The expert in **WATER ENVIRONMENTS**

DHI

Memo

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From:	Bo Brahtz Christensen, DHI
Project	11823523 Lynetteholm
Date:	12 May 2021
Subject:	Additional comments on the Esbo consultation responses

Following the Esbo consultation meeting on 22 April, a number of comments and responses were received from the Swedish environmental authorities. The consultation responses primarily address concerns related to the blocking effect of water and salt transport through Øresund and the consequences of dredged sediment disposal in Køge Bugt.

Flow/blockage in Øresund

The blocking effect of the project has been highlighted in the technical background report no.1 Hydraulic studies. This report revealed a blockage of the water flow of 0.23-0.25% and 0.21-0.23% for salt transport.

Lynetteholm is a filling by land, which has as a derived consequence that the flow cross section in Øresund is narrowed locally. The narrowing causes a local increase in current speeds and flow resistance and has a slightly dampening effect on the dynamics, which manifests itself in the calculated blockage. To change the frequency and amount of saltwater inflows to the Baltic Sea, the project must create an impact as a sill, and this is not the case for the Lynetteholm project. Hollænderdybet east of the Middelgrunden is deeper and broader than Kongedybet and will lead salt towards the Baltic Sea. The controlling flow cross-sections for the exchange of salt and water between the Baltic Sea and the Kattegat will continue to be the Drogden threshold and the funnel at Helsingore-Helsingborg. Therefore, the assessment is quite general that Lynetteholm will not change the frequency and amount of saltwater inflows to the Baltic Sea.

Lynetteholm differs from the Öresund Bridge project in that the impact is more local. The Öresund Bridge stretches across Øresund in the Drogden threshold area, where the actual regulation of water exchange takes place. Therefore, the Øresund Link could contribute further to the threshold effect, thereby making it more difficult to exchange water and salt between the Baltic Sea and the Kattegat via Øresund. This is not the case with Lynetteholm.

In connection with the Øresund Bridge project and the tunnel and bridge, a new island, Peberholm, was established and likewise reclamation of a larger area east of Copenhagen Airport, where the tunnel portal is established (see Figure 1). The filling resulted in a narrowing of the Drogden trench in an area where some of the highest current speeds occur, cf. Figure 2 and Figure 3. The flow resistance is proportional to the square of the currrent speed. The filling at the airport is located in an area where the narrowed cross-section significantly impacts flow resistance. The Lynetteholm filling is placed in an area where the current conditions are much more moderate and less critical for the flow resistance through Øresund. As part of the bridge project, compensation excavation was carried out to mitigate the blocking effect of the project. The most challenging part of the calculations was calculating how compensation pits should be excavated, bridge piers designed and placed, and the design and location of the island of Peberholm. A very complex calculation matrix. Compensation excavation does not make sense in the case of Lynetteholm since to minimise the volumes of excavated material, an area with high current speeds resulting in a high dispersion of excavated sediment spill will have to be selected. As shown in Figure 2 and Figure 3, such an area is far away from the Lynetteholm project's primary impact area, introducing a new and more significant and not least undesirable environmental impact.

Figure 1 Drogden before (1985) and the Öresund Link (2020).

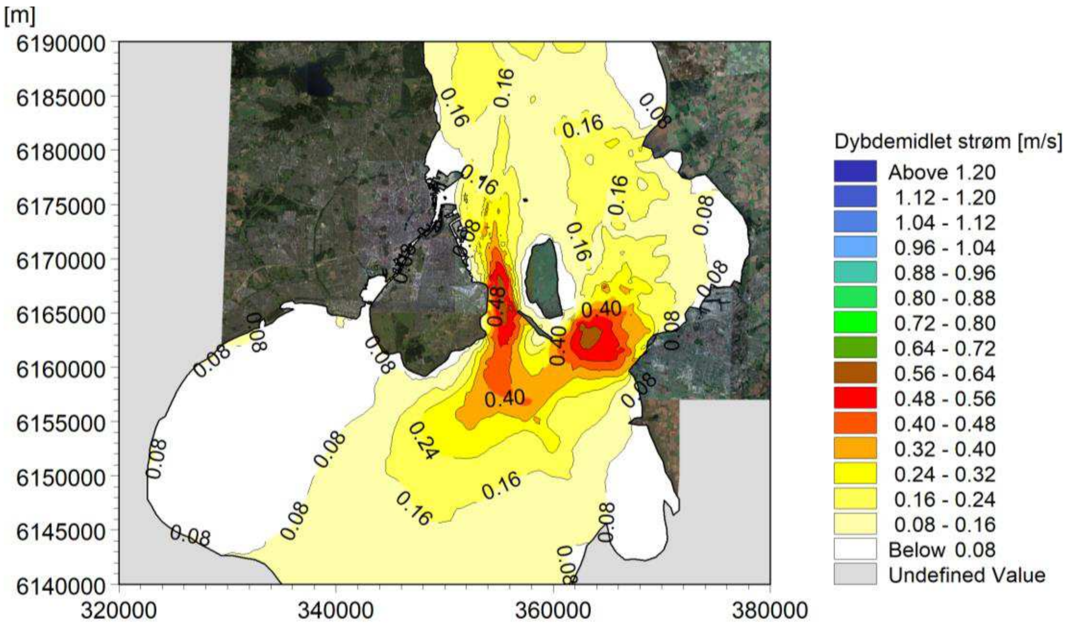

Figure 2 Annual mean of the depth-averaged current calculated without direction (gross current) for present conditions in 2018.

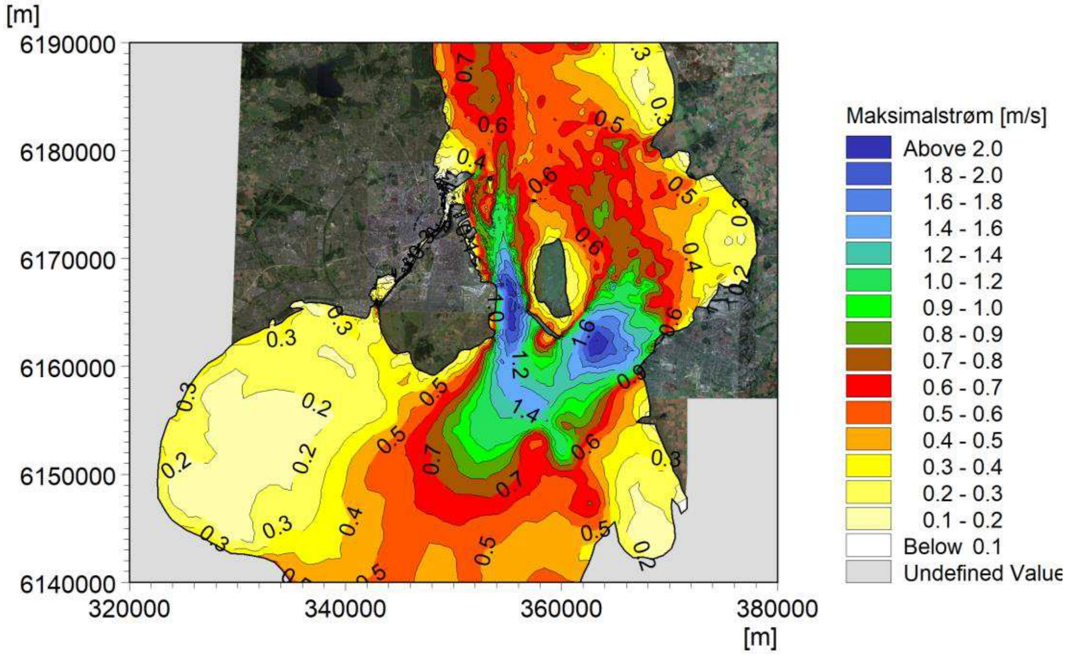

Figure 3 Depth-averaged maximum gross current 2018.

The blocking calculations carried out as part of the impact assessment for the Lynetteholm project have shown that it is necessary to calculate a minimum period of 5-6 months to achieve a stable blocking estimate. The blocking estimate specified for this project have been found based on a whole year so that seasonal variations are included, and an asymptotic value for the impact has been achieved. The blocking calculations from the Öresund link were carried out for a period covering 2-3 months. Therefore, there is more uncertainty in the estimates carried out at the time, as the model period needs a more extended period to converge fully towards an asymptotic value. In the calculations carried out at the time, the blocking requirement (to be obtained by compensation excavation) was set at less than 0.1%, with an uncertainty range estimated at +/- 0.25% within an uncertainty limited to a 95% confidence interval. The uncertainty accepted by the zero solution is thus more significant or of the same size as the estimated blockage of Lynetteholm. Twenty years after the link was established, there has been no significant impact on conditions south of the Drogden threshold. The same will apply to Lynetteholm.

In their consultation responses, SMHI states that they agree that viewed in isolation, a blocking effect of 0.25% is acceptable. However, they express concern that there may be other projects (bridges, wind farms and pipelines) that could cause an additional effect. There are currently no bridge projects in the Øresund region that will contribute to a blocking effect. Pipelines will typically be buried and thus not contribute to a blockage. HOFOR plans to establish a wind farm at Nordre Flint with a capacity of 160 MW, equivalent to 16 wind turbines of 10 MW. The blocking effect from the wind farm (if built) must be considered marginal and not give rise to a reassessment of the blocking estimates. Finally, sea level rises in the coming decades will cause the conductivity of water and salt transport through Øresund to increase, thus relatively quickly offsetting the calculated blocking effect.

DHI also considers the impact acceptable, as the estimated blockage of Lynetteholm is less than the permitted maximum uncertainty in the Øresund calculations – and no environmental impact has been observed after 20 years with the Øresund Bridge.

Sediment dispersion in connection with the disposal of dredged sediment in Køge Bay

A large part of the responses received concerns the excessive dispersion of the dredged material. It is important to emphasise that the contaminated part of the material, which is excavated in connection with bottom replacement along Lynetteholm's perimeter, is placed in Lynetten's deposit for harbour sediment. According to the instructions regarding disposal of dredged sediment, dredged sediment will be sediment containing contaminants below the "Upper Action Value". More specifically, 2.3 million.m^3 of the dredged material will be below the lower level for dredged sediment, while 0.2 million will be between the lower and upper level.

Table 1 Indicative action levels for dredged material.

Stof	Nedre aktionsniveau (TS)	Øvre aktionsniveau (TS)	
Kobber (Cu) mg/kg	20	90	200 kg/år/havn
Kviksølv (Hg) mg/kg	0,25	1	
Nikkel (Ni) mg/kg	30	60	
Zink (Zn) mg/kg	130	500	
Cadmium (Cd) mg/kg	0,4	2,5	
Arsen (As) mg/kg	20	60	
Bly (Pb) mg/kg	40	200	
Chrom (Cr) mg/kg	50	270	
TBT µ□g/kg	7	200	1 kg/år/havn
PCB µ□g/kg 1)	20	200	
PAH mg/kg 2)	3	30	

1) Summen af de følgende 7 PCB'er: 28, 52, 101, 118, 138, 153 og 180.
2) Summen af de følgende 9 PAH'er: Anthracen, benz [a] anthracen, benz [ghi] perylen, benz [a] pyren, chrysen, fluoranthen, indeno [1,2,3-cd] pyren, pyren og phenanthren.

Sediment dispersion calculations have been carried out in connection with the disposal of dredged sediment in Køge Bay. The calculations are carried out with a coupled near-field description, where the movement of the dredged material towards the bottom is described by a near-field model, which is transferred to the "far-field" model, when density-driven effects no longer determine the movement of the dredged material. The dredged material is estimated to have a relatively high moisture content, which entails a large loss in connection with the disposal of the dredged sediment itself, since the dry matter density is not large enough to send the dredged material directly down to the bottom, which is why it instead settles as a sediment cloud just above the bottom, from which it gradually deposits. It should be noted here that in the model calculations, it is assumed that the dry matter represents only 23% of the volume of the dredged material. Therefore, the relative loss from the dredging site will be reduced if the dry matter volume is found to form a larger part of the dredged material, in which case the density-driven effect of the fall towards the bottom is amplified.

Furthermore, the dry matter will tend to be consolidated in the lower part of the split barge's hopper during transport to the disposal sites, making it easier to deposit directly on the bottom. This is not taken into account in the model calculations, which are based on the fact that the dredged material is evenly mixed up in the hopper of the split barge during sediment disposal. The actual dry matter quantity/density of the disposed sediment can be determined when the volume of disposed sediment and the mass of the excavated material in the split barge are known.

The model calculations show that there will be a time slot where the spreading of the disposed sediment is large. Therefore, it will be possible to reduce the dispersion of the dredged material if sediment disposal is not taking place when it gives rise to an extensive or undesirable spreading to, for example, the Natura 2000 area at Falsterbo. A large spreading towards the northeast, as shown in Figure 4, is primarily related to isolated incidents of up to one day. For example, if a threshold is used as indicated by the red line, there will be a few days when no sediment disposal can take place and a few days when it is just some hours.

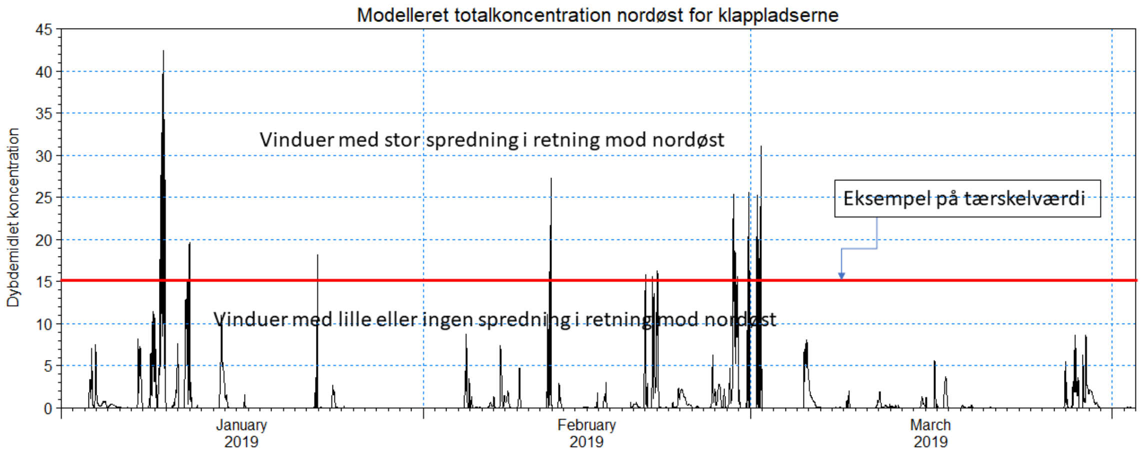

Figure 4 Modelled time series of the depth-centred concentration (mg/l) in the sediment plume northeast of the disposal sites.

The uncertainties in model calculations do not relate to the model description, which consists of a 3D flow description and a near-field calculation of the movement of the sediment cloud towards the bottom, but instead to the uncertainty of the dredged material characteristics, especially its dry density in the hopper, since this is the parameter having the strongest impcat on the nearfield sediment plume behavior.

To ensure optimal sediment disposal and a reduced spreading, it is proposed to establish a Turbidity Management Group (TMG) with stakeholder representatives, who can continuously follow the sediment disposal and its impact. To assess the impact, it is proposed to establish four stations with turbidity meters. One station is placed west of the disposal sites and is intended to measure the natural background concentration. The second station is located just inside the Natura 2000 area at Falsterbo, east of the sediment disposal sites. This station aims to detect and ensure that the site is not affected to any significant extent. The last two turbidity meters are located in the main current directions northeast and southwest of the disposal sites and aim to detect and monitor the spread of the sediment disposal.

In parallel with this, a planning tool is established to predict the spread of planned sediment disposals within, for example, a 2 – 5-day weather window. Detailed 3D calculations of curent fields support the planning tool; and the result of a forecast calculation can subsequently be used to evaluate when it is the optimal time for disposal of dredged sediment to ensure the least possible sediment disposal and not least when it should be avoided to prevent significant spreading. The planning tool makes it possible to adapt the sediment disposal while it is ongoing, thus minimising the risk of unwanted spreading. The planning tool is intended as a mitigating measure, where, based on the forecast for planned sediment disposal, which turns out to have an undesired large spread, it is possible to move it to another period within the following 24 hours, if with a revised forecast, it can be shown that the spread is significantly reduced.

The continuous monitoring of the impact of the sediment disposals also makes it possible to establish a hindcast model, which can be calibrated based on measurements and thereby used to estimate and document the actual impact of the sediment disposals. Likewise, the disposal sites should be checked at intervals to assess how large a portion of the dredged sediment is maintained at the site. These checks could also help determine whether the disposal sites will be filled to a level, where there is a risk of a significant re-suspension and the capacity of the site is exhausted.

DHI considers the effects of the spread of sediment from sediment disposal into Swedish waters to be negligible, especially if it is ensured by using a forecast system that sediment disposal is avoided during periods with an unwanted spreading towards northeast or towards the Swedish Natura 2000 areas at Falsterbo. Furthermore, to obtain the highest assurance, a TMG follow-up group can be set up with representatives from the Swedish authorities who can continuously follow the sediment disposal, impacts, and mitigating measures.