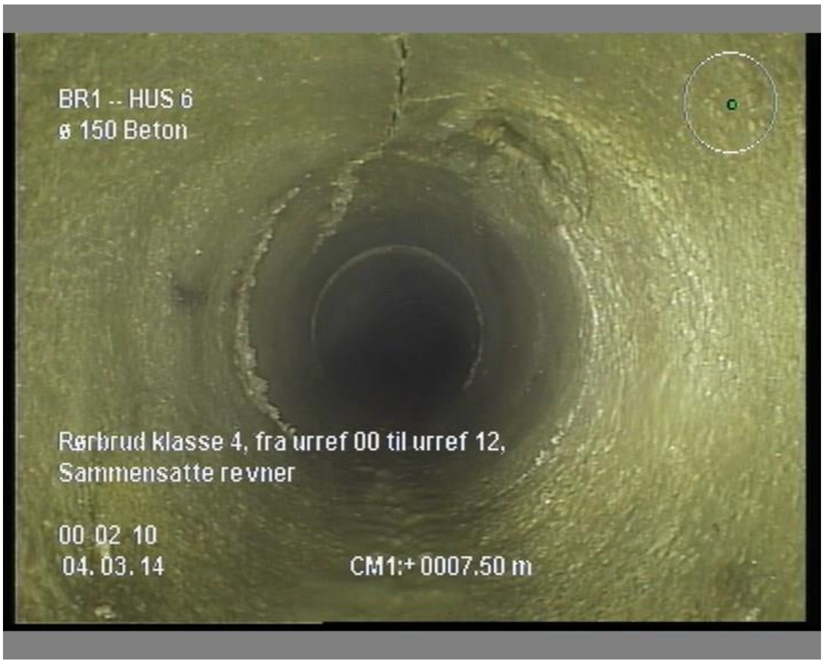


Figure I. 1. Picture from CCTV of Engvej in Hørning showing cracks in the pipe grade 4

Figure I. 2. Picture from CCTV Picture from CCTV of Engvej in Hørning showing a collapse of the pipe

Holst Kloakservice A/S, Horsensvej 6A, Skanderborg, Telf: 86511690, Fax:

Medlem af Danske TV-Inspektionsfirmaers kontrolordning

Analyseskema - 1

	Gade/Vej	: Engvej	Antal meter total: 197,40
Sagsnavn : 94691	Dato	: 05-03-2014	
Tegningsnr :	Videobåndnr.	: 3030314-2	

Brøndstrækning					Klassifikation af fejl og skader																		
Opstrøms knude nr.	Nedstrøms knude nr.	F	D mm	L m	VA 0 1 2 3 4	RB 1 2 3 4	OB 1 2 3 4	PF 1 2 3 4	DE 1 2 3 4	FS 1 2 3 4	IS 1 2 3 4	RØ 1 2 3 4	IN 1 2 3 4	AF 1 2 3 4	BE 1 2 3 4	FO 1 2 3 4	GR 0 1	SG 1 2 3	PH 1 2 3 4	PB 1 2 3 4	OS 1 2 3 4	OP 1 2 3 4	OK 0 1 2 3 4
HF06615	HF06610	10	ø150	88,10	2663																4 1		1
BR1	Opgravning	10	ø150	3,40	4	1				2 1													1
HUS 6	BR1	10	ø150	30,70	31	1 3 5	4			27													1
BR1.1	BR1	10	ø150	75,20	76	1 4	22			72				44					2				

Figure I. 3. Table from the CCTV inspection showing the state of the pipes. The physical index of all pipe sections is 10, because of several grade 4 remarks. All of the pipe section will need replacement

I.2. Catchments

This sensitivity analysis is made to examine the difference between the calculated imperviousness and the imperviousness found in the wastewater plan.

Table I. 1. Overview of runoff and discharge from CSO OV65 with different imperviousness.

	Imperviousness (%)	Total runoff (m^3)	Total discharge from CSO OV65 (m^3)
Imperviousness calculated	Weighted avg: 33.2	3154	469
Imperviousness from wastewater plan	31	3174	485

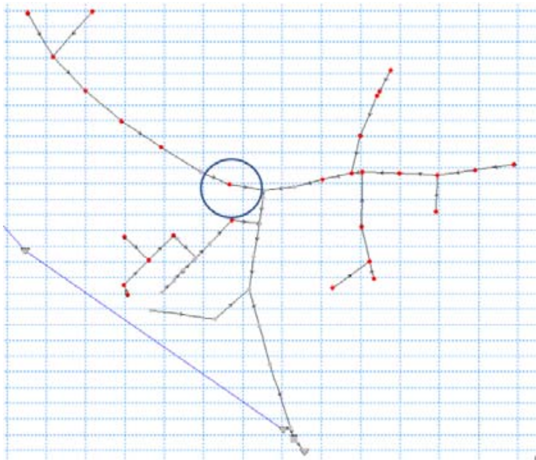


Figure I. 5. Flooding to terrain with a 10-year rain, no scaling factor and imperviousness calculated.

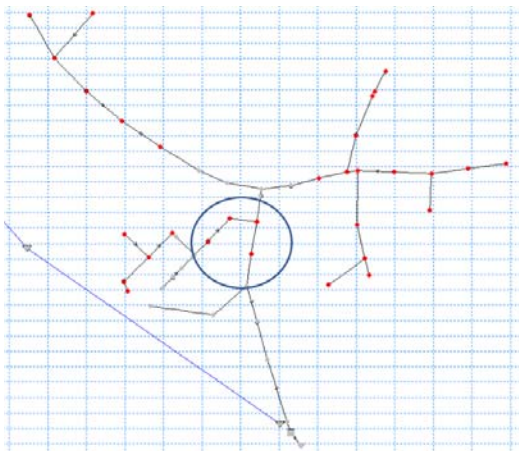


Figure I. 4. Flooding to terrain with a 10-year rain, no scaling factor and imperviousness from wastewater plan of 31 %.

The differences between the two flood maps are marked with blue circles. Despite very similar runoffs the flood maps are different, because the imperviousness differs. The imperviousness from the calculation is custom made for each plot, thus increasing the accuracy of the model. Therefor, these values are used in the model and not the one from the wastewater plan. Red dots are flooded manholes.

I.3. Basins

Figure I. 6. Picture of basin BLB0140 at Damvej in Blegind. In the bottom right corner, the inlet is visible. The outflow pipe is not visible on the picture; it is located in the bottom left corner

Figure I. 7. Showing of the crack in the side of basin

I.4. Pumping stations

There are two pumping stations in Blegind PS208 and PS209. They are used to pump the combined sewage to Hørning. At the courtesy of Skanderborg Forsyning the data for PS208 and PS209 has been supplied. Unfortunately, very little data is available for PS209. The data that is available is from the SRO data collection system. This type of data can be unreliable, but when taking the capacity of PS208 into consideration, the values seems trustworthy and is used in the model. Moreover, PS209 receives a small amount of wastewater from Blegind, which explains why it may have a higher capacity. The start/stop levels are only available for PS208. Since the capacity of the pumps are closely matched the same start/stop levels are used in PS209. The same is the case for the diameter of the pumping station.

Setup of the pumps:

PS208 has two pumps, but they take turns and only one is running at the time. If PS209 can't keep up PS208 registers this and shuts down. The inflow pipe at PS208 then becomes the overflow pipe, and sewage will flow back into OV65 and into the basin BLB0140. The reason for this setup is that there is no overflow structure located at PS209. The scenario described above is impossible when taking the capacity of the pumping station into consideration. This indicates that the validity of the data of PS209 is questionable.

In the model it is assumed that the pumps are running with a constant capacity and have an accelerating and decelerating time of 10 seconds.

Sensitivity analysis

In this analysis the capacity of both pumps is set to 40 l/s to see what effect this has on the sewer system in Blegind and Hørning. The status model is used, i.e. 10-year CDS rain, no scaling factor.

Table I. 2. Overview of key parameters

Name	Total discharge OV65 [m^3]	Total spilling from BLB0140 [m^3]	Total amount pumped [m^3]
PS208: 10 l/s & PS209 13 l/s	469	0	73.6
PS208: 40 l/s & PS209 40 l/s	379	0	160

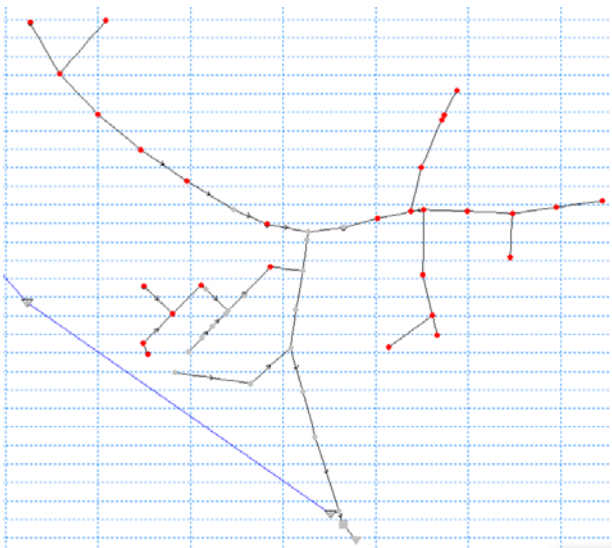


Figure I. 8. Sewer system of Blegind. PS208 with a pumping capacity of 10 l/s and PS209 13 l/s

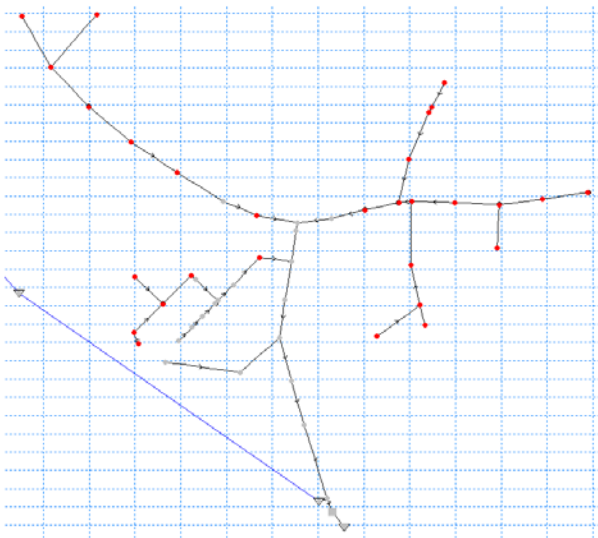


Figure I. 9. PS208 with a pumping capacity of 40 l/s and PS209 40 l/s

Figure I.8. and Figure I.9. are showing the sewer system of Blegind. The red dots indicated flooded manholes. There is no difference between the two figures, the reason for this being that the pumps are no the limiting factor of the system. Instead the pipes are too small, thus preventing more sewage from reaching the pumping stations in the scenario with a pumping capacity of 40 l/s.

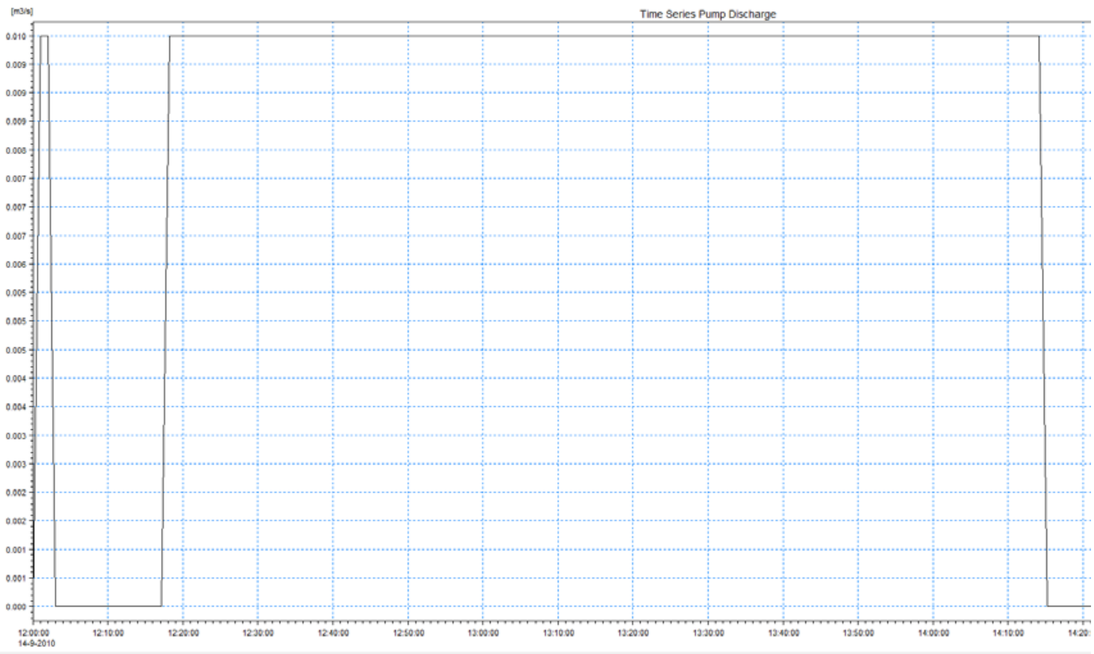


Figure I. 10. Pump discharge from PS208 with a pumping capacity of 10 l/s. The pump is running at capacity for almost two hours

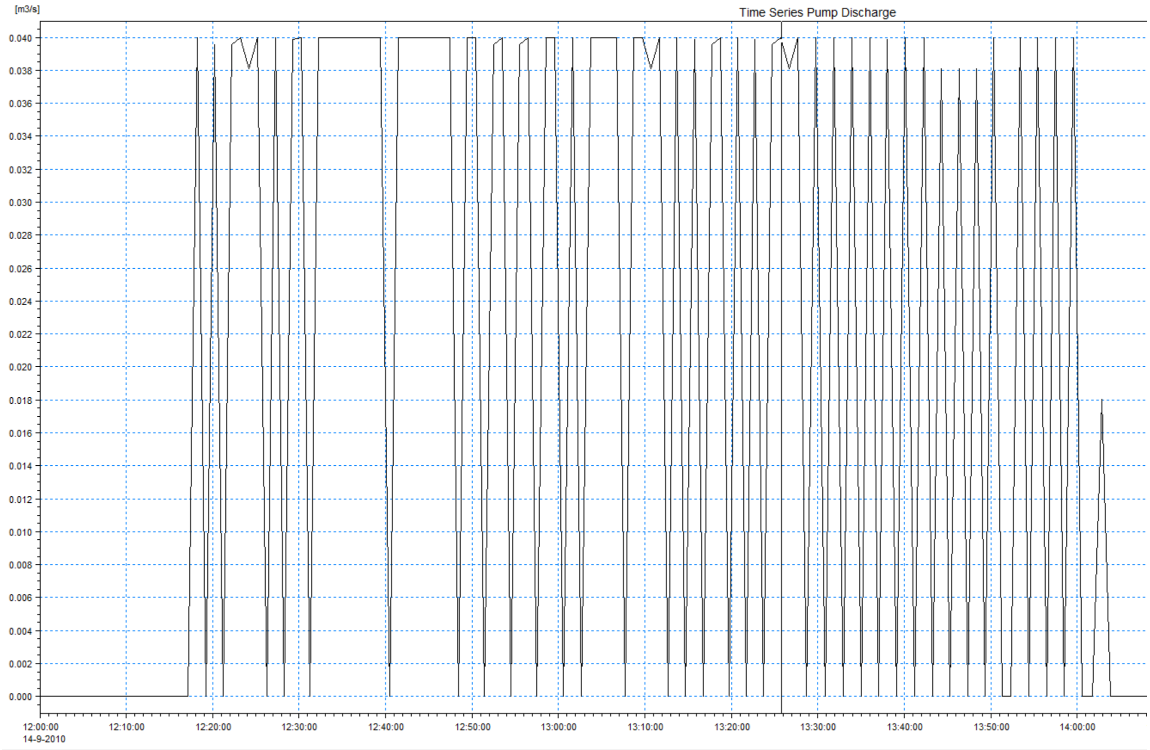


Figure I. 11. Pump discharge from PS208 with a pumping capacity of 40 l/s

The inlet pipe to the pumping station is too small to supply enough sewage to the pump, which fluctuates as a result. There is a discharge from OV65 of 379 m^3, which indicates that there is enough sewage in the system to supply the pump.

Figure I.4.5. Pump discharge from PS208 with a pumping capacity of 40 l/s. The inlet pipe to the pumping station is too small to supply enough sewage to the pump, which fluctuates as a result. There is a discharge from OV65 of 379 m^3, which indicates that there is enough sewage in the system to supply the pump.

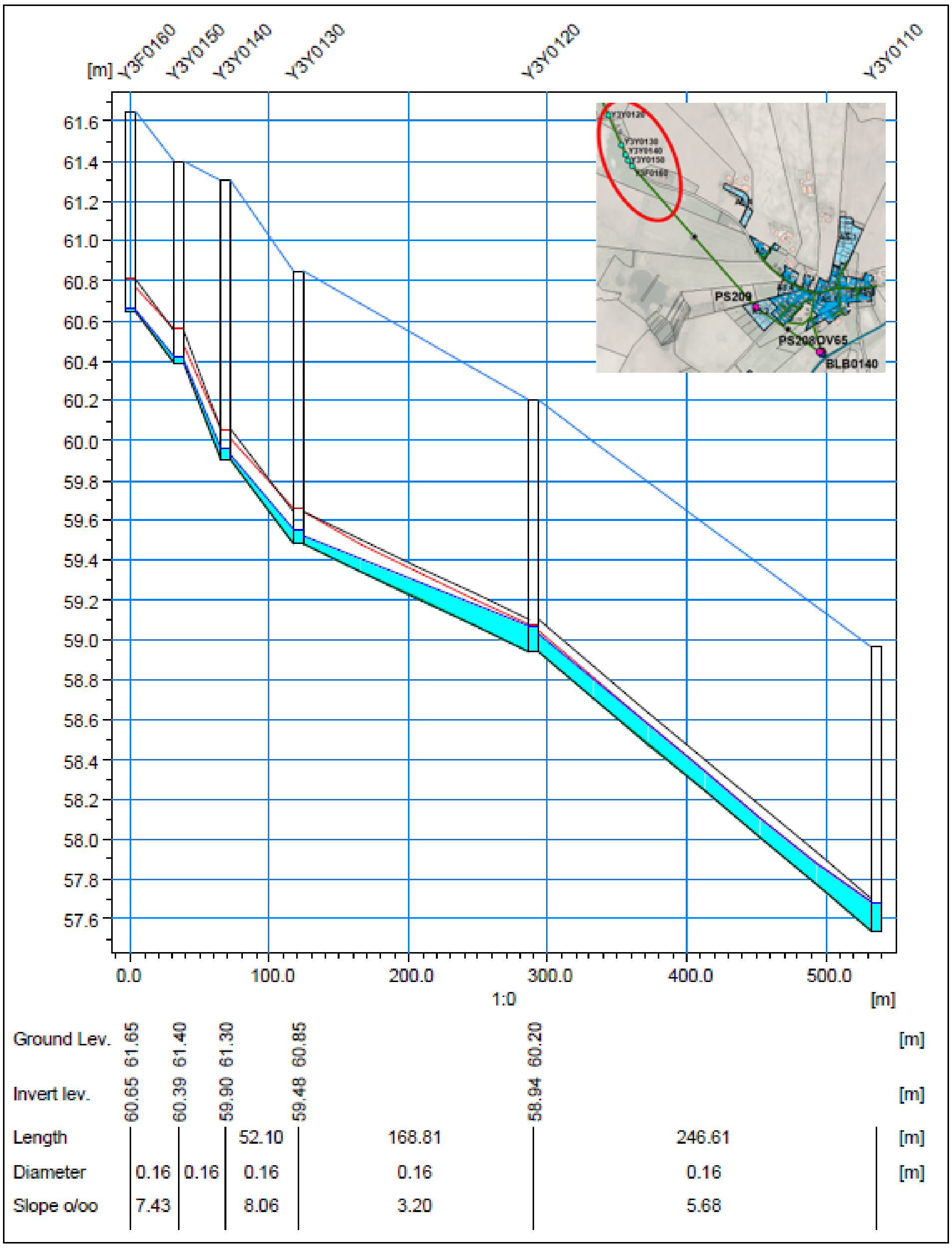


Figure I. 12. Discharge in pipes from manhole Y3F0160 to Y3Y0110, with a pumping capacity of 10 l/s. No capacity problems

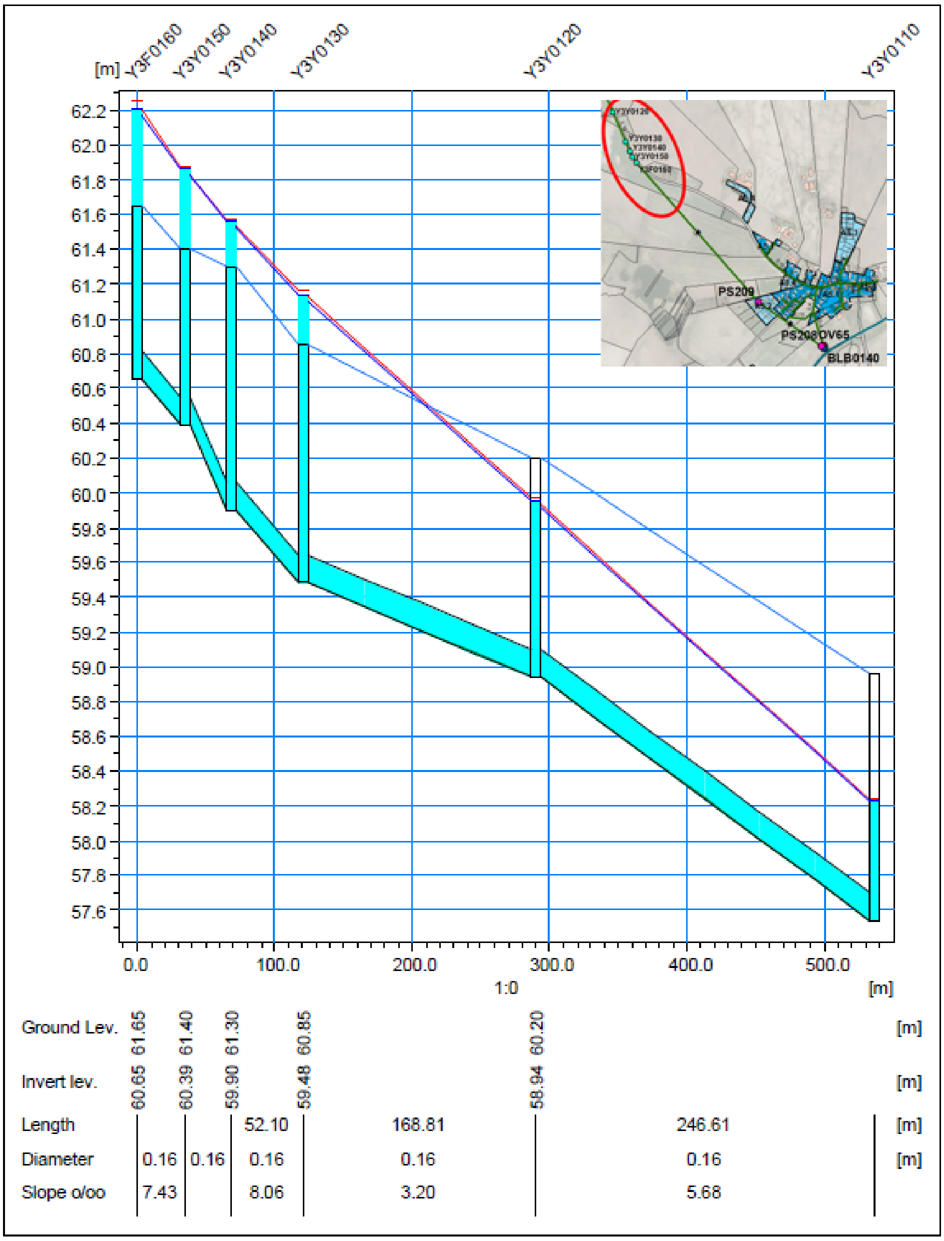


Figure I. 13. Discharge in pipes from manhole Y3F0160 to Y3Y0110, with a pumping capacity of 40 l/s.

Conclusion

The sewer system in Blegind does not benefit from the increased pumping capacity used in the analysis, because of a bottleneck in the sewer system being the limiting factor. The increased pumping capacity does result in less overflow from OV65, and therefore less sewage going into Aarhus Å. The capacity increase is causing flooding from manhole Y3F0160 (Figure I. 13)

In the model the values provided by Skanderborg Forsyning are used (Table I.3). The sensitivity analysis clearly illustrates that the pumping stations are not dimensioned for a capacity of 40 l/s. At this capacity the pumps are fluctuating, and the amount of start and stops is unsustainable (Figure I. 11). There is no benefit for the sewer system in Blegind with the increased pumping capacity.

Table I. 3. Overview of parameters of the pumping station

Name	Placement	Size	Pump capacity		Levels	
		(mm)	m^3/h	l/s	Start (cm)	Stop (cm)
PS208	Damvej	Ø1500	36	10	70	30
PS209	Søtoften	Ø1500	46,8	13	70	30

I.5. Mike Urban Parameters

I.5.1. Head loss in manholes

The head loss in the manholes is set at 0.25 km as default in Mike Urban. This value is used in the model.

I.5.2. Reduction factor

The reduction factor indicates how much of the precipitation falling on the impervious area ends up in the sewer system. The value depends on the state of the impervious areas, the green areas permeability, etc. If the green areas are particularly impermeable because of drought, the rain from the area will flow to the nearby sewer, so it can experience a reduction factor that exceeds 1. The Mike Urban default value is 0.9

Sensitivity analysis

Three scenarios are presented to better determine the effect of different reduction factors.

Table I. 4.Correlation between reduction factor and total runoff in the model

Reduction factor	Total runoff (m^3)
0.9	3,548
0.8	3,154
0.7	2,760

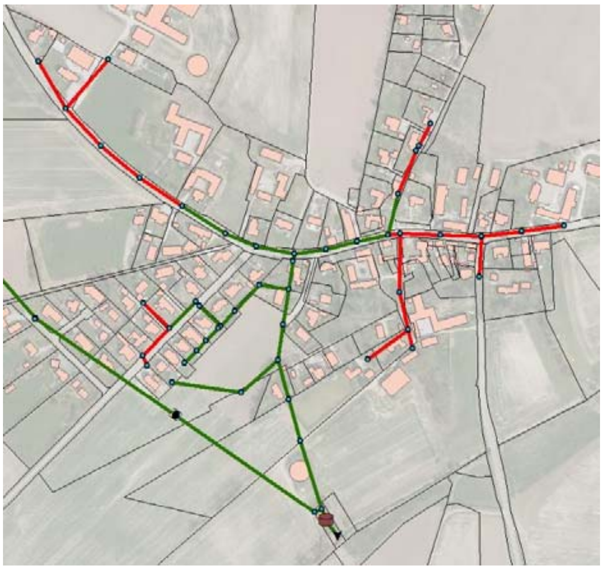


Figure I. 15. Simulation run with 10-year CDS rain, no scaling factors and a reduction factor of 0.7.

Figure I. 14. Simulation run with 10-year CDS rain, no scaling factors and a reduction factor of 0.9.

The red pipe sections indicate flooding to terrain. Looking at the scenarios, the pattern is the same in all three. With higher reduction factors, more runoff will go to the sewer system. Problems with flooding are greater furthest upstream, they start to occur further downstream when the reduction factor rises. In old towns like Blegind and Hørning, in the parts of the town with a combined sewer system, it is reasonable for the impervious areas to have some cracks and other gaps resulting in some of the water leaking through the surface. Furthermore, many areas in Blegind have gravel along the road, which are hard to distinguish from road surfaces on maps, resulting in the overestimation of the amount of water running into the sewer system. As a result, the reduction factor is set at 0.8 to compensate.

The only precise way to determine the reduction factor is to measure it, because it varies from area to area. This is done by measuring the amount of precipitation with a rain gauge and measuring the resulting flow in the sewer with a flowmeter. Thus, it can be calculated how much of the precipitation is going into the sewer system.

I.5.3. Manning value

Table I. 5. Manning numbers and their roughness. The calculations of the average max velocity and average discharge can be found in Appendix V.2.

Manning value	Roughness	Avg. max velocity in pipes (m/s)	Avg. discharge in pipes (l/s)
85	0.0005	274	1.088
75	0.0015	271	1.020
68	0.0030	269	0.968

Sensitivity analysis

Having tested three different manning numbers in the model, the system behaves remarkably similar in the different scenarios. In regard to flooding, it does not change the general picture; only one manhole is flooded with a manning value of 68. The highest manning number results in the highest velocity and discharge in the system and vice versa. This effect is reduced by the head loss in the manholes, because the flow velocity is squared in the head loss equation.

It is a challenge to determine the manning number of any sewer system, especially without having any physical inspection of the system. If the system is in poor condition and the pipes have rough surfaces, the manning number should be relatively low and vice versa. The default manning number in Mike Urban for a standard concrete pipe is 75, which is a reasonable value according to literature. Therefore, this value is chosen in the model.

The manning value for plastic pipes is set at 80 with a roughness of 0.001. As pipes are newer, they are less prone to surface degradation. Biofilm and sedimentation can occur, but this is taken into consideration in the manning value.

I.5.4. "New development factor"

The factor that takes future development into consideration is usually set at 1.1. This value is acceptable for the part of the sewer system located in Hørning, where future constructions are probable. In contrast, the municipality plan does not outline any further development for Blegind in the near future.[5] It could be argued that the factor should be 1.0 for Blegind; many of the road surfaces in the town are made of gravel and if all of these were to be upgraded to asphalt, there could be an argument of using a factor of 1.1. Since the sewer systems of the two towns are connected, for practical reasons and time constraints, it is not practical to differentiate between the two of them, the factor is set at 1,1 (worst case scenario).

I.5.5. Climate factor

To more accurately reflect the climate changes expected to occur in the future, a climate factor is used in the model. This factor varies depending on the time horizon (SVK, 2006) and rain event used. In this model a time horizon of 100 years is used, on the basis that a new sewer system is expected to be in use for the next 100 years. (SVK, 2006)

[5] Local plan webgis

Table I. 6. Climate factors proposed in Skrift 27

Climate factors 100 years horizon - Skrift 27		
Event	Standard	High
2-year event	1.2	1.45
10-year event	1.3	1.7
100-year event	1.4	2.0

I.5.6. Rain data

In the model a CDS rain is used; it is an artificial rain event made from historical rain data. The benefit of this, is that you get all the durations of the historical rains in one rain event. As a result, one does not have to take the different durations into consideration in the model. The CDS rain emphasises peak loads, making it ideal for dimensioning the pipes in the sewer system.

Table I. 7. Parameters used in the CDS rain

CDS rain	
Annual precipitation	650 mm
Return period	Status and plan of current system: 10-year rain Solution 1 (separated system): 5-year rain
Duration	60 min
Asymmetrical coefficient	0.5
Timestep	1 min

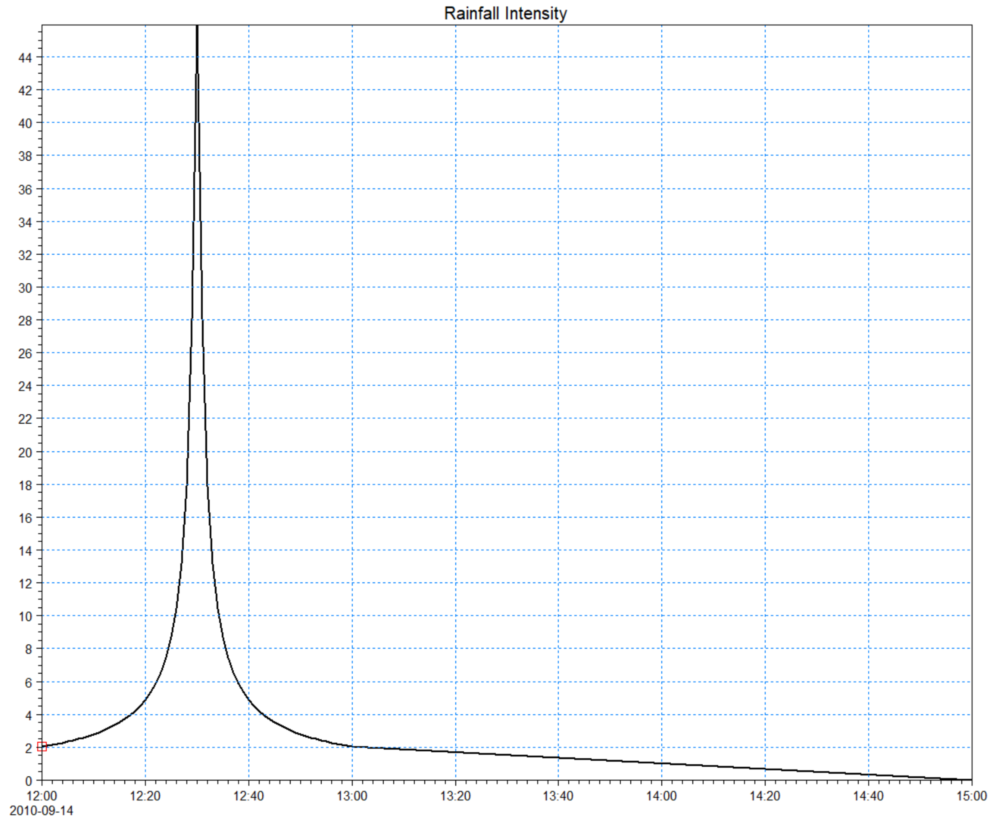


Figure I. 16. 10-year CDS rain with a duration of 60 min. The runtime is extended to 180 min to give the sewer system time to empty itself

I.5.7. Table of parameters used in Mike Urban

Table I. 8. Parameters used in Mike Urban

Parameter	Value
Imperviousness	- Catchments Blegind: Individual (GIS analysis) - Catchments Hørning: Wasterwater plan - Roads and sidewalks: 1.0 - Gravel roads: 0.5 - Green areas: 0.1
Concentration time	- Catchments in Blegind: 7 min - Catchments in Hørning: Individual
Roughness (Manning values)	- Concrete pipes: 75 - Plastic pipes: 80
Head loss	- 0.25 km
Reduction factor	- 0.8
Initial loss	- 0.0006 m
Climate factor	- 1.2-1.4
New development	- 1.1
Model uncertainties	- 1.2

I.6. Solution 1: Separate sewer system (classic)

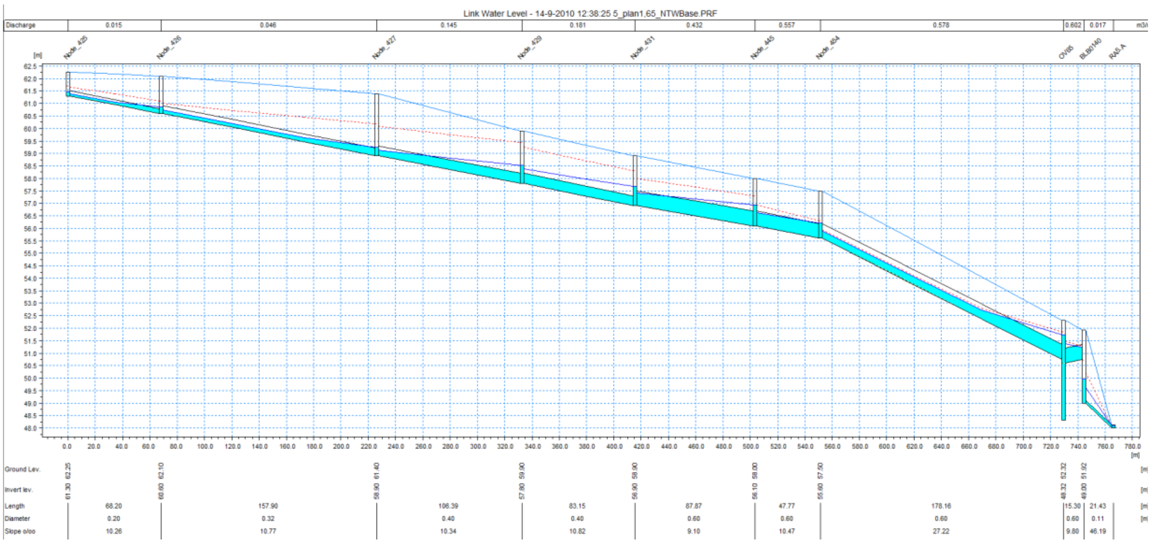


Figure I. 17. Length profile Solution 1

I.6.1. New basin

The new basin is dimensioned using SVK-Spreadsheet (Appendix V.5). The unknown factor is the outflow from the basin. In recent years the consensus, originating from SVK, is that the outflow from the basin should be based on the individual hydraulic capacity of the recipient. The current basin BLB0140 at Damvej, is constructed with an ø110 outflow pipe. According to the Mike Urban model, this pipe has a maximum discharge of 25 l/s. This basin has been operated since 1954, so the argument is that the recipient (Aarhus Å) is capable of handling this discharge. Therefor it is argued that the new basin can have a similar outflow. An outflow of 20 l/s is used in the SVK-spreadsheet.

Table I. 9. Parameters used in the dimensioning of the new basin

Name	Return period	Safety factor	Total area of catchments [ha]	Imperviousness [%]	Impervious area [ha]	Reduction factor	Outflow [l/s]	Total volume [m^3]
New basin	5-year	1.65	10	33.20	3.32	0.8	20	1,210

APPENDIX II. WASTEWATER TREATMENT PLANT

II.1. Requirements and plant description

In this section, the outlet BOD, COD, SS, TN and TP concentration values are calculated by utilizing the available values.[6]

First, the outlet values are obtained from the accessible data.

Table II. 1. Outlet values of BOD, COD, SS, TN and TP

	BOD avg (kg/y)	COD avg (kg/y)	SS avg (kg/y)	TN avg (kg/y)	TP avg (kg/y)	Flow avg (m^3/y)
2013	3096	20021	6281	2751	293	672983
2014	2857	20587	6008	2500	193	840305
2015	3668	25678	11922	2529	278	917057
2016	5206	18270	5218	3141	199	672507
2017	1431	15137	3960	2581	88	742805

After, the outlet concentrations are calculated by a conversion using the flow and the outlet data for each parameter.

Table II. 2. Calculated values fo the outlet concentrations of BOD, COD, SS, TN and TP

	BOD avg (mg/l)	COD avg (mg/l)	SS avg (mg/l)	TN avg (mg/l)	TP avg (mg/l)
2013	4.600	29.750	9.333	4.088	0.435
2014	3.400	24.499	7.150	2.975	0.230
2015	4.000	28.000	13.000	2.758	0.303
2016	7.741	27.167	7.759	4.671	0.296
2017	1.926	20.378	5.331	3.474	0.118

II.2. Temperature

The temperature of 2012 is obtained from the Wastewater Temperatures document. Nevertheless, the temperature of 2017 is acquired from the outlet data, as information for each month is available.

[6] Values obtained from Green Audit 2017 (Skandeborg forsyningsvirjsomhed, 2017)

Table II. 3. Hørning temperature in 2017

	Temperature (ºC)
16/01/2017	7.7
23/02/2017	8.2
14/03/2017	8.7
10/04/2017	9.7
18/05/2017	14.9
15/06/2017	16.1
04/07/2017	17.7
14/08/2017	17.2
04/09/2017	16.8
02/10/2017	14.6
13/11/2017	11.0
20/12/2017	9.5

II.3. Clarifier

II.3.1. Solids loading rate

Solids loading rate (SLR) comes defined by the next equation.

$$SLR = \frac{X_A * (Qi + Qr)}{A, clarifier} \qquad \text{(II.1)}$$

The return sludge values are the ones obtained in the previous section. To make the calculations, the area of the old clarifier, 430 m^2, is taken into account from 2013 to 2016; in 2017 the area of the new clarifier is considered, 629 m^2.

Table II. 4. Calculated value of the Solids Loading Rate

	X_A (g/l)	Qi avg (m^3/d)	Qr avg (m^3/h)	SLR (kg SS/m^2*h)
2013	4.94	76.82	27.88	1.56
2014	4.60	95.93	32.51	1.84
2015	3.88	104.69	35.03	1.79
2016	4.19	76.77	30.61	1.30
2017	4.46	84.80	36.58	1.24

II.3.2. Overflow rate

The overflow rate is defined as the volume of water flow per unit of time divided by the surface area of the clarifier.

$$OR = \frac{Qi}{A, clarifier} \tag{II.2}$$

Table II. 5. Calculated values of the Overflow rate

	Qi avg (m^3/d)	Qi max (m^3/d)	OR avg (m/h)	OR max (m/h)
2013	76.82	239.63	0.179	0.557
2014	95.93	239.21	0.223	0.556
2015	104.69	245.04	0.243	0.570
2016	76.77	213.58	0.179	0.497
2017	84.80	220.25	0.135	0.350

II.3.3. Hydraulic retention time

The hydraulic retention time is defined by the following equation.

$$HRT = \frac{Vclarifier}{(Qi, \max + Qr, \max)} \tag{II.3}$$

To estimate the maximum return flow, it is supposed that the maximum return flow is the 85 % of the maximum inlet flow. (Maribo, WWTP Chap. 5 Mechanical Purification, 2017)

Table II. 6. Calculated values of the hydraulic retention time

	Qi max (m^3/d)	Qr max (m^3/d)	HRT (h)
2013	239.63	203.68	2.425
2014	239.21	203.33	2.429
2015	245.04	208.29	2.371
2016	213.58	181.55	2.721
2017	220.25	187.21	5.711

To make the calculations, the volume of the old clarifier, 1075 m^3, is taken into account from 2013 to 2016; in 2017 the volume of the new clarifier is considered, 2327 m^3.

II.3.4. Sludge volume index

The data represented in the following graphs, starts on August and finishes on August of the next year. Therefore, for 2012 the data from August till December is only used. For 2016 there is missing data, but since more than half of a year is reported, it is taken into account.

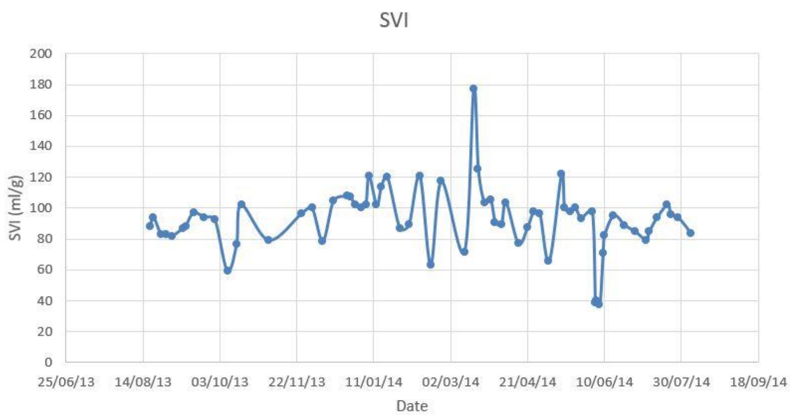


Figure II. 1. SVI from 2013-2014

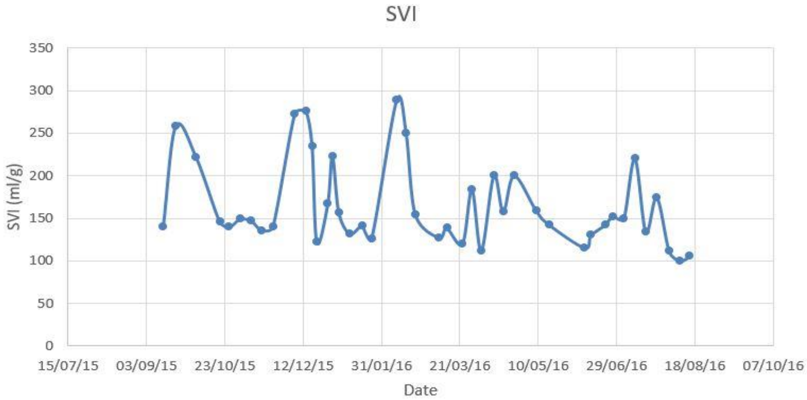


Figure II. 2. SVI from 2015-2016

II.4. OCO tank

II.4.1. Purification efficiency

The degree of purification, DP, is defined by the following equation:

$$DP = \frac{Ci - Co}{Ci} * 100 \qquad \text{(II.4)}$$

In Table II.7 the obtained values of the purification efficiency are shown. [7]

Table II. 7. Obtained values of the Degree of purification

	BOD (%)	COD (%)	TN (%)	TP (%)
2013	98.6	95.3	94.1	95.8
2014	98.4	93.6	91.6	96.1
2015	97.4	91.8	91.7	93.6
2016	96.7	93.5	93.6	96.2
2017	97.9	97.6	94.4	98.5

II.4.2. F/M ratio

The F/M ratio is defined as the total amount of organic matter supplied to the aeration basin per day divided by the total amount of microorganisms in the aeration basin. The VSS/SS ratio is usually between 60 - 85 %.

[7] Values obtained from Green Audit 2017 (Skandeborg forsyningsvirjsomhed, 2017)

$$\frac{F}{M} = \frac{Q * C_i}{V_A * X_A} = \frac{BOD_i}{V_A * X_A} \quad \text{(II.5)}$$

The F/M ratio in kg BOD/kg VSS*d is calculated, assuming that 80 % of SS is VSS. The aerobic volume is 1546 m^3.

Table II. 8. Calculated average F/M ratio values

	BOD,i avg (kg/d)	X_A (g/l)	F/M (kg BOD/kg SS*d)	F/M (kg BOD/kg VSS*d)
2013	626.888	4.94	0.082	0.103
2014	491.137	4.60	0.069	0.086
2015	384.411	3.88	0.064	0.080
2016	426.841	4.19	0.066	0.082
2017	533.483	4.46	0.077	0.097

To know in which loading is the plant working, the calculated values of the F/M are compared to Table II.8. (Maribo, WWTP Chap 6. Biological purification processes, 2018)

Table II. 9. Connection between F/M ratio, DP-or removal of organic matter- and the yield constant (sludge production)

F/M ratio [kg BOD·kg VSS^{-1}·d^{-1}]	Notation	DP for BOD [%]	Y_{tot} [kg DM/kg BOD]
0.0 – 0.3	Low loading	90 – 98	0.6 – 1.1
0.3 – 0.6	Intermediate loading	85 – 90	1.0 – 1.3
0.6 – 5	High loading (or: biosorption)	50 – 85	1.3 – 1.0

II.4.3. COD/BOD ratio

To determine de COD/BOD ratio, COD and BOD inlet values are utilized.

Table II. 10. Calculated COD/BOD ratios

	COD avg (kg/y)	BOD avg (kg/y)	COD/BOD
2013	228814	427344	1.868
2014	179265	322117	1.797
2015	140310	311799	2.222
2016	155797	280211	1.799
2017	194721	589166	3.029

II.4.4. Sludge production

The sludge production, SP, is defined as the total amount of sludge removed from the activated sludge plant per day. It is usually measured in kg SS, suspended solids including inorganic matter, but it can also be formulated taking into account only the organic part of the sludge, in VSS units.

To calculate the sludge production the sludge production from agriculture, the dry matter percentage and the quantity of suspended solids at the outlet are used.

$$SP_{tot} = (SP_{agriculture} * \frac{Dry\ matter}{100}) + SS_{outlet} \qquad (II.6)$$

Table II. 11. Calculations of the average Sludge Production

	SP, agriculture (kg SS/y)	Dry matter (%)	SS, outlet (kg SS/y)	Total SP (kg SS/y)
2013	731000	22.8	6281	172949
2014	839000	17.0	6008	148219
2015	945000	18.6	11922	187220
2016	964000	16.7	5218	166206
2017	1112000	19.2	3960	217464

Sludge production can be divided into two types, chemical sludge production and biological sludge production.

$$SP,tot = SP,bio + SP,chem \qquad (II.7)$$

Chemical sludge production is calculated considering that the chemical sludge formation is around 2.0 kg SS/kg Fe added. (Maribo, WWTP Chap 7. Chemical Wastwater purification, 2008)

$$SP, chem = 2 * m, Fe \quad (II.8)$$

Biological sludge production is obtained as the difference between the total sludge production and the chemical sludge production.

The total amount of iron is obtained by chemical conversion. The molar ratios of iron (Fe), sulfur (S), oxygen (O) and chlorine (Cl) are 55.845 kg/mol, 32.065 kg/mol, 16 kg/mol and 35.453 kg/mol respectively.

Table II. 12. Calculated values for the chemical SP and biological SP

	Tot amount sol (kg/y)	Tot-Fe (kg/y)	SP,chem (kg/y)	SP,bio (kg/y)	SP,tot (kg/y)
2013	25000	1838.09	3676.19	169272.81	172949
2014	18000	1323.43	2646.86	145571.64	148219
2015	55000	2345.41	4690.82	182528.68	187220
2016	100000	4264.38	8528.76	157677.24	166206
2017	140000	5970.13	11940.26	205523.99	217464

II.4.5. Excess sludge production

Excess sludge production, ESP, is defined by the following equations.

$$ESP = QES * XR \quad (II.9)$$

$$SP = ESP + Qo * Xo \quad (II.10)$$

Table II. 13. Calculated values for the Excess Sludge Production

	Flow,o avg (m^3/y)	SS,o avg (mg/l)	ESP (kg SS/d)
2013	672983	9.333	540.849
2014	840305	7.150	411.250
2015	917057	13.000	313.870
2016	672507	7.759	346.128
2017	742805	5.331	458.374

II.4.6. Yield constant

The total yield constant, Y, is defined as the production of biomass per kg of organic matter removed from the wastewater and is calculated using the next equation.

$$Y\ tot = \frac{SP, bio}{MBOD, i - MBOD, o} = \frac{SP, bio}{Q * (CBOD, i - CBOD, o)} \qquad \text{(II.11)}$$

The sludge production, $SP_{bio,}$ is expressed in kg SS/d.

Table II. 14. Calculated values for the Yield constant

	SP,bio (kg SS/d)	BOD,i (kg/d)	BOD,o (kg/d)	Y tot (kg SS/kg BOD*d)
2013	463.76	626.89	8.48	0.7
2014	398.83	491.12	7.83	0.8
2015	500.08	384.41	10.05	1.3
2016	431.99	426.84	14.26	1.0
2017	563.08	533.48	3.92	1.1

II.4.7. Sludge age

Sludge age is defined as the total sludge quantity divided by the sludge production in the treatment plant.

$$SA = V_A * X_A / SP \qquad \text{(II.12)}$$

Table II. 15. Calculated values for the aerobic sludge age

	SA (d)
2013	16.122
2014	17.517
2015	11.682
2016	14.229
2017	11.576

II.4.8. Return sludge rate

The return sludge rate is described as the return flow of sludge over the inlet flow.

$$R = \frac{Qr}{Qi} \tag{II.13}$$

To calculate the return flow a mass balance is applied.

$$Qr * X_R \ \geq \ (Qr + Qi) * X_A \tag{II.14}$$

Table II. 16. Calculated values of the Return Sludge and the Return Sludge rate

	X_A (g/l)	X_R (g/l)	Qi avg (m^3/d)	Qr avg (m^3/h)	R
2013	4.94	18.55	76.82	27.88	0.259
2014	4.60	18.17	95.93	32.51	0.233
2015	3.88	15.45	104.69	35.03	0.214
2016	4.19	14.70	76.77	30.61	0.179
2017	4.46	14.80	84.80	36.58	0.264

II.4.9. Denitrification rate

The denitrification rate is expressed by the next formula.

$$rDN = \frac{mN,DN}{V_{DN} * X_A} \tag{II.15}$$

$$mN,DN = mN,i - mN,o - mN,SP \tag{II.16}$$

Table II. 17. Calculated values of the denitrified mass of nitrogen

	mN,i (kg/d)	mN,o (kg/d)	mN,SP (kg/d)	mN,DN (kg/d)
2013	117.079	7.537	36.530	73.012
2014	65.148	5.485	31.169	28.493
2015	66.376	5.085	38.421	22.870
2016	80.819	8.612	35.285	36.922
2017	97.150	6.405	46.795	43.949

Table II. 18. Calculated values of the rDN

	mN,DN (kg/d)	X_A (g/l)	rDN (g N/kg VSS*h)
2013	73.012	4.94	0.398
2014	28.493	4.60	0.167
2015	22.870	3.88	0.159
2016	36.922	4.19	0.237
2017	43.949	4.46	0.266

II.4.10. Phosphorus removal

For the phosphorus removal, the total quantities of phosphorus and the solution are taken from the available data. The total amount of iron is the one calculated before.

To calculate the COD/P ratio, COD and P inlet data are used.

Table II. 19. COD and P inlet values and COD/P ratio

	COD (kg/y)	TP (kg/y)	COD/P
2013	427344	6696	63.821
2014	322117	4986	64.604
2015	311799	4585	68.004
2016	280211	4198	66.749
2017	589166	5133	114.788

The molar ratios of iron (Fe), sulfur (S), oxygen (O) and chlorine (Cl) are 55.845 kg/mol, 32.065 kg/mol, 16 kg/mol and 35.453 kg/mol respectively.

Table II. 20. Calculated values of Total Phosphorus, Total Iron and Total solution

Compound		Tot amount sol (kg/y)	Tot Fe (kg/y)	TP (kg/y)
Iron sulfate ($FeSO_4$)	2013	25000	1838.09	6696.00
Iron sulfate ($FeSO_4$)	2014	18000	1323.43	4986.00
Iron chloride ($FeCl_3$)	2015	55000	2345.41	4585.00
Iron chloride ($FeCl_3$)	2016	100000	4264.38	4198.00
Iron chloride ($FeCl_3$)	2017	140000	5970.63	5132.63

II.4.11. Oxygen requirements

The oxygen consumption for nitrification can be expressed as:

$$LN = (MN - 0.08 * SPb) * 4.6 \tag{II.17}$$

Furthermore, oxygen consumed due to the denitrification process comes defined by the next formula:

$$LDN = 2.86 * (LN/4.6 - Qdw * Cout, NO_3 - N) \tag{II.18}$$

The daily maximum oxygen consumption can be calculated as:

$$LD, tot = LBOD + LN - LDN \tag{II.19}$$

Table II. 21. Calculated values of LBOD, LDN, LN and LD,tot

	L_{BOD} (kg O_2/d)	L_{DN} (kg O_2/d)	L_N (kg O_2/d)	$L_{D,tot}$ (kg O_2/d)
2013	814.954	336.581	189.545	973.444
2014	638.478	147.049	76.540	711.930
2015	499.734	188.176	103.481	561.800
2016	554.893	242.266	127.319	656.930
2017	693.258	275.788	154.6652	797.450

II.4.12. Aeration system

The relation between the oxygenation capacity under actual conditions and the oxygenation capacity at standard conditions can be expressed as:

$$OC_a = OC_{std} * \frac{(ß * C_{walt} - C_{L)}}{9.17} * 1.024^{(T-20)*\alpha} \tag{II.20}$$

Table II. 22. Calculated values of OCstd and OCa

	α	ß	C_{walt} (mg O/l)	$C_{walt,alt}$ (mg O/l)	C_L (mg O/l)	T avg (ºC)	OC_{std} (kg O/d)	OC_a (kg O_2/d)
2013	0.85	1	10.770	10.716	2	12	1439.447	961.989
2014	0.85	1	10.770	10.716	2	12	1060.874	708.988
2015	0.85	1	10.770	10.716	2	12	874.496	584.430
2016	0.85	1	10.770	10.716	2	12	1002.299	669.841
2017	0.85	1	10.770	10.716	2	12	1620.328	814.663

II.5. Denitrification Rate Experiment

II.5.1. Description

One of the key parameters used to determine the plant capacity is the rate of nitrification and denitrification. In the process of nitrification ammonium is transformed to nitrate. The nitrification depends on the organisms present in the sludge, in relation to the sludge age and the temperature set in the plant. When the concentration of oxygen in the sludge is low, microorganisms can use the oxygen present in the nitrate as an energy source. The nitrate is converted to atmospheric nitrogen. This conversion is called denitrification. These rates depend on the sludge type and the wastewater composition of the plant and can be analysed by taking samples.

II.5.2. Experiment Page

1. *At the WWTP in Hørning:*

a. Sample of activated sludge

b. Sample of raw wastewater

c. Measure the temperature of the process tank.

Date:	Time:	Temperature:

3. *At the laboratory:*

Step 1:

1) Fill a 1 liter measuring glass with the sludge sample.
2) Let the sludge sample settle for approximately 30 minutes.
   a) Half of total volume.
3) Take out the water with a hose.
4) Put the raw wastewater into the measuring glass.
5) Note: 10 ml of sodium-nitrate will be added for the total amount of 1 liter.

Amount of raw wastewater:	

   a) Put in a known sodium-nitrate solution ($NaNO_3$)
      i) Mix 0.8 g of $NaNO_3$ with 10 ml of demineralized water.
   b) Calculate NO_3-N; this will be the starting concentration
   c) A liter of the sample is formed: activated sludge, raw wastewater and sodium-nitrate solution.
      i) Note: keep the sample slightly stirred; so the sludge is not settling.
   d) Measure the temperature of the sample.

Temperature sample in degrees:	

Step 2:

1) Take a 5-6 ml sample of the slightly stirred sample prepared in step 1.
   a) Note: filter the sample directly after sampling.
   b) Note: measure the temperature after the last sample.

Name:	Time interval	Amount (ml):	NO_3 concentration:	Difference in NO_3
C1	00:05			
C2	00:10			
C3	00:15 (00:20)			
C4	00:30			
C5	00:45			
C6	1:00			
C7	1:15			
C8	1:30			

2) The NO_3 concentration can be measured according the following:
   a) Note: clean the flask with demineralized water beforehand.

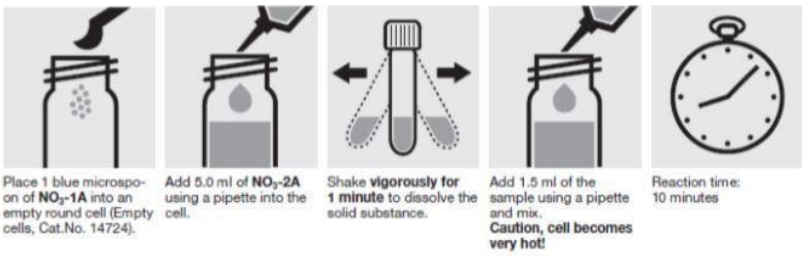


Figure II. 3. Process of measuring the NO_3-N concentration.

The picture above is given at the package of the nitrate-analysis.
   b) Put the flask into the spectrophotometer right after the analyses.
      i) Concentration (g NO_3/L) will be given.

Step 3:

1) Dry and weigh the filter by using the dryer unit (Mdry)
2) Weigh the measuring glass (50 ml glass).

Weight filter (dry):	
Weight measuring glass:	

3) Take a sample of 50 ml of the sludge sample and put it in the measuring class.
   a) Filter the water sample by using a funnel, beaker, filter and vacuum pump.
   b) Put the pre-dried filter in the filter device between the funnel and beaker.
   c) Put in the unsettled sludge sample.
   d) If there is anything left in the measuring glass, clean it with demineralised water. So the whole 50 ml is filtered.
4) Take out the filter and dry and weigh the filter by using the dryer unit.

Weight filter (dry + SS):	
Weight SS:	

5) Do this 3 times.
6) Suspended solids concentration:

$$G_a = \frac{M_{total} - M_{dry}}{V} \quad \frac{g}{l} \qquad \text{(II.21)}$$

II.5.3. The Method Step by Step

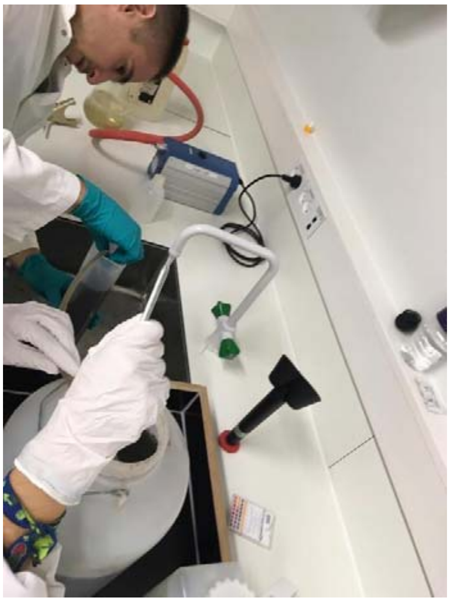


Figure II. 4. The activated sludge sample is put into the one-liter measuring glass by using a tube

Figure II. 5. The activated sludge is settling till have of the volume is activated sludge

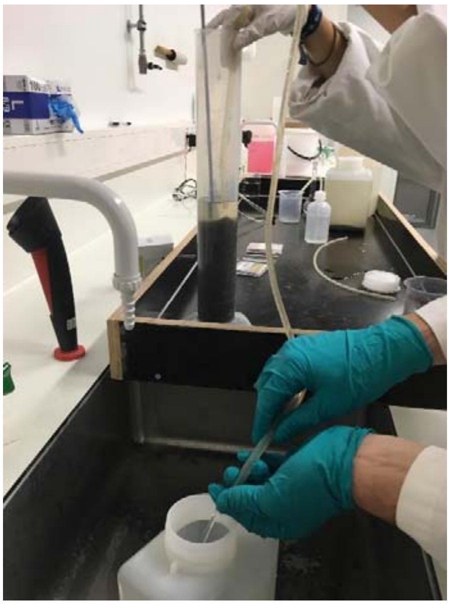


Figure II. 6. The water is taken out until the activated sludge

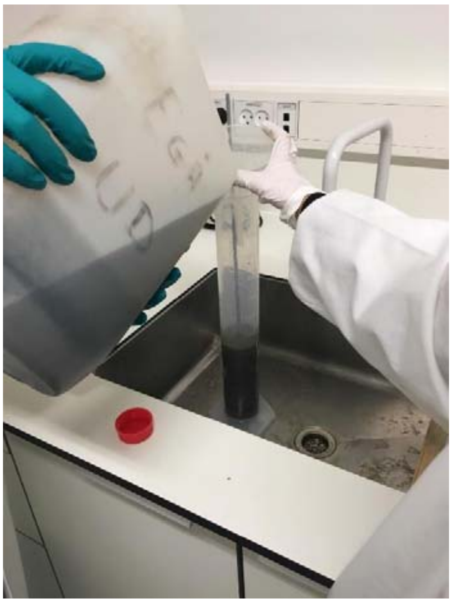


Figure II. 7. The raw wastewater is added to the activated sludge and is going to be the carbon source

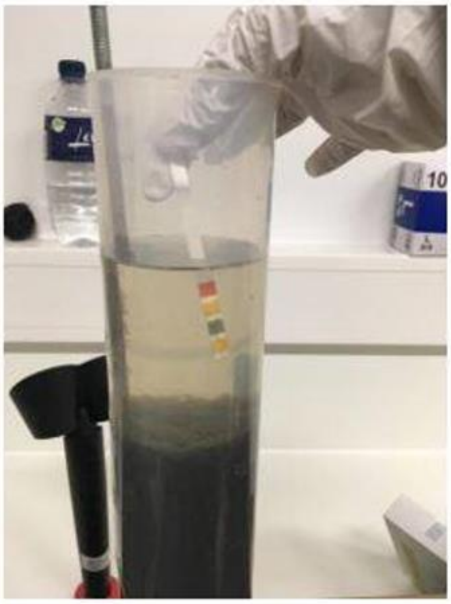


Figure II. 8. The pH of the sample is measured. Temperature is also measured.

Figure II. 9. The sample has to be under slightly stirred conditions to keep it anoxic

Figure II. 10. The amount of $NaNO_3$ used for the experiment

Figure II. 11. The amount of $NaNO_3$ used for the control-experiment

Figure II. 12. The funnel and volumetric flask used for adding the correct amount of the sodium nitrate solution

Figure II. 13. The sodium nitrate solution is added to a beaker

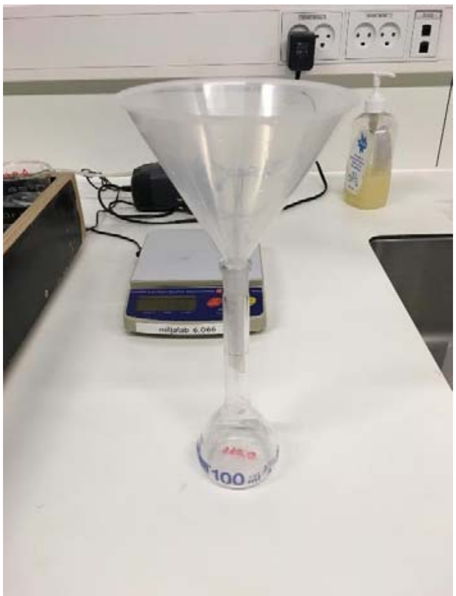


Figure II. 14. 10 ml of the sodium nitrate solution is taken out with a syringe

Figure II. 15. The 10 ml of the sodium nitrate solution is added to the one-liter sample

Figure II. 16. 1 ml of the filtered sample is taken

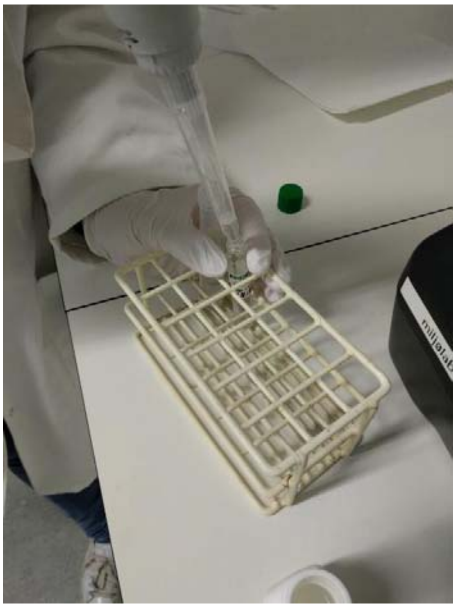


Figure II. 17. 1 ml is added to NO_3-1A

Figure II. 18. 0.2 ml of NO_3-1B is taken

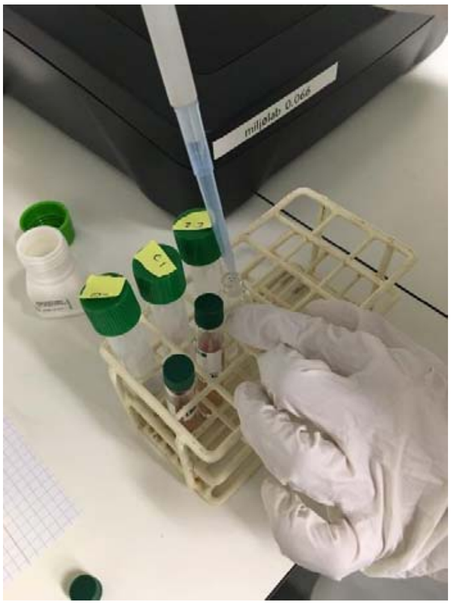


Figure II. 19. 0.2 ml of NO_3-1B is added to the sample prepared in Figure II. 17.

Figure II. 20. The sample is mixed by shaking the test tube

Figure II. 21. The sample is mixed by shaking the test tube

Figure II. 22. Dry and weigh the filter paper by using the weigh and dryer unit

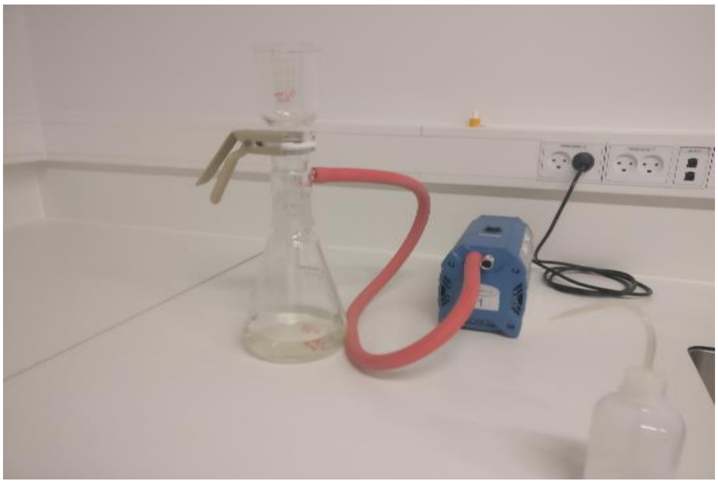


Figure II. 23. Filter de 50 ml sludge sample, by using the pred-dried filter

Figure II. 24. Dry the filter after the filtration and weigh the suspended solids on the filter paper

II.6. Estimation of Vacant Capacity and Future Predictions

II.6.1. Population

The population growth for the future years is estimated using excel's tendency and utilizing past years data. (Wikipedia, 2018)

Table II. 23. Estimated population

Year	Population
Avg 2013 - 2017	7750
2020	8092
2025	8749
2030	9407
2035	10065
2040	10722
2045	11380
2050	12038

II.6.2. Future performance of the WWTP

To estimate the future performance of the WWTP, first BOD, COD, TN and TP inlet quantities and the flow are calculated.

For the calculations, a water load of 0.2 m^3, 60 g BOD, 12 g N, 1.8 g P per person per day is assumed. Typical COD/BOD ratio for domestic raw wastewater to maintain a suitable degradability of the organic matter is between 2-2.5; to do the calculations the value of 2 is considered (120 g COD per person). (Henze M. , 2000)

Table II. 24. Typical ratios values are obtained from Table 1.12 of the compendium

Pollutant	g/person*d
BOD	60
COD (BOD*2)	120
TN	12
TP	1.8

To calculate the estimations for the flow, BOD, COD, TN and TP data from Table II.25. and previous years is used (average value from years 2013-2017). The difference in population from year to year is multiplied by the assumed values of pollutant per person and added to the amount.

Table II. 25. Calculated future values for the Q, BOD, COD, TN and TP

Year	Q, 85 % (m^3/d)	BOD (kg/d)	COD (kg/d)	TN (kg/d)	TP (kg/d)
2013 - 2017	3133.0	492.5	1057.8	95.4	14.0
2020	3201.4	513.0	1098.8	99.5	14.6
2025	3332.8	552.4	1177.7	107.4	15.8
2030	3464.4	591.9	1256.6	115.3	17.0
2035	3596.0	631.4	1335.6	123.2	18.2
2040	3727.4	670.8	1414.4	131.1	19.3
2045	3859.0	710.3	1493.4	139.0	20.5
2050	3990.6	749.8	1572.4	146.9	21.7

II.6.3. OCO tank

When obtaining the F/M ratio, the sludge production and the sludge age, the average sludge concentration from the available data of the previous years, from 2013 to 2017, is used. It has a value of 4.4 kg SS/m^3 and it is considered as a constant.

The calculations are made applying the following equations:

$$\frac{F}{M} = \frac{Q * Ci}{V_A * X_A} = \frac{BOD\ i}{V_A * X_A} \tag{II.22}$$

$$SP = Ytot * (M\ BOD, i - M\ BOD, o) \tag{II.23}$$

$$SA = V_A * X_A / SP \tag{II.24}$$

For the estimation of the yield constant, as data for the future years is not known, an interpolation is made using the F/M ratio and data from Table II.26.

Table II. 26. Connection between F/M ratio, DP - or removal of organic matter - and the yield constant (sludge production)

F/M ratio [kg BOD·kg VSS^{-1}·d^{-1}]	Notation	DP for BOD [%]	Y_{tot} [kg DM/kg BOD]
0.0 – 0.3	Low loading	90 – 98	0.6 – 1.1
0.3 – 0.6	Intermediate loading	85 – 90	1.0 – 1.3
0.6 – 5	High loading (or: biosorption)	50 – 85	1.3 – 1.0

Table II. 27. Calculated values for the F/M ratio, yield constant, sludge production and sludge age

Year	Ytot (kg SS/kg BOD*d)	F/M (kg BOD/Kg SS*d)	F/M (kg BOD/Kg VSS*d)	BODout (kg/d)	SP (kg SS/d)	SA (d)
Avg 2013-2017	0.94	0.072	0.091	31.3	432.8	15.7
2020	0.95	0.075	0.094	32.0	455.2	14.9
2025	0.96	0.081	0.102	33.3	499.1	13.6
2030	0.98	0.087	0.109	34.6	544.2	12.5
2035	0.99	0.093	0.116	36.0	590.5	11.5
2040	1.01	0.099	0.123	37.3	637.9	10.7
2045	1.02	0.104	0.131	38.6	686.4	9.9
2050	1.04	0.110	0.138	39.9	736.2	9.2

Volume analysis

The total volume is calculated supposing that the required sludge age is a constant, the following equation is applied.

$$SA = \frac{V_A * X_A}{SP} \tag{II.25}$$

Table II. 28. Expected total volume values

Year	SA (d)	X_A (kg SS/m^3)	SP (kg SS/d)	V_A (m^3)	V_{Anox} (m^3)	V_{Anae} (m^3)	$V_{tot,act}$ (m^3)	$V_{tot,15d}$ (m^3)
Avg 2013- 2017	15	4.4	401.5	1368.8	1316	523	3385	3207
2020	15	4.4	421.2	1436.0	1316	523	3385	3274
2025	15	4.4	459.6	1566.8	1316	523	3385	3405
2030	15	4.4	498.8	1700.4	1316	523	3385	3539
2035	15	4.4	538.7	1836.5	1316	523	3385	3675
2040	15	4.4	579.3	1974.8	1316	523	3385	3813
2045	15	4.4	620.7	2166.0	1316	523	3385	3954
2050	15	4.4	662.8	2259.6	1316	523	3385	4098

Denitrification
Knowing that the denitrification process will be fast and that at least 15 days are needed for nitrification, the aerobic and anaerobic volumes can be calculated. As an assumption, denitrification rate is kept constant with a value of 0.5 g N/kg VSS*h (0.4 kg N/kg SS*h).

To estimate the ESP, the average value of the SS in the outlet (2013-2017) has been used. This outlet value has been subtracted from the SP to get the ESP. For the ESP of the following years, this first ESP has been divided by the SP to get a ratio; this ratio is multiplied by the SP of each year to get the future ESP. The 8 % of this is going to be nitrogen.

To estimate the mass of sludge that has been denitrified, first of all, the aerobic volume has been calculated by supposing a 15-day sludge age, a denitrification rate of 0.5 g N/kg VSS*h and a sludge concentration of 4.4 kg SS/m^3. The anoxic volume can be calculated now and the denitrified mass too.

Finally, the nitrogen amount and its concentration in the outlet can be calculated.

Table II. 29. Expected values of aerobic and anaerobic volume

Year	SP (kg SS/d)	ESP (kg SS/d)	mN,ESP (kg/d)	mN,DN (kg/d)	mN,out (kg/d)	N out (mg/l)	V, DN (m^3)	VA (m^3)
Avg 2013-2017	432.8	414.5	33.163	58.6	3.7	1.2	1386	1476
2020	455.2	436.0	34.879	55.3	9.3	2.9	1310	1552
2025	499.1	478.0	38.242	49.0	20.1	6.0	1160	1702
2030	544.2	521.2	41.699	42.5	31.1	9.0	1007	1855
2035	590.5	565.5	45.244	35.9	42.1	11.7	849	2013
2040	637.9	610.9	48.872	29.0	53.2	14.3	687	2175
2045	686.4	657.4	52.594	22.0	64.3	16.7	522	2340
2050	736.2	705.1	56.404	14.9	75.6	18.9	352	2510

Oxygen consumption

For the analysis of the future oxygen consumption of the OCO tank, it is supposed that the three blowers are working at their maximum load.

$$Blowers\ \max load = 540\frac{N*m^3}{h} + 900\frac{N*m^3}{h} + 1140\frac{N*m^3}{h} = 2580\frac{N*m^3}{h}$$

Assuming that the air flow is 8 $N*m^3/h*m$, the O_2 input is obtained, being around 20 g $O_2/N*m^3*m$. The oxygen consumption under standard conditions is calculated applying the next equation.

$$OC_{std}20\ \frac{gO_2}{N*m^3*m} * 3.6\ m * 2580\frac{N*m^3}{h} * \frac{24\ h}{1\ d} * \frac{1\ kgO_2}{1000\ gO_2} = 4458.24\ \frac{kg\ O_2}{d}$$

To obtain the oxygen consumption under actual conditions, the next equation is applied.

$$OC_a = OC_{std} * \frac{(ß * C_{walt} - C_{L)}}{9.17} * 1.024^{(T-20)*\alpha}$$

$$OC_a = 4458.24\ \frac{gO_2}{d} * 0.668 = 2979.46\ \frac{kg\ O_2}{d}$$

II.6.4. Clarifier

To study the future performance of the clarifier, the overflow ratio, the solids loading rate and the hydraulic retention time are estimated with the following formulas.

The area of the clarifier, the volume of the clarifier and the sludge age are 629 m^2, 2327 m^3 and 4.4 g/l respectively.

$$OR = \frac{Qi}{Aclarifier} \tag{II.26}$$

Table II. 30. Expected values of the Overflow rate

	Q,i 85 % (m^3/h)	OR 85 % (m/h)
2017	130.542	0.221
2020	133.392	0.212
2025	138.867	0.221
2030	144.350	0.229
2035	149.833	0.238
2040	155.308	0.247
2045	160.792	0.256
2050	166.275	0.264

$$SLR = \frac{X_A * (Qi + Qr)}{A, clarifier} \quad \text{(II.27)}$$

A mass balance will be applied to calculate the return flow (Qr):

$$Q_r * X_R \geq (Q_r + Q_i) * X_A \quad \text{(II.28)}$$

Table II. 31. Expected values of the Solids Loading rate

	Q,i 85 % (m^3/h)	Q,r 85 % (m^3/h)	SLR (kg SS*m^2*h)
2017	130.542	110.960	1.770
2020	133.392	113.383	1.680
2025	138.867	118.037	1.745
2030	144.350	122.698	1.828
2035	149.833	127.358	1.887
2040	155.308	132.012	1.956
2045	160.792	136.673	2.025
2050	166.275	141.334	2.094

$$HRT = \frac{Vclarifier}{(Qi,max + Qr,max)} \tag{II.29}$$

Table II. 32. Expected values of the Overflow rate, Solids Loading rate and Hydraulic Retention Time

	Qi,max (m^3/h)	Qr,max (m^3/h)	HRT (h)
2017	232	197	5.712
2020	242	205	5.203
2025	261	222	4.812
2030	281	239	4.476
2035	301	256	4.183
2040	320	272	3.927
2045	340	289	3.700
2050	360	306	3.497

Dimensions

The validity of the dimensions of the clarifier in the future is analyzed by calculating the OR and HRT for the maximum possible inlet flow, 380 m^3/h. The sludge concentration and the return sludge concentration are supposed to remain constant along the years, 4.4 kg SS/m^3 and 16.34 kg SS/m^3 respectively.

$$OR,max = \frac{380\ \frac{m^3}{h}}{629\ m^2} = 0.604\ \frac{m}{h}$$

To obtain the SLR, return flow of the 85 % of the inlet flow and 95 % of the inlet flow are supposed.

<u>*85 % of the inlet flow*</u>

$$SLR,\text{max} = \frac{4.4\ \frac{kg\ SS}{m^3} * (380\frac{m^3}{h} + 323\frac{m^3}{h})}{629\ m^2} = 4.918\ \frac{kg\ SS}{m^2 * h}$$

<u>*95 % of the inlet flow*</u>

$$SLR,\text{max} = \frac{4.4\ \frac{kg\ SS}{m^3} * (380\frac{m^3}{h} + 361\frac{m^3}{h})}{629\ m^2} = 5.183\ \frac{kg\ SS}{m^2 * h}$$

Hereunder, the mass balance is calculated to verify if the clarifier will be able to perform well in the future.

$$Q_r * X_r \geq (Q_i + Q_r) * X_A$$

$$323\frac{m^3}{h} * 16.34\frac{kg\ SS}{m^3} \geq \left(380\frac{m^3}{h} + 323\frac{m^3}{h}\right) * 4.4\frac{kg\ SS}{m^3}$$

$$5277.82\frac{kg\ SS}{h} \geq 3093.20\ \frac{kg\ SS}{h}$$

APPENDIX III. RECEIVING WATER BODY

III.1. Macro Index

III.1.1. Before the CSO area

Table III. 1. Diversity groups found in the stream part before the CSO

Group	Specie
Odonata	Epitheca
Heteroptera	Notonecta
Megaloptera	Sialis
Odonata	Calopteryx Virgo
Crustacea	Gammarus
Plecoptera	Isoptena
Chironomidae	Chironomus
Coleoptera	Hydrophilus
Heteroptera	Corixinae

There is a total of eight different groups in the samples, in which the key group is the 'Plecoptera'. Since there is only one specie for this group, the result is a macro index of 7.

Table III. 2. Macro index for stream part before the CSO

Table 2		**Number of groups (Diversity-groups)**				
		0-1	2-5	6-10	11-16	17-20
Keygroups		**Macro index**				
Plecoptera	More than one specie		7	8	9	10
excl. Nemoura	Only one specie		6	7	8	9
Ephemeroptera	More than one specie		6	7	8	9
excl. Baetis rhodani	Only one specie		5	6	7	8
Trichoptera	More than one specie		5	6	7	8
or Nemoura or Baetis rhodani	Only one specie	4	4	5	6	7
Gammarus		3	4	5	6	7
Asellus		2	3	4	5	6
Chironomus with gills		1	2	3	4	
Red Oligochaeta		1	2	3		
Syrphidae		0	1	2		
No living invertebrates		00				

III.1.2. In the CSO area

Table III. 3. Diversity groups found in the stream part of the CSO's outlet

Group	**Specie**
Heteroptera	Notonecta
Megaloptera	Sialis
Odonata	Calopteryx Virgo
Crustacea	Gammarus
Plecoptera	Isoptena
Coleoptera	Dytiscus
Heteroptera	Corixinae

There is a total of seven different groups in the samples, in which the key group is the 'Plecoptera'. Since there is only one specie for this group, the result is a macro index of 7.

Table III. 4. Macro index for stream part in the CSO's outlet

Table 2		**Number of groups (Diversity-groups)**				
		0-1	2-5	6-10	11-16	17-20
Keygroups		**Macro index**				
Plecoptera	More than one specie		7	8	9	10
excl. Nemoura	Only one specie		6	7	8	9
Ephemeroptera	More than one specie		6	7	8	9
excl. Baetis rhodani	Only one specie		5	6	7	8
Trichoptera	More than one specie		5	6	7	8
or Nemoura or Baetis rhodani	Only one specie	4	4	5	6	7
Gammarus		3	4	5	6	7
Asellus		2	3	4	5	6
Chironomus with gills		1	2	3	4	
Red Oligochaeta		1	2	3		
Syrphidae		0	1	2		
No living invertebrates		00				

III.1.3. After the CSO area

Table III. 5. Diversity groups found in the stream part after the CSO

Group	Specie
Heteroptera	Notonecta
Megaloptera	Sialis
Odonata	Calopteryx Virgo
Crustacea	Gammarus
Chironomidae	Chironomus
Coleoptera	Dytiscus
Coleoptera	Acilius
Other species	Fish

There is a total of seven different groups in the samples, in which the key group is the 'Gammarus'. the result is a macro index of 5.

Table III. 6. Macro index for stream part after the CSO

Table 2		**Number of groups (Diversity-groups)**				
		0-1	2-5	6-10	11-16	17-20
Keygroups		**Macro index**				
Plecoptera	More than one specie		7	8	9	10
excl. Nemoura	Only one specie		6	7	8	9
Ephemeroptera	More than one specie		6	7	8	9
excl. Baetis rhodani	Only one specie		5	6	7	8
Trichoptera	More than one specie		5	6	7	8
or Nemoura or Baetis rhodani	Only one specie	4	4	5	6	7
Gammarus		3	4	5	6	7
Asellus		2	3	4	5	6
Chironomus with gills		1	2	3	4	
Red Oligochaeta		1	2	3		
Syrphidae		0	1	2		
No living invertebrates		00				

III.2. Water quality

The three parts of the stream have values between 5 and 8, equivalent to a "moderate to fine quality, slightly polluted" stream. The pollution index is two.

Table III. 7. Macro index - water quality and pollution index relation

Table 3 Macro index	Water quality	Pollution index
9, 10	Very good quality, no or only very slightly pollutet	I (II)
5, 6, 7, 8	Moderate to fine quality, slightly pollutet	II
2, 3, 4	Poor quality, pollutet	III
0, 1	Very poor quality, strongly pollutet	IV
0	Poisoned	

III.3. Pictures of Invertebrates from the Macro Index

Pictures of all the insects observed in the lab. Nearly all the pictures are taken from the internet, since the quality of the took ones were not the expected ones (it was difficult to distinguish the different species using that photos).

Figure III. 1. Odonata Epitheca

Figure III. 2. Heteroptera notonecta (Nonoctea, 2007)

Figure III. 3. Megaloptera Siglis (Aquatic Insects, 2010)

Figure III. 4. Megaloptera Sialis (Beautiful Demoiselle, 2010)

Figure III. 5. Crustacea Gammarus (Sunray, 2008)

Figure III. 6. Plecoptera Isoptena

Figure III. 7. Chironomidae Chironomus (First Nature, 2007)

Figure III. 8. Coleoptera hydrophilus (Flickr, 2013)

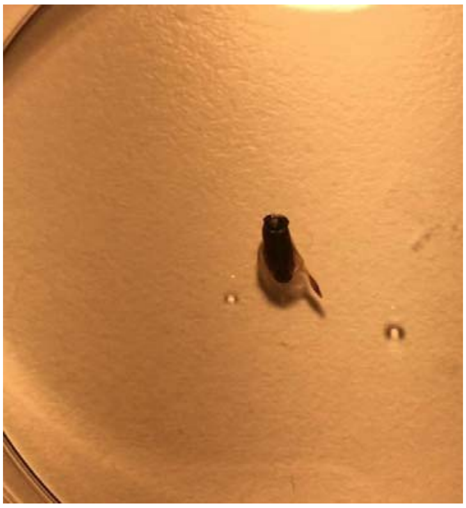


Figure III. 9. Heteroptera Corixinae

Figure III. 10. Coleoptera Dytiscus (Naturalist, 2015)

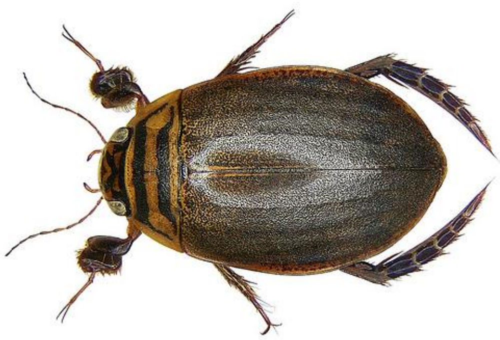
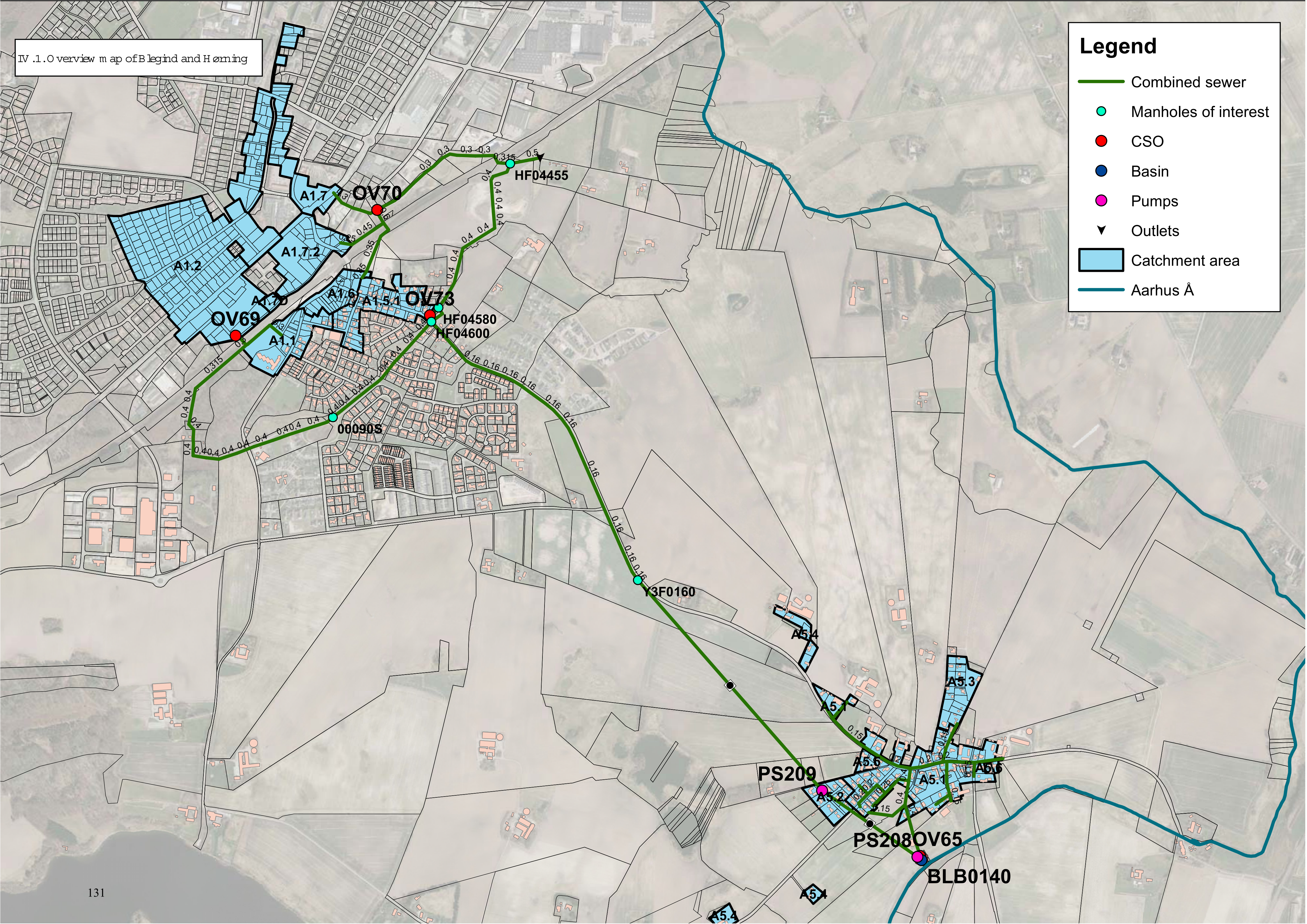


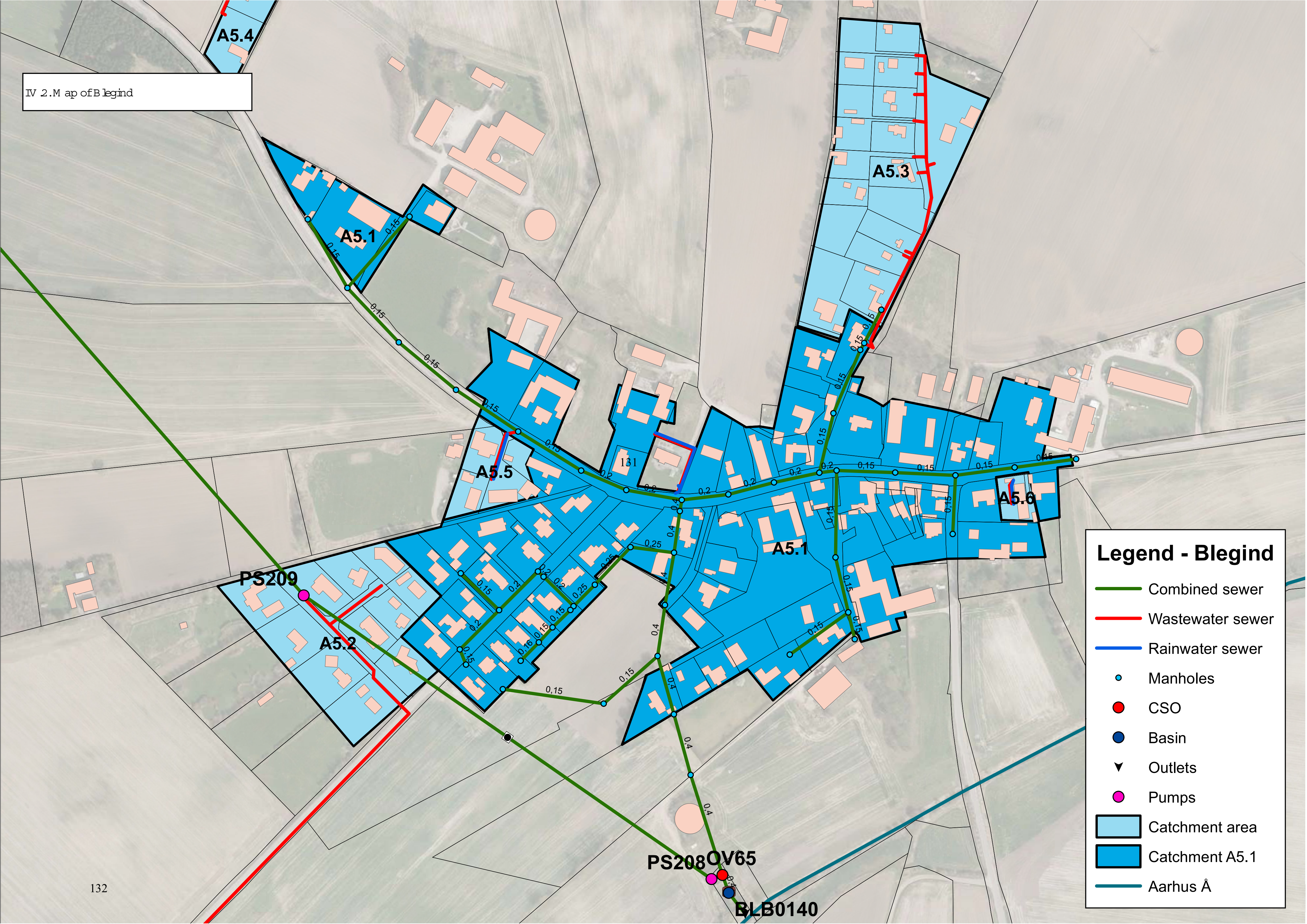
Figure III. 11. Coleoptera Acilius (Flickriver, 2013)

APPENDIX IV. PLANS

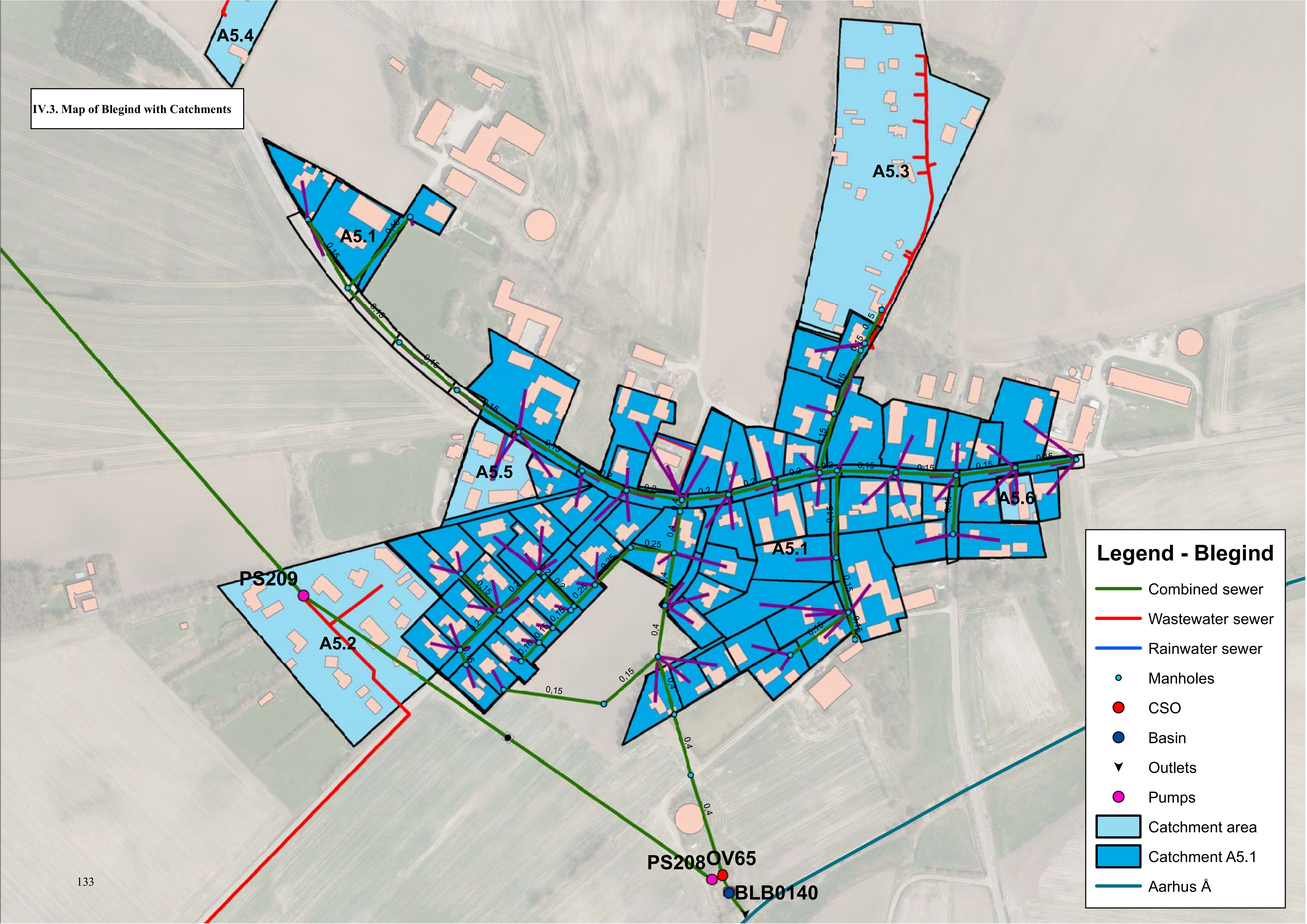
IV.1. Overview map of Blegind and Hørning



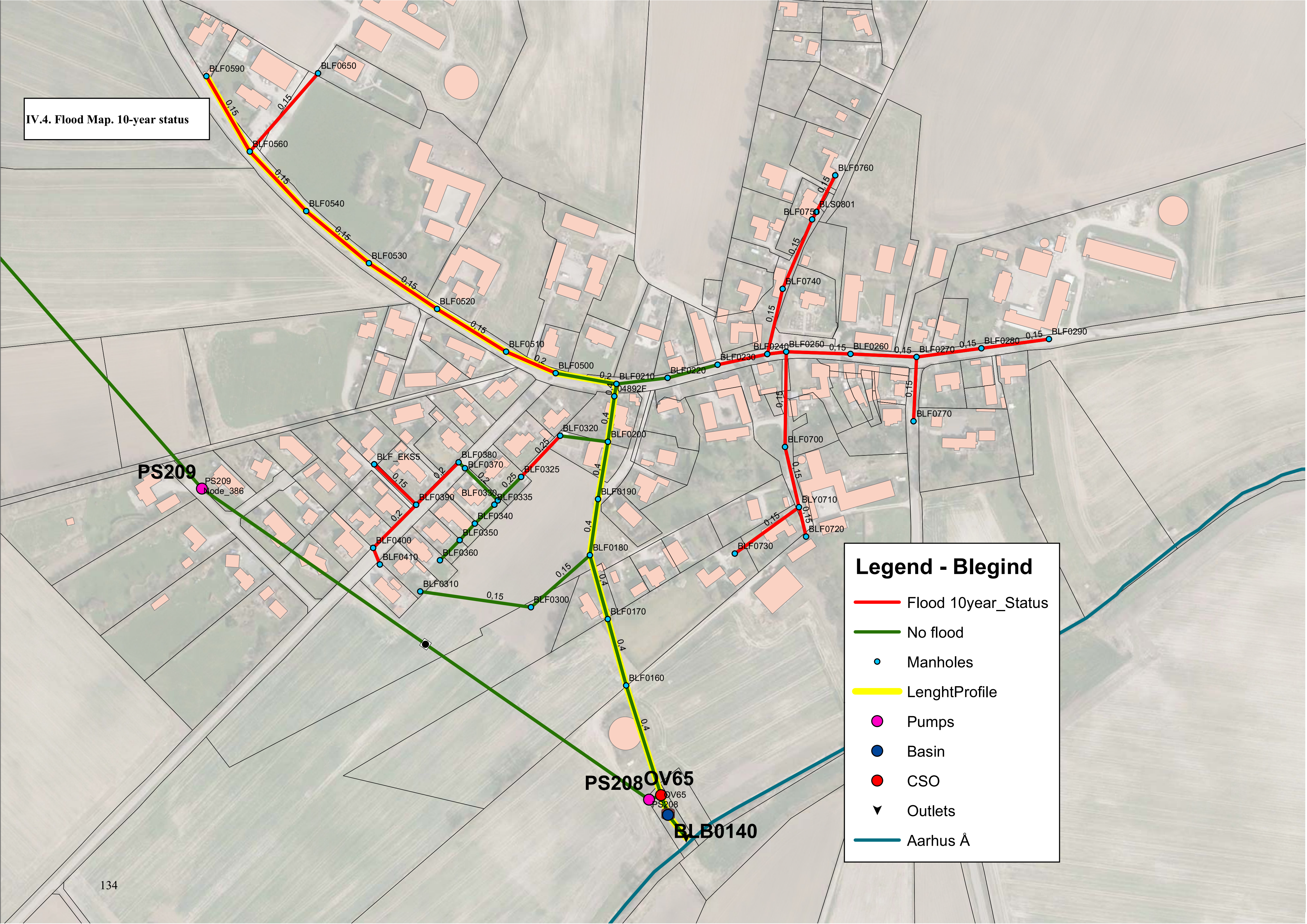
IV 2. Map of Blegind



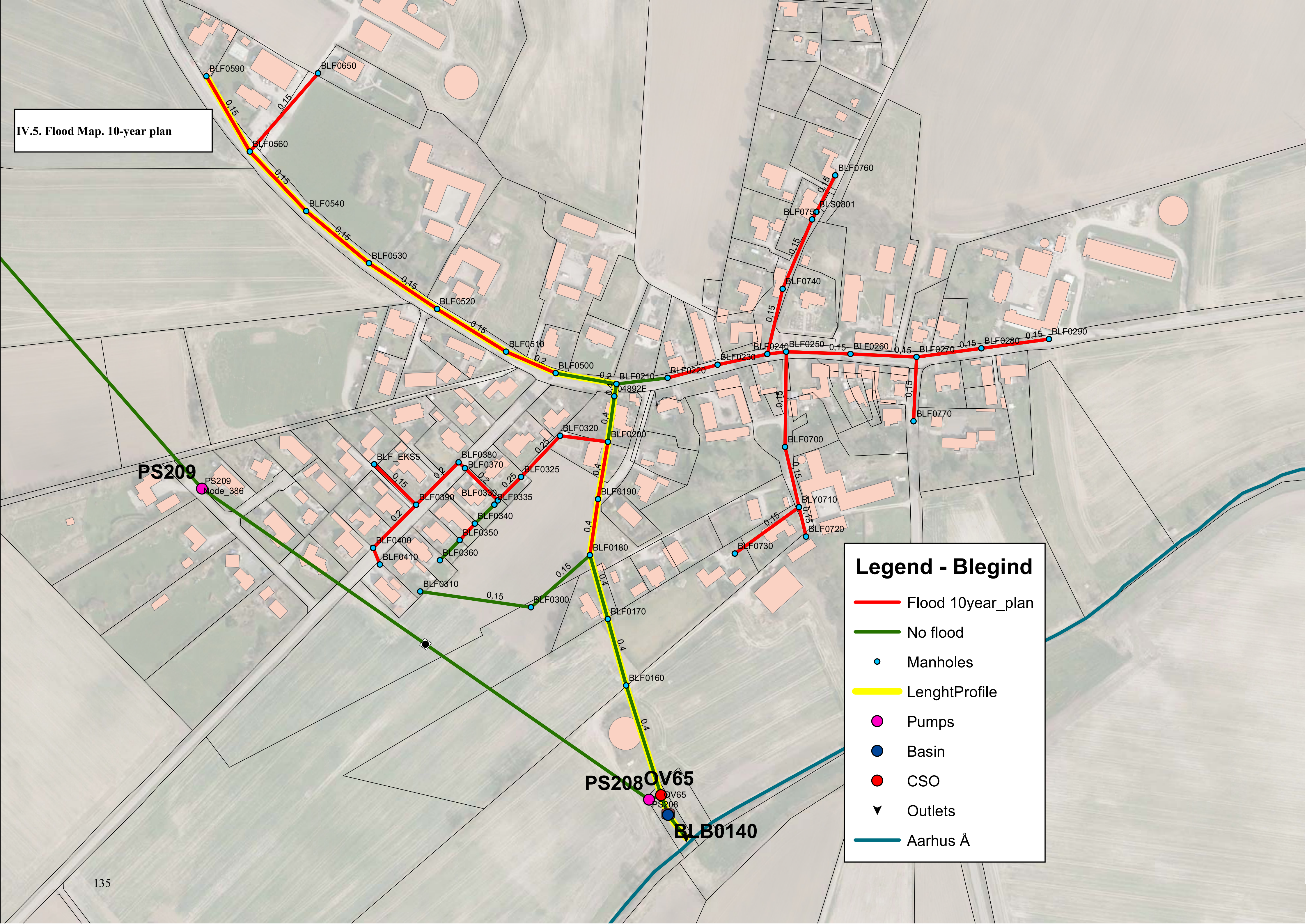
IV.3. Map of Blegind with Catchments



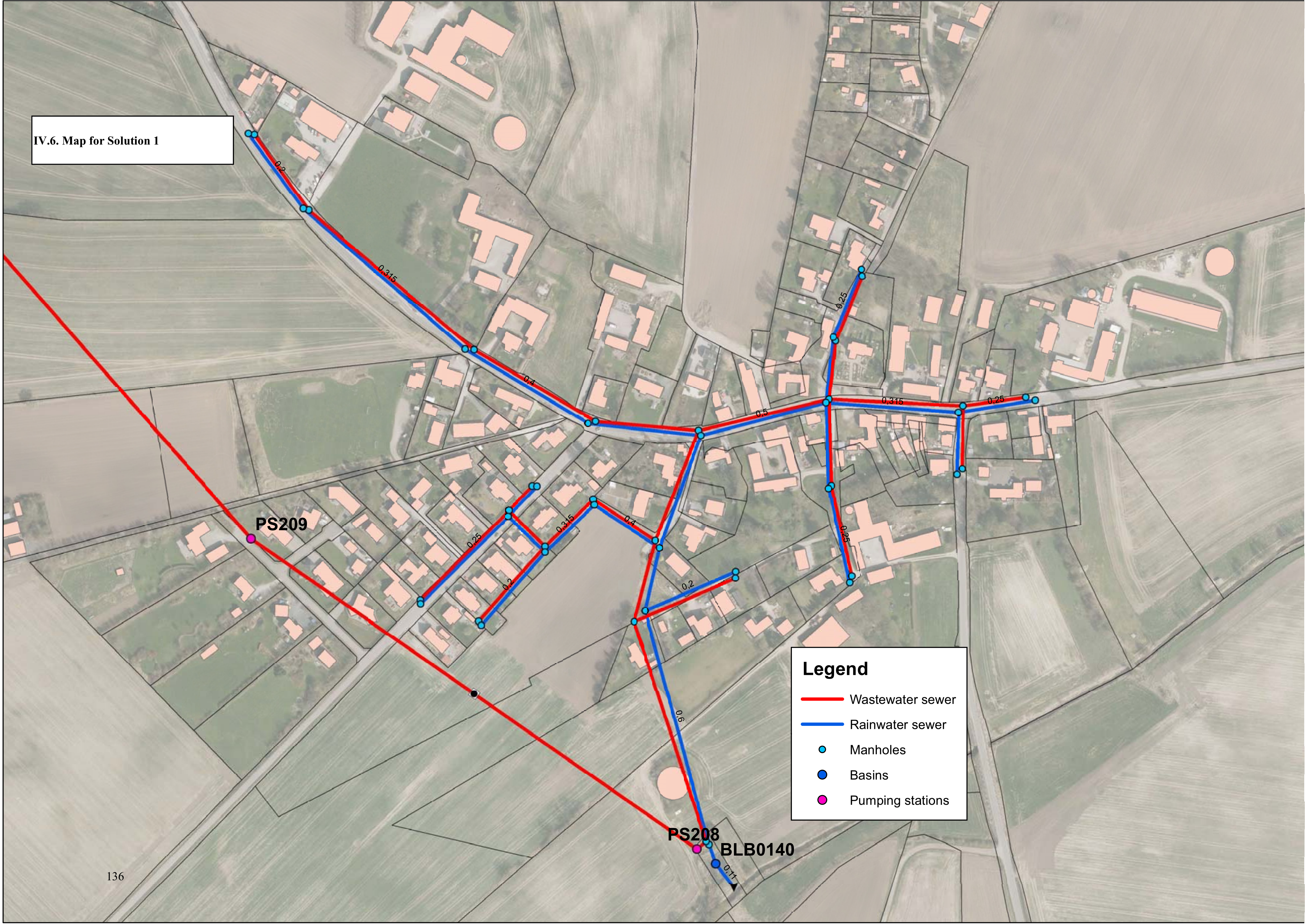
IV.4. Flood Map. 10-year status



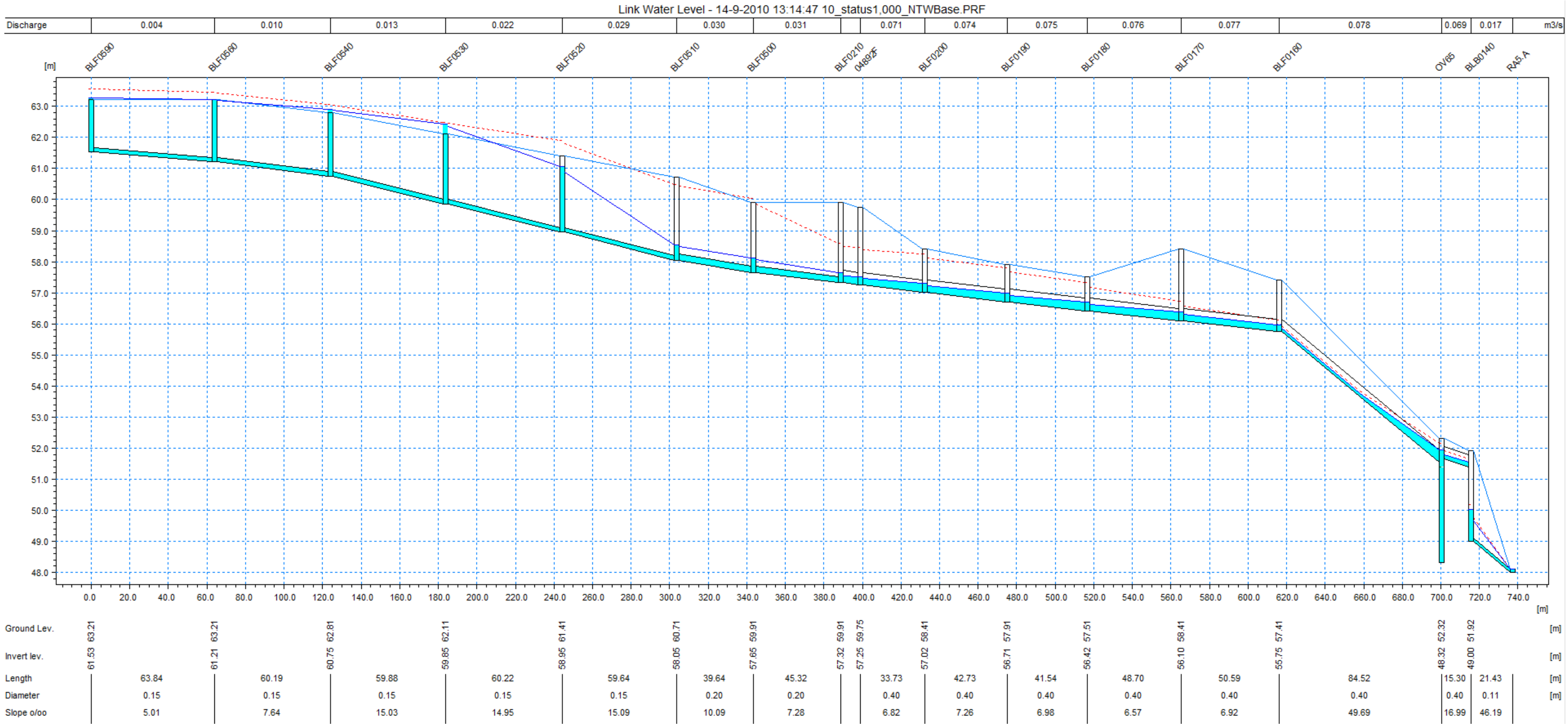
IV.5. Flood Map. 10-year plan



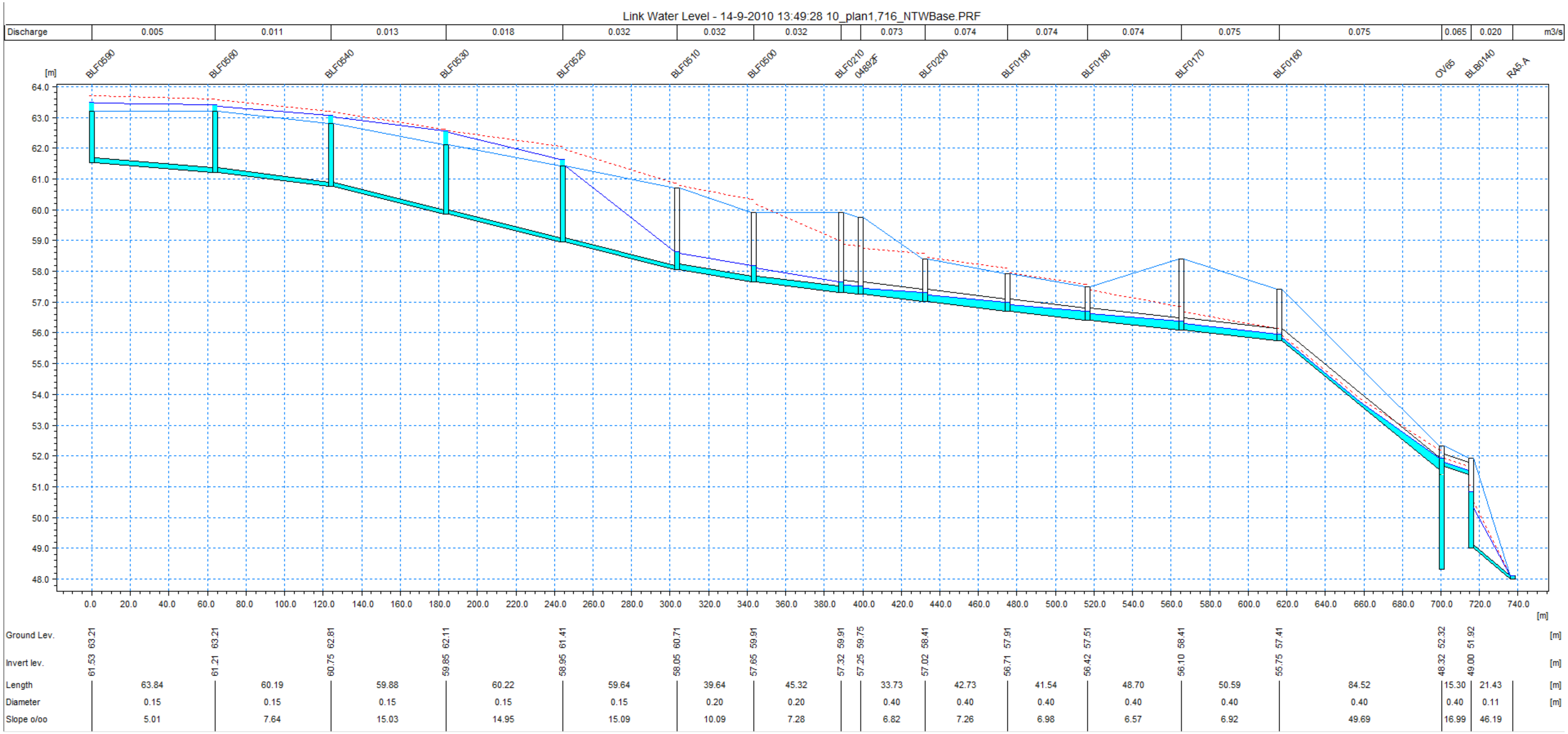
IV.6. Map for Solution 1



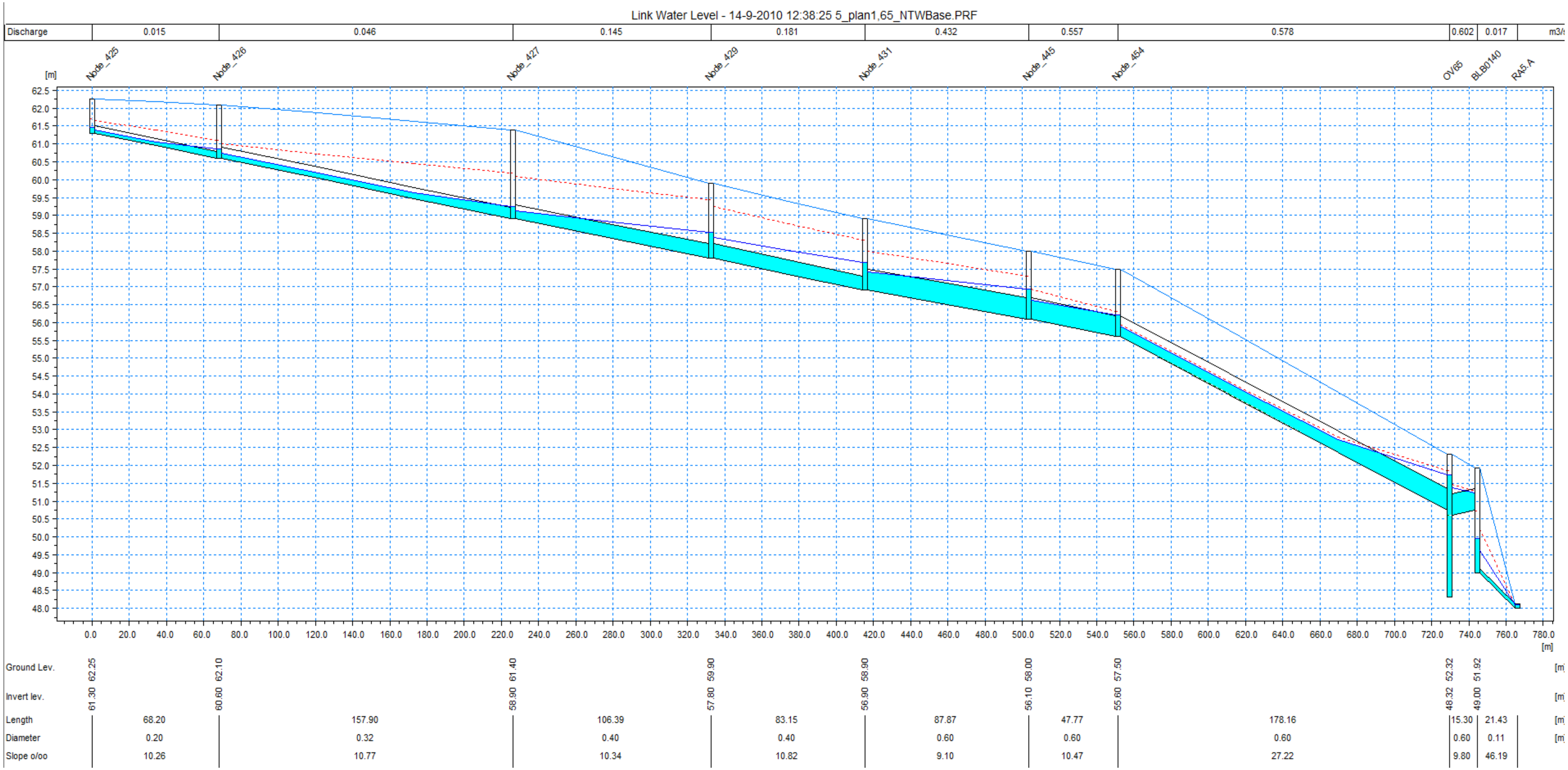
IV.7. Length profile status model



IV.8. Length profile plan model



IV.9. Length profile for Solution 1



APPENDIX V. EXCEL SPREADSHEETS

V.1. Imperviousness

MUID	Total Area [ha]	Total Area [m2]	Area Buildings [m2]	impv [%]	Area	Part of total area	In percentage	With Weight		Total area
Catchment_0001	0.099	990	255	26	Parcel	0.010	0.96	24.69		
Catchment_0002	0.101	1012	293	29	Parcel	0.010	0.98	28.37		
Catchment_0003	0.333	3331	791	24		0.032	3.23	76.60	Parcel	24.78
Catchment_0004	0.136	1364	249	18		0.013	1.32	24.11		
Catchment_0005	0.425	4248	1003	24		0.041	4.11	97.13		
Catchment_0006	0.156	1557	148	10		0.015	1.51	14.33		
Catchment_0007	0.076	756	118	16		0.007	0.73	11.43		
Catchment_0008	0.077	773	200	26		0.007	0.75	19.37		
Catchment_0009	0.097	974	216	22		0.009	0.94	20.92		
Catchment_0010	0.099	986	206	21	Parcel	0.010	0.95	19.95		
Catchment_0011	0.140	1399	241	17		0.014	1.35	23.34		
Catchment_0012	0.099	995	164	16	Parcel	0.010	0.96	15.88		
Catchment_0013	0.097	973	180	18	Parcel	0.009	0.94	17.43		
Catchment_0014	0.104	1044	200	19		0.010	1.01	19.37		
Catchment_0015	0.100	999	249	25	Parcel	0.010	0.97	24.11		
Catchment_0016	0.077	767	186	24		0.007	0.74	18.01		
Catchment_0017	0.100	1001	282	28	Parcel	0.010	0.97	27.31		
Catchment_0018	0.126	1255	349	28	Parcel	0.012	1.22	33.80		
Catchment_0019	0.144	1442	277	19	Parcel	0.014	1.40	26.82		
Catchment_0020	0.081	807	247	31	Parcel	0.008	0.78	23.92		
Catchment_0021	0.076	765	200	26		0.007	0.74	19.37		
Catchment_0022	0.098	984	165	17	Parcel	0.010	0.95	15.98		
Catchment_0023	0.069	695	175	25	Parcel	0.007	0.67	16.95		
Catchment_0024	0.069	695	274	39	Parcel	0.007	0.67	26.53		
Catchment_0025	0.080	800	159	20	Parcel	0.008	0.77	15.40		
Catchment_0026	0.080	802	275	34	Parcel	0.008	0.78	26.63		
Catchment_0027	0.070	699	184	26	Parcel	0.007	0.68	17.82		
Catchment_0028	0.080	800	209	26	Parcel	0.008	0.77	20.24		
Catchment_0029	0.160	1600	352	22		0.015	1.55	34.09		
Catchment_0030	0.115	1150	168	15		0.011	1.11	16.27		
Catchment_0031	0.159	1594	141	9		0.015	1.54	13.65		
Catchment_0032	0.113	1128	169	15		0.011	1.09	16.37		
Catchment_0033	0.086	863	252	29		0.008	0.84	24.40		
Catchment_0034	0.087	872	173	20		0.008	0.84	16.75		
Catchment_0035	0.117	1170	216	18		0.011	1.13	20.92		
Catchment_0036	0.141	1406	224	16	Parcel	0.014	1.36	21.69		
Catchment_0037	0.114	1138	291	26	Parcel	0.011	1.10	28.18		
Catchment_0038	0.106	1064	219	21		0.010	1.03	21.21		
Catchment_0039	0.155	1547	300	19		0.015	1.50	29.05		

Catchment_0040	0.103	1032	201	19	0.010	1.00	19.46
Catchment_0041	0.210	2095	690	33	0.020	2.03	66.82
Catchment_0042	0.359	3593	924	26	0.035	3.48	89.48
Catchment_0043	0.097	966	267	28	0.009	0.94	25.86
Catchment_0044	0.121	1213	256	21	0.012	1.17	24.79
Catchment_0045	0.191	1910	407	21	0.018	1.85	39.41
Catchment_0046	0.078	784	215	27	0.008	0.76	20.82
Catchment_0047	0.103	1035	294	28	0.010	1.00	28.47
Catchment_0048	0.264	2641	218	8	0.026	2.56	21.11
Catchment_0049	0.121	1208	137	11	0.012	1.17	13.27
Catchment_0050	0.250	2503	817	33	0.024	2.42	79.12
Catchment_0051	0.159	1586	154	10	0.015	1.54	14.91
Catchment_0052	0.059	591	240	41	0.006	0.57	23.24
Catchment_0053	0.098	977	401	41	0.009	0.95	38.83
Catchment_0054	0.177	1772	97	5	0.017	1.72	9.39
Catchment_0055	0.118	1181	158	13	0.011	1.14	15.30
Catchment_0056	0.113	1130	402	36	0.011	1.09	38.93
Catchment_0057	0.074	744	270	36	0.007	0.72	26.15
Catchment_0058	0.219	2188	400	18	0.021	2.12	38.74
Catchment_0059	0.230	2300	203	9	0.022	2.23	19.66
Catchment_0060	0.172	1717	485	28	0.017	1.66	46.97
Catchment_0061	0.328	3282	867	26	0.032	3.18	83.96
Catchment_0062	0.096	962	217	23	0.009	0.93	21.01
Catchment_0063	0.208	2077	235	11	0.020	2.01	22.76
Catchment_0064	0.100	999	234	23	0.010	0.97	22.66
Catchment_0065	0.211	2111	211	10	0.020	2.04	20.44
Catchment_0066	0.152	1525	193	13	0.015	1.48	18.69
Catchment_9976	0.041	415	207	50	0.004	0.40	20.09
Catchment_9977	0.028	280	140	50	0.003	0.27	13.56
Catchment_9978	0.052	517	517	100	0.005	0.50	50.08
Catchment_9979	0.058	575	575	100	0.006	0.56	55.73
Catchment_9980	0.057	570	285	50	0.006	0.55	27.61
Catchment_9981	0.053	533	266	50	0.005	0.52	25.79
Catchment_9982	0.054	535	535	100	0.005	0.52	51.85
Catchment_9983	0.050	502	502	100	0.005	0.49	48.65
Catchment_9984	0.053	533	533	100	0.005	0.52	51.65
Catchment_9985	0.046	458	458	100	0.004	0.44	44.32
Catchment_9986	0.053	526	526	100	0.005	0.51	50.97
Catchment_9987	0.038	381	381	100	0.004	0.37	36.90
Catchment_9988	0.040	400	400	100	0.004	0.39	38.70

Catchment_9989	0.028	278	139	50		0.003	0.27	13.46	
Catchment_9990	0.070	698	698	100		0.007	0.68	67.55	
Catchment_9991	0.095	951	951	100		0.009	0.92	92.05	
Catchment_9992	0.060	596	596	100		0.006	0.58	57.74	
Catchment_9993	0.069	693	693	100		0.007	0.67	67.14	
Catchment_9994	0.065	650	650	100		0.006	0.63	62.97	
Catchment_9995	0.066	656	656	100		0.006	0.64	63.54	
Catchment_9996	0.044	445	445	100		0.004	0.43	43.05	
Catchment_9997	0.067	666	666	100		0.006	0.65	64.52	
Catchment_9998	0.047	471	471	100		0.005	0.46	45.58	
Catchment_9999	0.037	373	373	100		0.004	0.36	36.12	
		103265	30858	40	Avg	1.000	100.000	33.20	%
		Without roads		22	Avg	From wastewater plan:		31.00	%

V.2. Manning analysis

V.2.1 Manning analysis. Discharge

	Manning 68					Manning 75					Manning 85				
Link Discharge	Minimum	Maximum	Min.Time	Max.Time	Acumm.value	Minimum	Maximum	Min.Time	Max.Time	Acumm.value	Minimum	Maximum	Min.Time	Max.Time	Acumm.value
Link_261 (HF07610 -> HF07600) 16.47	0.00	0.01	9/14/2010 12:01	9/14/2010 14:15	74	0.00	0.01	9/14/2010 12:01	9/14/2010 13:02	71	0.00	0.01	9/14/2010 12:01	9/14/2010 13:22	67
Link_262 (HF07600 -> HF04600) 18.06	0.00	0.01	9/14/2010 12:01	9/14/2010 14:16	74	0.00	0.01	9/14/2010 12:01	9/14/2010 13:03	71	0.00	0.01	9/14/2010 12:01	9/14/2010 13:24	66
Link_262 (HF07600 -> HF04600) 54.19	0.00	0.01	9/14/2010 12:00	9/14/2010 14:16	74	0.00	0.01	9/14/2010 12:04	9/14/2010 13:03	71	0.00	0.01	9/14/2010 12:04	9/14/2010 13:24	66
Link_262 (HF07600 -> HF04600) 90.31	0.00	0.01	9/14/2010 12:23	9/14/2010 14:13	74	0.00	0.01	9/14/2010 12:26	9/14/2010 14:15	71	0.00	0.01	9/14/2010 12:26	9/14/2010 13:24	66
Link_263 (HF04600 -> HF04590) 23.22	0.00	0.08	9/14/2010 12:22	9/14/2010 13:36	476	0.00	0.09	9/14/2010 12:22	9/14/2010 13:29	477	0.00	0.09	9/14/2010 12:22	9/14/2010 13:24	478
Link_264 (HF04590 -> HF04580) 12.35	0.00	0.08	9/14/2010 12:19	9/14/2010 13:37	476	0.00	0.09	9/14/2010 12:19	9/14/2010 13:29	477	0.00	0.09	9/14/2010 12:20	9/14/2010 13:24	477
Link_265 (HF04580 -> HF04570) 19.20	0.00	0.09	9/14/2010 12:00	9/14/2010 12:57	570	0.00	0.09	9/14/2010 12:00	9/14/2010 13:05	576	0.00	0.10	9/14/2010 12:00	9/14/2010 13:03	583
Link_266 (HF04570 -> HF04560) 5.00	0.00	0.09	9/14/2010 12:00	9/14/2010 12:57	570	0.00	0.09	9/14/2010 12:00	9/14/2010 13:05	576	0.00	0.10	9/14/2010 12:00	9/14/2010 13:04	583
Link_267 (HF04560 -> HF04550) 22.02	0.00	0.09	9/14/2010 12:00	9/14/2010 13:06	569	0.00	0.09	9/14/2010 12:00	9/14/2010 13:06	575	0.00	0.10	9/14/2010 12:00	9/14/2010 13:04	582
Link_268 (HF04550 -> HF04540) 6.02	0.00	0.09	9/14/2010 12:08	9/14/2010 13:07	568	0.00	0.09	9/14/2010 12:08	9/14/2010 13:06	575	0.00	0.10	9/14/2010 12:08	9/14/2010 13:04	582
Link_269 (HF04540 -> HF04530) 29.97	0.00	0.09	9/14/2010 12:00	9/14/2010 13:08	567	0.00	0.09	9/14/2010 12:00	9/14/2010 13:07	574	0.00	0.10	9/14/2010 12:00	9/14/2010 13:04	582
Link_270 (HF04530 -> HF04520) 31.22	0.00	0.09	9/14/2010 12:00	9/14/2010 13:09	566	0.00	0.09	9/14/2010 12:00	9/14/2010 13:07	573	0.00	0.10	9/14/2010 12:00	9/14/2010 13:05	581
Link_271 (HF04520 -> HF04510) 32.11	0.00	0.09	9/14/2010 12:13	9/14/2010 13:09	564	0.00	0.09	9/14/2010 12:11	9/14/2010 13:08	572	0.00	0.10	9/14/2010 12:12	9/14/2010 13:05	580
Link_272 (HF04510 -> HF04500) 32.75	0.00	0.09	9/14/2010 12:00	9/14/2010 13:09	559	0.00	0.09	9/14/2010 12:00	9/14/2010 13:08	567	0.00	0.10	9/14/2010 12:00	9/14/2010 13:05	575
Link_273 (HF04500 -> HF04490) 27.52	0.00	0.09	9/14/2010 12:19	9/14/2010 13:10	553	0.00	0.09	9/14/2010 12:18	9/14/2010 13:08	562	0.00	0.10	9/14/2010 12:17	9/14/2010 13:05	570
Link_274 (HF04490 -> HF04480) 27.57	0.00	0.09	9/14/2010 12:31	9/14/2010 13:10	544	0.00	0.09	9/14/2010 12:30	9/14/2010 13:08	553	0.00	0.10	9/14/2010 12:29	9/14/2010 13:06	561
Link_275 (HF04480 -> HF04470) 27.50	0.00	0.09	9/14/2010 12:21	9/14/2010 13:10	542	0.00	0.09	9/14/2010 12:30	9/14/2010 13:09	551	0.00	0.10	9/14/2010 12:18	9/14/2010 13:06	560
Link_276 (HF04470 -> HF04465) 7.43	0.00	0.09	9/14/2010 12:33	9/14/2010 13:11	541	0.00	0.09	9/14/2010 12:32	9/14/2010 13:09	550	0.00	0.10	9/14/2010 12:30	9/14/2010 13:06	559
Link_277 (HF04465 -> HF04455) 20.21	0.00	0.09	9/14/2010 12:33	9/14/2010 13:11	539	0.00	0.09	9/14/2010 12:31	9/14/2010 13:09	549	0.00	0.10	9/14/2010 12:30	9/14/2010 13:06	559
Link_277 (HF04465 -> HF04455) 60.63	-0.01	0.09	9/14/2010 12:32	9/14/2010 13:11	537	-0.01	0.09	9/14/2010 12:30	9/14/2010 13:09	547	-0.01	0.10	9/14/2010 12:28	9/14/2010 13:06	557
Link_278 (HF04455 -> HF04450) 5.00	0.00	0.11	9/14/2010 12:25	9/14/2010 13:11	645	0.00	0.12	9/14/2010 12:24	9/14/2010 13:09	662	0.00	0.13	9/14/2010 12:00	9/14/2010 13:06	682
Link_279 (HF04450 -> HF04440) 25.93	0.00	0.11	9/14/2010 12:01	9/14/2010 13:11	643	0.00	0.12	9/14/2010 12:21	9/14/2010 13:09	661	0.00	0.13	9/14/2010 12:22	9/14/2010 13:07	681
Link_280 (HF04440 -> HF04430) 23.93	0.00	0.11	9/14/2010 12:01	9/14/2010 13:12	641	0.00	0.12	9/14/2010 12:01	9/14/2010 13:10	660	0.00	0.13	9/14/2010 12:01	9/14/2010 13:07	680
Link_281 (BLF0770 -> BLF0270) 23.61	-0.01	0.02	9/14/2010 12:34	9/14/2010 13:43	20	-0.01	0.02	9/14/2010 12:34	9/14/2010 13:37	20	-0.01	0.02	9/14/2010 12:34	9/14/2010 13:29	20
Link_282 (BLF0290 -> BLF0280) 25.03	0.00	0.01	9/14/2010 14:44	9/14/2010 13:16	17	0.00	0.01	9/14/2010 14:35	9/14/2010 13:12	17	0.00	0.01	9/14/2010 14:24	9/14/2010 13:02	17
Link_283 (BLF0280 -> BLF0270) 24.02	0.00	0.01	9/14/2010 12:00	9/14/2010 12:51	38	0.00	0.01	9/14/2010 12:01	9/14/2010 12:49	38	0.00	0.01	9/14/2010 12:01	9/14/2010 12:46	38
Link_284 (BLF0270 -> BLF0260) 24.27	0.00	0.02	9/14/2010 12:00	9/14/2010 13:40	74	0.00	0.02	9/14/2010 12:00	9/14/2010 13:35	74	0.00	0.02	9/14/2010 12:01	9/14/2010 13:28	74
Link_285 (BLF0260 -> BLF0250) 23.62	0.00	0.02	9/14/2010 12:01	9/14/2010 12:29	112	0.00	0.02	9/14/2010 12:01	9/14/2010 12:29	112	0.00	0.03	9/14/2010 12:01	9/14/2010 12:29	112
Link_286 (BLF0250 -> BLF0240) 7.00	0.00	0.04	9/14/2010 12:04	9/14/2010 12:43	169	0.00	0.04	9/14/2010 12:04	9/14/2010 12:43	169	0.00	0.04	9/14/2010 12:04	9/14/2010 12:41	169
Link_287 (BLF0240 -> BLF0230) 18.66	0.00	0.04	9/14/2010 12:00	9/14/2010 13:04	198	0.00	0.04	9/14/2010 12:00	9/14/2010 12:54	198	0.00	0.05	9/14/2010 12:01	9/14/2010 12:51	198
Link_288 (BLF0230 -> BLF0220) 18.98	0.00	0.04	9/14/2010 12:00	9/14/2010 12:47	213	0.00	0.05	9/14/2010 12:00	9/14/2010 12:46	213	0.00	0.05	9/14/2010 12:01	9/14/2010 12:45	213
Link_289 (BLF0220 -> BLF0210) 18.87	0.00	0.05	9/14/2010 12:01	9/14/2010 12:32	229	0.00	0.06	9/14/2010 12:01	9/14/2010 12:32	229	0.00	0.06	9/14/2010 12:01	9/14/2010 12:32	229
Link_290 (BLF0210 -> 04892F) 5.00	0.00	0.12	9/14/2010 12:04	9/14/2010 12:32	417	0.00	0.13	9/14/2010 12:04	9/14/2010 12:33	417	0.00	0.14	9/14/2010 12:04	9/14/2010 12:33	417
Link_291 (04892F -> BLF0200) 16.87	0.00	0.12	9/14/2010 12:04	9/14/2010 12:34	417	0.00	0.13	9/14/2010 12:04	9/14/2010 12:34	417	0.00	0.14	9/14/2010 12:01	9/14/2010 12:34	417
Link_292 (BLF0200 -> BLF0190) 21.36	0.00	0.16	9/14/2010 12:01	9/14/2010 12:36	519	0.00	0.18	9/14/2010 12:01	9/14/2010 12:36	519	0.00	0.19	9/14/2010 12:01	9/14/2010 12:35	519
Link_293 (BLF0190 -> BLF0180) 20.77	0.00	0.17	9/14/2010 12:02	9/14/2010 12:35	530	0.00	0.18	9/14/2010 12:01	9/14/2010 12:35	530	0.00	0.20	9/14/2010 12:01	9/14/2010 12:35	530
Link_294 (BLF0730 -> BLY0710) 29.05	0.00	0.01	9/14/2010 12:34	9/14/2010 13:07	8	0.00	0.01	9/14/2010 12:34	9/14/2010 13:04	8	0.00	0.01	9/14/2010 12:33	9/14/2010 12:58	8
Link_295 (BLF0720 -> BLY0710) 11.11	-0.01	0.00	9/14/2010 12:31	9/14/2010 13:09	0	-0.01	0.00	9/14/2010 12:31	9/14/2010 13:06	0	-0.01	0.00	9/14/2010 12:31	9/14/2010 13:01	0
Link_296 (BLY0710 -> BLF0700) 22.68	0.00	0.01	9/14/2010 12:00	9/14/2010 13:06	36	0.00	0.01	9/14/2010 12:00	9/14/2010 13:02	36	0.00	0.01	9/14/2010 12:00	9/14/2010 12:57	36
Link_297 (BLF0700 -> BLF0250) 17.48	0.00	0.01	9/14/2010 12:00	9/14/2010 12:55	45	0.00	0.02	9/14/2010 12:00	9/14/2010 12:52	45	0.00	0.02	9/14/2010 12:01	9/14/2010 12:49	45
Link_297 (BLF0700 -> BLF0250) 52.45	0.00	0.01	9/14/2010 12:00	9/14/2010 12:55	45	0.00	0.02	9/14/2010 12:00	9/14/2010 12:52	45	0.00	0.02	9/14/2010 12:00	9/14/2010 12:49	45
Link_298 (BLF0760 -> BLS0801) 15.03	-0.01	0.01	9/14/2010 12:29	9/14/2010 13:24	0	-0.01	0.01	9/14/2010 12:34	9/14/2010 13:20	0	-0.01	0.01	9/14/2010 12:29	9/14/2010 13:15	0
Link_299 (BLS0801 -> BLF0750) 5.00	-0.01	0.01	9/14/2010 12:35	9/14/2010 13:23	8	-0.01	0.01	9/14/2010 12:35	9/14/2010 13:19	8	-0.01	0.01	9/14/2010 12:35	9/14/2010 13:14	8
Link_300 (BLF0750 -> BLF0740) 27.71	-0.01	0.01	9/14/2010 12:36	9/14/2010 13:22	13	-0.01	0.01	9/14/2010 12:36	9/14/2010 13:18	13	-0.01	0.01	9/14/2010 12:35	9/14/2010 13:13	13
Link_301 (BLF0740 -> BLF0240) 24.58	-0.01	0.01	9/14/2010 12:35	9/14/2010 13:22	20	-0.01	0.01	9/14/2010 12:35	9/14/2010 13:18	20	-0.01	0.01	9/14/2010 12:34	9/14/2010 13:13	20
Link_302 (BLF0410 -> BLF0400) 6.55	0.00	0.01	9/14/2010 12:34	9/14/2010 12:49	5	0.00	0.01	9/14/2010 12:34	9/14/2010 12:47	5	0.00	0.01	9/14/2010 12:34	9/14/2010 12:44	5
Link_303 (BLF0400 -> BLF0390) 22.37	0.00	0.02	9/14/2010 14:07	9/14/2010 12:48	25	0.00	0.02	9/14/2010 14:01	9/14/2010 12:46	25	0.00	0.02	9/14/2010 14:22	9/14/2010 12:44	25
Link_304 (BLF0390 -> BLF0380) 22.06	0.00	0.03	9/14/2010 12:00	9/14/2010 12:47	54	0.00	0.03	9/14/2010 12:01	9/14/2010 12:45	54	0.00	0.03	9/14/2010 12:01	9/14/2010 12:43	54
Link_305 (BLF0380 -> BLF0370) 5.00	0.00	0.04	9/14/2010 12:00	9/14/2010 12:32	74	0.00	0.04	9/14/2010 12:00	9/14/2010 12:32	74	0.00	0.05	9/14/2010 12:00	9/14/2010 12:32	74
Link_306 (BLF0370 -> BLF0330) 16.91	0.00	0.04	9/14/2010 12:00	9/14/2010 12:32	74	0.00	0.04	9/14/2010 12:00	9/14/2010 12:32	74	0.00	0.04	9/14/2010 12:01	9/14/2010 12:32	74
Link_309 (BLF0335 -> BLF0330) 5.00	0.00	0.01	9/14/2010 12:32	9/14/2010 12:36	14	0.00	0.01	9/14/2010 12:32	9/14/2010 12:36	14	0.00	0.01	9/14/2010 12:31	9/14/2010 12:40	14
Link_310 (BLF0330 -> BLF0325) 12.16	0.00	0.04	9/14/2010 12:00	9/14/2010 12:44	88	0.00	0.05	9/14/2010 12:00	9/14/2010 12:42	88	0.00	0.05	9/14/2010 12:05	9/14/2010 12:41	88
Link_311 (BLF0325 -> BLF0320) 20.82	0.00	0.05	9/14/2010 12:00	9/14/2010 12:43	95	0.00	0.05	9/14/2010 12:00	9/14/2010 12:42	95	0.00	0.05	9/14/2010 12:00	9/14/2010 12:40	95
Link_312 (BLF0320 -> BLF0200) 17.66	0.00	0.05	9/14/2010 12:07	9/14/2010 12:41	95	0.00	0.05	9/14/2010 12:07	9/14/2010 12:40	95	0.00	0.06	9/14/2010 12:07	9/14/2010 12:39	95
Link_313 (BLF0310 -> BLF0300) 20.51	0.00	0.00	9/14/2010 12:01	9/14/2010 12:34	3	0.00	0.00	9/14/2010 12:01	9/14/2010 12:34	3	0.00	0.00	9/14/2010 12:02	9/14/2010 12:33	3
Link_313 (BLF0310 -> BLF0300) 61.54	0.00	0.00	9/14/2010 12:00	9/14/2010 12:34	3	0.00	0.00	9/14/2010 12:00	9/14/2010 12:34	3	0.00	0.00	9/14/2010 12:00	9/14/2010 12:34	3
Link_314 (BLF0300 -> BLF0180) 28.89	0.00	0.00	9/14/2010 12:08	9/14/2010 12:38	3	0.00	0.00	9/14/2010 12:09	9/14/2010 12:37	3	0.00	0.00	9/14/2010 12:08	9/14/2010 12:34	3
Link_317 (BLF0540 -> BLF0530) 29.94	0.00	0.01	9/14/2010 12:01	9/14/2010 13:32	60	0.00	0.02	9/14/2010 12:01	9/14/2010 13:24	60	0.00	0.02	9/14/2010 12:01	9/14/2010 13:17	60
Link_318 (BLF0530 -> BLF0520) 30.11	0.00	0.02	9/14/2010 12:01	9/14/2010 13:23	72	0.00	0.03	9/14/2010 12:01	9/14/2010 13:19	72	0.00	0.03	9/14/2010 12:01	9/14/2010 13:13	72
Link_319 (BLF0520 -> BLF0510) 29.82	0.00	0.03	9/14/2010 12:01	9/14/2010 13:07	126	0.00	0.03	9/14/2010 12:01	9/14/2010 13:06	126	0.00	0.04	9/14/2010 12:01	9/14/2010 12:54	126
Link_320 (BLF0510 -> BLF0500) 19.82	0.00	0.03	9/14/2010 12:04	9/14/2010 12:45	138	0.00	0.03	9/14/2010 12:04	9/14/2010 12:45	138	0.00	0.04	9/14/2010 12:04	9/14/2010 12:45	138
Link_321 (BLF0500 -> BLF0210) 22.66	0.00	0.05	9/14/2010 12:01	9/14/2010 12:32	165	0.00	0.05	9/14/2010 12:01	9/14/2010 12:32	165	0.00	0.06	9/14/2010 12:01	9/14/2010 12:32	165
Link_327 (BLF0180 -> BLF0170) 24.35	0.00	0.18	9/14/2010 12:01	9/14/2010 12:35	542	0.00	0.20	9/14/2010 12:01	9/14/2010 12:35	542	0.00	0.21	9/14/2010 12:01	9/14/2010 12:35	542
Link_328 (BLF0170 -> BLF0160) 25.30	0.00	0.18	9/14/2010 12:01	9/14/2010 12:35	542	0.00	0.20	9/14/2010 12:07	9/14/2010 12:35	542	0.00	0.21	9/14/2010 12:06	9/14/2010 12:35	542
Link_329 (BLF0160 -> OV65) 21.13	0.00	0.18	9/14/2010 12:09	9/14/2010 12:36	542	0.00	0.20	9/14/2010 12:09	9/14/2010 12:35	542	0.00	0.21	9/14/2010 12:09	9/14/2010 12:35	542
Link_329 (BLF0160 -> OV65) 63.39	0.00	0.18	9/14/2010 12:04	9/14/2010 12:36	542	0.00	0.20	9/14/2010 12:04	9/14/2010 12:36	542	0.00	0.21	9/14/2010 12:09	9/14/2010 12:35	542
Link_330 (OV65 -> BLB0140) 7.65	0.00	0.17	9/14/2010 12:00	9/14/2010 12:36	465	0.00	0.19	9/14/2010 14:04	9/14/2010 12:36	469	0.00	0.20	9/14/2010 12:01	9/14/2010 12:35	474
Link_345 (BLF_EKS5 -> BLF0390) 21.41	0.00	0.01	9/14/2010 12:00	9/14/2010 12:48	11	0.00	0.01	9/14/2010 12:00	9/14/2010 12:46	11	0.00	0.01	9/14/2010 12:00	9/14/2010 12:44	11
Link_347 (HF04610 -> HF04600) 31.02	0.00	0.04	9/14/2010 12:40	9/14/2010 13:33	202	0.00	0.04	9/14/2010 12:40	9/14/2010 13:28	204	0.00	0.04	9/14/2010 12:39	9/14/2010 13:25	206
Link_350 (BLF0350 -> BLF0340) 8.19	0.00	0.00	9/14/2010 12:31	9/14/2010 12:55	6	0.00	0.00	9/14/2010 12:31	9/14/2010 12:53	6	0.00	0.00	9/14/2010 12:31	9/14/2010 12:50	6
Link_351 (BLF0340 -> BLF0335) 10.02	0.00	0.01	9/14/2010 12:31	9/14/2010 12:36	11	0.00	0.01	9/14/2010 12:31	9/14/2010 12:36	11	0.00	0.01	9/14/2010 12:31	9/14/2010 12:41	11
Link_352 (HF07100 -> HF04580) 13.45	0.00	0.03	9/14/2010 13:30	9/14/2010 12:36	96	0.00	0.04	9/14/2010 14:03	9/14/2010 12:36	101	0.00	0.04	9/14/2010 13:57	9/14/2010 12:36	107
Link_353 (HF07025 -> HF07020) 12.17	0.00	0.09	9/14/2010 13:54	9/14/2010 12:35	113	0.00	0.09	9/14/2010 15:00	9/14/2010 12:35	113	0.00	0.09	9/14/2010 14:27	9/14/2010 12:35	113

Link_354 (HF07020 -> HF07010) 22.11	0.00	0.09	9/14/2010 13:50	9/14/2010 12:36	113	0.00	0.09	9/14/2010 13:51	9/14/2010 12:34	113	0.00	0.09	9/14/2010 14:00	9/14/2010 12:35	113
Link_354 (HF07020 -> HF07010) 66.33	0.00	0.09	9/14/2010 12:00	9/14/2010 12:36	112	0.00	0.09	9/14/2010 12:00	9/14/2010 12:36	112	0.00	0.09	9/14/2010 12:00	9/14/2010 12:37	113
Link_354 (HF07020 -> HF07010) 110.56	0.00	0.09	9/14/2010 12:00	9/14/2010 12:36	112	0.00	0.09	9/14/2010 12:00	9/14/2010 12:36	112	0.00	0.09	9/14/2010 12:00	9/14/2010 12:37	112
Link_355 (HF07010 -> HF07000) 17.23	0.00	0.08	9/14/2010 12:00	9/14/2010 12:38	112	0.00	0.08	9/14/2010 12:01	9/14/2010 12:38	112	0.00	0.09	9/14/2010 12:01	9/14/2010 12:41	112
Link_356 (HF07000 -> HF06500) 14.37	0.00	0.08	9/14/2010 12:09	9/14/2010 12:39	112	0.00	0.08	9/14/2010 12:09	9/14/2010 12:44	112	0.00	0.10	9/14/2010 12:09	9/14/2010 12:41	112
Link_357 (HF06500 -> HF05990) 25.29	0.00	0.27	9/14/2010 12:00	9/14/2010 12:39	419	0.00	0.29	9/14/2010 12:05	9/14/2010 12:39	422	0.00	0.31	9/14/2010 12:05	9/14/2010 12:38	422
Link_358 (HF05990 -> OV70) 5.00	0.00	0.47	9/14/2010 12:06	9/14/2010 12:40	785	0.00	0.49	9/14/2010 12:05	9/14/2010 12:40	788	0.00	0.51	9/14/2010 12:05	9/14/2010 12:39	788
Link_361 (HF05980 -> HF05975) 26.58	0.00	0.03	9/14/2010 12:00	9/14/2010 12:40	113	0.00	0.03	9/14/2010 12:00	9/14/2010 12:40	120	0.00	0.03	9/14/2010 12:00	9/14/2010 12:39	129
Link_362 (HF05975 -> HF05970) 19.73	0.00	0.03	9/14/2010 12:00	9/14/2010 12:40	113	0.00	0.03	9/14/2010 12:00	9/14/2010 12:40	120	0.00	0.03	9/14/2010 12:01	9/14/2010 12:39	129
Link_363 (HF05970 -> HF05960) 24.39	0.00	0.03	9/14/2010 12:10	9/14/2010 12:41	113	0.00	0.03	9/14/2010 12:08	9/14/2010 12:40	120	0.00	0.03	9/14/2010 12:04	9/14/2010 12:39	129
Link_364 (HF05960 -> HF05950) 25.08	0.00	0.03	9/14/2010 12:00	9/14/2010 12:42	113	0.00	0.03	9/14/2010 12:00	9/14/2010 12:41	120	0.00	0.03	9/14/2010 12:00	9/14/2010 12:40	129
Link_365 (HF05950 -> HF05940) 20.75	0.00	0.03	9/14/2010 12:00	9/14/2010 12:43	113	0.00	0.03	9/14/2010 12:11	9/14/2010 12:42	120	0.00	0.03	9/14/2010 12:09	9/14/2010 12:40	129
Link_366 (HF05940 -> HF05930) 20.58	0.00	0.03	9/14/2010 12:00	9/14/2010 12:43	113	0.00	0.03	9/14/2010 12:00	9/14/2010 12:43	120	0.00	0.03	9/14/2010 12:00	9/14/2010 12:41	129
Link_367 (HF05930 -> HF05925) 14.00	0.00	0.03	9/14/2010 12:00	9/14/2010 12:44	113	0.00	0.03	9/14/2010 12:13	9/14/2010 12:43	120	0.00	0.03	9/14/2010 12:13	9/14/2010 12:41	129
Link_368 (HF05925 -> HF05920) 12.50	0.00	0.03	9/14/2010 12:00	9/14/2010 12:45	113	0.00	0.03	9/14/2010 12:00	9/14/2010 12:44	120	0.00	0.03	9/14/2010 12:01	9/14/2010 12:41	129
Link_369 (HF05920 -> HF05910) 31.76	0.00	0.03	9/14/2010 12:00	9/14/2010 12:46	113	0.00	0.03	9/14/2010 12:00	9/14/2010 12:44	120	0.00	0.03	9/14/2010 12:00	9/14/2010 12:42	129
Link_370 (HF05910 -> HF05900) 31.86	0.00	0.03	9/14/2010 12:00	9/14/2010 12:47	114	0.00	0.03	9/14/2010 12:05	9/14/2010 12:45	120	0.00	0.03	9/14/2010 12:05	9/14/2010 12:43	129
Link_371 (HF05900 -> HF05899) 5.00	0.00	0.03	9/14/2010 12:00	9/14/2010 12:48	113	0.00	0.03	9/14/2010 12:20	9/14/2010 12:46	120	0.00	0.03	9/14/2010 12:19	9/14/2010 12:44	129
Link_372 (HF05899 -> HF05898) 11.28	0.00	0.03	9/14/2010 12:21	9/14/2010 12:48	114	0.00	0.03	9/14/2010 12:20	9/14/2010 12:46	120	0.00	0.03	9/14/2010 12:10	9/14/2010 12:44	129
Link_373 (HF05720 -> HF05710) 26.16	0.00	0.11	9/14/2010 14:14	9/14/2010 12:38	277	0.00	0.12	9/14/2010 14:08	9/14/2010 12:38	277	0.00	0.13	9/14/2010 14:03	9/14/2010 12:37	278
Link_374 (HF05710 -> HF05705) 25.33	0.00	0.07	9/14/2010 12:00	9/14/2010 12:45	278	0.00	0.07	9/14/2010 14:57	9/14/2010 12:44	277	0.00	0.08	9/14/2010 14:49	9/14/2010 12:43	277
Link_375 (HF05705 -> HF05700) 24.93	0.00	0.06	9/14/2010 12:00	9/14/2010 13:26	277	0.00	0.06	9/14/2010 12:00	9/14/2010 12:59	277	0.00	0.06	9/14/2010 14:59	9/14/2010 12:55	277
Link_376 (HF05700 -> HF04840) 5.00	-0.01	0.07	9/14/2010 12:08	9/14/2010 13:24	277	-0.01	0.07	9/14/2010 12:08	9/14/2010 13:23	277	-0.01	0.07	9/14/2010 12:08	9/14/2010 13:22	277
Link_377 (HF04840 -> HF04830) 7.80	0.00	0.08	9/14/2010 12:00	9/14/2010 12:45	417	0.00	0.09	9/14/2010 12:00	9/14/2010 12:47	420	0.00	0.09	9/14/2010 12:00	9/14/2010 12:57	422
Link_379 (HF04820 -> HF04810) 30.09	0.00	0.08	9/14/2010 12:00	9/14/2010 12:48	416	0.00	0.08	9/14/2010 12:00	9/14/2010 12:59	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:03	422
Link_380 (HF04810 -> HF04800) 32.73	0.00	0.08	9/14/2010 12:00	9/14/2010 12:48	416	0.00	0.08	9/14/2010 12:00	9/14/2010 12:59	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:03	422
Link_381 (HF04800 -> HF04790) 12.49	0.00	0.08	9/14/2010 12:00	9/14/2010 12:49	416	0.00	0.08	9/14/2010 12:00	9/14/2010 12:58	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:02	422
Link_382 (HF04790 -> HF04780) 16.78	0.00	0.08	9/14/2010 12:00	9/14/2010 12:50	416	0.00	0.08	9/14/2010 12:00	9/14/2010 12:58	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:02	422
Link_383 (HF04780 -> HF04770) 6.63	0.00	0.08	9/14/2010 12:00	9/14/2010 12:50	416	0.00	0.08	9/14/2010 12:00	9/14/2010 12:58	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:02	422
Link_384 (HF04770 -> HF04760) 21.39	0.00	0.08	9/14/2010 12:00	9/14/2010 12:51	416	0.00	0.08	9/14/2010 12:00	9/14/2010 12:58	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:02	422
Link_385 (HF04760 -> HF04750) 22.76	0.00	0.08	9/14/2010 12:00	9/14/2010 12:52	416	0.00	0.08	9/14/2010 12:00	9/14/2010 12:59	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:02	422
Link_386 (HF04750 -> HF04740) 21.96	0.00	0.08	9/14/2010 12:00	9/14/2010 12:52	416	0.00	0.08	9/14/2010 12:00	9/14/2010 13:00	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:01	422
Link_387 (HF04740 -> HF04730) 33.39	0.00	0.08	9/14/2010 12:00	9/14/2010 12:54	416	0.00	0.08	9/14/2010 12:00	9/14/2010 13:00	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:00	422
Link_388 (HF04730 -> HF04720) 30.29	0.00	0.08	9/14/2010 12:00	9/14/2010 12:57	416	0.00	0.08	9/14/2010 12:00	9/14/2010 13:00	419	0.00	0.09	9/14/2010 12:00	9/14/2010 13:00	422
Link_389 (HF04720 -> HF04710) 34.64	0.00	0.08	9/14/2010 12:00	9/14/2010 13:02	416	0.00	0.08	9/14/2010 12:00	9/14/2010 12:57	419	0.00	0.09	9/14/2010 12:01	9/14/2010 12:59	422
Link_390 (HF04710 -> HF04700) 13.23	0.00	0.08	9/14/2010 12:21	9/14/2010 13:02	416	0.00	0.08	9/14/2010 12:19	9/14/2010 12:58	419	0.00	0.09	9/14/2010 12:20	9/14/2010 12:59	422
Link_391 (HF04700 -> 007268S) 16.97	0.00	0.08	9/14/2010 12:00	9/14/2010 13:02	416	0.00	0.08	9/14/2010 12:00	9/14/2010 12:59	419	0.00	0.09	9/14/2010 12:00	9/14/2010 12:59	422
Link_392 (007268S -> HF04690) 25.73	0.00	0.08	9/14/2010 12:00	9/14/2010 13:02	415	0.00	0.08	9/14/2010 12:00	9/14/2010 12:59	419	0.00	0.09	9/14/2010 12:00	9/14/2010 12:58	421
Link_393 (HF04690 -> HF04680) 21.44	0.00	0.08	9/14/2010 12:01	9/14/2010 13:02	415	0.00	0.08	9/14/2010 12:01	9/14/2010 13:00	418	0.00	0.09	9/14/2010 12:01	9/14/2010 12:57	421
Link_393 (HF04690 -> HF04680) 64.33	0.00	0.08	9/14/2010 12:00	9/14/2010 13:02	415	0.00	0.08	9/14/2010 12:00	9/14/2010 13:00	418	0.00	0.09	9/14/2010 12:23	9/14/2010 12:57	421
Link_394 (HF04680 -> 00090S) 13.03	0.00	0.08	9/14/2010 12:29	9/14/2010 13:02	415	0.00	0.08	9/14/2010 12:28	9/14/2010 12:59	418	0.00	0.09	9/14/2010 12:27	9/14/2010 12:57	421
Link_395 (00090S -> HF04670) 18.25	0.00	0.08	9/14/2010 12:21	9/14/2010 13:01	413	0.00	0.08	9/14/2010 12:07	9/14/2010 12:59	417	0.00	0.09	9/14/2010 12:02	9/14/2010 12:57	420
Link_396 (HF04670 -> HF04660) 29.89	0.00	0.08	9/14/2010 12:00	9/14/2010 13:00	413	0.00	0.08	9/14/2010 12:00	9/14/2010 12:59	417	0.00	0.08	9/14/2010 12:00	9/14/2010 13:24	420
Link_397 (HF04660 -> HF04650) 30.10	0.00	0.08	9/14/2010 12:00	9/14/2010 12:59	413	0.00	0.08	9/14/2010 12:00	9/14/2010 12:58	416	0.00	0.08	9/14/2010 12:00	9/14/2010 13:24	420
Link_398 (HF04650 -> HS04645) 19.94	0.00	0.07	9/14/2010 12:34	9/14/2010 12:59	414	0.00	0.08	9/14/2010 12:33	9/14/2010 13:28	415	0.00	0.08	9/14/2010 12:04	9/14/2010 13:24	420
Link_399 (HS04645 -> HF04640) 9.68	0.00	0.07	9/14/2010 12:00	9/14/2010 12:59	407	0.00	0.08	9/14/2010 12:00	9/14/2010 13:28	409	0.00	0.08	9/14/2010 12:00	9/14/2010 13:25	413
Link_400 (HF04640 -> 00144S) 34.82	0.00	0.07	9/14/2010 12:00	9/14/2010 13:33	407	0.00	0.08	9/14/2010 12:00	9/14/2010 13:28	410	0.00	0.08	9/14/2010 12:00	9/14/2010 13:25	414
Link_401 (00144S -> HF04620) 31.09	0.00	0.07	9/14/2010 12:00	9/14/2010 13:33	406	0.00	0.08	9/14/2010 12:35	9/14/2010 13:28	409	0.00	0.08	9/14/2010 12:33	9/14/2010 13:25	413
Link_402 (HF04620 -> HF04610) 32.48	0.00	0.07	9/14/2010 12:00	9/14/2010 13:33	406	0.00	0.08	9/14/2010 12:00	9/14/2010 13:28	409	0.00	0.08	9/14/2010 12:00	9/14/2010 13:25	413
Link_403 (HF04610 -> HF04600) 31.02	0.00	0.04	9/14/2010 12:40	9/14/2010 13:33	202	0.00	0.04	9/14/2010 12:40	9/14/2010 13:28	204	0.00	0.04	9/14/2010 12:39	9/14/2010 13:25	206
Link_406 (HF06800 -> HF06520) 19.57	0.00	0.23	9/14/2010 14:36	9/14/2010 12:31	309	0.00	0.24	9/14/2010 14:30	9/14/2010 12:31	312	0.00	0.26	9/14/2010 14:22	9/14/2010 12:32	311
Link_407 (HF06520 -> HF06500) 22.05	0.00	0.21	9/14/2010 14:36	9/14/2010 12:31	308	0.00	0.23	9/14/2010 14:29	9/14/2010 12:32	311	0.00	0.25	9/14/2010 14:20	9/14/2010 12:33	310
Link_407 (HF06520 -> HF06500) 66.15	0.00	0.20	9/14/2010 12:00	9/14/2010 12:32	307	0.00	0.23	9/14/2010 12:00	9/14/2010 12:32	310	0.00	0.25	9/14/2010 12:00	9/14/2010 12:33	310
Link_407 (HF06520 -> HF06500) 110.25	0.00	0.20	9/14/2010 12:01	9/14/2010 12:32	307	0.00	0.23	9/14/2010 12:01	9/14/2010 12:32	310	0.00	0.25	9/14/2010 12:01	9/14/2010 12:33	310
Link_408 (HF06035 -> HF06030) 21.88	0.00	0.20	9/14/2010 14:12	9/14/2010 12:42	366	0.00	0.20	9/14/2010 14:50	9/14/2010 12:41	366	0.00	0.20	9/14/2010 14:10	9/14/2010 12:40	366
Link_409 (HF06030 -> HF06020) 21.20	0.00	0.20	9/14/2010 14:59	9/14/2010 12:42	366	0.00	0.20	9/14/2010 14:44	9/14/2010 12:41	366	0.00	0.20	9/14/2010 14:59	9/14/2010 12:40	366
Link_410 (HF06020 -> HF06010) 13.96	0.00	0.20	9/14/2010 12:01	9/14/2010 12:42	366	0.00	0.20	9/14/2010 12:01	9/14/2010 12:41	366	0.00	0.20	9/14/2010 12:02	9/14/2010 12:40	366
Link_411 (HF06010 -> HF06000) 17.58	0.00	0.20	9/14/2010 12:01	9/14/2010 12:42	366	0.00	0.20	9/14/2010 12:01	9/14/2010 12:41	366	0.00	0.20	9/14/2010 12:01	9/14/2010 12:40	366
Link_414 (OV70 -> HF05980) 7.57	0.00	0.03	9/14/2010 12:00	9/14/2010 12:39	113	0.00	0.03	9/14/2010 12:00	9/14/2010 12:32	120	0.00	0.03	9/14/2010 12:00	9/14/2010 12:32	129
Link_416 (HF04880 -> OV69) 6.59	0.00	0.81	9/14/2010 13:28	9/14/2010 12:40	1322	0.00	0.83	9/14/2010 13:28	9/14/2010 12:39	1322	0.00	0.83	9/14/2010 13:27	9/14/2010 12:38	1322
Link_417 (OV69 -> HF04860) 5.00	0.00	0.04	9/14/2010 12:00	9/14/2010 12:31	140	0.00	0.04	9/14/2010 12:00	9/14/2010 12:30	142	0.00	0.04	9/14/2010 12:00	9/14/2010 12:30	145
Link_418 (HF07110 -> OV73) 5.00	0.00	0.16	9/14/2010 13:25	9/14/2010 12:36	221	0.00	0.16	9/14/2010 13:24	9/14/2010 12:36	221	0.00	0.16	9/14/2010 13:24	9/14/2010 12:36	221
Link_419 (OV73 -> HF07100) 6.38	0.00	0.03	9/14/2010 13:30	9/14/2010 12:36	96	0.00	0.04	9/14/2010 12:00	9/14/2010 12:36	101	0.00	0.04	9/14/2010 12:00	9/14/2010 12:36	107
Link_420 (HF06000 -> HF05990) 10.73	0.00	0.20	9/14/2010 12:01	9/14/2010 12:42	366	0.00	0.20	9/14/2010 12:01	9/14/2010 12:41	366	0.00	0.20	9/14/2010 12:02	9/14/2010 12:41	366
Link_426 (BLB0140 -> RA5.A) 10.72	0.00	0.02	9/14/2010 12:00	9/14/2010 13:47	143	0.00	0.02	9/14/2010 12:00	9/14/2010 13:41	156	0.00	0.02	9/14/2010 12:00	9/14/2010 13:36	173
Link_429 (BLF0590 -> BLF0560) 15.96	0.00	0.01	9/14/2010 12:00	9/14/2010 12:30	23	0.00	0.01	9/14/2010 12:00	9/14/2010 12:30	23	0.00	0.01	9/14/2010 12:00	9/14/2010 12:30	23
Link_429 (BLF0590 -> BLF0560) 47.88	0.00	0.01	9/14/2010 12:00	9/14/2010 12:30	23	0.00	0.01	9/14/2010 12:00	9/14/2010 12:30	23	0.00	0.01	9/14/2010 12:00	9/14/2010 12:30	23
Link_430 (BLF0650 -> BLF0560) 19.04	0.00	0.00	9/14/2010 12:00	9/14/2010 12:26	14	0.00	0.01	9/14/2010 12:00	9/14/2010 12:27	14	0.00	0.01	9/14/2010 12:00	9/14/2010 12:27	14
Link_430 (BLF0650 -> BLF0560) 57.12	0.00	0.01	9/14/2010 12:27	9/14/2010 13:32	14	0.00	0.01	9/14/2010 12:00	9/14/2010 13:26	14	0.00	0.01	9/14/2010 12:00	9/14/2010 13:19	14
Link_431 (BLF0560 -> BLF0540) 30.09	0.00	0.01	9/14/2010 12:00	9/14/2010 13:32	47	0.00	0.01	9/14/2010 12:00	9/14/2010 13:27	47	0.00	0.01	9/14/2010 12:00	9/14/2010 13:20	47
Link_434 (Node_386 -> PS209) 5.00	0.00	0.00	9/14/2010 12:01	9/14/2010 12:00	0	0.00	0.00	9/14/2010 14:39	9/14/2010 12:00	0	0.00	0.00	9/14/2010 14:15	9/14/2010 12:00	0
Average	0.00	0.08			269	0.00	0.08			271	0.00	0.09			274
50 percentile	0.00	0.07			217	0.00	0.08			217	0.00	0.08			217

V.2.2. Manning analysis. Velocity

	Manning 68				Manning 75				Manning 85			
Link Velocity	Minimum	Maximum	Min.Time	Max.Time	Minimum	Maximum	Min.Time	Max.Time	Minimum	Maximum	Min.Time	Max.Time
Link_261 (HF07610 -> HF07600) 16.47	0.055	0.826	9/14/2010 12:03	9/14/2010 14:15	0.059	0.88	9/14/2010 12:05	9/14/2010 13:02	0.062	0.956	9/14/2010 12:12	9/14/2010 13:22
Link_262 (HF07600 -> HF04600) 90.31	0	0.672	9/14/2010 12:39	9/14/2010 14:39	0	0.694	9/14/2010 12:40	9/14/2010 14:32	0	0.683	9/14/2010 12:41	9/14/2010 14:24
Link_263 (HF04600 -> HF04590) 23.22	-0.1	0.661	9/14/2010 12:22	9/14/2010 13:36	-0.109	0.702	9/14/2010 12:22	9/14/2010 13:29	-0.123	0.751	9/14/2010 12:22	9/14/2010 13:24
Link_264 (HF04590 -> HF04580) 12.35	-0.16	0.661	9/14/2010 12:12	9/14/2010 13:37	-0.166	0.702	9/14/2010 12:11	9/14/2010 13:29	-0.176	0.751	9/14/2010 12:12	9/14/2010 13:24
Link_265 (HF04580 -> HF04570) 19.20	0.03	0.693	9/14/2010 12:00	9/14/2010 12:57	0.033	0.731	9/14/2010 12:00	9/14/2010 13:05	0.037	0.791	9/14/2010 12:00	9/14/2010 13:03
Link_266 (HF04570 -> HF04560) 5.00	0.029	0.689	9/14/2010 12:00	9/14/2010 12:54	0.032	0.729	9/14/2010 12:00	9/14/2010 13:05	0.036	0.79	9/14/2010 12:01	9/14/2010 13:04
Link_267 (HF04560 -> HF04550) 22.02	0.022	0.729	9/14/2010 12:08	9/14/2010 12:53	0.021	0.766	9/14/2010 12:08	9/14/2010 12:52	0.026	0.81	9/14/2010 12:08	9/14/2010 12:50
Link_268 (HF04550 -> HF04540) 6.02	0.043	0.766	9/14/2010 12:09	9/14/2010 12:53	0.05	0.805	9/14/2010 12:08	9/14/2010 12:51	0.056	0.851	9/14/2010 12:08	9/14/2010 12:50
Link_269 (HF04540 -> HF04530) 29.97	0.033	0.742	9/14/2010 12:00	9/14/2010 12:53	0.034	0.783	9/14/2010 12:10	9/14/2010 12:51	0.041	0.83	9/14/2010 12:00	9/14/2010 12:49
Link_270 (HF04530 -> HF04520) 31.22	0.016	0.679	9/14/2010 12:13	9/14/2010 12:53	0.036	0.726	9/14/2010 12:00	9/14/2010 13:07	0.041	0.787	9/14/2010 12:03	9/14/2010 13:05
Link_271 (HF04520 -> HF04510) 32.11	0.038	0.676	9/14/2010 12:13	9/14/2010 13:09	0.04	0.726	9/14/2010 12:12	9/14/2010 13:08	0.046	0.787	9/14/2010 12:13	9/14/2010 13:05
Link_272 (HF04510 -> HF04500) 32.75	0.014	0.675	9/14/2010 12:00	9/14/2010 13:09	0.015	0.726	9/14/2010 12:00	9/14/2010 13:08	0.017	0.787	9/14/2010 12:00	9/14/2010 13:05
Link_273 (HF04500 -> HF04490) 27.52	0.026	0.675	9/14/2010 12:19	9/14/2010 13:10	0.028	0.726	9/14/2010 12:18	9/14/2010 13:08	0.031	0.786	9/14/2010 12:17	9/14/2010 13:05
Link_274 (HF04490 -> HF04480) 27.57	-0.055	0.675	9/14/2010 12:00	9/14/2010 13:10	-0.061	0.726	9/14/2010 12:00	9/14/2010 13:08	-0.069	0.786	9/14/2010 12:00	9/14/2010 13:06
Link_275 (HF04480 -> HF04470) 27.50	0.054	0.799	9/14/2010 12:31	9/14/2010 12:34	0.061	0.863	9/14/2010 12:30	9/14/2010 12:33	0.06	0.952	9/14/2010 12:29	9/14/2010 12:32
Link_276 (HF04470 -> HF04465) 7.43	0.001	0.675	9/14/2010 12:33	9/14/2010 13:11	0.001	0.725	9/14/2010 12:32	9/14/2010 13:09	0.001	0.786	9/14/2010 12:30	9/14/2010 13:06
Link_277 (HF04465 -> HF04455) 60.63	-0.229	0.675	9/14/2010 12:29	9/14/2010 13:11	-0.248	0.725	9/14/2010 12:28	9/14/2010 13:09	-0.272	0.786	9/14/2010 12:26	9/14/2010 13:06
Link_278 (HF04455 -> HF04450) 5.00	-0.054	0.628	9/14/2010 12:25	9/14/2010 13:09	-0.059	0.666	9/14/2010 12:24	9/14/2010 13:07	-0.067	0.711	9/14/2010 12:00	9/14/2010 13:05
Link_279 (HF04450 -> HF04440) 25.93	0.023	0.765	9/14/2010 12:01	9/14/2010 13:09	0.026	0.807	9/14/2010 12:18	9/14/2010 13:07	0.019	0.856	9/14/2010 12:24	9/14/2010 13:05
Link_280 (HF04440 -> HF04430) 23.93	0.034	1.118	9/14/2010 12:01	9/14/2010 13:12	0.023	1.177	9/14/2010 12:27	9/14/2010 13:10	0.043	1.251	9/14/2010 12:01	9/14/2010 13:07
Link_281 (BLF0770 -> BLF0270) 23.61	-0.602	1.021	9/14/2010 12:34	9/14/2010 13:43	-0.643	1.109	9/14/2010 12:34	9/14/2010 13:37	-0.696	1.228	9/14/2010 12:34	9/14/2010 13:29
Link_282 (BLF0290 -> BLF0280) 25.03	0.013	0.322	9/14/2010 13:45	9/14/2010 12:12	0.016	0.327	9/14/2010 13:39	9/14/2010 12:11	0.019	0.335	9/14/2010 14:13	9/14/2010 12:10
Link_283 (BLF0280 -> BLF0270) 24.02	0.025	0.545	9/14/2010 15:00	9/14/2010 12:51	0.026	0.594	9/14/2010 14:44	9/14/2010 12:49	0.026	0.661	9/14/2010 14:27	9/14/2010 12:46
Link_284 (BLF0270 -> BLF0260) 24.27	0.026	1.077	9/14/2010 12:05	9/14/2010 13:40	0.029	1.171	9/14/2010 12:05	9/14/2010 13:35	0.034	1.302	9/14/2010 12:05	9/14/2010 13:28
Link_285 (BLF0260 -> BLF0250) 23.62	0.021	1.203	9/14/2010 12:03	9/14/2010 12:29	0.023	1.326	9/14/2010 12:03	9/14/2010 12:29	0.026	1.469	9/14/2010 12:03	9/14/2010 12:29
Link_286 (BLF0250 -> BLF0240) 7.00	0.034	1.146	9/14/2010 12:04	9/14/2010 12:43	0.038	1.245	9/14/2010 12:04	9/14/2010 12:43	0.042	1.378	9/14/2010 12:04	9/14/2010 12:41
Link_287 (BLF0240 -> BLF0230) 18.66	0.034	1.308	9/14/2010 12:05	9/14/2010 13:04	0.037	1.41	9/14/2010 12:05	9/14/2010 12:54	0.042	1.554	9/14/2010 12:05	9/14/2010 12:51
Link_288 (BLF0230 -> BLF0220) 18.98	0.037	1.4	9/14/2010 12:04	9/14/2010 12:47	0.04	1.51	9/14/2010 12:04	9/14/2010 12:46	0.045	1.655	9/14/2010 12:04	9/14/2010 12:45
Link_289 (BLF0220 -> BLF0210) 18.87	0.025	1.63	9/14/2010 12:01	9/14/2010 12:32	0.027	1.751	9/14/2010 12:01	9/14/2010 12:32	0.031	1.909	9/14/2010 12:01	9/14/2010 12:32
Link_290 (BLF0210 -> 04892F) 5.00	0.053	0.978	9/14/2010 12:04	9/14/2010 12:32	0.057	1.039	9/14/2010 12:04	9/14/2010 12:33	0.064	1.121	9/14/2010 12:04	9/14/2010 12:33
Link_291 (04892F -> BLF0200) 16.87	0.045	0.963	9/14/2010 12:05	9/14/2010 12:34	0.049	1.026	9/14/2010 12:05	9/14/2010 12:34	0.056	1.108	9/14/2010 12:05	9/14/2010 12:34
Link_292 (BLF0200 -> BLF0190) 21.36	0.053	1.294	9/14/2010 12:05	9/14/2010 12:36	0.057	1.39	9/14/2010 12:05	9/14/2010 12:36	0.063	1.512	9/14/2010 12:05	9/14/2010 12:35
Link_293 (BLF0190 -> BLF0180) 20.77	0.052	1.368	9/14/2010 12:04	9/14/2010 12:35	0.057	1.465	9/14/2010 12:04	9/14/2010 12:35	0.064	1.59	9/14/2010 12:04	9/14/2010 12:35
Link_294 (BLF0730 -> BLY0710) 29.05	-0.136	0.357	9/14/2010 12:34	9/14/2010 13:07	-0.13	0.338	9/14/2010 12:34	9/14/2010 13:04	-0.117	0.318	9/14/2010 12:33	9/14/2010 12:58
Link_295 (BLF0720 -> BLY0710) 11.11	-0.45	0.159	9/14/2010 12:31	9/14/2010 13:09	-0.446	0.161	9/14/2010 12:31	9/14/2010 13:06	-0.434	0.143	9/14/2010 12:31	9/14/2010 13:01
Link_296 (BLY0710 -> BLF0700) 22.68	0.031	0.638	9/14/2010 12:03	9/14/2010 13:06	0.034	0.677	9/14/2010 12:03	9/14/2010 13:02	0.038	0.743	9/14/2010 12:03	9/14/2010 12:57
Link_297 (BLF0700 -> BLF0250) 52.45	0.005	0.794	9/14/2010 12:06	9/14/2010 12:55	0.006	0.861	9/14/2010 12:06	9/14/2010 12:52	0.009	0.951	9/14/2010 12:06	9/14/2010 12:49
Link_298 (BLF0760 -> BLS0801) 15.03	-0.391	0.41	9/14/2010 12:29	9/14/2010 13:24	-0.386	0.431	9/14/2010 12:34	9/14/2010 13:20	-0.437	0.45	9/14/2010 12:29	9/14/2010 13:15
Link_299 (BLS0801 -> BLF0750) 5.00	-0.417	0.603	9/14/2010 12:35	9/14/2010 13:23	-0.443	0.639	9/14/2010 12:35	9/14/2010 13:19	-0.474	0.681	9/14/2010 12:35	9/14/2010 13:14
Link_300 (BLF0750 -> BLF0740) 27.71	-0.432	0.657	9/14/2010 12:36	9/14/2010 13:22	-0.459	0.699	9/14/2010 12:36	9/14/2010 13:18	-0.492	0.747	9/14/2010 12:35	9/14/2010 13:13
Link_301 (BLF0740 -> BLF0240) 24.58	-0.452	0.694	9/14/2010 12:35	9/14/2010 13:22	-0.45	0.739	9/14/2010 12:35	9/14/2010 13:18	-0.446	0.791	9/14/2010 12:34	9/14/2010 13:13
Link_302 (BLF0410 -> BLF0400) 6.55	-0.192	0.426	9/14/2010 12:34	9/14/2010 12:49	-0.173	0.434	9/14/2010 12:34	9/14/2010 12:47	-0.14	0.441	9/14/2010 12:34	9/14/2010 12:44
Link_303 (BLF0400 -> BLF0390) 22.37	0.018	0.505	9/14/2010 13:49	9/14/2010 12:48	0.019	0.53	9/14/2010 13:48	9/14/2010 12:46	0.019	0.556	9/14/2010 13:48	9/14/2010 12:44
Link_304 (BLF0390 -> BLF0380) 22.06	0.036	0.939	9/14/2010 15:00	9/14/2010 12:47	0.039	0.993	9/14/2010 15:00	9/14/2010 12:45	0.043	1.061	9/14/2010 15:00	9/14/2010 12:43
Link_305 (BLF0380 -> BLF0370) 5.00	0.022	1.324	9/14/2010 12:00	9/14/2010 12:32	0.025	1.387	9/14/2010 12:00	9/14/2010 12:32	0.028	1.478	9/14/2010 12:00	9/14/2010 12:32
Link_306 (BLF0370 -> BLF0330) 16.91	0.023	1.157	9/14/2010 12:00	9/14/2010 12:32	0.026	1.224	9/14/2010 12:00	9/14/2010 12:32	0.026	1.329	9/14/2010 12:04	9/14/2010 12:32
Link_309 (BLF0335 -> BLF0330) 5.00	-0.039	0.467	9/14/2010 12:32	9/14/2010 12:36	-0.013	0.473	9/14/2010 12:32	9/14/2010 12:36	-0.019	0.496	9/14/2010 12:31	9/14/2010 12:40
Link_310 (BLF0330 -> BLF0325) 12.16	0.006	0.892	9/14/2010 12:07	9/14/2010 12:44	0.007	0.952	9/14/2010 12:07	9/14/2010 12:42	0.008	1.025	9/14/2010 12:07	9/14/2010 12:41
Link_311 (BLF0325 -> BLF0320) 20.82	0.005	0.954	9/14/2010 13:41	9/14/2010 12:43	0.01	1.018	9/14/2010 13:35	9/14/2010 12:42	0.024	1.093	9/14/2010 13:29	9/14/2010 12:40
Link_312 (BLF0320 -> BLF0200) 17.66	0.003	1.046	9/14/2010 14:08	9/14/2010 12:41	0.003	1.106	9/14/2010 12:08	9/14/2010 12:40	0.004	1.17	9/14/2010 12:08	9/14/2010 12:39
Link_313 (BLF0310 -> BLF0300) 61.54	0.016	0.47	9/14/2010 13:50	9/14/2010 12:32	0.017	0.474	9/14/2010 13:48	9/14/2010 12:33	0.017	0.489	9/14/2010 13:44	9/14/2010 12:33
Link_314 (BLF0300 -> BLF0180) 28.89	0.001	0.204	9/14/2010 14:00	9/14/2010 12:38	0.001	0.193	9/14/2010 13:52	9/14/2010 12:37	0.001	0.165	9/14/2010 13:44	9/14/2010 12:34
Link_317 (BLF0540 -> BLF0530) 29.94	0.04	0.775	9/14/2010 12:04	9/14/2010 13:32	0.043	0.844	9/14/2010 12:04	9/14/2010 13:24	0.048	0.942	9/14/2010 12:04	9/14/2010 13:17
Link_318 (BLF0530 -> BLF0520) 30.11	0.024	1.335	9/14/2010 12:05	9/14/2010 13:23	0.028	1.455	9/14/2010 12:05	9/14/2010 13:19	0.033	1.619	9/14/2010 12:05	9/14/2010 13:13
Link_319 (BLF0520 -> BLF0510) 29.82	0.035	1.685	9/14/2010 12:03	9/14/2010 13:07	0.039	1.827	9/14/2010 12:03	9/14/2010 13:06	0.044	2.019	9/14/2010 12:03	9/14/2010 12:54
Link_320 (BLF0510 -> BLF0500) 19.82	0.04	1.001	9/14/2010 12:04	9/14/2010 12:45	0.035	1.089	9/14/2010 12:05	9/14/2010 12:45	0.04	1.209	9/14/2010 12:05	9/14/2010 12:45
Link_321 (BLF0500 -> BLF0210) 22.66	0.023	1.619	9/14/2010 12:01	9/14/2010 12:32	0.026	1.733	9/14/2010 12:01	9/14/2010 12:32	0.029	1.883	9/14/2010 12:01	9/14/2010 12:32
Link_327 (BLF0180 -> BLF0170) 24.35	0.051	1.451	9/14/2010 12:04	9/14/2010 12:35	0.056	1.553	9/14/2010 12:04	9/14/2010 12:35	0.063	1.681	9/14/2010 12:04	9/14/2010 12:35
Link_328 (BLF0170 -> BLF0160) 25.30	0.051	1.449	9/14/2010 12:03	9/14/2010 12:35	0.048	1.551	9/14/2010 12:08	9/14/2010 12:35	0.059	1.696	9/14/2010 12:06	9/14/2010 12:31
Link_329 (BLF0160 -> OV65) 63.39	0.12	1.556	9/14/2010 12:04	9/14/2010 12:18	0.128	1.637	9/14/2010 12:04	9/14/2010 12:17	0.139	1.694	9/14/2010 12:09	9/14/2010 12:35
Link_330 (OV65 -> BLB0140) 7.65	0.017	2.077	9/14/2010 12:19	9/14/2010 12:36	0.058	2.277	9/14/2010 14:04	9/14/2010 12:36	0.038	2.559	9/14/2010 12:18	9/14/2010 12:35
Link_345 (BLF_EKS5 -> BLF0390) 21.41	0.01	0.47	9/14/2010 13:49	9/14/2010 12:48	0.011	0.488	9/14/2010 13:54	9/14/2010 12:46	0.008	0.511	9/14/2010 13:53	9/14/2010 12:44
Link_347 (HF04610 -> HF04600) 31.02	0	0.48	9/14/2010 12:41	9/14/2010 12:46	0	0.5	9/14/2010 12:40	9/14/2010 12:45	0	0.519	9/14/2010 12:39	9/14/2010 12:43
Link_350 (BLF0350 -> BLF0340) 8.19	-0.096	0.292	9/14/2010 12:31	9/14/2010 12:26	-0.099	0.304	9/14/2010 12:31	9/14/2010 12:26	-0.07	0.319	9/14/2010 12:31	9/14/2010 12:26
Link_351 (BLF0340 -> BLF0335) 10.02	-0.005	0.363	9/14/2010 12:31	9/14/2010 12:36	-0.007	0.369	9/14/2010 12:31	9/14/2010 12:36	-0.004	0.378	9/14/2010 12:31	9/14/2010 12:41
Link_352 (HF07100 -> HF04580) 13.45	-0.001	1.192	9/14/2010 13:30	9/14/2010 12:18	0	1.277	9/14/2010 14:03	9/14/2010 12:19	0	1.379	9/14/2010 13:57	9/14/2010 12:31

Link_353 (HF07025 -> HF07020) 12.17	0.024	0.97	9/14/2010 14:15	9/14/2010 12:35	0.024	0.975	9/14/2010 13:26	9/14/2010 12:35	0.025	0.976	9/14/2010 13:28	9/14/2010 12:35
Link_354 (HF07020 -> HF07010) 110.56	0.044	0.947	9/14/2010 14:01	9/14/2010 12:36	0.047	0.94	9/14/2010 13:57	9/14/2010 12:36	0.052	0.938	9/14/2010 13:57	9/14/2010 12:37
Link_355 (HF07010 -> HF07000) 17.23	0.035	0.819	9/14/2010 12:09	9/14/2010 12:38	0.043	0.831	9/14/2010 12:09	9/14/2010 12:38	0.05	0.92	9/14/2010 12:03	9/14/2010 12:41
Link_356 (HF07000 -> HF06500) 14.37	0.001	0.802	9/14/2010 12:10	9/14/2010 12:39	0.001	0.848	9/14/2010 12:10	9/14/2010 12:44	0.001	1.037	9/14/2010 12:10	9/14/2010 12:41
Link_357 (HF06500 -> HF05990) 25.29	0.034	0.959	9/14/2010 12:08	9/14/2010 12:39	0.016	1.018	9/14/2010 12:08	9/14/2010 12:39	0.033	1.106	9/14/2010 12:08	9/14/2010 12:38
Link_358 (HF05990 -> OV70) 5.00	0.063	1.662	9/14/2010 12:07	9/14/2010 12:40	0.07	1.727	9/14/2010 12:06	9/14/2010 12:40	0.076	1.815	9/14/2010 12:06	9/14/2010 12:39
Link_361 (HF05980 -> HF05975) 26.58	0.022	0.791	9/14/2010 12:01	9/14/2010 12:40	0.024	0.857	9/14/2010 12:01	9/14/2010 12:40	0.027	0.946	9/14/2010 12:01	9/14/2010 12:39
Link_362 (HF05975 -> HF05970) 19.73	0.024	0.791	9/14/2010 12:00	9/14/2010 12:40	0.026	0.857	9/14/2010 12:00	9/14/2010 12:40	0.026	0.946	9/14/2010 12:01	9/14/2010 12:39
Link_363 (HF05970 -> HF05960) 24.39	0.039	0.902	9/14/2010 12:12	9/14/2010 12:15	0.038	0.932	9/14/2010 12:11	9/14/2010 12:15	0.054	0.969	9/14/2010 12:10	9/14/2010 12:14
Link_364 (HF05960 -> HF05950) 25.08	0.023	0.679	9/14/2010 12:00	9/14/2010 12:17	0.026	0.744	9/14/2010 12:00	9/14/2010 12:17	0.029	0.77	9/14/2010 12:00	9/14/2010 12:16
Link_365 (HF05950 -> HF05940) 20.75	0.034	0.653	9/14/2010 12:00	9/14/2010 12:18	0.037	0.727	9/14/2010 12:12	9/14/2010 12:17	0.042	0.754	9/14/2010 12:12	9/14/2010 12:16
Link_366 (HF05940 -> HF05930) 20.58	0.033	0.678	9/14/2010 12:15	9/14/2010 12:18	0.037	0.697	9/14/2010 12:13	9/14/2010 12:18	0.042	0.763	9/14/2010 12:13	9/14/2010 12:17
Link_367 (HF05930 -> HF05925) 14.00	0.02	0.616	9/14/2010 12:17	9/14/2010 12:19	0.037	0.658	9/14/2010 12:15	9/14/2010 12:18	0.041	0.694	9/14/2010 12:14	9/14/2010 12:17
Link_368 (HF05925 -> HF05920) 12.50	0.03	0.627	9/14/2010 12:00	9/14/2010 12:21	0.034	0.667	9/14/2010 12:00	9/14/2010 12:20	0.037	0.705	9/14/2010 12:03	9/14/2010 12:19
Link_369 (HF05920 -> HF05910) 31.76	0.031	0.715	9/14/2010 12:18	9/14/2010 12:23	0.036	0.778	9/14/2010 12:16	9/14/2010 12:22	0.012	0.802	9/14/2010 12:17	9/14/2010 12:21
Link_370 (HF05910 -> HF05900) 31.86	0.023	0.617	9/14/2010 12:18	9/14/2010 12:23	0.011	0.7	9/14/2010 12:19	9/14/2010 12:22	0.009	0.787	9/14/2010 12:18	9/14/2010 12:21
Link_371 (HF05900 -> HF05899) 5.00	0	0.579	9/14/2010 12:00	9/14/2010 12:37	-0.001	0.632	9/14/2010 12:20	9/14/2010 12:36	-0.004	0.705	9/14/2010 12:19	9/14/2010 12:36
Link_372 (HF05899 -> HF05898) 11.28	0.003	0.787	9/14/2010 15:00	9/14/2010 12:23	0.003	0.808	9/14/2010 15:00	9/14/2010 12:22	0.003	0.851	9/14/2010 15:00	9/14/2010 12:21
Link_373 (HF05720 -> HF05710) 26.16	0.002	1.617	9/14/2010 13:11	9/14/2010 12:38	0.001	1.737	9/14/2010 13:10	9/14/2010 12:38	0.002	1.896	9/14/2010 13:11	9/14/2010 12:37
Link_374 (HF05710 -> HF05705) 25.33	0.034	0.692	9/14/2010 14:46	9/14/2010 12:45	0.035	0.739	9/14/2010 14:53	9/14/2010 12:44	0.039	0.799	9/14/2010 14:45	9/14/2010 12:43
Link_375 (HF05705 -> HF05700) 24.93	0.007	0.597	9/14/2010 12:07	9/14/2010 13:26	0.007	0.629	9/14/2010 12:07	9/14/2010 12:59	0.009	0.669	9/14/2010 12:07	9/14/2010 12:55
Link_376 (HF05700 -> HF04840) 5.00	-0.256	0.698	9/14/2010 12:08	9/14/2010 13:24	-0.363	0.713	9/14/2010 12:08	9/14/2010 13:23	-0.209	0.734	9/14/2010 12:08	9/14/2010 13:22
Link_377 (HF04840 -> HF04830) 7.80	0.043	1.158	9/14/2010 12:00	9/14/2010 12:45	0.047	1.201	9/14/2010 12:00	9/14/2010 12:47	0.054	1.252	9/14/2010 12:00	9/14/2010 12:57
Link_379 (HF04820 -> HF04810) 30.09	0.03	0.775	9/14/2010 12:00	9/14/2010 12:15	0.027	0.813	9/14/2010 12:10	9/14/2010 12:15	0.038	0.836	9/14/2010 12:00	9/14/2010 12:14
Link_380 (HF04810 -> HF04800) 32.73	0.029	0.688	9/14/2010 12:00	9/14/2010 12:15	0.032	0.745	9/14/2010 12:00	9/14/2010 12:15	0.036	0.805	9/14/2010 12:00	9/14/2010 12:15
Link_381 (HF04800 -> HF04790) 12.49	0.029	0.638	9/14/2010 12:00	9/14/2010 12:49	0.032	0.668	9/14/2010 12:00	9/14/2010 12:58	0.036	0.699	9/14/2010 12:00	9/14/2010 13:02
Link_382 (HF04790 -> HF04780) 16.78	0.029	0.635	9/14/2010 12:14	9/14/2010 12:50	0.031	0.666	9/14/2010 12:13	9/14/2010 12:58	0.037	0.699	9/14/2010 12:00	9/14/2010 13:02
Link_383 (HF04780 -> HF04770) 6.63	0.025	0.64	9/14/2010 12:00	9/14/2010 12:28	0.028	0.668	9/14/2010 12:00	9/14/2010 12:29	0.032	0.704	9/14/2010 12:00	9/14/2010 12:46
Link_384 (HF04770 -> HF04760) 21.39	0.025	0.683	9/14/2010 12:16	9/14/2010 12:19	0.035	0.675	9/14/2010 12:00	9/14/2010 12:35	0.035	0.752	9/14/2010 12:15	9/14/2010 12:18
Link_385 (HF04760 -> HF04750) 22.76	0.031	0.677	9/14/2010 12:00	9/14/2010 12:28	0.033	0.713	9/14/2010 12:16	9/14/2010 12:29	0.038	0.756	9/14/2010 12:00	9/14/2010 12:31
Link_386 (HF04750 -> HF04740) 21.96	0.029	0.724	9/14/2010 12:00	9/14/2010 12:22	0.031	0.712	9/14/2010 12:17	9/14/2010 12:30	0.013	0.755	9/14/2010 12:17	9/14/2010 12:31
Link_387 (HF04740 -> HF04730) 33.39	0.03	0.709	9/14/2010 12:00	9/14/2010 12:23	0.033	0.733	9/14/2010 12:00	9/14/2010 12:23	0.017	0.812	9/14/2010 12:18	9/14/2010 12:22
Link_388 (HF04730 -> HF04720) 30.29	0.024	0.698	9/14/2010 12:00	9/14/2010 12:25	0.015	0.711	9/14/2010 12:20	9/14/2010 12:39	0.03	0.757	9/14/2010 12:00	9/14/2010 12:43
Link_389 (HF04720 -> HF04710) 34.64	0.029	0.746	9/14/2010 12:00	9/14/2010 12:38	0.032	0.783	9/14/2010 12:00	9/14/2010 12:39	0.037	0.828	9/14/2010 12:01	9/14/2010 12:40
Link_390 (HF04710 -> HF04700) 13.23	0.047	0.732	9/14/2010 12:21	9/14/2010 12:30	0.017	0.77	9/14/2010 12:23	9/14/2010 12:30	0.058	0.823	9/14/2010 12:20	9/14/2010 12:31
Link_391 (HF04700 -> 007268S) 16.97	0.027	0.614	9/14/2010 12:00	9/14/2010 13:02	0.03	0.644	9/14/2010 12:00	9/14/2010 12:59	0.034	0.681	9/14/2010 12:00	9/14/2010 12:59
Link_392 (007268S -> HF04690) 25.73	0.013	0.652	9/14/2010 12:00	9/14/2010 12:39	0.014	0.689	9/14/2010 12:00	9/14/2010 12:39	0.016	0.732	9/14/2010 12:00	9/14/2010 12:39
Link_393 (HF04690 -> HF04680) 64.33	0.035	0.67	9/14/2010 12:00	9/14/2010 12:31	0.039	0.707	9/14/2010 12:00	9/14/2010 12:30	0.042	0.766	9/14/2010 12:25	9/14/2010 12:29
Link_394 (HF04680 -> 00090S) 13.03	0.015	0.61	9/14/2010 12:29	9/14/2010 13:02	0.018	0.639	9/14/2010 12:28	9/14/2010 12:59	0.019	0.673	9/14/2010 12:27	9/14/2010 12:57
Link_395 (00090S -> HF04670) 18.25	-0.033	0.609	9/14/2010 12:08	9/14/2010 13:01	-0.035	0.638	9/14/2010 12:07	9/14/2010 12:59	-0.039	0.673	9/14/2010 12:02	9/14/2010 12:57
Link_396 (HF04670 -> HF04660) 29.89	0.03	0.729	9/14/2010 12:00	9/14/2010 12:35	0.034	0.763	9/14/2010 12:00	9/14/2010 12:34	0.038	0.823	9/14/2010 12:00	9/14/2010 12:33
Link_397 (HF04660 -> HF04650) 30.10	0.029	0.725	9/14/2010 12:05	9/14/2010 12:36	0.032	0.754	9/14/2010 12:00	9/14/2010 12:49	0.036	0.79	9/14/2010 12:00	9/14/2010 12:52
Link_398 (HF04650 -> HS04645) 19.94	0.002	0.776	9/14/2010 14:52	9/14/2010 12:36	0.01	0.818	9/14/2010 15:00	9/14/2010 12:35	0.008	0.787	9/14/2010 15:00	9/14/2010 12:33
Link_399 (HS04645 -> HF04640) 9.68	-0.154	0.588	9/14/2010 12:00	9/14/2010 12:59	-0.17	0.622	9/14/2010 12:00	9/14/2010 13:28	-0.192	0.671	9/14/2010 12:00	9/14/2010 13:25
Link_400 (HF04640 -> 00144S) 34.82	0.026	0.923	9/14/2010 12:08	9/14/2010 12:42	0.029	0.957	9/14/2010 12:12	9/14/2010 12:41	0.032	1.016	9/14/2010 12:00	9/14/2010 12:39
Link_401 (00144S -> HF04620) 31.09	0.037	0.932	9/14/2010 12:00	9/14/2010 12:43	0.037	0.982	9/14/2010 12:39	9/14/2010 12:42	0.042	1.04	9/14/2010 12:36	9/14/2010 12:40
Link_402 (HF04620 -> HF04610) 32.48	0.029	0.931	9/14/2010 12:00	9/14/2010 12:47	0.032	0.979	9/14/2010 12:00	9/14/2010 12:46	0.014	1.05	9/14/2010 12:38	9/14/2010 12:45
Link_403 (HF04610 -> HF04600) 31.02	0	0.48	9/14/2010 12:41	9/14/2010 12:46	0	0.5	9/14/2010 12:40	9/14/2010 12:45	0	0.519	9/14/2010 12:39	9/14/2010 12:43
Link_406 (HF06800 -> HF06520) 19.57	0.02	4.626	9/14/2010 13:17	9/14/2010 12:31	0.019	4.811	9/14/2010 13:17	9/14/2010 12:31	0.017	5.229	9/14/2010 13:16	9/14/2010 12:32
Link_407 (HF06520 -> HF06500) 110.25	0.013	1.227	9/14/2010 13:25	9/14/2010 12:32	0.014	1.453	9/14/2010 13:24	9/14/2010 12:32	0.016	1.58	9/14/2010 13:24	9/14/2010 12:33
Link_408 (HF06035 -> HF06030) 21.88	0.04	2.828	9/14/2010 13:33	9/14/2010 12:42	0.044	2.844	9/14/2010 13:31	9/14/2010 12:41	0.047	2.849	9/14/2010 13:30	9/14/2010 12:40
Link_409 (HF06030 -> HF06020) 21.20	0.087	2.828	9/14/2010 13:47	9/14/2010 12:42	0.096	2.872	9/14/2010 13:45	9/14/2010 12:41	0.109	3.03	9/14/2010 13:42	9/14/2010 12:40
Link_410 (HF06020 -> HF06010) 13.96	0.104	2.96	9/14/2010 12:05	9/14/2010 12:42	0.113	3.12	9/14/2010 12:03	9/14/2010 12:41	0.123	3.356	9/14/2010 12:02	9/14/2010 12:42
Link_411 (HF06010 -> HF06000) 17.58	0.096	2.828	9/14/2010 13:49	9/14/2010 12:42	0.092	2.844	9/14/2010 13:46	9/14/2010 12:41	0.097	2.849	9/14/2010 13:45	9/14/2010 12:40
Link_414 (OV70 -> HF05980) 7.57	0.033	0.791	9/14/2010 12:00	9/14/2010 12:39	0.037	0.861	9/14/2010 12:00	9/14/2010 12:32	0.042	0.949	9/14/2010 12:00	9/14/2010 12:32
Link_416 (HF04880 -> OV69) 6.59	0.021	5.068	9/14/2010 13:27	9/14/2010 12:40	0.021	5.187	9/14/2010 13:27	9/14/2010 12:39	0.022	5.193	9/14/2010 13:26	9/14/2010 12:38
Link_417 (OV69 -> HF04860) 5.00	0.049	1.334	9/14/2010 12:00	9/14/2010 12:31	0.054	1.372	9/14/2010 12:00	9/14/2010 12:30	0.061	1.394	9/14/2010 12:00	9/14/2010 12:30
Link_418 (HF07110 -> OV73) 5.00	0.011	2.262	9/14/2010 13:39	9/14/2010 12:36	0.031	2.262	9/14/2010 13:17	9/14/2010 12:36	0.028	2.264	9/14/2010 13:20	9/14/2010 12:36
Link_419 (OV73 -> HF07100) 6.38	-0.001	1.051	9/14/2010 13:30	9/14/2010 12:36	0.001	1.13	9/14/2010 13:22	9/14/2010 12:36	0.004	1.234	9/14/2010 13:32	9/14/2010 12:36
Link_420 (HF06000 -> HF05990) 10.73	0.017	1.591	9/14/2010 13:30	9/14/2010 12:42	0.022	1.6	9/14/2010 13:29	9/14/2010 12:41	0.027	1.609	9/14/2010 13:47	9/14/2010 12:41
Link_426 (BLB0140 -> RA5.A) 10.72	0.059	1.75	9/14/2010 12:00	9/14/2010 13:47	0.065	1.9	9/14/2010 12:00	9/14/2010 13:41	0.074	2.099	9/14/2010 12:00	9/14/2010 13:36
Link_429 (BLF0590 -> BLF0560) 47.88	0.011	0.445	9/14/2010 14:22	9/14/2010 12:30	0.011	0.5	9/14/2010 14:06	9/14/2010 12:30	0.011	0.527	9/14/2010 13:57	9/14/2010 12:30
Link_430 (BLF0650 -> BLF0560) 57.12	-0.039	0.297	9/14/2010 12:27	9/14/2010 13:32	0.01	0.309	9/14/2010 12:06	9/14/2010 13:26	0.013	0.336	9/14/2010 14:06	9/14/2010 13:19
Link_431 (BLF0560 -> BLF0540) 30.09	0.029	0.71	9/14/2010 12:03	9/14/2010 13:33	0.031	0.767	9/14/2010 12:04	9/14/2010 13:27	0.035	0.845	9/14/2010 12:04	9/14/2010 13:20
Link_434 (Node_386 -> PS209) 5.00	0	0.038	9/14/2010 12:01	9/14/2010 12:00	0	0.041	9/14/2010 14:39	9/14/2010 12:00	0	0.047	9/14/2010 14:15	9/14/2010 12:00
Average	-0.009	0.968			-0.008	1.020			-0.005	1.088		

V.3. Wastewater calculation

Parameter	Value	Unit	Reference
fh,max	2.0		
fd,max	2.0		
PE	103	l/d	Danva - Vand i tal 2018
Houshold	2.5	PE	
Discharge from on household	258	l/d	
Total PE Catchment A1.24	1340	PE	Wasewater plan page 27
Safety margin	0		
Max discharge in pipe [status 10year]	75	l/s	

	Per houshold	Total A1.24	Unit
qmax,d	515	276040	l/d
qmax,h	43	23003.33333	l/h
qmax,s	0.012	**6.39**	l/s

The safety margin is not used in this calculation.

Area	Day factor	Hour factor
Hollyday houses, campsites etc.	2,0-4,0	2,0-4,0
Rural area with farmning/agriculture	2,0-3,0	2,0-3,0
Villages without bigger industry	1,5-2,0	1,5-2,5
Cities with all kind of industry	1,3-1,5	1,5-1,7

From "Afløbsteknik"

Flow for dimensioning of pipe

- Max daily flow, $q_{max,d}$:

$$q_{max,d} = f_d^{max} \cdot q_{m,d}$$

(f_d^{max}: day factor, $q_{m,d}$: average daily flow)

- Max hourly flow, $q_{max,h}$:

$$q_{max,h} = f_h^{max} \cdot q_{max,d}/24$$

(f_h^{max}: hour factor)

- Max hourly flow is used for dimensioning wastewater pipes (with 100 % safety margin)

V.4. Dimensioning of wastewater pipes

V.4.1.. Dimensioning of wastewater pipes. Calculation.

Parameter	Value	Unit	Reference
fh,max	2.0		
fd,max	2.0		
PE	103	l/d	Danva - Vand i tal 2018
Houshold	2.5	PE	
Discharge from on household	258	l/d	
Total PE Blegind	183	PE	Wasewater plan page 27
Safety margin	2		

	Per houshold	Total blegind	Unit
qmax,d	1030	75396	l/d
qmax,h	86	6283	l/h
qmax,s	0.024	1.75	l/s

The calculation shows that the ø160 pipe chosen is adequate both in the most and least extreme situation. To see the calculation of the self-cleaning effect of the pipes look in the next tab

Area	Day factor	Hour factor
Hollyday houses, campsites etc.	2,0-4,0	2,0-4,0
Rural area with farmning/agriculture	2,0-3,0	2,0-3,0
Villages without bigger industry	1,5-2,0	1,5-2,5
Cities with all kind of industry	1,3-1,5	1,5-1,7

From "Afløbsteknik"

Flow for dimensioning of pipe

- Max daily flow, $q_{max,d}$:

$$q_{max,d} = f_d^{max} \cdot q_{m,d}$$

(f_d^{max}: day factor, $q_{m,d}$: average daily flow)

- Max hourly flow, $q_{max,h}$:

$$q_{max,h} = f_h^{max} \cdot q_{max,d}/24$$

(f_h^{max}: hour factor)

- Max hourly flow is used for dimensioning wastewater pipes (with 100 % safety margin)

V.4.2. Self-cleaning

Flow depth Blegind

$y_g =$ 0.026 m (Guess of flow depth)

$D_{out} =$ 0.16 (Outside diameter of the pipe)

$D =$ 0.1506 m (Indside diameter of the pipe)

$A =$ 0.002053 m^2 (Area of the cross-section of the pipe)

$\theta =$ 0.856992 (Dimensionsless angle TETA)

$P =$ 0.129063 m (Wet perimeter)

$R =$ 0.015908 m (Hydraulic radius)

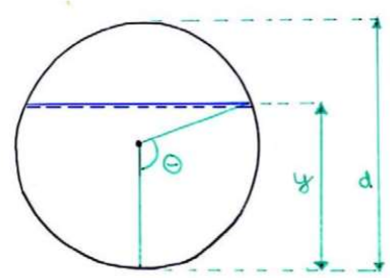
$M =$ 80 (Manning number)

$I =$ 0.01 (An assumption of the slope)

$Q =$ 0.001 m^3/s ~ $Q_g =$ 0.00104 m^3/s

V 0.506028 m/s

$\tau =$ 1.5 < 1.59



- An assumption of the flow depth (y_g) is done. Using this depth of flow, a flow (Q_g) corresponding the waterdepth can be calculated by using the Manning number, set on 80, and an assumption of the slope, set on 10 ‰. The calculated flow has to be approximatly 1L/sec, which can be reached by chancing the flow depth. It is assumed that the minimum flow is 1 L/sec, because Blegind contributes a small amount of wastewater to the system (L/sec) and has a total PE below 200. τ needs to be above 1,5 to have a self-cleaning effect.

V.5. SVK Blegind

Regnkurve karakteristika

Northing (WGS84 ZONE 32)	6213643	
Easting (WGS84 ZONE 32)	566900	
Årsmiddelnedbør [mm]	717	Beregnes ud fra N og E koordinater
Middelværdi ekstrem døgnnedbør DMI Klimagrid [mm/dag]	25.2	Beregnes ud fra N og E koordinater
Gentagelsesperiode (år)	5	
Sikkerhedsfaktor (Fra Skrift 27)	1.65	Defineret i Skrift 27, Faktor til beskrivelse af usikkerhed, klima, mv. Typisk 1.0 - 1.8
Varighed (min)	Intensitet givet ovenstående input (μm/s)	
20	19.70	

Ledningsdimensionering

CDS karakteristika

CDS-regn varighed (min)	240
Tidsskridt (min)	1
Asymmetri koefficient	0.5

Bassindimensionering opstrøms udløb

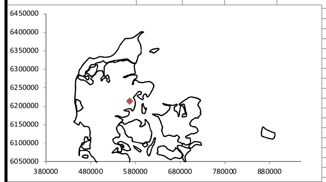
Oplandskarakteristika

Befæstet areal (ha)	3.32
Hydrologisk reduktionsfaktor (-)	0.8
Afskærende lednings kapacitet (l/s)	20

NB. Frekvens- og sikkerhedsfaktorer på regnen indgår ved beregning af bassinvolumen

Design regnkurve

Varighed (min)	z_T (μm/s)	$S\{z_T\}$ (μm/s)	f^*z_T (μm/s)	Regression (μm/s)
1	36.68	3.37	60.51	60.77
2	32.40	2.75	53.47	53.67
5	24.51	1.62	40.44	40.39
10	18.03	1.36	29.75	29.35
30	9.31	0.87	15.37	15.17
60	5.72	0.64	9.44	9.40
180	2.50	0.23	4.12	4.20
360	1.49	0.10	2.47	2.49
720	0.88	0.06	1.45	1.47
1440	0.52	0.04	0.86	0.87
2880	0.32	0.02	0.52	0.51



CDS regn

Plot af CDS regn:
Tilpas SERIE(..) i CDS regn
til at plotte fra H18 til H257

Tid (min)	Intensitet (μm/s)
0	0.835098587
1	0.840792748
2	0.846576605
3	0.85245238
4	0.85842237
5	0.86448895
6	0.870654577
7	0.876921794
8	0.883293231
9	0.889771616
10	0.896359769
11	0.903060616
12	0.909877188
13	0.916812626
14	0.923870192
15	0.931053266
16	0.938365358
17	0.945810113
18	0.953391315
19	0.961112897
20	0.968978946
21	0.976993714
22	0.985161622
23	0.993487272
24	1.001975455
25	1.010631161
26	1.019459591
27	1.028466164
28	1.037656535
29	1.047036602
30	1.056612524
31	1.066390734
32	1.076377952
33	1.086581206
34	1.097007845
35	1.107665564
36	1.118562417
37	1.129706844
38	1.141107694
39	1.152774248
40	1.164716247
41	1.176943921
42	1.18946802
43	1.202299849
44	1.215451304
45	1.228934908
46	1.242763861
47	1.256952076
48	1.271514239
49	1.286465855
50	1.301823311
51	1.31760394
52	1.333826087
53	1.350509189
54	1.367673855
55	1.385341956
56	1.403536726
57	1.422282868
58	1.441606675
59	1.461536156
60	1.482101185
61	1.503333655
62	1.525267654
63	1.547939659
64	1.571388747
65	1.595656835
66	1.62078894
67	1.646833475
68	1.673842578
69	1.701872471
70	1.730983879
71	1.761242482
72	1.792719439
73	1.82549197
74	1.859644015
75	1.895266985
76	1.932460614
77	1.971333928
78	2.012006353
79	2.054608987
80	2.099286066
81	2.146196646
82	2.195516561
83	2.247440692
84	2.302185617
85	2.35999271
86	2.421131795
87	2.48590545
88	2.554654126
89	2.627762243
90	2.705665509
91	2.78885973
92	2.877911501
93	2.973471252
94	3.076289264
95	3.187235486
96	3.307324233
97	3.437745215
98	3.579902876
99	3.735466719
100	3.906436359
101	4.095226547
102	4.304779619
103	4.538716209
104	4.801540148
105	5.098921486
106	5.438094351
107	5.82842728
108	6.28225886
109	6.816152773

Volumen af bassin

1210 m3

Effekten af koblede regn ER inkluderet (20 % ekstra volumen)

Mellemresultater svarende til Skrift 16

Dvs. at effekt af koblede regn IKKE er indkluderet i mellemresultaterne.

Reduceret areal (ha)	2.66
Afløbstal (mu-m/s	0.75
Varighed (h)	4.36
Vr,k (mm)	37.97

Regression

Estimates, 3 parameters:

Alpha	231.2222
Theta	4.696656
Nu	0.768017

Dur (min)	Intensity	ln(dur)	ln(dur+Theta)	ln(int)	ln(dur+Theta)^2	ln(dur+Theta)*ln(int)	Est. Intensity	Obj.Func
1	60.51	0	1.73987937	4.1028899	3.027180223	7.138533435	60.77161413	1.79178E-05
2	53.47	0.693147	1.901608326	3.9790347	3.616114227	7.566565532	53.67311817	1.50356E-05
5	40.44	1.609438	2.271781104	3.6996994	5.160989384	8.404907245	40.39126077	1.17936E-06
10	29.75	2.302585	2.687619998	3.3929509	7.223301255	9.118962558	29.34852439	0.000187925
30	15.37	3.401197	3.546643319	2.732364	12.57867883	9.690720621	15.17270508	0.000165532
60	9.44	4.094345	4.169709518	2.2447137	17.38647747	9.359804175	9.40247459	1.39937E-05
180	4.12	5.192957	5.218714783	1.4159024	27.23498399	7.389190695	4.200986792	0.000377022
360	2.47	5.886104	5.899065929	0.902755	34.79897884	5.325411066	2.491284576	0.000100872
720	1.45	6.579251	6.585753162	0.3720392	43.37214471	2.450158386	1.470218862	0.000178812
1440	0.86	7.272398	7.275654652	-0.1547843	52.93515062	-1.126156763	0.865502926	0.00010691
2880	0.52	7.965546	7.967175028	-0.6456621	63.47587793	-5.144102793	0.50887969	0.000892909
	Sum		49.26360519	22.041903	270.8098775	60.17399416		0.002058109

	Afløbstal	tr, 3 par	Vr,k 3 par	dV/dt	(dV/dt)^2
	mu-m/s	1153.531525	(mm)	(…)	(…)
Faktisk opland	0.753012	261.7	37.97	0.025636082	0.025636082
Initialisering		258.40			

Tilnærmet volumenkurve excl koblede regn. Tilnærmelsen er god op til ca. T=5 år

Volumenkurve	0.010	71778.95	142.6
Tilnærmet for store afl	0.012	56610.73	134.9
	0.014	44647.83	127.7
	0.017	35212.92	120.9
	0.021	27771.78	114.4
	0.025	21903.09	108.2
	0.030	17274.56	102.4
	0.036	13624.12	96.9
	0.043	10745.10	91.7
	0.052	8474.46	86.8
	0.062	6683.65	82.1
	0.074	5271.27	77.7
	0.089	4157.35	73.5
	0.100	3580.49	71.0
	0.120	2823.86	67.2
	0.144	2227.13	63.6
	0.173	1756.49	60.1
	0.207	1385.31	56.9
	0.249	1092.57	53.8
	0.299	861.69	50.8
	0.358	679.60	48.0
	0.430	535.99	45.4
	0.516	422.72	42.8
	0.619	333.39	40.4
	0.743	262.94	38.1
	1.000	178.60	34.6
	1.200	140.86	32.5
	1.440	111.09	30.5
	1.728	87.62	28.5
	2.074	69.10	26.6
	2.488	54.50	24.8
	2.986	42.98	23.0
	3.583	33.90	21.1
	4.300	26.74	19.4
	5.160	21.09	17.6
	6.192	16.63	15.8
	7.430	13.12	14.1
	8.916	10.34	12.4
	10.000	8.91	11.3

Sæt optimering i gang

Initdummy					
1					
idftheta	theta				
0.22385912	1				
derividf	x				
-0.199990102	1				
bisectidf	min	max	middel	tiny	
4.696656195	0	60	30	0.00001	
dbasvol	alpha	nu	theta	t	a
-0.375388	231.2222	0.768016604	1.0	638.0	0.753012048
bisectvol	xl	xr	xmid	tiny	
261.6518769	77.52087	775.2087435	426.3648	0.00001	

110	7.452836419
111	8.224293688
112	9.176887222
113	10.38022362
114	11.94332392
115	14.0460637
116	17.00535797
117	21.42945037
118	28.63023601
119	41.96210886
120	60.77161413
121	41.96210886
122	28.63023601
123	21.42945037
124	17.00535797
125	14.0460637
126	11.94332392
127	10.38022362
128	9.176887222
129	8.224293688
130	7.452836419
131	6.816152773
132	6.28225886
133	5.82842728
134	5.438094351
135	5.098921486
136	4.801540148
137	4.538716209
138	4.304779619
139	4.095226547
140	3.906436359
141	3.735466719
142	3.579902876
143	3.437745215
144	3.307324233
145	3.187235486
146	3.076289264
147	2.973471252
148	2.877911501
149	2.78885973
150	2.705665509
151	2.627762243
152	2.554654126
153	2.48590545
154	2.421131795
155	2.35999271
156	2.302185617
157	2.247440692
158	2.195516561
159	2.146196646
160	2.099286066
161	2.054608987
162	2.012006353
163	1.971333928
164	1.932460614
165	1.895266985
166	1.859644015
167	1.82549197
168	1.792719439
169	1.761242482
170	1.730983879
171	1.701872471
172	1.673842578
173	1.646833475
174	1.62078894
175	1.595656835
176	1.571388747
177	1.547939659
178	1.525267654
179	1.503333655
180	1.482101185
181	1.461536156
182	1.441606675
183	1.422282868
184	1.403536726
185	1.385341956
186	1.367673855
187	1.350509189
188	1.333826087
189	1.31760394
190	1.301823311
191	1.286465855
192	1.271514239
193	1.256952076
194	1.242763861
195	1.228934908
196	1.215451304
197	1.202299849
198	1.18946802
199	1.176943921
200	1.164716247
201	1.152774248
202	1.141107694
203	1.129706844
204	1.118562417
205	1.107665564
206	1.097007845
207	1.086581206
208	1.076377952
209	1.066390734
210	1.056612524
211	1.047036602
212	1.037656535
213	1.028466164
214	1.019459591
215	1.010631161
216	1.001975455
217	0.993487272
218	0.985161622
219	0.976993714
220	0.968978946
221	0.961112897
222	0.953391315
223	0.945810113
224	0.938365358
225	0.931053266
226	0.923870192
227	0.916812626
228	0.909877188
229	0.903060616
230	0.896359769
231	0.889771616
232	0.883293231
233	0.876921794
234	0.870654577
235	0.86448895
236	0.85842237
237	0.85245238
238	0.846576605
239	0.840792748

V.6. Denitrification rate

Denitrification

1)

	2013	2014	2015	2016	2017
Total sludge production (kg SS/year)	172949	148219	187220	166206	217464
Chemical sludge production (kg SS/year)	3676.19	2646.86	8087.62	14704.76	20586.66
Ratio Chem,sp / Tot,sp	0.021256	0.017858	0.043198	0.088473	0.094667

Average chemical sludge percentage: 5.309045

$$r_{DN} = \frac{\mu_{max}}{Y_{max}} * \boxed{\frac{S_{NO3}}{S_{NO3} + K_{S,NO3}}} * \frac{S}{S + K_S} * X_B$$

Describes the effect of the nitrate concentration.

2)

$$r_{DN} = k * \frac{S_{NO3}}{S_{NO3} + K_{S,NO3}}$$

$k =$ 18.000

$K_{S,NO3} =$ 2

$t =$	$S_{NO3} =$	$r_{DN} =$	$\Delta S_{NO3} =$
0.00	9.92	14.98	0.00
0.10	8.42	14.55	-1.50
0.20	6.97	13.99	-1.45
0.30	5.57	13.24	-1.40
0.40	4.24	12.23	-1.32
0.50	3.02	10.83	-1.22
0.60	1.94	8.86	-1.08
0.70	1.05	6.21	-0.89
0.80	0.43	3.20	-0.62
0.90	0.11	0.96	-0.32
1.00	0.02	0.15	-0.10
1.10	0.00	0.02	-0.01
1.20	0.00	0.00	0.00
1.30	0.00	0.00	0.00
1.40	0.00	0.00	0.00
1.50	0.00	0.00	0.00
1.60	0.00	0.00	0.00
1.70	0.00	0.00	0.00
1.80	0.00	0.00	0.00
1.90	0.00	0.00	0.00
2.00	0.00	0.00	0.00
2.10	0.00	0.00	0.00
2.20	0.00	0.00	0.00
2.30	0.00	0.00	0.00
2.40	0.00	0.00	0.00
2.50	0.00	0.00	0.00