Engineering of a lagoon for energy and water management for Copenhagen

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INTRODUCTION

This project originates from a desire to find an alternative to groundwater to sustain then Copenhagen drinking water demand. A driving factor is the EU Water Framework Directive that restricts the amount of groundwater allowed to be abstracted. One alternative to groundwater could be to construct and implementation of an alternative water supply including a lagoon. Such a lagoon is investigated in this project with regard to energy and water storage.

ENERGY STORAGE – GREEN POWER ISLAND

The energy storage potential of the lagoon was analyzed according to the Green Power Island principle and based on yearly, monthly and daily variation in wind power production. This resulted in lagoon surface of 280 km^2, 70 km^2 and 10 km^2 respectively. Beside the very large sizes of the lagoon a conflict between energy and water storage was identified. It is therefore not recommendable to stored energy and water in the lagoon at the same time. Regarding the energy aspect of the lagoon the location at Avedøre Holme was geological unsuitable as deep clay layer was missing to minimize infiltration into the lagoon, which would result in uncontrolled loss of energy.

WATER STORAGE – FRESHWATER LAGOON

If the lagoon only is to be used for water storage, the location at Avedøre Holme is suitable. The water supply lagoon was dimensioned based on extreme rain events, which resulted in a lagoon surface area of 1 km^2. Three different abstraction methods were simulated in the groundwater modeling program GMS MODFLOW. A relative large uncertainty is related to the model results. From sensitivity analyze and calibration it was found that boundary condition in the limestone and conductivities of the limestone was key model parameters that should be improved to reduce uncertainty. It was concluded that the lagoon could supply large amounts of water (16.5million m3/yr) depending on the abstraction method. The most promising method for extraction the lagoon water was by horizontal abstraction wells (Case C1) which had low effect on the surrounding groundwater level, a low risk of saltwater intrusions and easy clogging maintenances.

The water quality aspect in this project was estimated based on retention times. The retention time in the lagoon was estimated to approximately 3 month. The long retention time could give problems with algae growth. The retention times in the ground were estimate from 4 hour for the horizontal abstraction (Case C1) and to 40 days for the direct injection (Case B). The best water quality is likely to be achieved by direct injection method (Case B) due to the longest retention time the ground.

Abstracting water from the lagoon was estimated to be an energy efficient way (0.02 to 0.08 kWh/m^3) to get an alternative water sources, compared with other alternatives such as desalination (1.6 to 4 kWh/m^3).

Based on the investigation preformed in this project it was concluded that combining a lagoon with horizontal abstraction well (Case C1) is energy effective and a promising approach for alternative water supply for Copenhagen.