DHI CASE STORY

MODELLING LAKE FURESOE

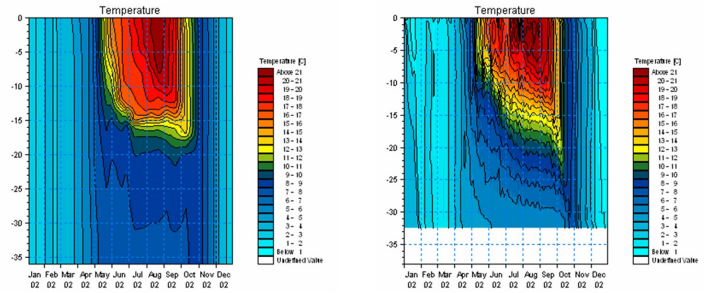
Complex analysis of nature restoration in an entire catchment system

Rapidly increasing urbanisation in Copenhagen has exposed Lake Fureso to increasing pollution over the years. We evaluated the different lake restoration measures to properly assess their impacts on the lake and catchment area. Based on our modelling analyses, recirculation of highly treated and purified sewage has been considered to speed up the rehabilitation of the lake and ensure sufficient flow in the downstream river. This will re-establish the natural water balance in the catchment.

LAKE FURESOE – HIGH POLLUTION LOADS AND REDUCED FLOW

With a maximum depth of 36 m, Lake Fureso – located in Northeastern Zealand – is Denmark's deepest lake. It is used for recreational activities all year round.

Examinations from the early 20th century describe the lake as clear enough for fish to be seen swimming in deep water and bottom vegetation down to a depth of 8-12 m. However, rapidly increasing urbanisation of the Danish capital, Copenhagen, exposed the lake to steadily increasing pollution from the 1900s to the late 1960s. Although pollution loads were reduced significantly in the following two decades, the lake is still not in an acceptable condition.



Measured (left) and modelled (right) temperature stratification during the year at the central part of Lake Furesoe

Water from the catchment has been abstracted for drinking and industrial purposes. After utilisation, the abstracted water is diverted to the sea as partially treated sewage. This has resulted in constant reduction of water flows through the lakes and streams in the catchment area.

In-lake restorations, with artificial oxygenation helped improve the condition. However, the entire lake and stream system within the catchment still suffers from enhanced pollution and reduced flow.

SUMMARY

CLIENT

Nature Agency, Danish Ministry of Environment, Denmark

CHALLENGE

- Large pollution loads to Lake Furesoe, Denmark
- Need to find out the maximum loads at which water quality objectives – set by national environmental authorities aligned to the European Union Water Framework Directive – could be met.
- Need to evaluate different lake restoration methods to re-establish the natural balance within the catchment

SOLUTION

- Coupled 3D hydrodynamic, water quality and eutrophication modelling
- Simulation of hydrodynamic and ecological conditions in lakes and streams, with high spatial and time resolution
- Quantification of the effect of different load reduction scenarios as well as restoration and flow scenarios
- Quantification of the impacts of different lake restoration methods

VALUE

- Quantification of maximum nutrient loads at which water quality objectives could be fulfilled
- Extensive evaluation of different lake restoration methods, pinpointing the most effective one
- Ability to meet the water quality objectives and bring back the natural balance of the catchment area

LOCATION / COUNTRY

Lake Furesoe, Denmark

EUTROPHICATION – A GRAVE PROBLEM IN NEED OF ADDRESSING

Long-term pollution had caused heavy eutrophication in the lake. The ecosystem responded with:

- algal blooms
- anoxic conditions in the bottom water
- periodically extensive growth of certain species of fast growing macro vegetation in shallow waters, together with filamentous algae

During the summer period, algae grow widely in the Lake Fureso, causing the water to turn brownish-green periodically with floating blue-green algae. Moreover, the water is thermally stratified during the summer. The sedimentation of algae and other organic material in the bottom water, combined with the thermally stratified water causes anoxic conditions in the lake bottom water. Recently artificial oxygenation has been introduced to combat the anoxic water.

Thus, it became necessary to deal with these challenges and evaluate all possible lake restoration methods. This was required in order to meet the water quality objectives – set by national environmental authorities aligned to the European Union Water Framework Directive. It was also required to bring back the lake to its past glory and natural balance within a near future plan-horizon.

OUR 3D HYDRODYNAMIC, WATER QUALITY AND EUTROPHICATION MODEL

We undertook the project to establish the technical basis for decision of measures to ensure that the water quality objectives were fulfilled within the defined timescale.

The developments from 1902 up to the present were described based on load estimates, monitoring data and modelling analyses. Balances for water and pollutants were then established, covering a period of 1900 to the present day.

We calibrated and used a 3D Hydrodynamic, Water Quality and Eutrophication model to quantify the effects of different scenarios (with respect to load reduction, restoration and flow). This model described the temperature and oxygen stratification as well as nutrient dynamics such as:

- sediment-water interaction
- algal growths
- macro vegetation development

Achieving a sufficiently low pollution load required:

- highly efficient treatment technology
- optimum management of a sewage plant
- significant reduction of storm water overflow from sewage system form all urban areas within the catchment

Based on our 3D model, we quantified the maximum load at which defined water quality objectives for the lake could be fulfilled.

EVALUATION OF LAKE RESTORATION METHODS

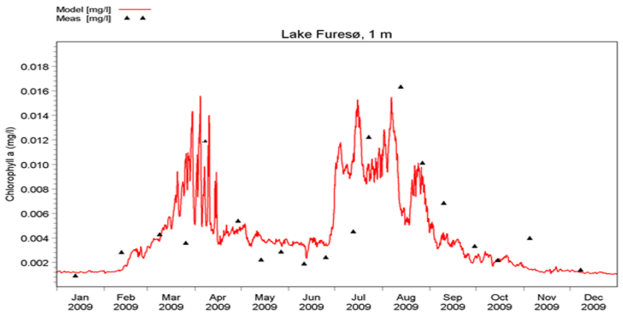
We evaluated the different lake restoration measures to properly assess their impacts on the lake and catchment area (in terms of nutrient loads, sedimentation, water flows and so on). These measures include:

- sewage diversion
- traditional biological and chemical purification
- advanced purification processes
- immobilisation of earlier accumulated phosphorus pools in sediments of upstream lakes
- in-lake restoration measures (such as re-circulation of highly treated sewage water, re-aeration and biological manipulation)

Apart from these, we also analysed sensitivity of the lake to storm water overflow and diffuse non-point pollution.

Monitoring data and modelling analysis showed that the external load has been reduced to a level at which the water quality objectives can be fulfilled in the future. It is however also expected to take several decades to achieve this.

The modelling analysis also quantified the positive impact on internal phosphorus loads from the in-lake oxygenation of the bottom water. In addition, it quantified the expected set-back in lake condition in case of a shutdown of the oxygenation activity.



Algae biomass as Chlorophyll. Simulated (red line) and measured (black dots) values

To speed up the rehabilitation of the lake and ensure sufficient flow in the downstream river, recirculation of highly treated and purified sewage has been considered. This will re-establish the natural water balance in the catchment. Due to a limitation in treatment technologies, such an initiative will result in a slight increase in nitrogen loads and to some extent, phosphorus loads as well. The established eutrophication model was used to describe the delicate balance of nitrogen and phosphorus limitation of the algae production in the lake and thereby the impacts of this project.

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