Interreg
EUROPEAN UNION
2 Seas Mers Zeeën
FRESH4Cs
European Regional Development Fund

Investment 3: Nature Based Solution for concentrate treatment, Koksijde (BE)

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Date: 31/03/2023

FRESH4Cs has received funding from the Interreg 2 Seas programme 2014-2020 co-funded by the European Regional Development Fund under subsidy contract No 2S06-028.

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In FRESH4Cs a full scale a nature based system, a willow marsh, was constructed to treat concentrate of an existing membrane filtration system. This willow marsh is based in the DEMOWARE project (ENV.2013.WATER INNO&DEMO-1 – Water Innovation and Demonstration Projects, no. 619040), where small scale pilots were tested. (Van Houtte et al., 2016). The willow marsh is operational since beginning 2022. The reduction of the nutrient content of the discharged water, demonstrated withing this first year of operation, is a valuable contribution to the environment and the quality of the accepting canal and in the end the ocean as the canal discharges into the North Sea in Nieuwpoort.

Lessons learned

To start a new initiative like this willow marsh it is important to involve all stakeholders. But once all obstacles are cleared and the project offers real opportunities for both ecological and economical improvement, as was the case here based on long lasting preliminary research, the implementation showed that it was valuable as there was indeed a real added value by reducing nutrient content. At the end of this first year of operation Aquaduin was the winner of the ‘Blue Innovation Captain Award 2022’ with this project, an appreciation for all the positive work that has been performed.

Introduction

The Intermunicipal Water Company from the Veurne Region (IWVA), now Aquaduin, historically produces its drinking-water from a fresh-water lens under the dunes in Koksijde. Aquaduin serves drinking-water to about 62,000 people living permanently in the distribution area, but during summer they serve up to double that amount of people. This results in a big difference between the minimal and maximum daily consumption. As the fresh dune aquifers are surrounded by salt water, both north under the sea and south under the polder area, the extraction capacity of fresh dune water is limited.

To obtain sustainable groundwater management in the dunes, in 2002 Aquaduin started with managed aquifer recharge (MAR) of the dune aquifer of St-André based on water reuse from the adjacent wastewater treatment plant of Wulpen, operated by Aquafin. At the Water Production Center (WPC) Torreele, the effluent, approximately 3 Mm3/yr, is treated using ultrafiltration and reverse osmosis (RO), thus based on a multiple-barrier approach (Van Houtte and Verbauwhede, 2021a). The RO membranes produce concentrate that is discharged to the adjacent canal that ends into the sea. Within the DEMOWARE project (ENV.2013.WATER INNO&DEMO-1 – Water Innovation and Demonstration Projects, no. 619040), treatment of this concentrate was demonstrated using a natural system based on willows. The main objective of the test was to investigate the potential to remove nutrients from the concentrate. About 30–35% of both phosphorous and nitrogen were removed (Van Houtte, 2015 and Van Houtte et al., 2016).

In the FRESH4Cs project Aquaduin was enabled to build the natural system based on willows full-scale (2021) and to demonstrate the performance of the treatment since beginning 2022. In this document it will be further called ‘willow marsh’.

In the future it could be a first step for further treatment to produce alternative fresh water for the region, so besides a reduction of the impact of wastewater discharge an increase of the overall recovery of WPC Torreele could be achieved.

Technical aspects of the demo

Demo setup

The principle of the willow marsh is based on a subsurface flow constructed wetland with the RO concentrate flowing horizontally from one side of the basin, that is filled with gravel, to the other side of the basin where it is collected using drains. The total area amounts 8.000 m² and all over the willow marsh there is an impermeable layer at the bottom preventing RO concentrate to leak to the environment (photo 1). Instead of Phragmites, the traditional plant used in wetlands, based on experiences with Short Rotation Coppice (SRC), willows are used as they tolerate the salt content of the RO concentrate. SRC is a crop of wooden species planted at very high density with the intention to produce wood. ‘Short Rotation’ reflects to the frequency of harvesting which is in the order of 2 to 4 years. The willow marsh can thus be considered as a combination of a constructed wetland and the technique of SRC.

In figure 1, the plan of the willow marsh is shown. In deliverable D4.7.1 more technical details are available.

At one side of the marsh, the south side, the RO concentrate flows into a distribution duct (photo 2). At the other side, the north side, the treated water is collected by a drain placed at the bottom (figure

2). The collected water flows into a reservoir (photo 3) from where it is pumped to the existing discharge infrastructure canal. It is possible to adjust the level in the willow marsh by adjusting the level in reservoir.

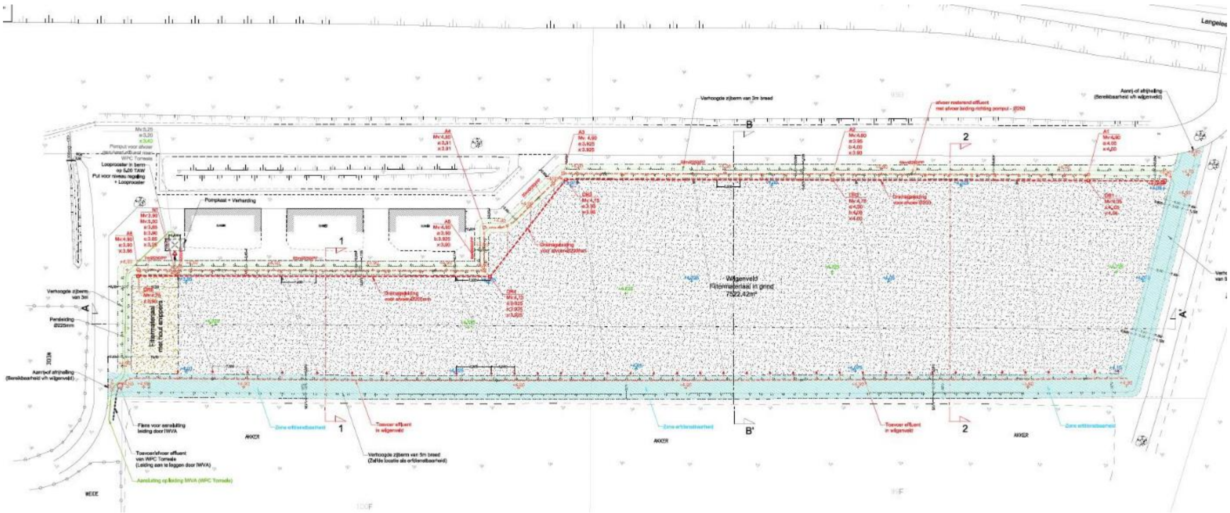

Figure 1. Scheme of the willow marsh

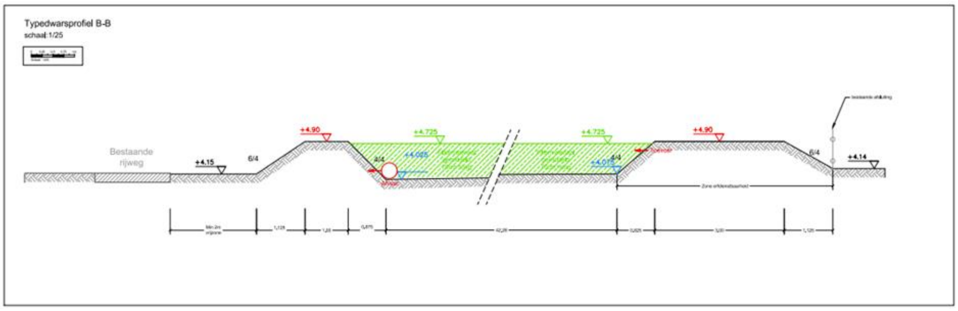

Figure 2. Cross section through the willow marsh

Photo 1. Placement of an impermeable layer at the bottom of the willow marsh

Photo 2. The distribution duct at the south side of the willow marsh

Photo 3. The collection well of the effluent of the willow marsh

The willow marsh is filled with gravel (photo 2) and partly wood chips (figure 1). The thickness of gravel is 70 cm. South, where the duct is placed and north, where the drain is placed, the gravel is somewhat coarser.
The willow stools, variety Salix x rubens, are planted into the gravel. They are placed in rows with a distance between the stools of 50 cm and 70 cm distance between the rows (figure 3). Approximately 20.000 stools were planted into the gravel or woodchips: no organic matter was present in the gravel.

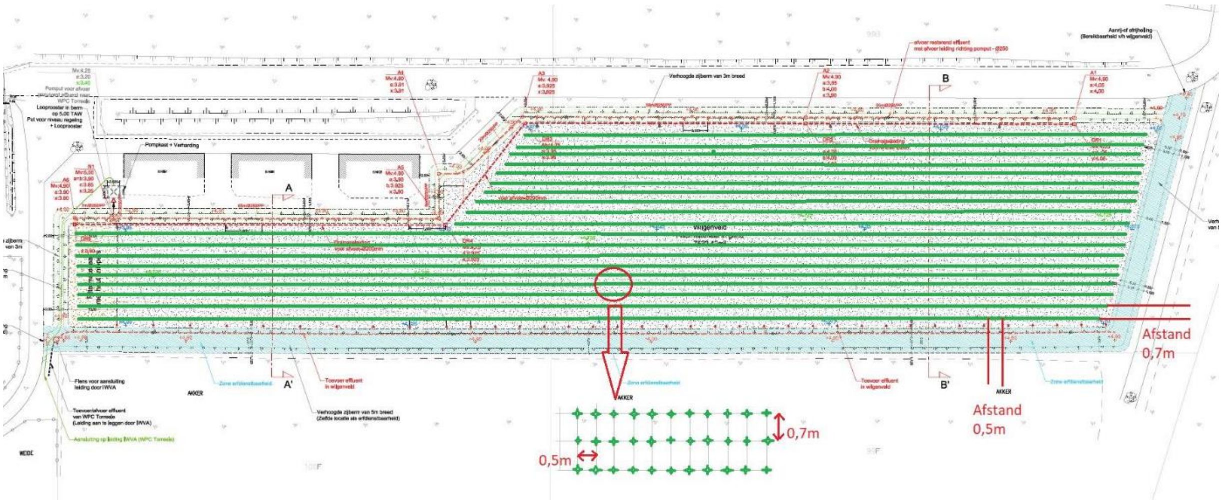

Figure 3. Scheme of the placement of willow stools into the willow marsh

The mean residence time of the RO concentrate into the willow field is 1 day.

The willow marsh was ready for use at the end of 2022 when some preliminary tests were started. Beginning of January 2023 the willow marsh was taken into operation.

Technical performance

The willows in the willow marsh take up some elements but the main treatment is done by microorganisms that degrade organics and transform nitrate, nitrite and ammonia into nitrogen gas. As the root system had to develop the first year of operation was not expected to yield great results.
Two samplers were installed: one taking the RO concentrate that is pumped to the marsh and one that samples the effluent, thus the treated RO concentrate of the willow marsh. Every day a sample is taken, representative for the quality of that day. The removal rate, thus performance of the willow marsh, is analyzed based on input sample of DAY 1 and output sample of DAY 1+1, one day being the estimated residence time.

Starting in March 2023, a monthly sample was compared and during the yearly sampling campaign in August, a sample was taken daily. In table 1 the results are shown for total nitrogen. There was a consistent removal and in summer this removal rate reached almost 50% on a certain day (table 1). For total phosphorous, the removal was very good in summer, that is when the highest phosphorous content was monitored. However the results were not totally consistent during the year (table 2).

Table 1. Total nitrogen content of influent and effluent of the willow marsh and the according removal rate

DATE	INFLUENT WILLOW MARSH (mgN/l)	DATE	EFFLUENT WILLOW MARSH (mgN/l)	REMOVAL RATE (%)
3/03/2022	19,5	4/03/2022	16,5	15,4%
12/04/2022	16,1	13/04/2022	13,4	16,8%
3/05/2022	13,8	4/05/2022	9,8	29,2%
12/07/2022	16,5	13/07/2022	10,4	37,0%
8/08/2022	14,4	9/08/2022	8,2	43,1%
9/08/2022	12,4	10/08/2022	7,2	41,9%
10/08/2022	12,5	11/08/2022	6,7	46,4%
11/08/2022	11,8	12/08/2022	6,7	43,2%
12/08/2022	13,0	17/08/2022	10,2	21,5%
6/09/2022	14,9	7/09/2022	8,9	40,4%
15/11/2022	21,1	16/11/2022	15,5	26,5%
6/12/2022	13,4	7/12/2022	11,7	12,7%

Table 2. Total phosphorous content of influent and effluent of the willow marsh and the according removal rate

DATE	INFLUENT WILLOW MARSH (mgP/l)	DATE	EFFLUENT WILLOW MARSH (mgP/l)	REMOVAL RATE (%)
3/03/2022	1,1	4/03/2022	1,0	10,9%
8/03/2022	1,3	9/03/2022	1,0	23,8%
12/04/2022	1,4	13/04/2022	1,2	14,3%
3/05/2022	1,6	4/05/2022	1,4	12,5%
12/07/2022	2,5	13/07/2022	2,0	20,0%
8/08/2022	4,1	9/08/2022	4,4	-6,1%
9/08/2022	5,7	10/08/2022	4,4	23,4%
10/08/2022	5,8	11/08/2022	4,0	32,1%
11/08/2022	5,4	12/08/2022	4,0	27,4%
12/08/2022	6,0	17/08/2022	3,8	36,9%
6/09/2022	7,5	7/09/2022	6,6	12,0%
15/11/2022	1,5	16/11/2022	2,1	-40,0%
6/12/2022	1,0	7/12/2022	1,3	-30,0%

The relation between conductivity of the in- and effluent (used for samples in table 1 to 3) is shown in fugure 4. There is a good correlation which confirms the residence time of 1 day.

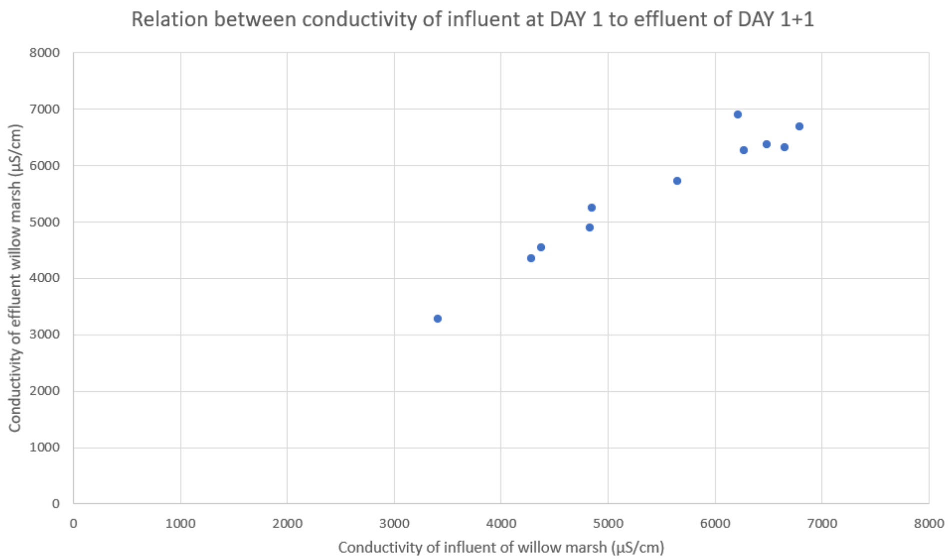

Figure 4. Conductivity of samples of in- and effluent of willo marsh

Metals are low in concentration in the RO concentrate. Zinc is the metal with the highest concentration and just like was done in the DEMOWARE research it was used as the example. The results are shown in table 3. They are not 100% consistent but overall there is a removal rate comparable with was observed in the DEMOWARE project (Van Houtte, 2015 and Van Houtte et al., 2016).

Table 3. Content of zinc in the influent and effluent of the willow marsh and the according removal rate

DATE	INFLUENT WILLOW MARSH (µgZn/l)	DATE	EFFLUENT WILLOW MARSH (µgZn/l)	REMOVAL RATE (%)
3/03/2022	100	4/03/2022	220	-120,0%
8/03/2022	100	9/03/2022	93	7,0%
12/04/2022	97	13/04/2022	87	10,3%
3/05/2022	120	4/05/2022	100	16,7%
12/07/2022	100	13/07/2022	130	-30,0%
8/08/2022	92	9/08/2022	85	7,6%
9/08/2022	0	10/08/2022	86	
10/08/2022	111	11/08/2022	87	21,6%
11/08/2022	112	12/08/2022	87	22,3%
6/09/2022	130	7/09/2022	100	23,1%
15/11/2022	130	16/11/2022	120	7,7%
6/12/2022	120	7/12/2022	120	0,0%

At the exception of the sampling campaing in August, during which all samples were analyzed by SERVACO in Wevelgem, Belgium, all other samples were analyzed by ECCA, in Merelbeke, Belgium. Both labs are accredited labs.

Besides the monitoring of the quality the total flow of the willow marsh was registered and a the total flow is registered every day. In the beginning of the summer of 2022 Aquaduin observed that the willow field was not functioning optimally from the hydraulicalkly point of view: the discharge flow rate of the drainage pipe as well as the collection pipe was insufficient to handle the influent volume. As a result, the full capacity of the willow field could not be be used. In addition, there was no overflow, so there is no safety in case of calamities and the willow field would therefore overflow.
After the summer it was temporarily solved by installing an 'overflow' in the willow marsh. Since then it performs well but plans were made to solve the problem structurally (figure 5).

The hydraulic capacity was recalculated and it was decided that:

- part of the drain pipe should be doubled;
- part of the collection pipe should be doubled;
- an overflow should be installed.

These works are planned in January/February 2023.

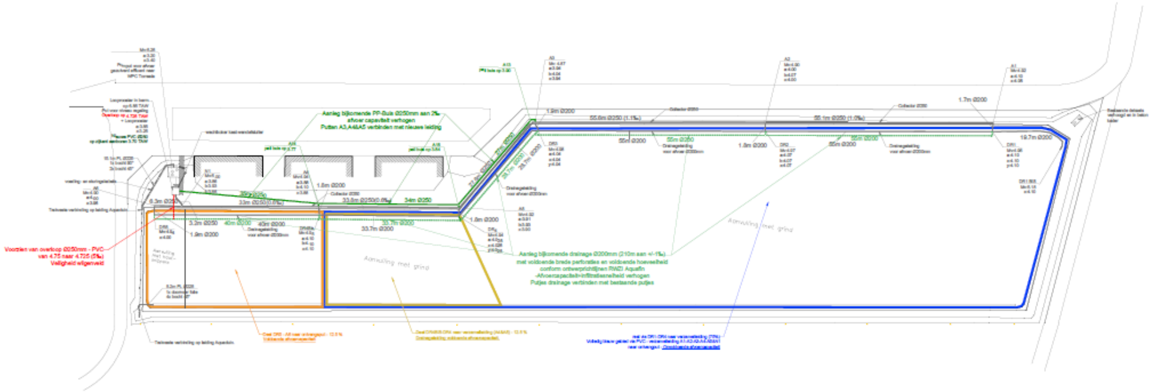

Figure 5. Scheme of the proposed changes to the drain and discharge pipe in the willow marsh

Lessons learned

The removal of zinc and phosphorous in the first year of operation was lower compared to the test at pilot scale (figure 4). However, the substrate of this pilot was old filter sand containing oxidized iron. The removal of total nitrogen, the main nutrient component of the RO concentrate, was far better compared to the removal rate in the first yest of the pilot test (figure 6). The removal of chemical and biological oxygen demand was according to the results of the pilot test.
A longer operational period will be needed in order to allow for a more thorough evaluation of the willow marsh.

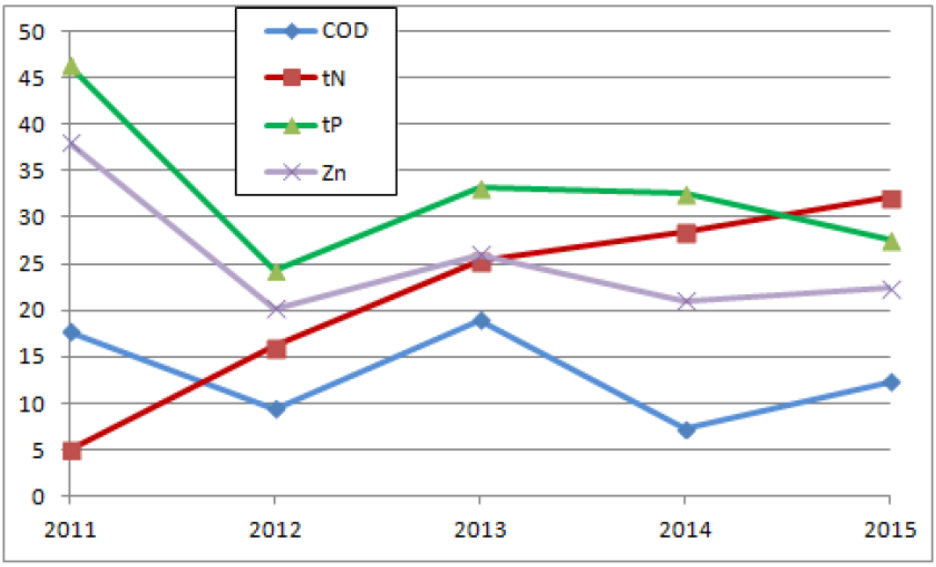

Figure 6. Yearly removal based on average concentrations of in- and effluent of willow field (Van Houtte et al., 2016)

Non-technical aspects of the demo

Regulatory framework

To start the construction and the use of the willow marsh an environmental permit was needed. This is discussed in deliverable D4.7.2. The permit procedure started in July 2020 and the permit was agreed the 25th of January 2021.

Business setup

Aquaduin is a public company. The shareholders are the 6 communities where drinking-water is distributed. As Aquaduin was unable to purchase land next to WPC Torreele, the community of Koksijde agreed to make available a piece of land at 800 meters distance from WPC Torreele (figure 7). Aquaduin can use this land for 27 years. The infrastructure is financed and owned by Aquaduin and thanks to the FRESH4Cs project subsidized by the European Community.

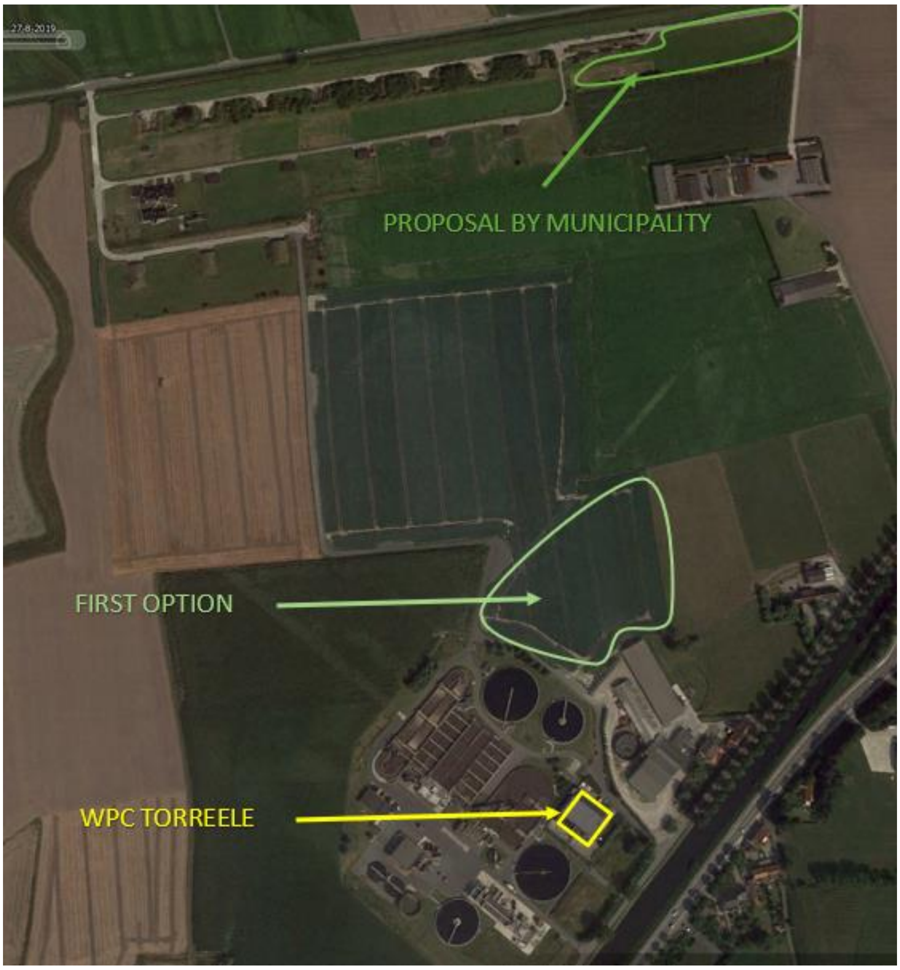

Figure 7. Location of WPC Torreele and potential places for the full-scale willow marsh

Business case

A price calculation, based on 20 year lifetime was part of the DEMOWARE project (figure 5). A small negative yearly cost, thus gain, was calculated.

Table 4. Price calculation of the willow marsh based on a 20 years lifetime (Van Houtte et aL, 2016)

INVESTMENT	*Cost* (EUR)	*Depreciation period* (years)	*Yearly cost* (EUR/jr)
Preparation cost	25.000	20	1.381
Construction cost	200.000	20	11.046
Purchuse of land	100.000	33	3.347
Plants	20.000	20	1.105
Total	**345.000**		**15.774**
OPERATIONAL COSTS			
Maintenance	5.000		5.000
Harvest	5.000		5.000
Total	**10.000**		**10.000**
Discharge	30.000		-30.000
Biomass production	2.000		-2.000
Total	**32.000**		**-32.000**
TOTAL			**-6.226**
Period of loan	*10*	*Interest rate (in %)*	*1,0*

This calculation was renewed prior to the construction with similar results.

The reduced nutrient content of the discharged water in 2022 already resulted in an estimated reduction of discharge tax by 30.000 euros.

Lessons learned

The first year of full operation of the willow marsh confirmed the results of the DEMOWARE pilot case. This kind of treatment, reducing the nutrient content of the discharged water, is a valuable contribution to the environment and the quality of the accepting canal and in the end the ocean as the canal discharges into the North Sea in Nieuwpoort. It is in line with SDG 14 "reducing marine pollution and protecting and restoring ecosystems".
The challenge for the coming years is to look for potential uses (with maybe necessary additional treatments) for the effluent of the willow marsh.

Finally at the end of the first year of operation Aquaduin was the winner of the 'Blue Innovation Captain Award 2022' with this project, an appreciation for all the positive work that has been performed.

Conclusions and replication potential

This type of treatment can be used to treat wastewaters of any kind. The advantage is not only the improvement of the water to be discharged but the system offers also a green buffer.
With a substantial removal of nitrogen and phosphorous, this willow marsh contributes to SDG 14 reducing marine pollution and protecting and restoring ecosystems.
If it is also used as a green buffer it could also contribute to SDG 15, life on earth, but in this way also offer cooler areas in a changing climate and producing wood chips when the willows are harvested. These wood chips could be used for heating or to improve soil.
Willow branches could also be used for construction of mats for flood protection or even baskets or chairs as was done up to the 1950's.

References

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