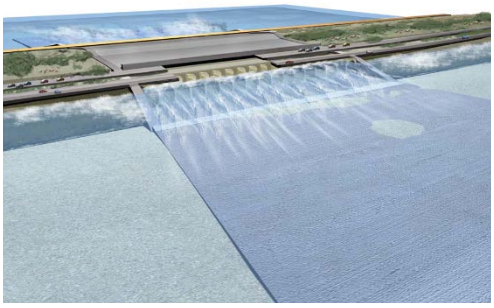
Offshore & Dredging Engineering

Technische Universiteit Delft

The consideration of constrained flow solutions for the purpose of implementing a tidal power ploant in the Brouwersdam reconnecting Lake Grevelingen and the North Sea

After the construction of the Grevelingendam (1965) and Brouwersdam (1971) the water quality in Lake Grevelingen deteriorated in the course of the years. This caused a decline of ecological parameters influencing surrounding flora and fauna. Amongst others, Rijkswaterstaat and the provinces of Zeeland and South-Holland established a plan to reconnect Lake Grevelingen with the North Sea again to infuse oxygen enriched water into Lake Grevelingen and create increase the quality of the local ecology. This plan will be executed by installing culverts in the Brouwersdam, thereby restoring the connection between the two water bodies. As part of an integrated approach, Rijkswaterstaat intends to develop the hydraulic structure to a tidal power plant and implement turbines to not only generate power, but also perform water management measures as installation of these devices are able to influence and control the discharge through the culverts.

From the literature study can be concluded that implementing constrained flow devices, wherein the entire mass flow is guided through the turbine, offers a solid solution for the posed problem. In order to broaden the insight in the behaviour of the water level, which has its influence on the local flora and fauna, in Lake Grevelingen due to the construction of the tidal barrage, three hydraulic models are set up wherein input water level data from the North Sea is used to simulated the tidal action in the lake. The considered cases include a configuration wherein *11* of the *18* culverts measuring *8* m by *8* m are equipped with unidirectional turbines. The remaining culverts are left unequipped. Thereafter, two culvert configurations wherein each culvert is equipped with respectively a unidirectional and bidirectional turbine are considered. By simulating the water level variation in the lake, one can also estimate the generated power and the energy output of the considered models. Besides, to provide a larger view on the possibilities, a multivariable analysis of the three cases is carried out wherein power generation and water



management requirements are considered. Herein varying the cross-sectional area of the culverts and their number. For the first considered case, also the number of empty culverts is varied. From these analyses, one can conclude that installing bidirectional turbines increases the controllability of the flow

which is desired. Moreover, implementing unequipped culverts in the array will diminish the controllability and is in terms of water management not desired. Finally, full time turbine modulation, wherein the turbines are not generating the optimal amount of power over the full scope of the tidal range for the purpose of water management is preferred over intermittent turbine modulation, wherein turbine modulation only occurs when the water level surpass certain water levels.
Nevertheless, to fully satisfy the posed requirements, additional turbine modulation should be executed as the monthly averaged and maximum tidal range standards are not fully met.

From the analyses, a bidirectional culvert configuration existing of *24* culverts measuring *9* m by *9* m is preferred. To investigate if this configuration is economically feasible, a cost estimate is established after which the Net Present Value, Internal Rate of Return, Payback Period and Levelised Cost of energy are determined.

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