Catalogue of measures

Management of shallow groundwater levels

January 2022

COLOFON

The TopSoil catalogue is published by Central Denmark Region and compiled by the partners of the Interreg TOPSOIL project in collaboration with EU LIFE IP Coast to Coast Climate Challenge (C2C CC).

Questions and suggestions
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Download the publication at https://northsearegion.eu/topsoil

Publisher
Central Denmark Region

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FOREWORD

The Interreg project TOPSOIL is a collaboration between 24 partners from five different countries in the North Sea region. The project started in December 2015 and runs until March 2022. TOPSOIL examines the potentials of using the upper part of the soil layers as part of the solution to current and future water challenges.

There is a total of 16 pilot areas in TOPSOIL and this catalogue specifically relies on the results and experiences from the pilot area in Sunds close to Herning in Denmark, but also on experiences from the Netherlands and Belgium.

With the goal of improving the knowledge on the shallow groundwater, the project in Sunds seeks to investigate the potential consequences of future climate changes in relation to the shallow groundwater and evaluate on the effect of different solutions that can contribute to the lowering of the groundwater table in cities.

As a result of the synergies between the subproject in Sunds and one of the themes in the Coast to Coast Climate Challenge (C2C CC) project, this catalogue is disseminated in joint partnership.

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INTRODUCTION

With a changing climate, the groundwater is expected to rise and thereby affect the shallow groundwater table which is already high in some areas. This can result in an increasing need to protect cultural and societal values.

Today, we have a lot of the knowledge and data that is required to map where the shallow groundwater is high and where it will be in the future.

Water, including groundwater, cross administrative boundaries. Traditionally, the solution has been to drain the water to lower the water level in a given area. The drain water can be led to streams, lakes or the sea, as long as it does not move the problem further down the system.

This catalogue provides an overview of selected measures and solutions as examples of how to deal with the shallow groundwater. The examples should be additionally examined in specific contexts before implementation.

Multiple factors play a part in the effect of the different measures in relation to lowering the groundwater table. Among them are the state of sewer pipes, soil type (clay, sand, humus, and more) as well as the nature of the landscape, such as valleys.

USING CLIMATE SCENARIOS

The UN Intergovernmental Panel on Climate Change has developed a set of scenarios on the projection of the future climate of Earth. These are projections of the amount of carbon emissions, and by that the accumulation of CO_2 in the atmosphere.

In the pilot project in Sunds, model calculations based on the climate scenarios have been made for the two periods: near future (2041-2060) and distant future (2081-2100).

In the near future climate scenario (2041-2060), compared to the situation of today (1996-2026), there is a 5-10 cm. rise in the groundwater level in some parts of Sunds. In the distant future scenario (2081-2100), the groundwater level in the southeast part of Sunds is projected to rise by 10-20 cm.

The use of climate scenarios can contribute to ensure that potential solutions are able to withstand the increase in precipitation and the changing conditions of the climate in the future.

ABOUT SUNDS

Sunds is located in the municipality of Herning and is one of the pilot sites in TOPSOIL. The town is surrounded by flat agricultural fields and multiple streams run from the hinterland of the river Storaa. The shallow groundwater in Sunds is already high and within recent years, Sunds has experienced climate-related challenges regarding rising groundwater levels due to an increase in frequency and intensity in precipitation, especially in the winter months. As a result, the inhabitants of Sunds are experiencing flooded basements and flooding of lowlying areas.

Several of the examples in this catalogue is based on the model calculations made by GEUS on the challenges and potential solutions in Sunds.

Project area in Sunds.

The following sections provide a general overview of potential measures to deal with shallow groundwater.

Every solution is accompanied by an example on the implementation of the concrete effort in a selected area.

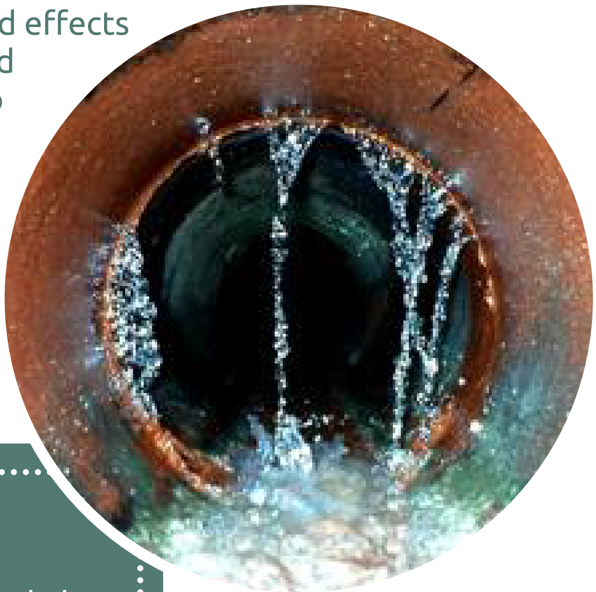
THE THIRD PIPE

In the Netherlands, a common solution to counteract challenges with rising groundwater is the use of the third pipe. This means laying a drain pipe to supplement the sewer pipe and rainwater pipe. The third pipe is an effective method to lead the shallow groundwater away from values at (flood) risk to another place in the water cycle.

The drained groundwater is led to an adjacent stream or lake. Therefore, a natural fall in terrain or the installation of a pumping system is required.

To make sure that the solution is cost-effective, it is optimal to establish the third pipe simultaneously with sewage renovation in a given area. As a result of renovation and replacement of old and leaking sewer pipes, the groundwater rises as the surplus water was previously diverted through the leakage in the old pipes. The renovation of the sewer pipes also have the advantage to prevent flooding and humidity issues in basements.

The third pipe reduces the risk of the unwanted effects of a high groundwater table around houses and other values. The method is relatively cheap to operate but requires a large digging and construction work if the construction of the pipe is not carried out in relation to planned sewer renovation and/or the construction of a separate sewer system.



Leaking sewer pipes have a draining effect on areas with a high groundwater table. However, the additional water in the pipes generates higher operating costs for the water companies, for instance for purification.

SEWER RENOVATION

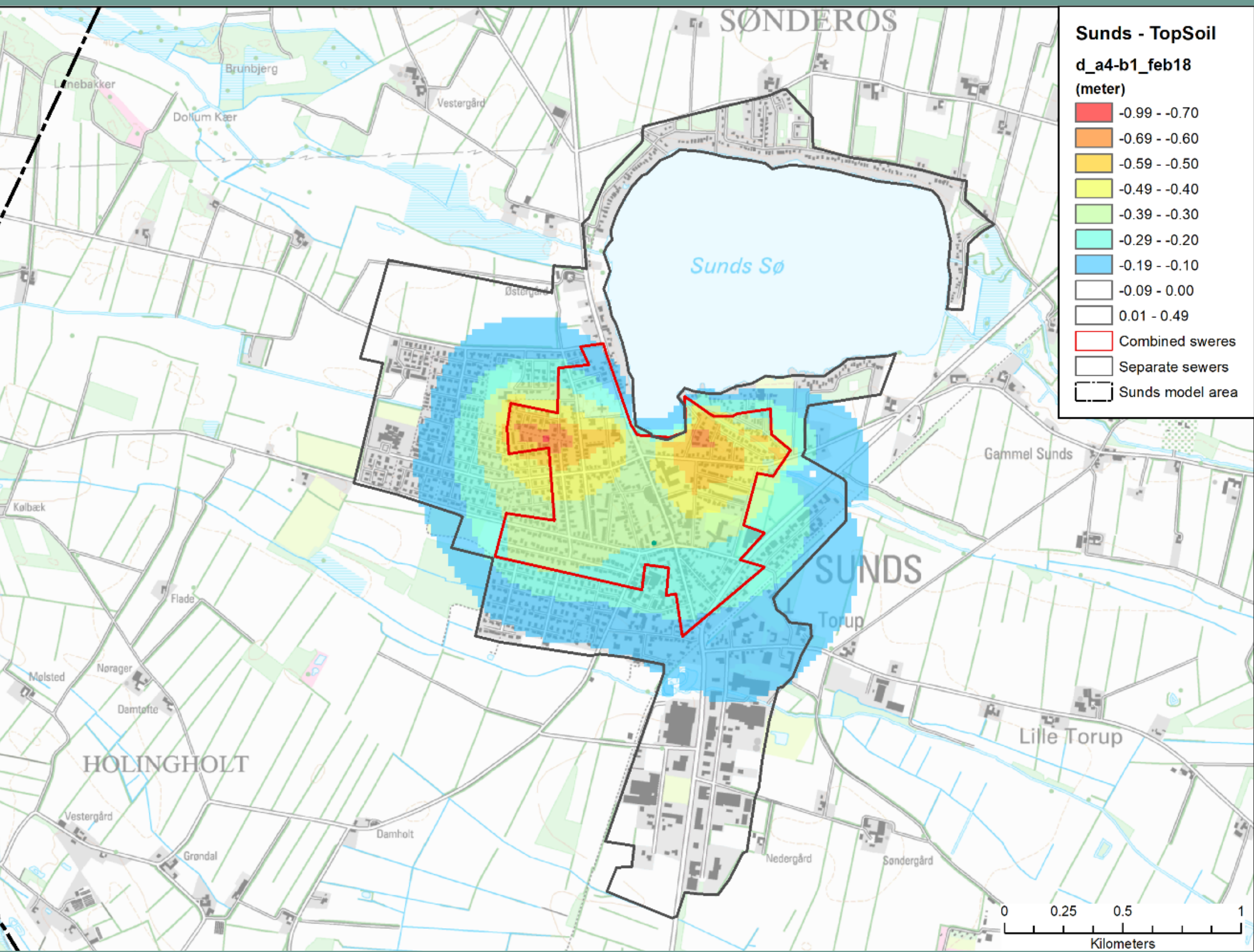
The renovation of older, leaking sewer pipes and the construction of a separate sewer system reduces the inadvertant intake of grundwater in the sewer system.

One consequence is that the shallow groundwater is no longer diverted through leaking pipes which can result in a rise in the shallow groundwater as well as flooded basements.

EXAMPLE OF THE THIRD PIPE

With the implementation of the third pipe in all of Sunds, the average lowering of the groundwater table in the town is up to 20 cm. The GEUS calculations are based on the winter period with a high groundwater table. In the new urban area in Sunds, the groundwater table is lowered by up to 30 cm. while in the other areas, the third pipe lowers the shallow groundwater with up to 50 cm.

The majority of the town area in Sunds already has a separate sewer system, and it is therefore socio-economic unprofitable to introduce a third pipe in the area.



The calculated change in depth to the groundwater level in a winter situation 2018 (GEUS)

DITCHES

Another possible instrument to lower the shallow groundwater table is the construction of a ditch. This can be an advantage in urban areas that already have a separate sewer system. In this case, the natural fall in terrain is important to ensure the water flow. However, existing infrastructure and architecture can be an obstacle in the construction of a new ditch. Consequently, the construction requires a certain investment as the existing sewer system is relocated over or under the ditch. Hereafter, the operational costs are relatively cheap.

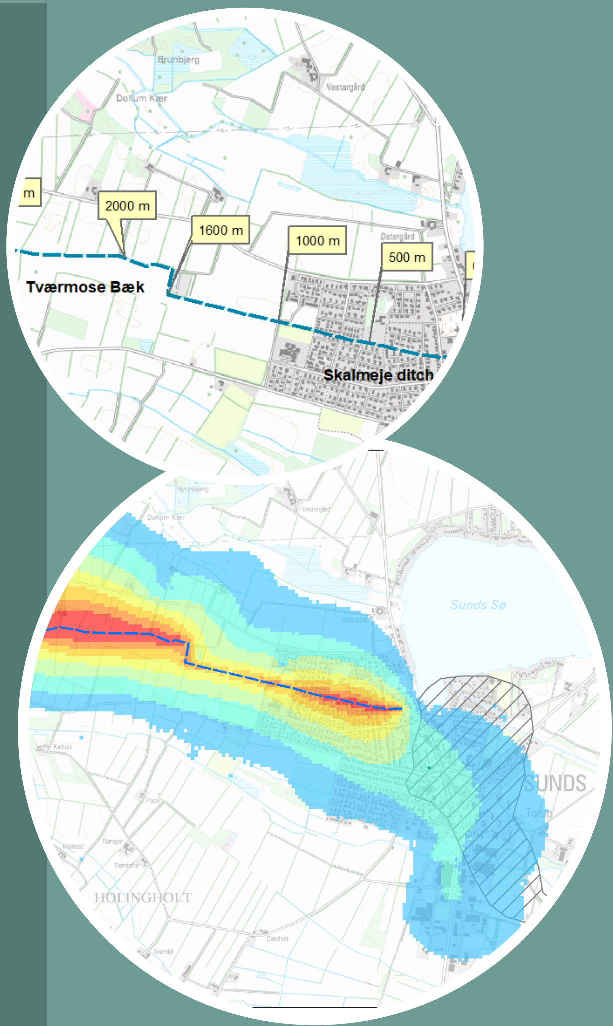
The construction of a new ditch requires a comparably large amount of space but can be combined with beautification of urban spaces and the creation of added value. This may include multifunctional storage reservoirs with recreative spots that adds greening to the urban space.

EXAMPLE

In Sunds, the model calculations show that a v-shaped ditch (1,5 m. wide x 1,0-2,0 m. deep) will have a significant effect on the depth to the groundwater table. The ditch solution in Sunds is as effective as the construction of a third pipe. The calculations are based on a ditch running in a cross section through the new urban area in Sunds.

A highly permeable ditch in the newly constructed urban area in Sunds can lower the groundwater table in a large range, especially in the winter months, and even has a positive effect on the groundwater table in the east part of Sunds that lies in a buried valley. The upper soil layers in Sunds are highly sandy which leads to the large effect of the measure.

Dependent on the depth of the ditch, the groundwater level is lowered by up to 1 meter in the west of Sunds that lies closest to the ditch while in the older part of town towards east, the groundwater table is lowered by up to 30 cm. The construction of a ditch can be cohesively designed in relation to the beautification of an area while adding recreational value.



Upper: the location of the model calculated ditch.
Bottom: the calculated change in depth to the groundwater level in a winter situation 2018 (GEUS)

URBAN FORESTRY

Urban forestry can lower the groundwater table locally. Trees with high evaporation are planted to delay some of the water from rain events and cloudbursts before it reaches the terrain surface. Rainwater is further delayed as the evaporation from the leaves is improved. Evergreen trees have an even evaporation loss throughout the year whereas deciduous trees do not slow down precipitation in the winter season, as the trees lose their leaves.

Deciduous trees have not been examined as part of this catalogue but ought to be tested both in terms of its capacity to lower the shallow groundwater table as well as in regards to added value like carbon capture and urban cooling during the summer.

Forestry has multiple potentials to create added value in an area, for example in terms of nature in urban areas as well as to secure the drinking water supply through spray-free agricultural production. Additionally, the cost and maintenance of forest areas is generally low.

EXAMPLE OF FORESTRY

In the model calculations, multiple test areas around Sunds have been laid out for forestry and planting of coniferous trees in different scenarios.

The planting of 252 ha evergreen forest west and east of Sunds has a limited effect on lowering the groundwater tabel in the whole town. However, in the areas where the trees have been planted, the groundwater table is lowered by 10-20 cm. locally.

In another scenario, evergreen coniferous trees are planted both south, west and east of Sunds with a total area of 395 ha. of forest. The effect on the groundwater table is a lowering by 10-30 cm. in the urban areas encircled by forest on all three sides. Hence, the overall effect is local and limited to the areas in the immediate vicinity of the forest.

INJECTION INTO DEEP GROUNDWATER AQUIFERS

An effective but costly solution is targeted injection of the shallow groundwater to a deeper groundwater aquifer. Mitigation wells to the shallow groundwater are constructed to pump the groundwater away from the surface level while injecting it into a deeper groundwater aquifer in the winter season. Here, it can be stored for the purpose of pumping it up the following summer to be utilised for heat production, cooling or irrigation.

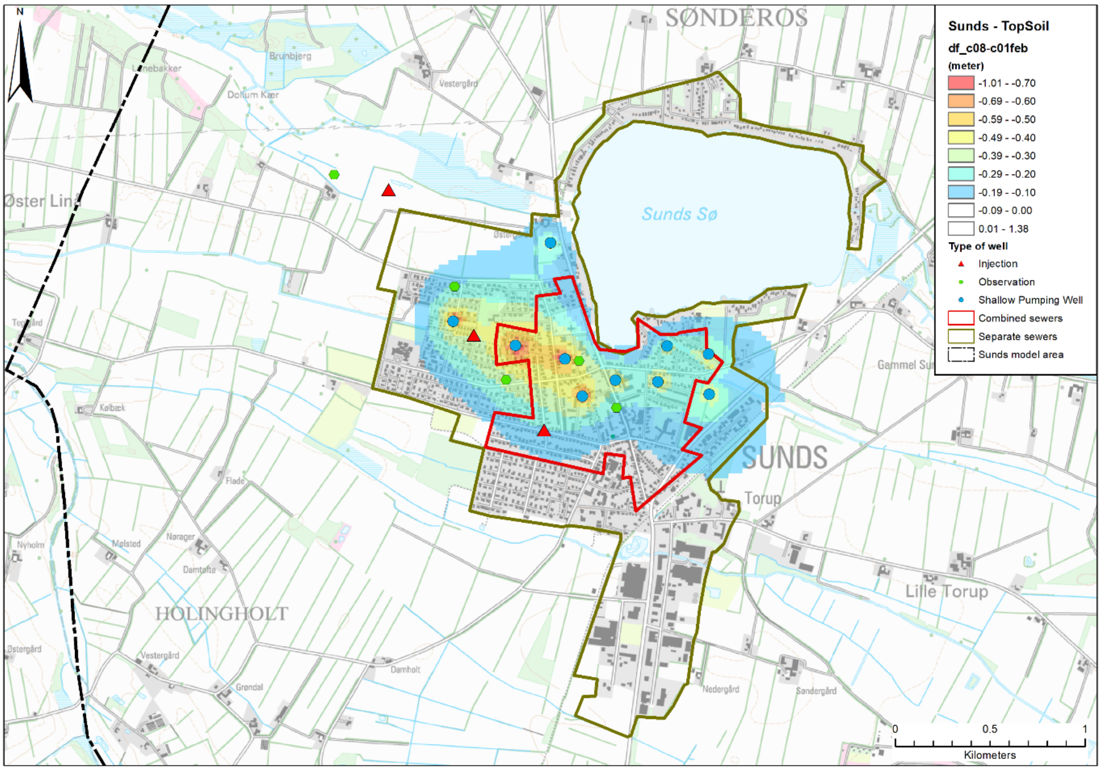
In the dry summer months, the groundwater can be pumped up and used for irrigation in the area. For other purposes, there can be potential water quality issues in relation to the deep groundwater aquifers that are used for storage. This is because the shallow groundwater can contain pollutants that can contaminate the deep aquifer at injection. This is specifically an issue in Denmark where all drinking water is pumped from deep groundwater aquifers.

EXAMPLE

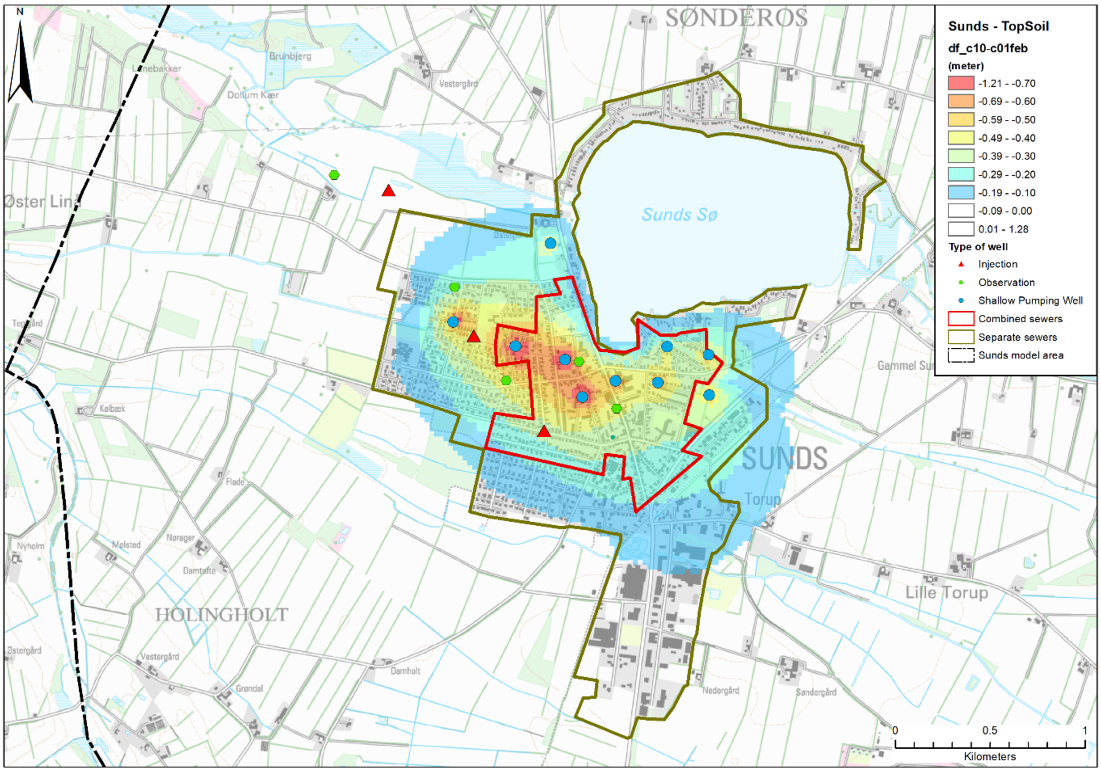
The model calculations include a total of 10 mitigation wells in central Sunds, and two scenarios where the pumped groundwater from the 10 mitigation wells has been pumped down in the two groundwater aquifers, respectively approx. 55-80 m. under terrain and approx. 125-150 m. under terrain.

The greatest effect from pumping the shallow groundwater in both range and lowering of the water table occurs by injection into the deepest aquifer. This is because the deep aquifer to a greater extent is separated from the shallow groundwater by a layer of clay.

Another factor is the recovery of 300.000 m^3/year groundwater from the deep aquifer carried out by Herning Vand. The effect of terminating the recovery from the deep aquifer is minimal - less than 5 cm. The explanation is as above mentioned that the local geology of a clay layer is separating the two aquifers.



The calculated change in depth to the groundwater level by injection into the Odderup groundwater aquifer (55-80 m. ut) in a winter situation 2018 (GEUS)



The calculated change in depth to the groundwater level by injection into the Bastrup groundwater aquifer (125-150 m. ut) in a winter situation 2018 (GEUS)

THE EFFECT OF PUMPING THE SHALLOW GROUNDWATER

The effect of pumping from five mitigation wells in the winter months reduces the risk of problems with the shallow groundwater in the central part of Sunds.

With a total pumping capacity of 10.000 m^3 per year per well, the maximum lowering of the groundwater table in the winter months is 10-20 cm., while the effect is insignificant at the end of the summer period.

EXAMPLE OF STORING WATER IN A WETLAND

In Vlaamse Milieumaatschappij in Belgium, a solution of lowering the shallow groundwater has been tested through targeted pumping of the drain water and storing it in a wetland surrounded by dikes or embankments.

This method makes it possible to target and redirect the water away from the areas with the greatest challenges. Furthermore, the wetland can store water in wet periods to be used in dry periods for irrigation.

PUMPING FOR ENERGY PRODUCTION

In continuation of pumping the shallow groundwater as a potential solution, the groundwater can also be used for energy production for heating or cooling.

In this case, the shallow groundwater is pumped up and utilised in the district heating system, power2X, comfort cooling for companies and similar, where it contributes to the green transition of the energy production. By redirecting the groundwater away from the area, for example to a nearby stream, it is possible to lower the shallow groundwater table in a risk-prone area while utilising its potential for energy production at the same time.

Feasibility studies on how the redirected groundwater will affect the water cycle downstream is necessary in order to not simply move the problem elsewhere.

EXAMPLE

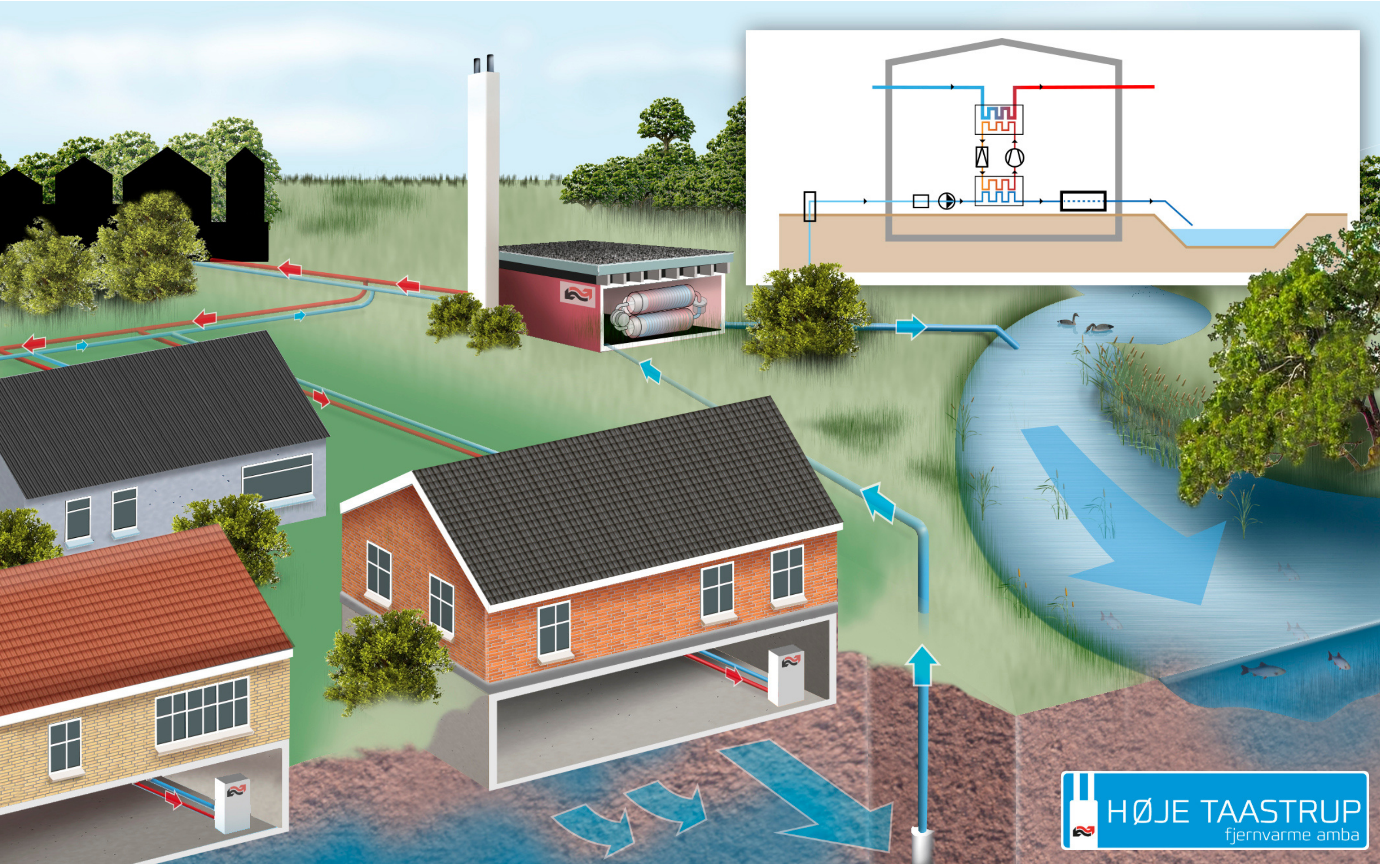
An area in Høje-Taastrup was highly exposed to flooded basements from shallow groundwater.

The area is built on old marsh land and surrounded by lakes and in close proximity to a stream. The shallow groundwater is estimated to have risen 5 m. since the houses were built in the 1970s as a result of closing multiple groundwater drillings and changes in the pattern of pumping drinking water. In 2014 another groundwater drilling for drinking water was closed which further contributed to the issue in the area. Households experience issues with both flooding and mold.

Høje-Taastrup Fjernvarme has established a new energy central where an electric heating pump can pump 1 mio. m³ groundwater on a yearly basis. The groundwater can be used in the local production of district heating. Afterwards, the clean, cold water is discharged into the nearby stream which even has a beneficial effect on the water quality in the stream.

The facility is estimated to be able to produce approx. 10.000 Megawatt-hours per year, which corresponds to circa 2 pct. of the district heating consumption in Høje-Taastrup. The facility has an estimated life cycle of 20 years and the investment should be profitable after 11 years.

The electric heat pump co-produces district heat and cooling by using the surplus heating from the cooling of the water. The cold water is then redirected to a nearby stream.



The groundwater is pumped up and diverted from the area while producing heat and cooling for approx. 500 households in Høje-Taastrup.

REFERENCES

Rapport on the results from GEUS model calculations on Sunds: https://northsearegion.eu/media/15938/geusrapport_sunds_2020_12_inkl-omslag_final.pdf

Do you want to know more about TOPSOIL and the other pilot projects? Visit our webpage: https://northsearegion.eu/topsoil/.

Here, you can find summaries and presentations from project meetings, scientific articles, news and much more. The webpage is continuously updated.

Read more on the pumping of groundwater for energy production in Høje Taastrup here: https://www.htf.dk/nyheder/ny-varmepumpe-paa-moelleholmen-7727 and https://politiken.dk/indland/art7014279/I-Taastrup-luner-de-sig-ved-grundvandspumpen

C2C Coast to Coast Climate Challenge

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