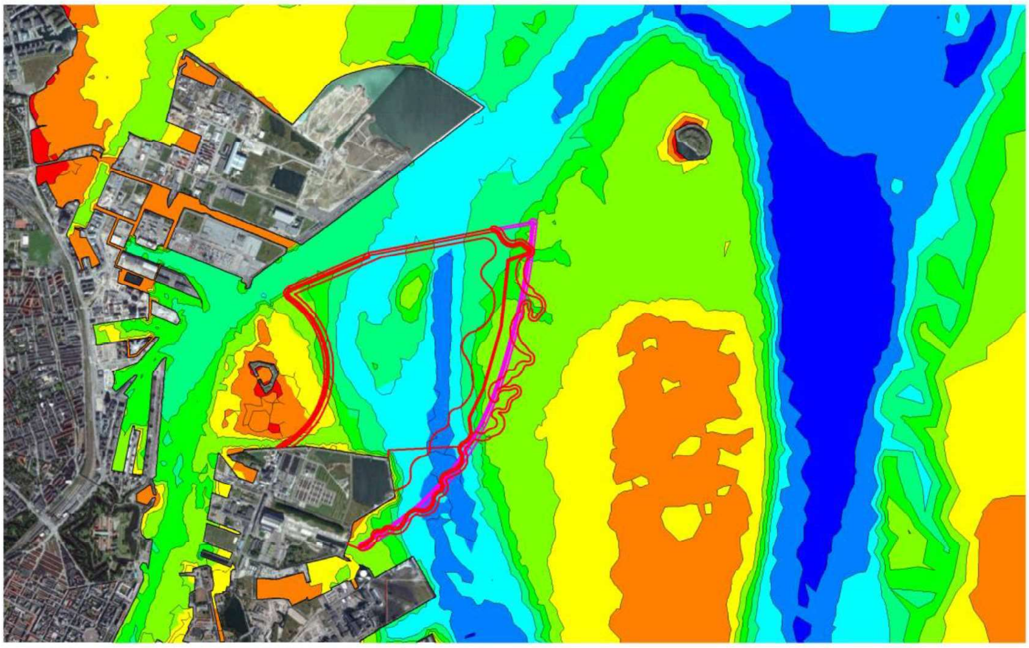
Construction of Lynetteholm

EIA – Technical Background Report No 1

Hydraulic Surveys



Udviklingsselskabet By & Havn I/S

Report

October 2021

The expert in WATER ENVIRONMENTS

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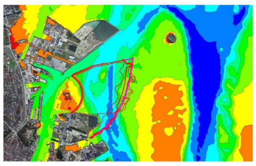
Prepared for	Udviklingsselskabet By & Havn I/S
Represented by	Hans Vasehus, Harbour & Construction Manager



Main proposals 1 and 2

Project manager	Bo Brahtz Christensen
Quality manager	Jacob H Jensen

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DHI A/S • Agern Allé 5 • DK-2970 Hørsholm
Telephone: +45 4516 9200 • dhi@dhigroup.com • www.dhigroup.com • CVR No.: 36466871

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1 Introduction

As part of the EIA process for the establishment of Lynetteholmen, a reclamation planned between Nordhavn and Refshaleøen, 4 technical background reports have been prepared to document the studies and calculations which form the basis for the environmental impact assessments. This report constitutes background report number 1 and focuses on the hydraulic impacts of the project, as well as the conditions of discharge and mixing of surplus water from the borrow area and the environmental pollutants emitted during the construction and operational phases. In addition, the report describes the effects of waste during digging associated with the replacement of the gyttja-containing sediments found along the entire outer perimeter. This bottom replacement is necessary to ensure sufficient carrying capacity.

Background report 2 describes water quality topics, focusing on the occurrence of seaweed, bathing water quality, and overall water quality. The third background report focuses on design parameters for the construction of the outer perimeter, as well as effects generated by expected future sea level rises.

The first three reports are all based on a variant of the two final main proposals, but the deviation from the final designs is slight and only has a local impact on the hydraulic conditions. Background report number 4 compares the examined and final designs, to document that the minor modification of the dog-leg in the funnel between Nordhavn and Lynetteholm has only a local impact on the hydraulic conditions, and that the three technical background reports can therefore fully assess the impacts of the project and its final design as documented in the EIA.

2 Summary

Not included

3 Background

The storm Bodil - which caused extensive damage in areas such as Copenhagen and Roskilde in December 2013 - was a first warning of what may be in store, at more frequent intervals, as climate-created sea level rise accelerates and the risk of flooding increases. As parts of Copenhagen are low-lying, such as Sluseholmen, there is a need to do something long-term to future-proof Copenhagen from storm surge. In Copenhagen, there are large amounts of surplus land from infrastructure projects and intense construction activity. Furthermore, as a metropolis, Copenhagen attracts people, thus increasing the need for new residential development areas.

Lynetteholm is intended as a project that together can meet the above three challenges, namely:1) As an essential element in the storm surge protection of Copenhagen with the preparation of storm surge ports/lock gates for securing and closing the harbour entrance. 2) Meeting the need to dispose of surplus soil, and 3) Be a part of a new central district connected to the Metro and Østre Ringvej, and access to nature and potentially also beaches.

Two similar project proposals have been prepared for Lynetteholm. Main proposal 1 is a reclamation without a coastal landscape, where the outer perimeter consists of sheet piling walls and rubble mound protections. Main proposal 2 is a reclamation where a varied semi-open coastal landscape is established along the eastern perimeter. The coastal landscape of the project proposal contains both beaches with pebbles and sandy beaches shielded from impact by strong currents.

Lynetteholm will be connected to Refshaleøen, which means that the Lynette entrance used today by yachtsmen will be closed and filled up. With the establishment of Lynetteholm, their access to Copenhagen harbour will only be via Kronløbet, which means that in future, this entrance will have to be shared between commercial traffic and yachters. Today, Kronløbet is reserved for commercial traffic.

A blueprint of the Main Proposal 1 reclamation (without a coastal landscape) is shown in Figure 3-1. The eastern perimeter of the reclamation is designed with a convex shape to reduce the flow resistance along the reclamation. The northeasternmost point is located so that there is a smooth transition to the northern tip of the Nordhavn reclamation. The design ensures that the reclamation does not shield the incoming waves along the beaches at Svanemøllen, Hellerup and Charlottenlund. Likewise, the design ensures that incoming waves at Amager beach park are also not affected.

Figure 3-2 shows a blueprint of the Main Proposal 2 reclamation. The proposal, which contains a coastal landscape. This proposal only differs from Main Proposal 1 along the eastern perimeter, where a sinuous course has been built instead of a convex circle layer. The beach line must have concave elements for the sandy beaches to keep their material. Therefore, it is necessary to break up the convex circle layer in a sinuous course so that a series of concavely designed bays can be established, where protruding hardpoints help maintain the beaches. The water depths in the area nearby are so large that sand eroded from the beaches cannot be transported back onto the beaches. Therefore, hardpoints and the orientation of the beaches must be designed to retain the sand that makes up the artificially landscaped beach areas.

In both layouts, space has been made for a future gate barrier. A gate barrier or lock becomes necessary when the effects of a sea-level rise are so well manifested that the risk of flooding in Copenhagen in the event of a storm surge becomes too high. Because of the expected development in the mean water level (sea level rise adjusted for land elevation), a gate barrier solution may become relevant around 2050. That is, at the same time as it is expected that the area will be reclaimed.

When Lynetteholm is built, Trekroner's "arms" will be removed, i.e. the two stone piers at each side of the Trekroner Island that shield the harbour from wave impacts today. Likewise, the approach to the narrow harbour entrance will be adjusted, which means that the projecting northern pier with the lighthouse at the opening to the Orient Basin is removed. These changes, together with the reclaimed areas, are included in the examined scenarios.

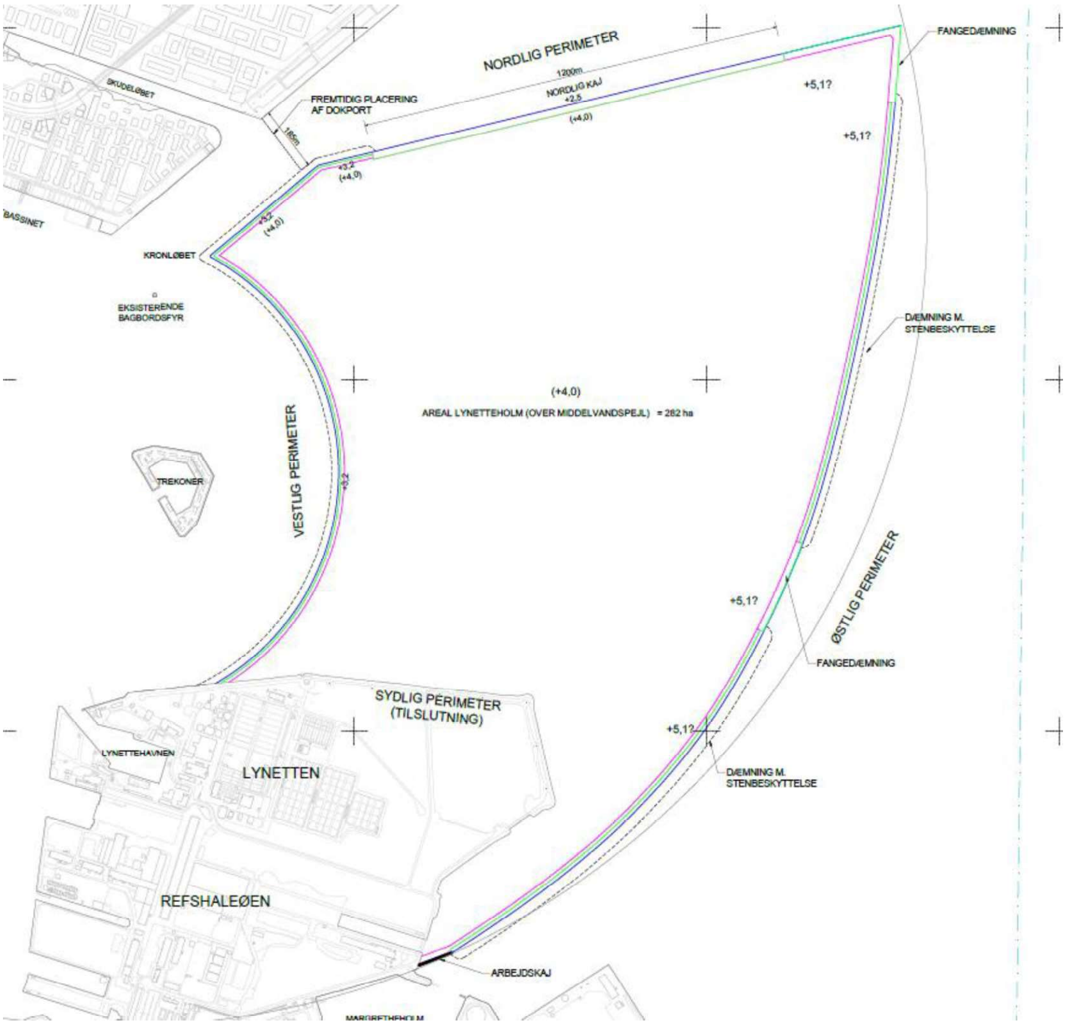


Figure 3-1 Blueprint of the examined Main Proposal 1.

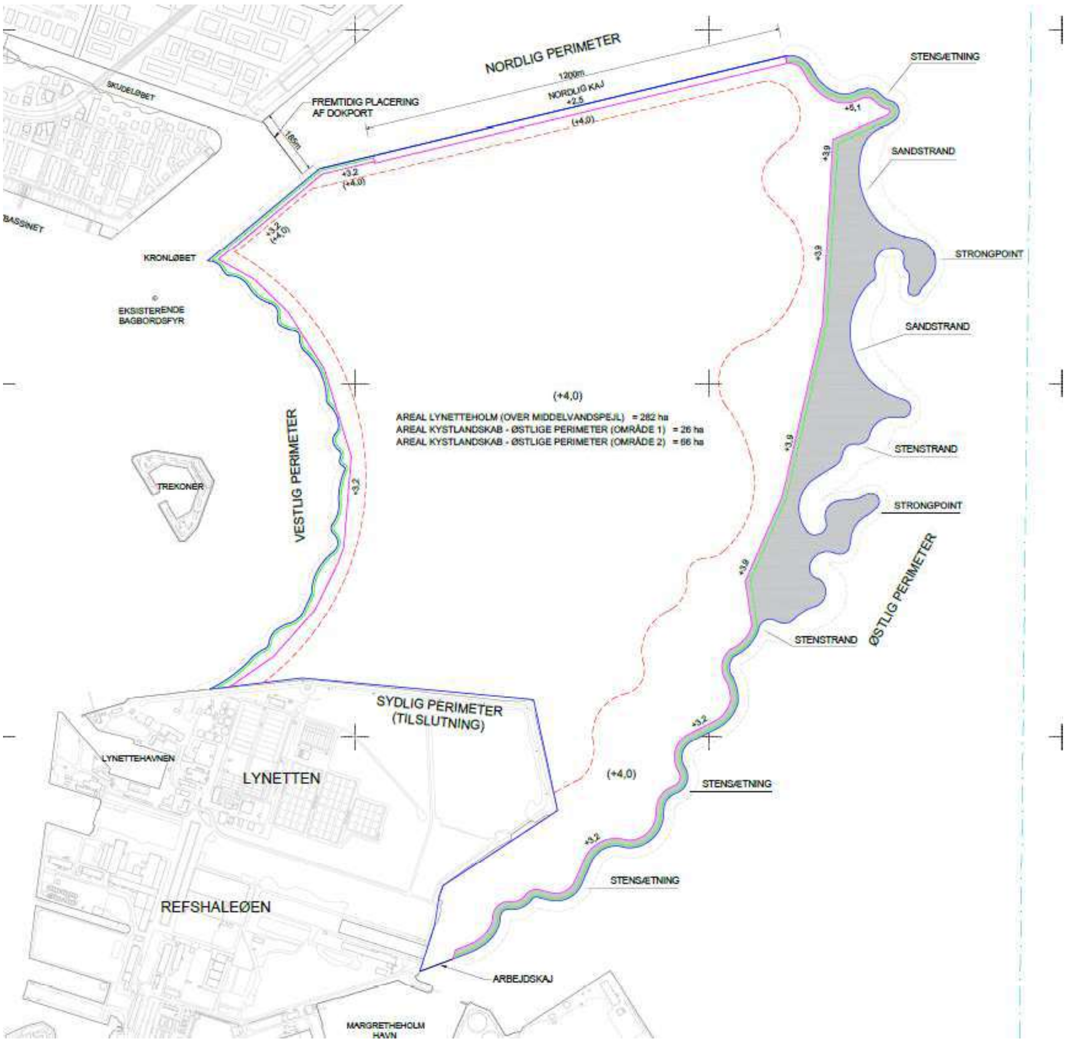


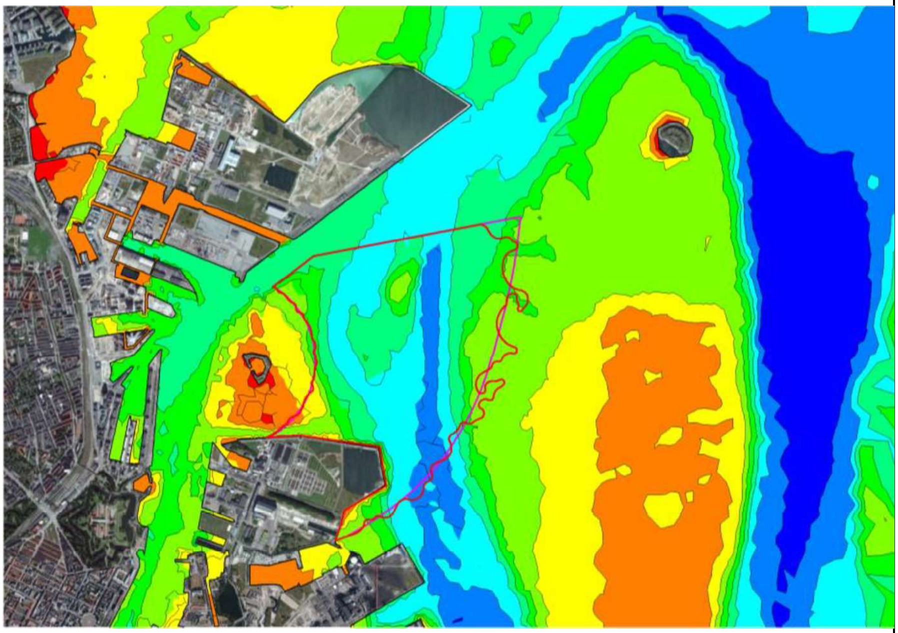
Figure 3-2 Blueprint of the examined Main Proposal 2.

The blueprints shown above are variants of the final main proposals, as in June 2020, a minor modification of the dog-leg in the funnel between Nordhavn and Lynetteholmen was made. The change in the layout has only a very local impact on the hydraulic conditions, as the flow cross-section increases slightly over a relatively short distance. The design change only has a local effect on the hydraulic conditions, and the conditions described herein are therefore comprehensive and sufficient to assess the influences of the project and its final design as documented EIA.

The two examined main proposals are superposed on the bathymetry (seabed level) in the area around Lynetteholm and shown at the top of Figure 3-3.

Similarly, a figure is shown at the bottom with the final outlines of the two main proposals. It can be seen that the difference is relatively small and does not change the blocking of Kongedybet and the perimeter's course towards Øresund. The current in Havneløbet (the inner harbour) is regulated mainly by the sluice gates in Sydhavnen and will therefore not be influenced by the design changes.

Studied layouts for Main Proposals 1 and 2



Final layouts for Main Proposals 1 and 2

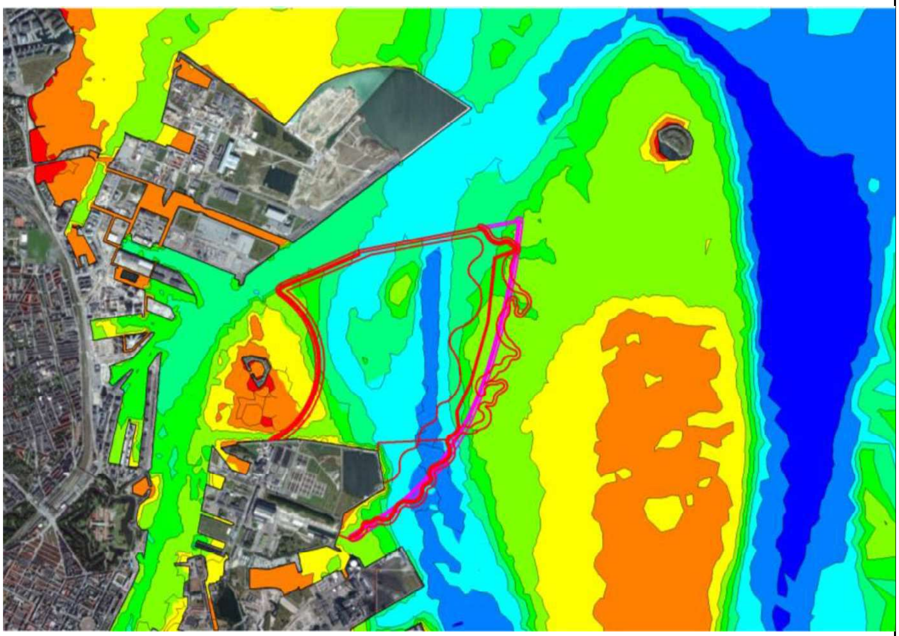


Figure 3-3 Top: Indication of studies for Main Proposal 1 (pink curve) and Main Proposal 2 (red curve). Bottom: Indication of final layouts for Main Proposal 1 (pink curve) and Main Proposal 2 (red curve). The red curve shows the crest elevation of the profile, the water level line, and the profile's foot, where it joins the natural seabed.

4 Basic studies

4.1 Hydraulic basic surveys

The following sections describe the existing current-, wave-, and water level conditions in Øresund and the area around the planned reclamation, also called Lynetteholmen. Furthermore, the section describes the hydrodynamic 3D model used, which represents water depths, wind and tidal-generated currents, salt and temperature in Øresund and Copenhagen Harbour. The model has been used to assess the following:

- Impact of reclamation on the water and salt balance through Øresund and the exchange of water between Kattegat and the Baltic Sea
- Impact of reclamation on local currents and water levels
- The local effect of reclamation on water temperature and salinity
- The impact of the reclamation on the cooling water of Amager Power Station
- The importance of the reclamation for the coastal morphology
- The general morphological influence of the reclamation

In addition, the model is used to calculate the spread of:

- Environmental pollutants emitted with surplus water from the borrow area
- Sediments associated with excavation work
- Contaminated substances tied to the sediment and released into the water phase

4.2 Basic description of the hydraulic conditions in the area

4.2.1 General description of the hydrographic conditions of Øresund

Øresund is the second largest of the three belts Lillebælt, Storebælt and Øresund, which connect Kattegat and the Baltic Sea. The northernmost part of the Sound is shaped like a funnel, which from the section of Gilleleje-Kullen gradually narrows towards Helsingør-Helsingborg. The area contains a natural deep trench (>30 m) where stratification occurs due to the exchange between brackish water from the Baltic Sea and salty seawater from the North Sea/Kattegat. In the deepest parts of the water column, salinity is almost as in the North Sea. The deep trench runs east around Ven to just south of Landskrona. South of Landskrona Øresund gradually becomes wider, and the depths of the trenches are reduced accordingly, see Figure 4-1. In the south, the flow is divided into two by Saltholm.

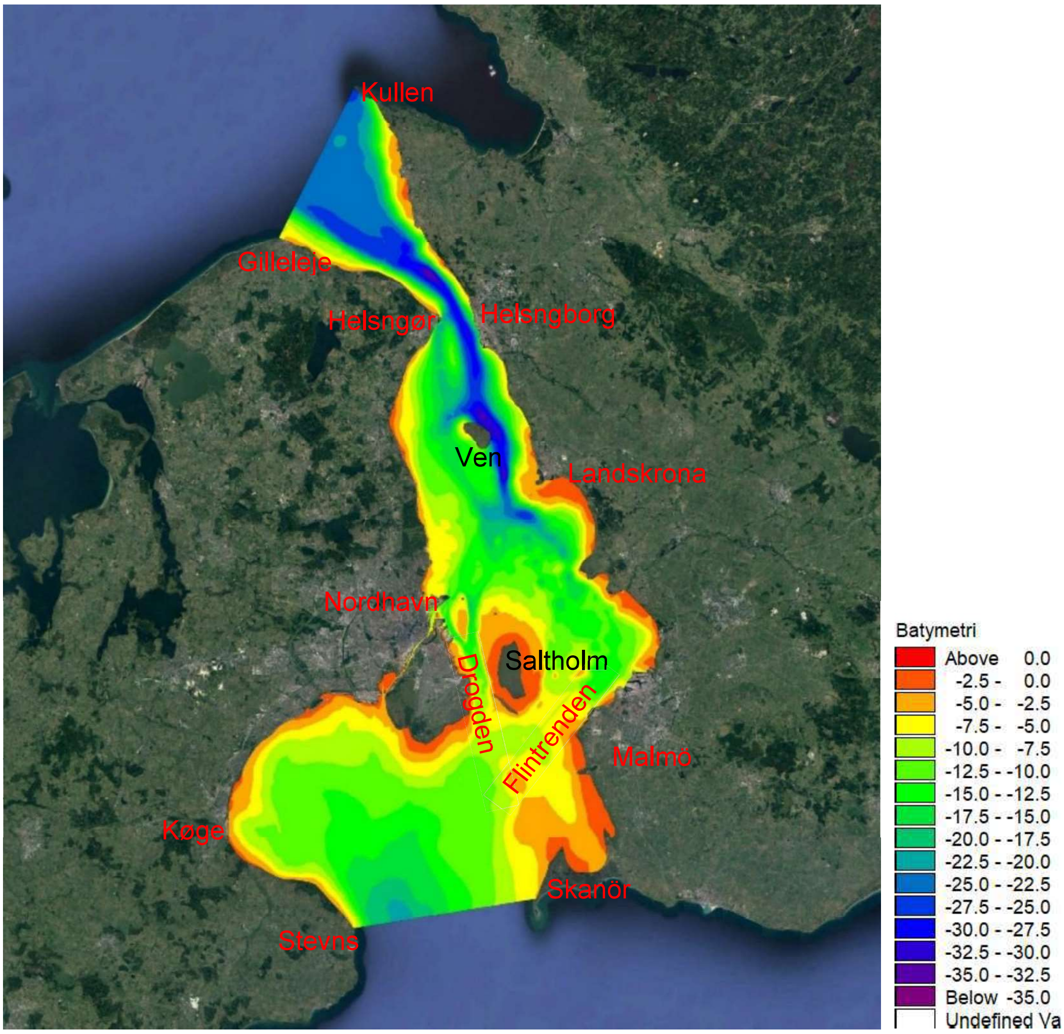


Figure 4-1 Øresund's bathymetric conditions and the extent of the baseline model.

On the Danish side of Øresund to the west, the current is focused on the deep trenches: Hollænderdybet east of Middelgrunden, Kongedybet west of Middelgrunden and Kronløbet northwest of Middelgrunden. Further south to Hollænderdybet and Kongedybet lies the Drogden shipping lane, which is deepened to guarantee a depth of at least 8 meters at mean water level, see Figure 4-2. On the Swedish side of Øresund, Lommabugten to the west and north of Malmö is a broader area with water depths between 10-15 metres. To the south is the Drodgden threshold, where the water depth is between 5-8 meters. In the Swedish part, the Drogden threshold is bisected by Flinterenden, which has been further excavated to somewhere between 8 and 10 meters. Due to the relatively narrow flow width and the low water depths, the Drogden threshold is the part of Øresund where the cross-sectional area of the flow is the smallest. Therefore, the Drogden threshold is the area that provides the most significant blockage and thus determines the exchange of water and salt with the Baltic Sea. South of Drogden, the cross-section expands and moves on to Køge Bay to finally become part of the Baltic Sea.

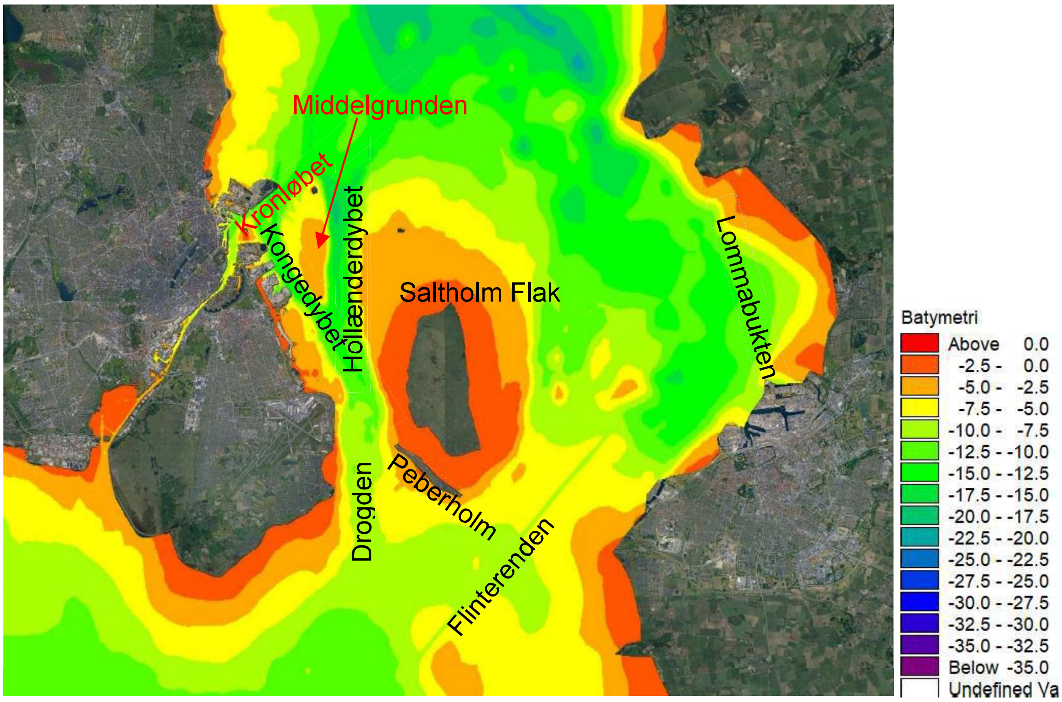


Figure 4-2 Depth and areas in the southern part of Øresund. Depths are indicated in relation to DVR90.

4.2.2 General description of current and water levels

In quiet weather conditions, the current conditions in Øresund are determined by the tides and the surplus supply of fresh water supplied from rivers and streams with estuaries in the Baltic Sea. During quiet periods there are therefore changing calm currents, but with predominantly northbound currents. During periods of more severe weather conditions, the regional wind and air pressure conditions around the Baltic Sea and Kattegat have a major impact on the water exchange through Øresund. The effect of the wind causes water to be stowed up in either the Western Baltic Sea or the Kattegat depending on the wind direction. Measured water level time series for Hornbæk and Copenhagen are shown in Figure 4-3 for the period 1999-2019. It can be seen that the water level variations in Copenhagen are generally smaller than in Hornbæk, partly due to a slightly weaker tide but also due to a less pronounced stowing effect of the wind. Figure 4-4 shows a comparison of the trend-free water levels in[1] Hornbæk and Copenhagen in connection with the 15 worst storm surge events recorded in Copenhagen in the period 1889-2019. It can be seen that the level of a storm surge event will typically be 30 cm higher at Hornbæk than in Copenhagen.

Strong winds from directions between the west and northeast thus give rise to high water levels in the southern part of the Kattegat and in Øresund north of the Drogden threshold, while strong winds from the southeast give rise to low water levels in Øresund. The difference in water levels north and south of the Drogden threshold determines the dominant current direction in the Sound. Regional strong winds with directions between the southwest and north-west cause water from the North Sea to be squeezed into the Kattegat, thus creating the basis for southbound currents in Øresund. Strong winds with directions between northeast and south causes water to be pile up in the western part of the Baltic Sea or to be squeezed out of the Kattegat with a northbound current as a result.

[1] A trend-free water level is cleaned of effects of changing sea level and land elevation.

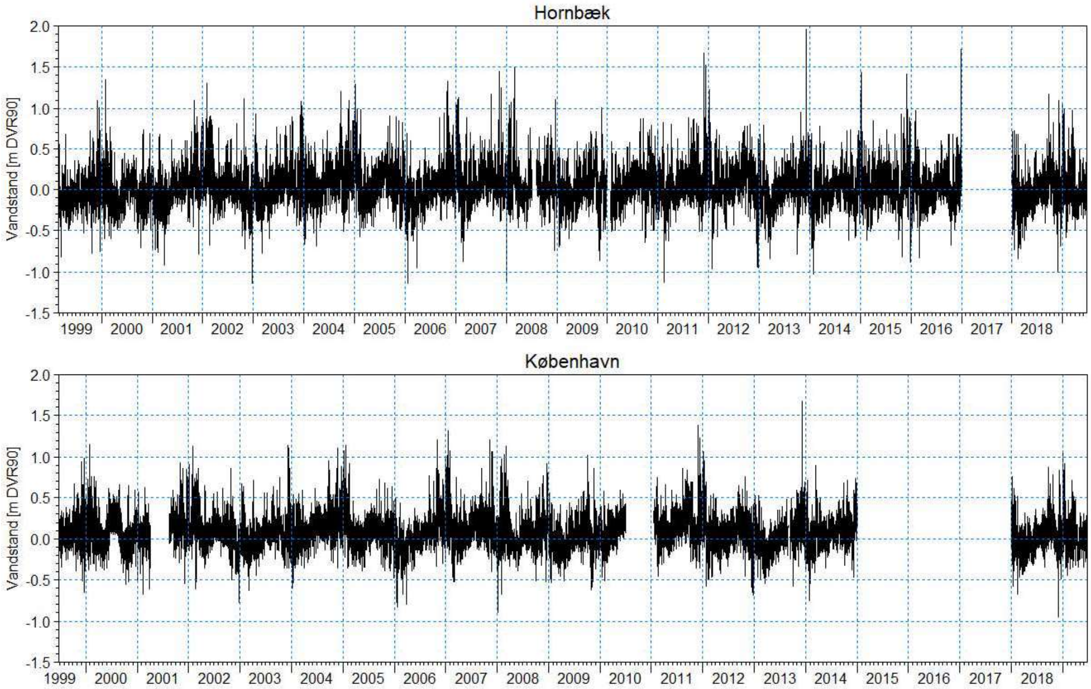


Figure 4-3 Measured water level variations in Hornbæk and Copenhagen in the period 1999-2019.

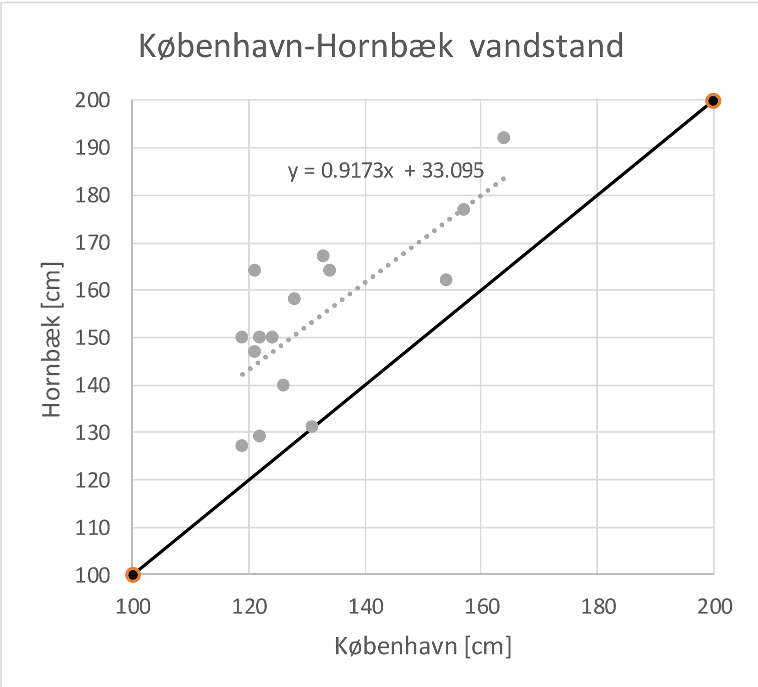


Figure 4-4 Corelation between trend-free storm surge levels in Copenhagen and Hornbæk (1881-2019).

In addition, the local wind also has an impact on the local surface current in parts of Øresund.

There is a frequent stratification in the deeper trenches of Øresund (and in the Kattegat) because the water in Kattegat's deeper layers has a salinity - and thus a density - almost as in the large oceans (30-35 ‰), while the water in the Baltic Sea is lighter brackish water due to the ample supply of freshwater from rivers with outlet in the Baltic Sea. The stratification means that there is often a relatively fresh northbound surface current and a salty southbound bottom current. The stratification in Øresund is further maintained by the Drogden threshold, which inhibits the heavy bottom current and salt transport to the Baltic Sea. The net flow in Øresund is northbound due to the flow of water from the estuary rivers into the Baltic Sea, as Øresund, the Great Belt, and the Little Belt are the only outlets from the Baltic Sea. The transport of salt to the Baltic Sea occurs primarily by saltwater intrusions, i.e. incidents where water from the Kattegat is pushed through Øresund over the Drogden threshold and through the belts for an extended period.

4.2.3 Numeric model

In order to estimate the blocking effect of Lynetteholmen on the transport of water and salt through Øresund and Copenhagen harbour and on the regional dynamics described above, it has been chosen to set up the three-dimensional (3D) hydrodynamic model so that it covers the entire Øresund from the Gilleleje-Kullen cross-section in the north to the cross-section Stevns-Falsterbonæsset in the south.

A 3D model divides the water depth into a series of layers vertically, so that the currents of the water can be calculated in all three directions. The model is formulated with a sigma-z solution, which means that all areas with a water depth less than 15 meters are resolved in 10 layers above the vertical, each with a height equal to 1/10 of the water depth. A fixed vertical mesh width is used on water depths greater than 15 meters, which in the part of the water column below 15 m is gradually stretched from 1.5 meters to 3 meters. The calculation network is designed to gradually be refined towards the Lynetteholm area, see Figure 4-5. The bathymetry is interpolated on the basis of survey data received from By & Havn, covering Copenhagen's water bodies, as well as the confluence south of Middelgrunden. In the other areas, navigation chart data from other sources have been used.

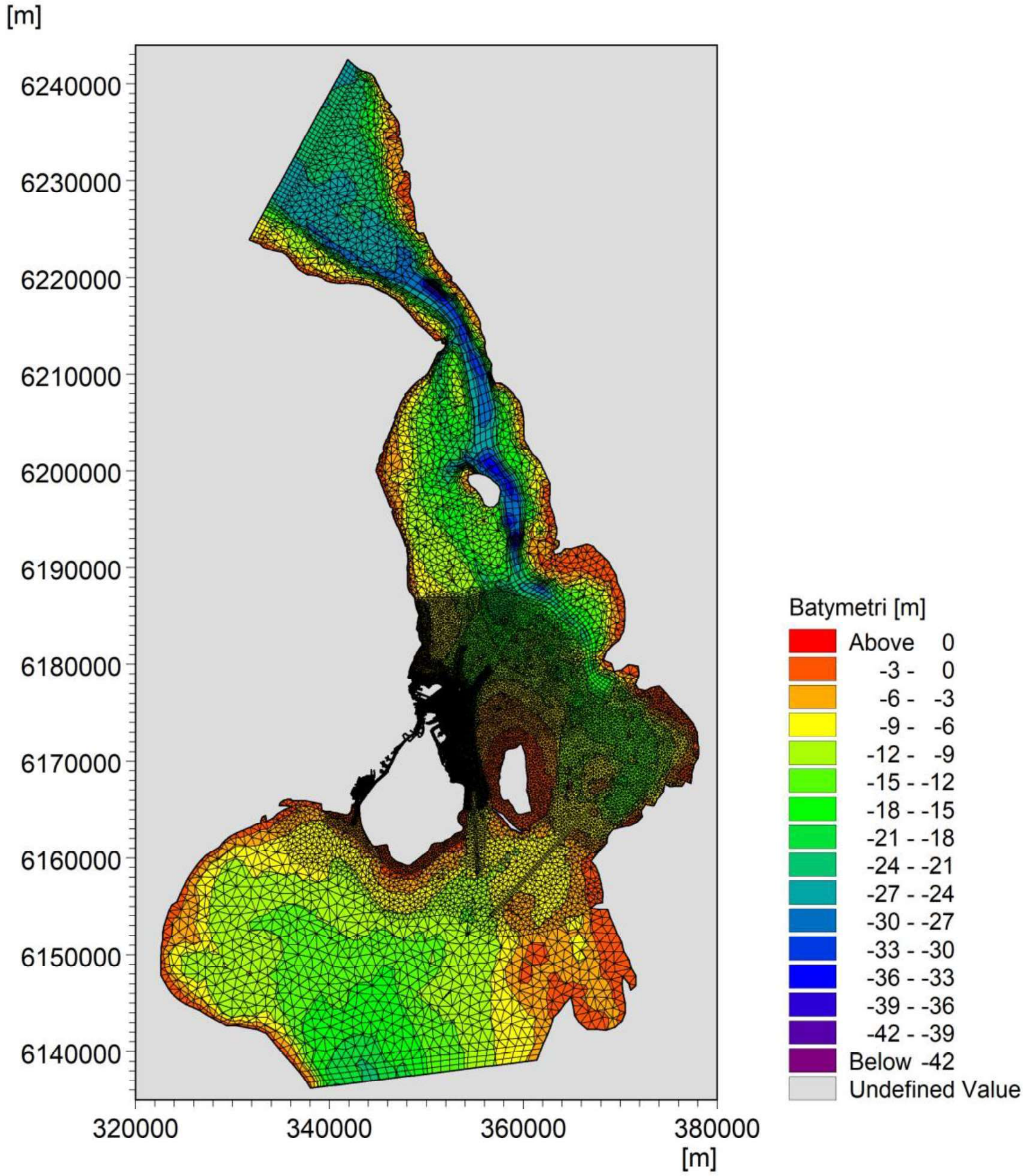


Figure 4-5 Bathymetry and computational mesh of the baseline model.

4.2.4 Selected modelling period

Minor tidal oscillations control the water exchange through the Sound with a period of 12.5 hours. Tidal oscillations are typically superposed by more long-term oscillations lasting several days. The long-term period oscillations are mainly related to the passage of weather systems (storm low pressure systems), which guide the dynamic water exchange between the Baltic Sea and the North Sea. Saltwater intrusions occur during the more extreme events of this type, i.e. incidents where high salinity water (20-22 ‰) passes across the Drogden threshold. Large saltwater intrusions occur irregularly in time and often with intervals of every several years. On top of this dynamic, there is a contribution from the general run-off of the surplus supply of freshwater stemming from rivers and streams with their estuary in the Baltic Sea. The water flow contribution from the rivers varies throughout the year, as do the water temperatures, so it is chosen to model an entire year to cover all seasonal variations. As a model year, it has been selected to use the most recent full calendar year of the surveys (2018). Results for model calibration against measured water levels and salinity profiles are shown in Annex A.

5 Assessment of the environmental impact during the construction phase

Not included

6 Assessment of impacts during the operational phase

6.1 Hydraulic and coastal morphological conditions

6.1.1 Assessment of changing sea levels

Both main proposals for the Lynetteholm reclamation will close Kongedybet completely and will therefore significantly change the local flow conditions and thus also to some extent the water level conditions. Lynetteholm's impact on local water levels is illustrated below.

6.1.1.1 Mean water level

As expected, both main proposal for Lynetteholm have virtually no impact on the mean water level. Based on the water level variation throughout the year 2018, Figure 6-1 and Figure 6-2 show the expected change in mean water levels that Lynetteholm will cause without and with a coastal landscape along the eastern perimeter, respectively. The figures show that the mean level will decrease by between 5-10 mm in the funnel between Nordhavnen and Lynetteholmen and along the northeastern part of the perimeter. In the proposal without a coastal landscape, the reduction can be felt all the way to Kvæsthusbroen. In the other areas, the change is less than 5 mm and thus no areas can be identified where the expansion will lead to an increase in the mean water level.

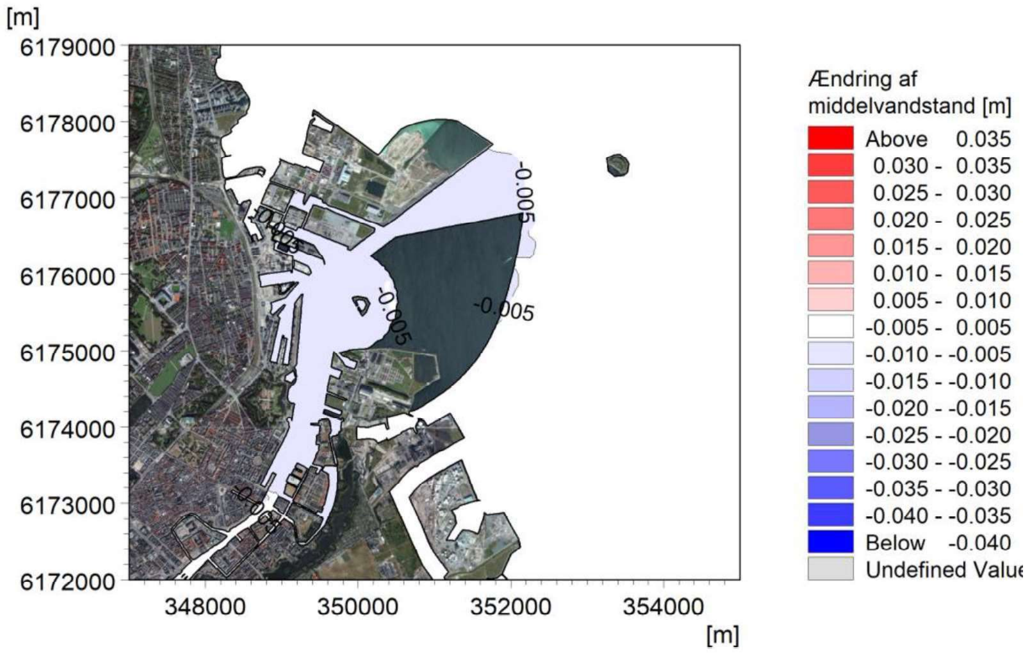


Figure 6-1 Change in the mean water level in 2018 with a Lynetteholm reclamation without a coastal landscape.

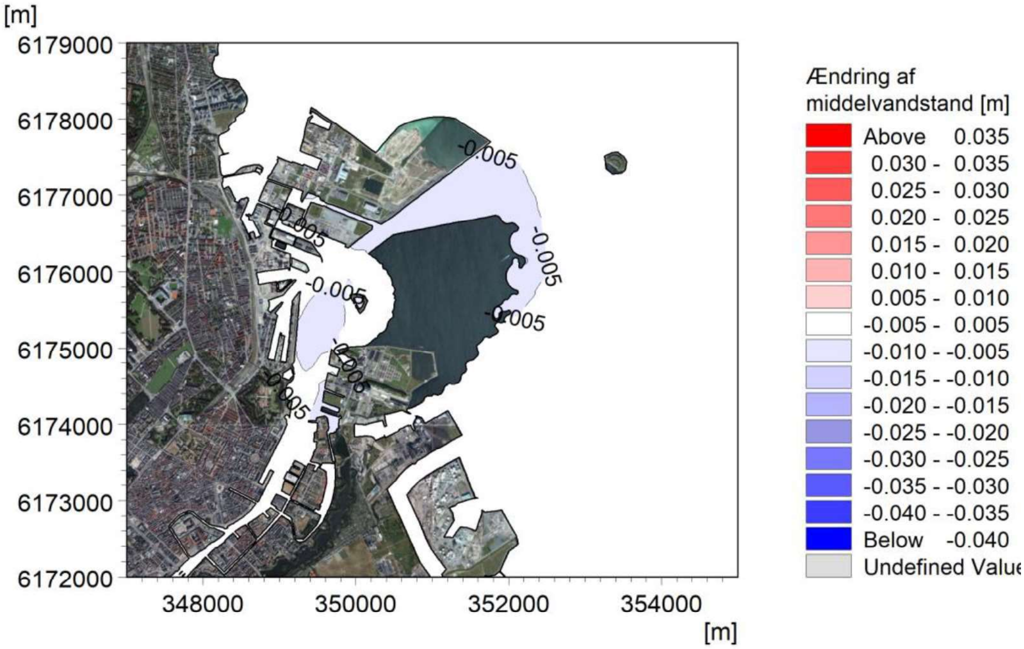


Figure 6-2 Change in the mean water level in 2018 with a Lynetteholm reclamation with a coastal landscape.

6.1.1.2 Maximum water level

The year 2018 does not contain any actual storm surge events. The maximum water level is therefore associated with a moderate high-water event. Figure 6-3 shows the highest modelled water levels in 2018 for baseline and the two main proposals for a Lynetteholm reclamation. The plots are based on a statistical analysis and therefore do not represent the conditions at one specific moment. In general, the high-water levels north and south of the Drogden threshold will be associated with two different events. The Drogden threshold can be identified by the yellow and orange bands, where the water level is lowest.

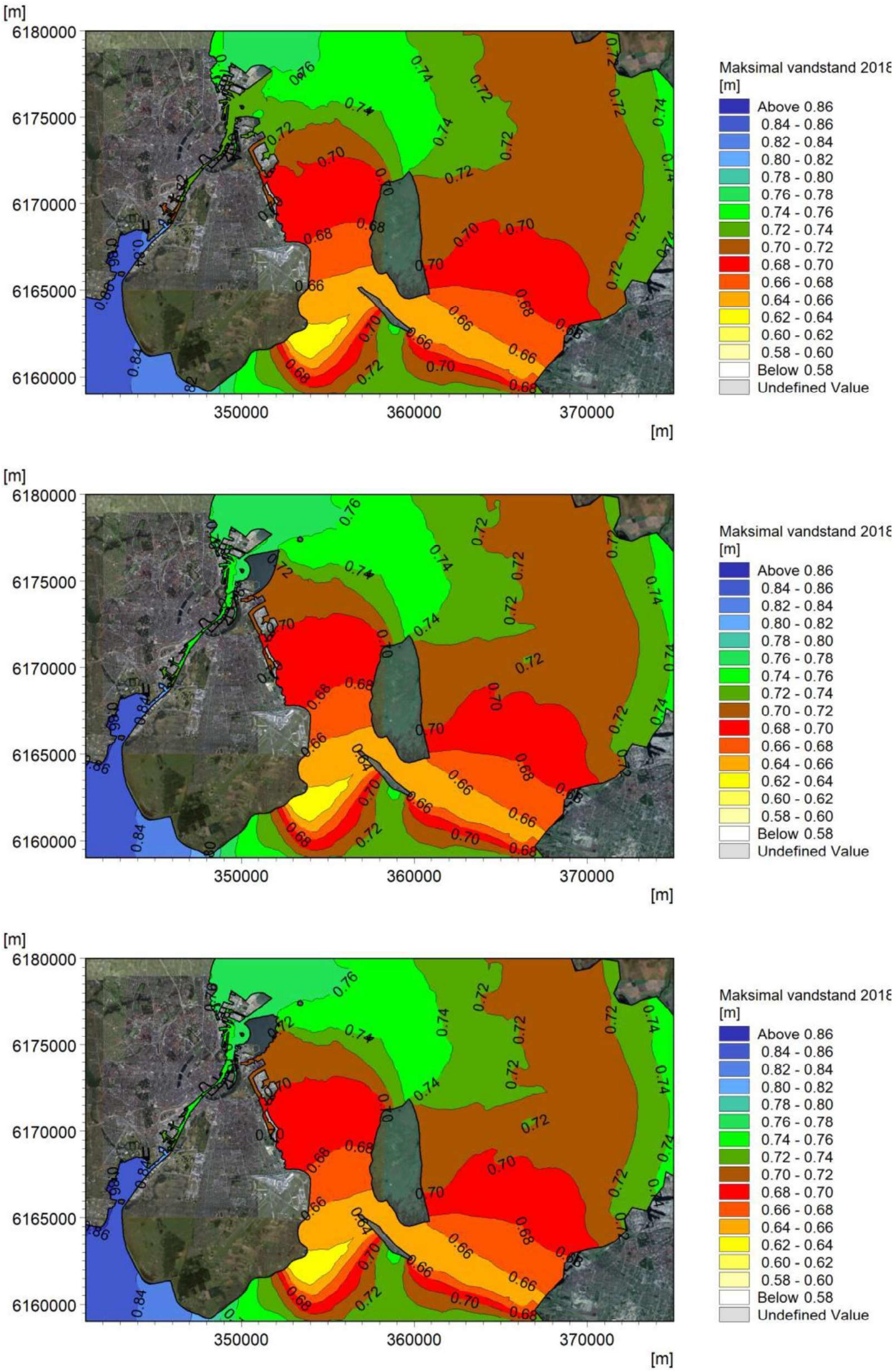


Figure 6-3 Modelled maximum water level year 2018 for baseline conditions (top), with a Lynetteholm reclamation without a coastal landscape (centre) and a Lynetteholm reclamation with a coastal landscape (bottom).

The change in maximum water levels is calculated and shown in Figure 6-4 for Main Proposal 1, which does not contain a coastal landscape. It can be seen that there is a tendency towards slightly increased water levels throughout the harbour towards the sluice gates in Sydhavnen. The increase is between 20-25 mm in the area east of Trekroner and in the inner part of the Kronløbet. In the area southeast of Lynetteholm there is a reduction in the maximum water level of up to 30 mm. In general, it varies between 15-30 mm along the eastern perimeter.

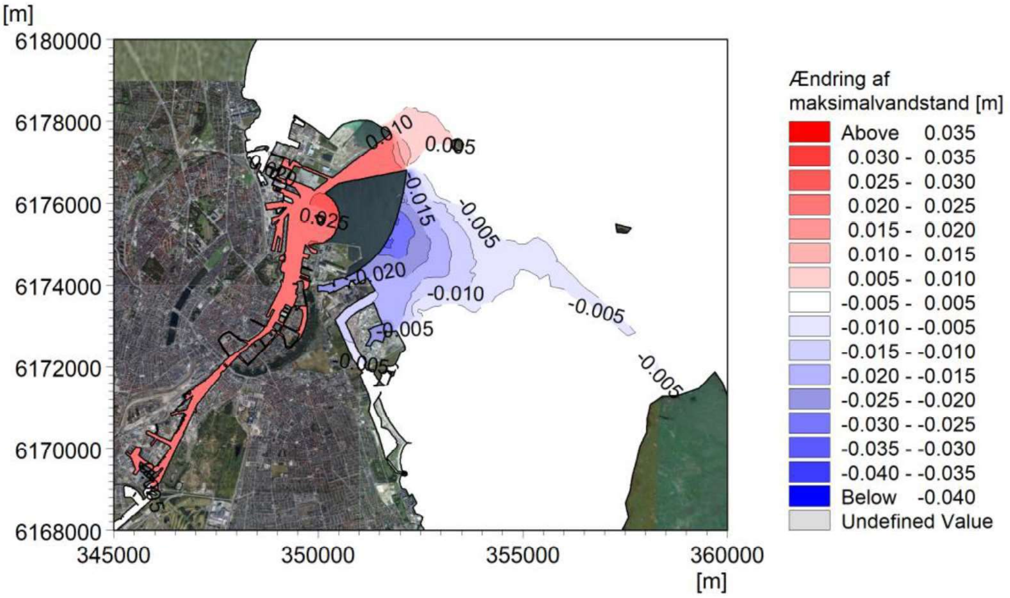


Figure 6-4 Change of the present maximum water level owing to a Lynetteholm expansion without a coastal landscape.

The increase in the high-water level inside the harbour, as shown in Figure 6-5, is much the same for Main Proposal 2 (25-30 mm) but a reduction the maximum water level along the eastern perimeter is slightly bigger. During most of the stretch along the eastern perimeter, the reduction is between 30-35 mm.

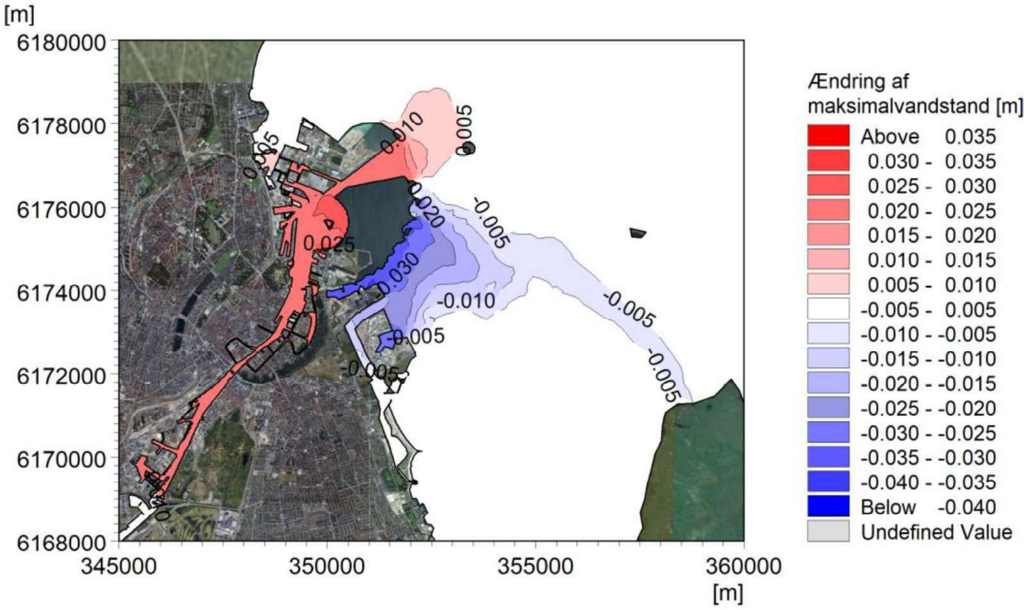


Figure 6-5 Change of the present maximum water level as a result of Lynetteholm's reclamation with a coastal landscape.

The effects on maximum water levels are local but imply that there will be a slightly increased water level in the harbour right up to the sluice gates in connection with a storm surge.

The Lynetteholm reclamation is intended as an essential element in the future storm surge protection of Copenhagen but has as an additional effect that it will slightly increase storm surge levels in the harbour until the establishment of a storm surge gate, which can be closed in connection with an increase of the water level. It can therefore be inferred that the Lynetteholm reclamation will accelerate the need for a storm surge gate as sea level rises of the mean water level prevail.

6.1.1.3 Minimum water level

In 2018 an incident occurred with very low water levels which has not been surpassed in the past 20 years. Figure 6-6 shows the lowest modelled water levels in 2018 for baseline conditions and the two main proposals for a Lynetteholm reclamation. The plots are based on a statistical analysis and therefore do not represent the conditions at one specific moment.

The change of minimum water levels is calculated and shown in Figure 6-7 for Main Proposal 1, which does not contain a coastal landscape. It can be seen that there is a tendency towards slightly reduced water levels throughout the harbour towards the sluice gates in Sydhavnen. The reduction is between 25-62 mm and decreasing towards the sluice gates. The largest reduction of 50-62 mm occurs in the funnel between Nordhavnen and Lynetteholm and the effect with reduced water levels extends into Øresund in the form of a northeast oriented cone, which extends past the Middelgrund fort. In the area north of the Nordhavn reclamation there is a water level increase of up to 13 mm. In the area southeast of Lynetteholmen and all the way down to Peberholm there is an increase in the minimum water level of between 5-35 mm.

As Figure 6-8 shows, the changes to the minimum water level for Main Proposal 2 are virtually identical to Main Proposal 1.

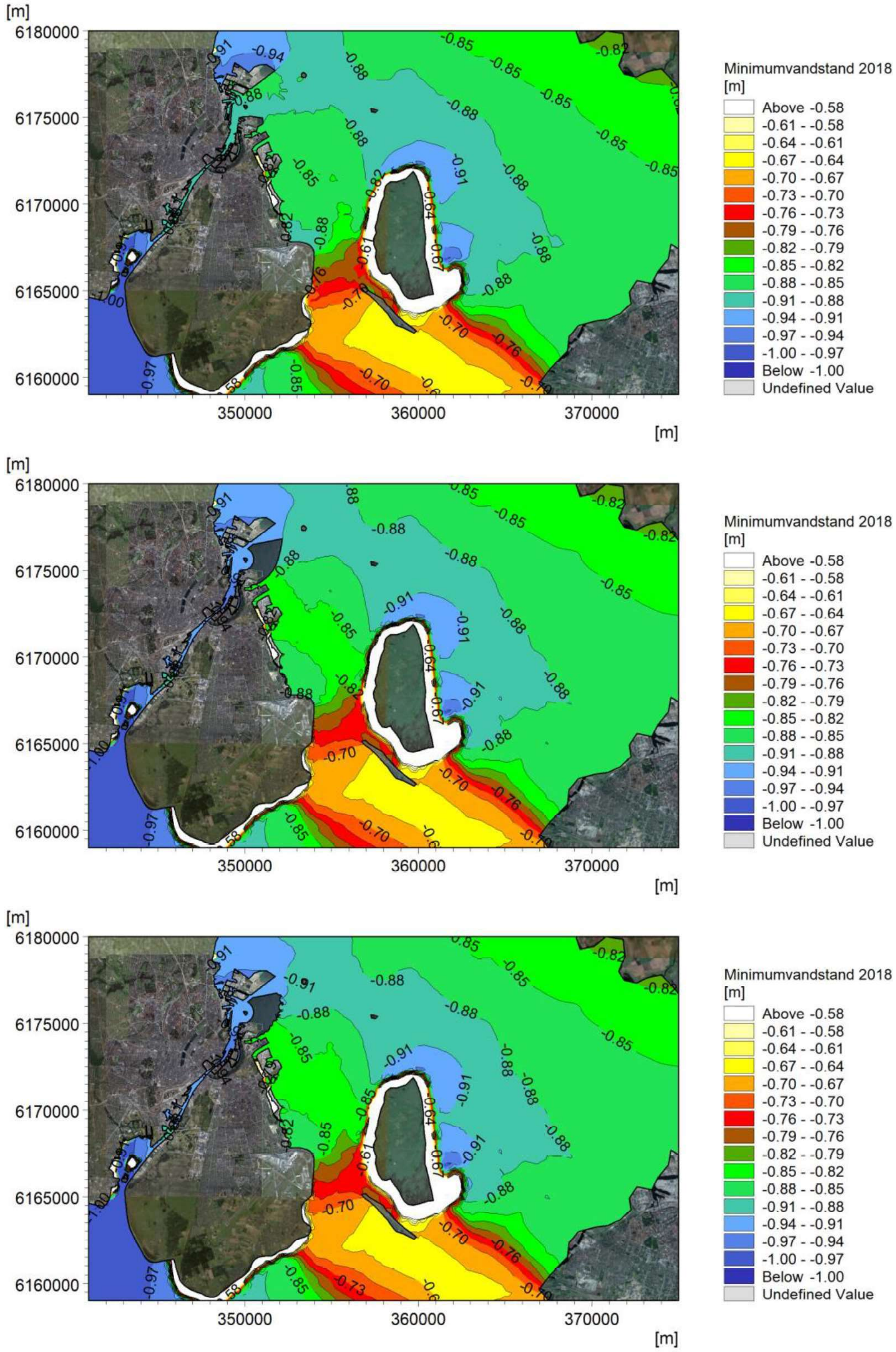


Figure 6-6 Modelled minimum water level year 2018 for baseline conditions (top), with the Lynetteholm reclamation without a coastal landscape (centre) and the Lynetteholm reclamation with a coastal landscape (bottom).

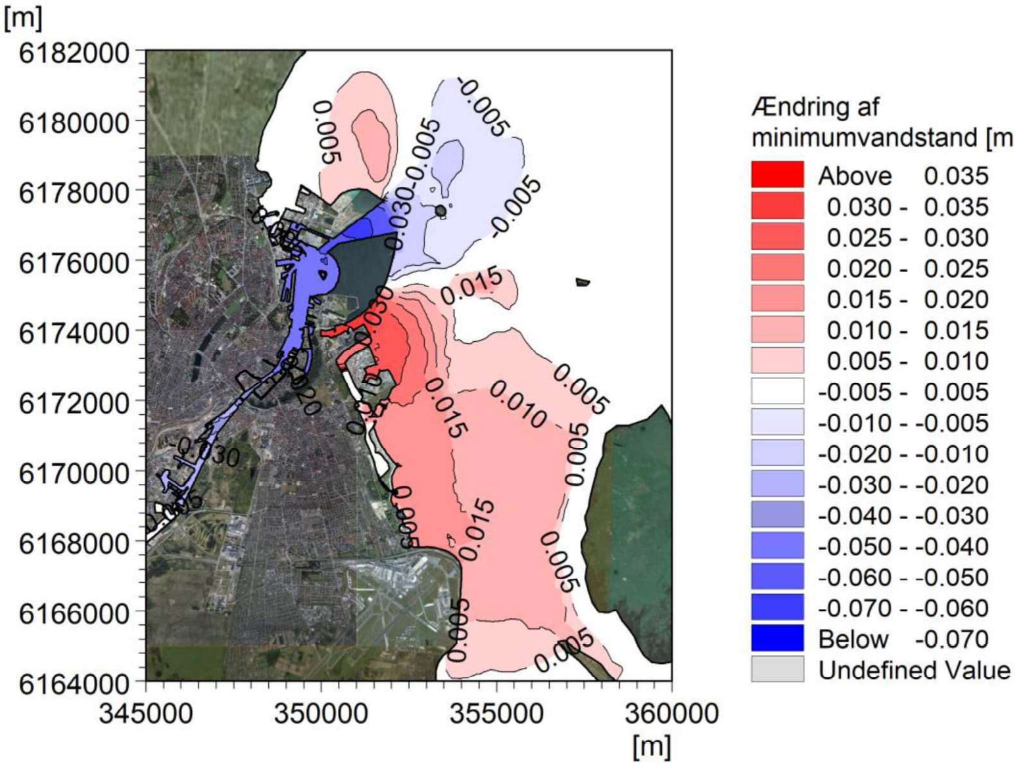


Figure 6-7 Change of the minimum water level with a Lynetteholm reclamation without a coastal landscape.

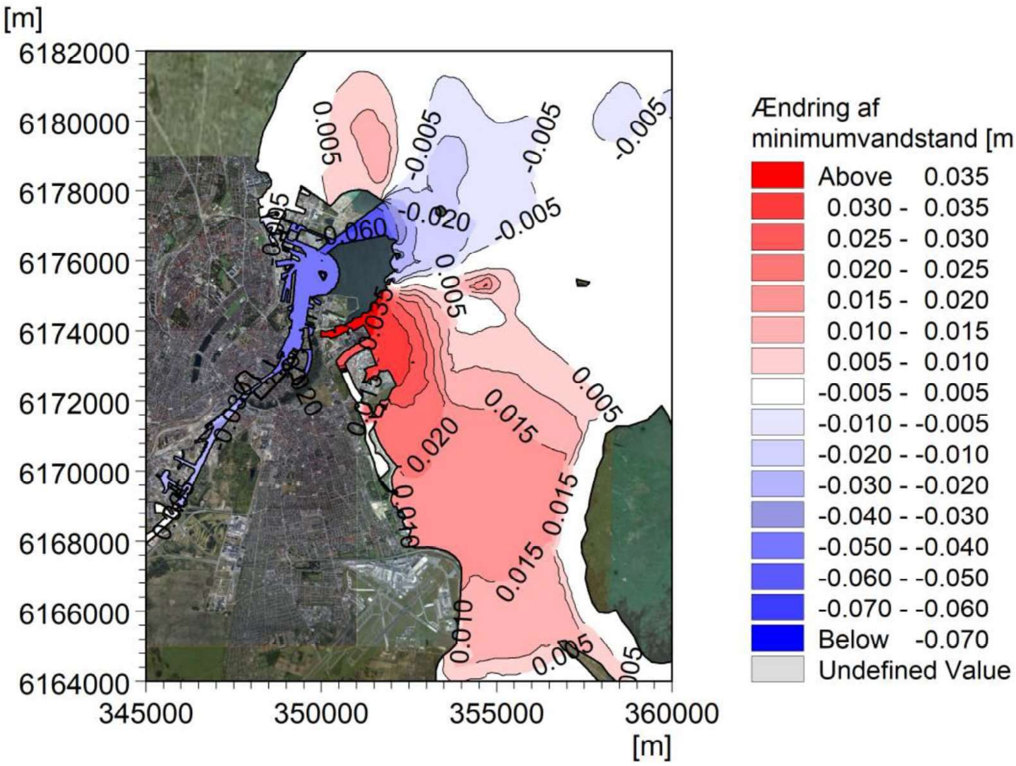


Figure 6-8 Change of the minimum water level with a Lynetteholm reclamation with a coastal landscape.

6.1.2 Assessment of changing current conditions

This section describes the local current conditions and the current changes that the Lynetteholm reclamation will cause. The current conditions and their impact are described for the two similar designs (i.e. with and without a coastal landscape). In the calculations carried out, it is assumed that the wings of the Trekronerfort (the two breakwaters at each side of the Trekroner Island) will be removed since, with the establishment of Lynetteholm, they have no purpose any longer. In addition, the protruding pier at the Orient Basin has been removed to improve the entry conditions through Kronløbet to the harbour.

6.1.2.1 Conditions with strong southbound current

The reclamation of Lynetteholm will close Kongedybet in both its designs and, therefore, significantly affect the local flow conditions. The impact will be most prominent in situations with strondg northbound or southbound currents, as the current from Kongedybet is forced east around Lynetteholm. The current from Kongedybet will be distributed so that a current amplification is created over parts of Middelgrunden and more water passes through Hollænderdybet.

In Figure 6-9, the depth averaged current fields are shown for a situation with a strong southbound current (28 January 2018) for the existing conditions (top) and for a Lynetteholm reclamation without a landscape (centre). To help understand the current patterns, a plot of water depths (bottom) has also been inserted. The corresponding figure for a Lynetteholm reclamation with a coastal landscape along the eastern perimeter is inserted in Figure 6-10.

The current images show that for both designs a current increase occurs in the area east of the reclamation, but that the current weakens east of the Nordhavn tip and in Kongedybet off Amager power station as well as the Prøvestenen south of Lynetteholm. As the current is southbound, it is primarily the conditions off and downstream Lynetteholmen that are affected. It can be seen that the current attenuation in the area off the Amager power station is most substantial in the design with a coastal landscape.

Current conditions are described by a speed and a direction. Current changes can therefore be calculated and illustrated in two ways; as a vector change, considering the effects of changes in the speed and direction of the current and as a scalar change, considering only the speed of the current. Both calculation methods are used in the plots shown in Figure 6-11 and Figure 6-12. These plots are zoomed out to cover the entire impact area. The figures show noticeable current reduction in Kongedybet and Kronløbet at the mouth of the harbour. The current reduction in Kongedybet off Amager power station may impact the power station's use of cooling water. There is a natural current shelter in the beach pockets and therefore also strong current reduction in these areas.

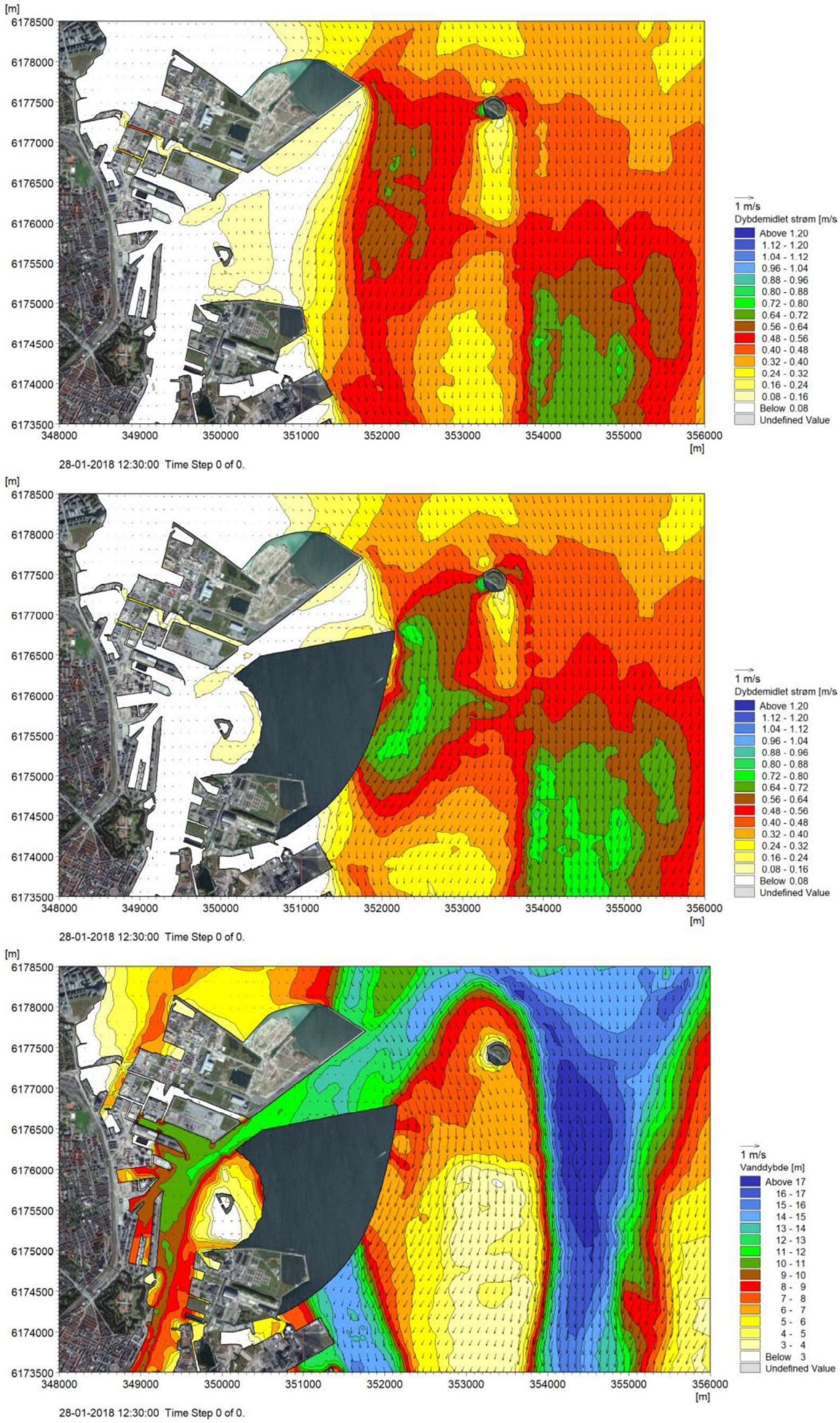


Figure 6-9 Depth-average current speed and water depths for conditions with strong southbound currents on January 28, 2018. Top: Existing conditions, Middle: Lynetteholm without coastal landscape, Bottom: Water depths superimposed with current vectors.

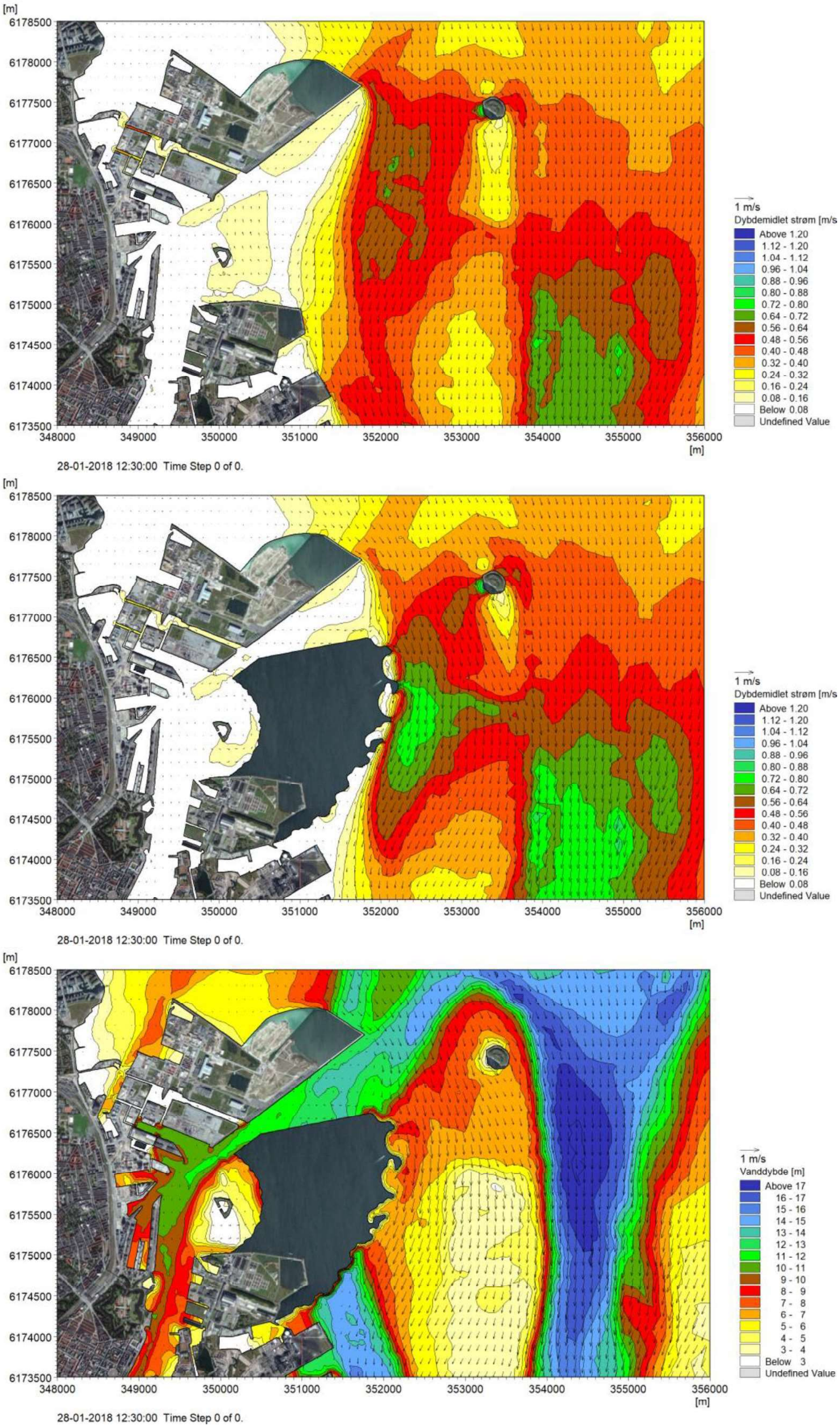
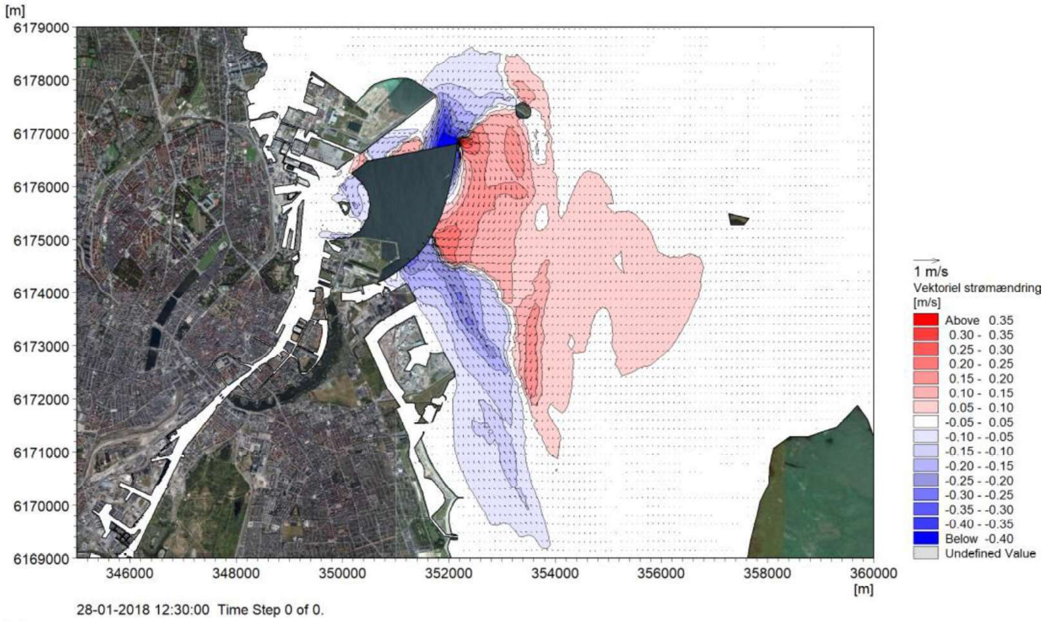


Figure 6-10 Depth-averaged current speed and water depths for conditions with strong southbound currents on January 28, 2018. Top: Existing conditions, Middle: Lynetteholm with coastal landscape, Bottom: Water depths superimposed with current vectors.

East of Lynetteholm is a larger area that will experience a current amplification. The current amplification decreases in the direction away from Lynetteholmen but can be identified as a current increase of more than 5 cm/s at a distance of up to 5 km. Likewise, there is a current amplification in Hollænderdybet, especially along the southernmost part of the Middelgrunden. East of Trekroner, there is also current reduction, as, after the reclamation, the area will be a foreclosed part of the harbour; today, it is part of Øresund.



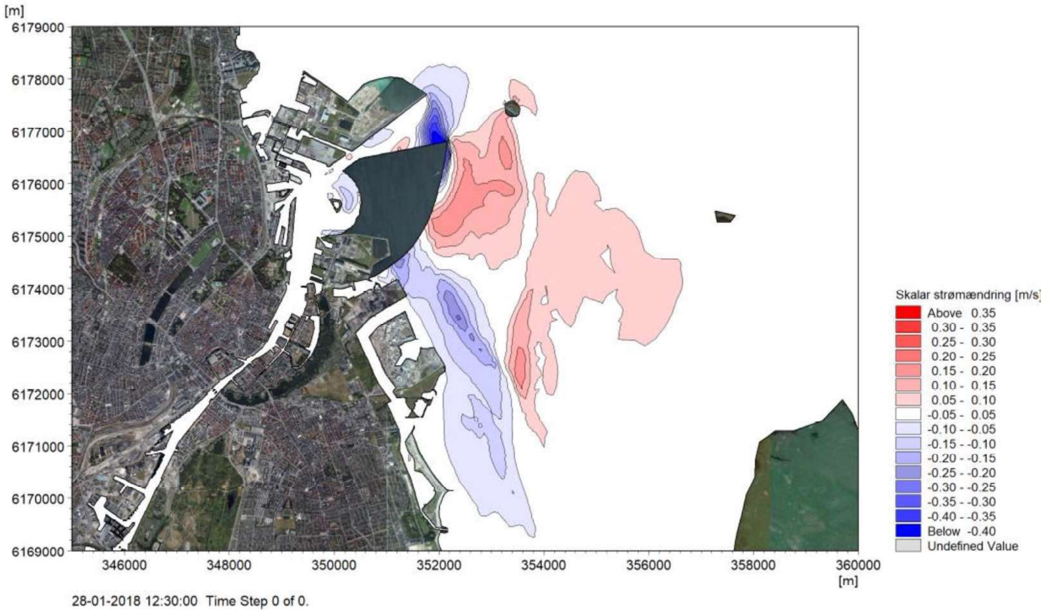


Figure 6-11 Vectorial (top) and scalar (bottom) calculated change of depth-averaged current for conditions with strong southbound current and reclamation without coastal landscape.

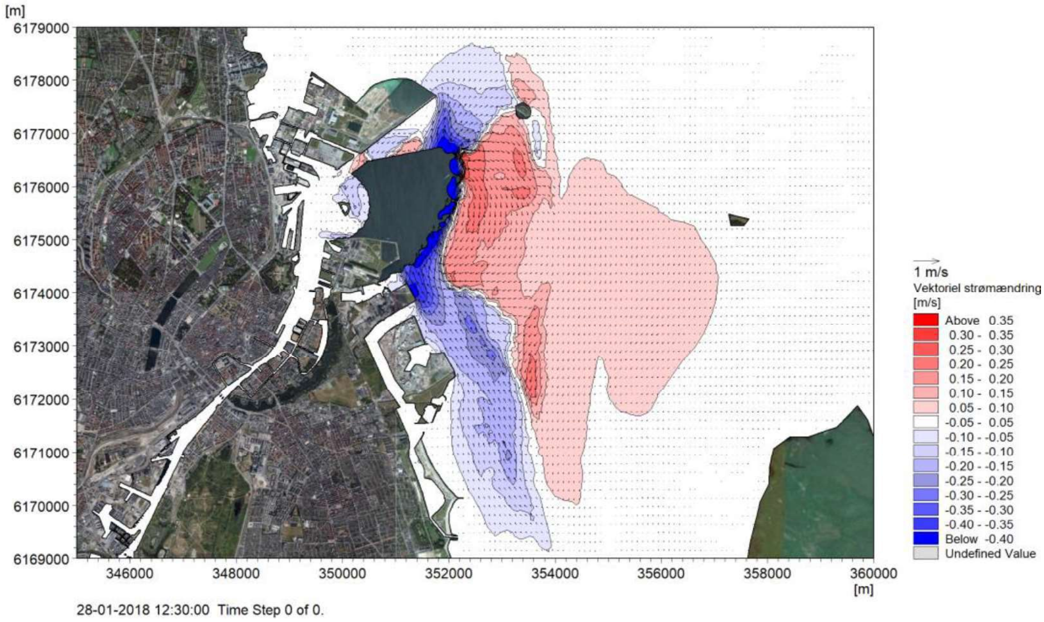


Figure 6-12 Vectorial (top) and scalar (bottom) calculated change of depth-averaged current for conditions of strong southbound flow and reclamation with coastal landscape.

For the same current situation with a solid southbound current, the surface velocities are shown in Figure 6-13 for the existing conditions and Lynetteholm expansion without coastal landscape and in Figure 6-14 for Lynetteholm with a coastal landscape. The surface velocities are higher than the depth-averaged velocities, so the impact appears relatively larger in these plots. A plot of water depths has been inserted again at the bottom of the shape to better understand the current image. The flow is reduced in the area at the north-eastern tip of the Nordhavn reclamation, where surplus water is currently discharged from the ongoing reclamation works. The reduced current conditions will make it easier to dock at the planned container terminal along the north-eastern quay of the Nordhavn reclamation due to the reduced cross-current effects.

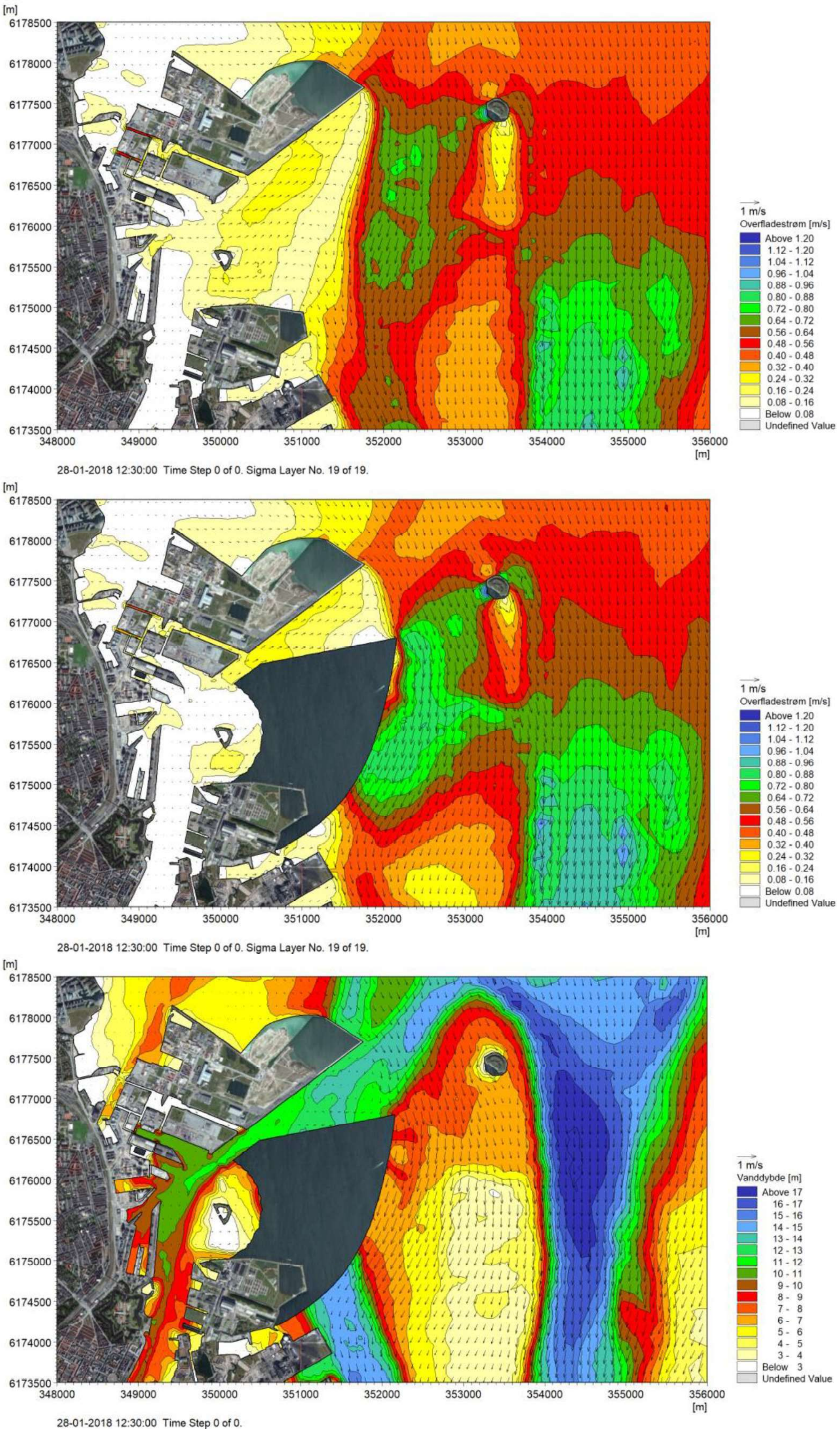


Figure 6-13 Surface velocity under conditions with strong southbound current on 28 January 2018. Top: Existing conditions, Middle: Lynetteholm without coastal landscape, Bottom: Water depths superimposed with the depth-averaged current vectors.

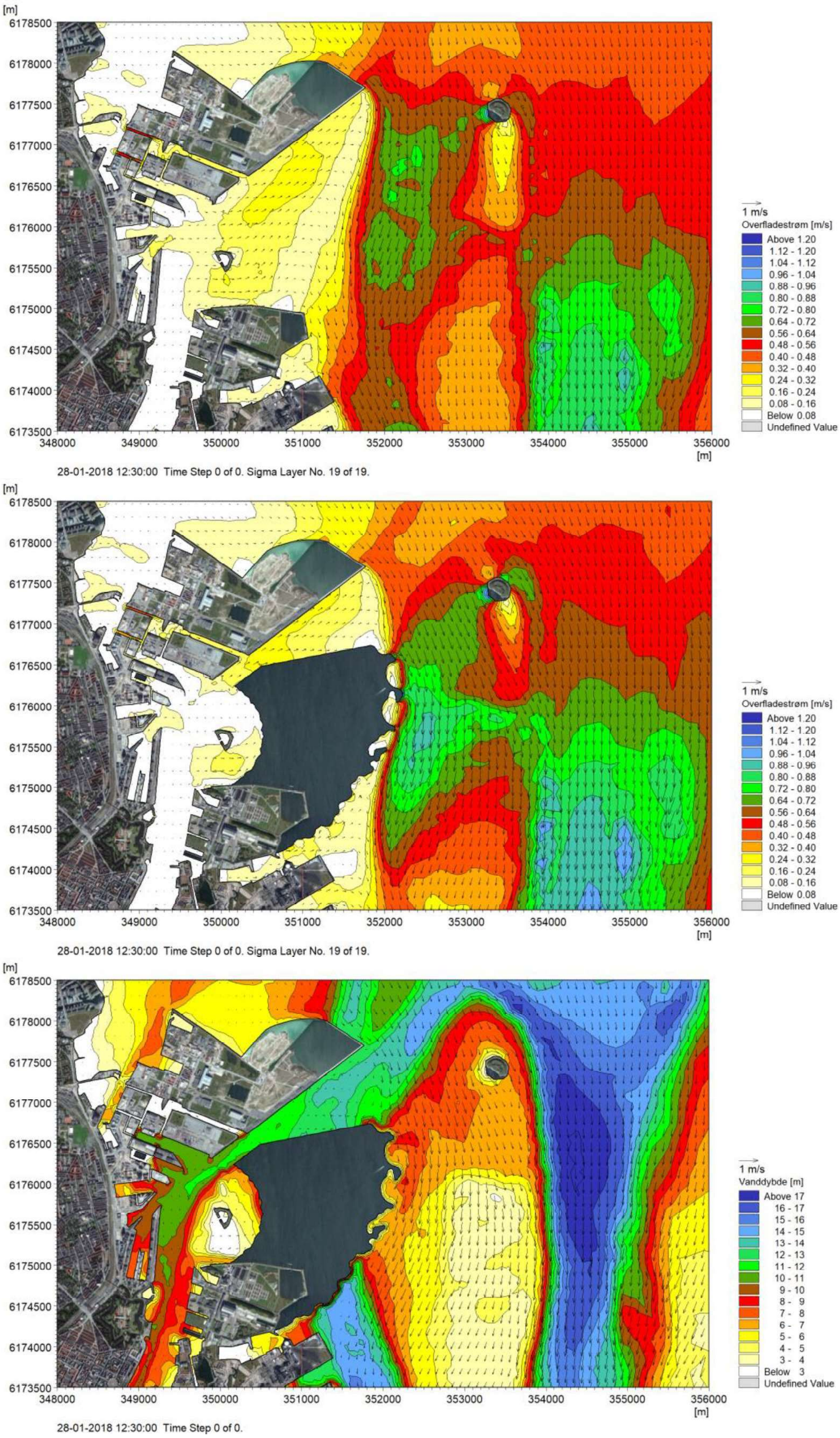


Figure 6-14 Surface velocity under conditions with strong southbound current on 28 January 2018. Top: Existing conditions, Middle: Lynetteholm with coastal landscape, Bottom: Water depths superimposed with the depth-averaged current vectors.

The changes in the surface current of a reclamation without coastal landscape are shown at the top of Figure 6-15, calculated as the vector difference, considering changes in the direction of the current and at the bottom of a scalar calculation, considering only the change in the magnitude of the current. The impact on the surface current is analogous to the depth-averaged change, but the changes are more significant.

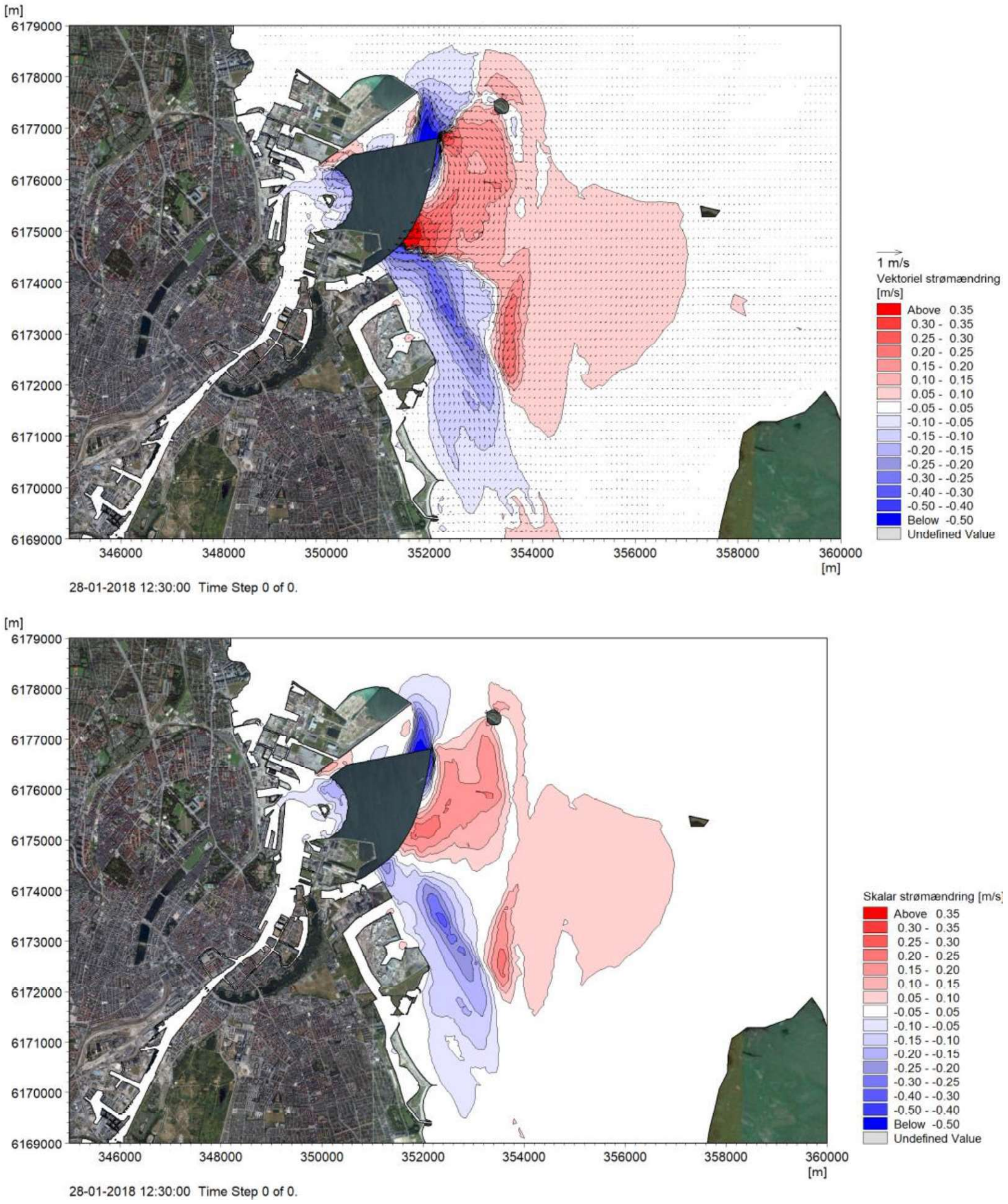


Figure 6-15 Vectorial (top) and scalar (bottom) calculated change of surface current for conditions with strong southbound current and Lynetteholm expansion without coastal landscape.

The corresponding current changes for a reclamation with a coastal landscape are shown in Figure 6-16. In the reclamation with a coastal landscape, the current reduction off the Amager power station is somewhat more considerable than by a reclamation without a coastal landscape. It can also be seen that the current increase in the area east of Lynetteholm is slightly more significant than for a reclamation without a coastal landscape.

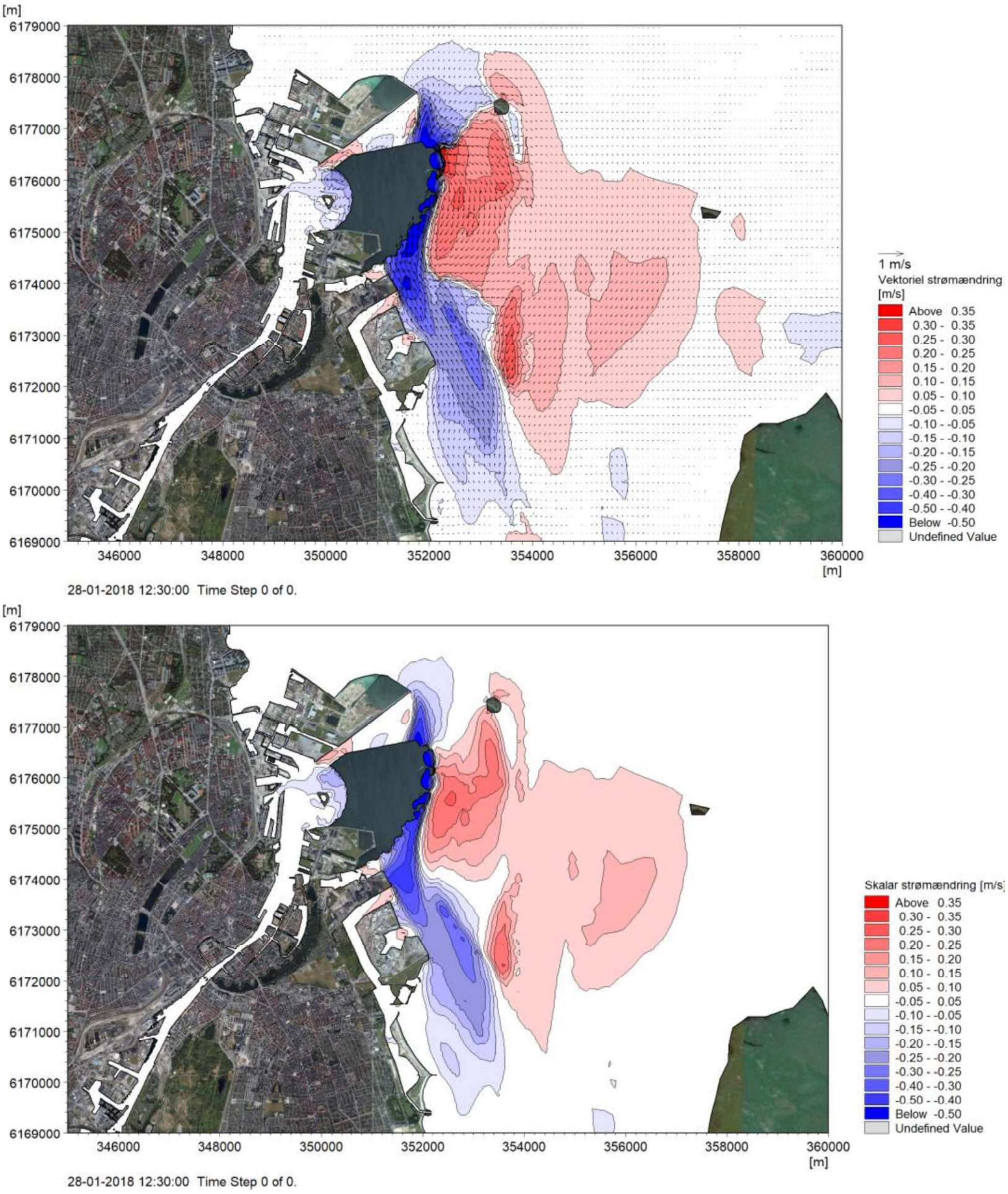


Figure 6-16 Vectorial (top) and scalar (bottom) calculated change of surface current for conditions with strong southbound current and Lynetteholm expansion with coastal landscape.

South of the area shown in the figures above, there is a slight impact on the surface current in the central part of the Drogden trench, which can be seen up to about 4 km south of the Øresund Connection. The impact is typically between 5-7 cm/s. The impact areas for the two reclamations are shown in Figure 6-17. The expansion without a coastal landscape mainly creates a current increase in the area, while the reclamation with a coastal landscape shows an increased current in the western part and damping of the current in the eastern part of the Drogden trench.

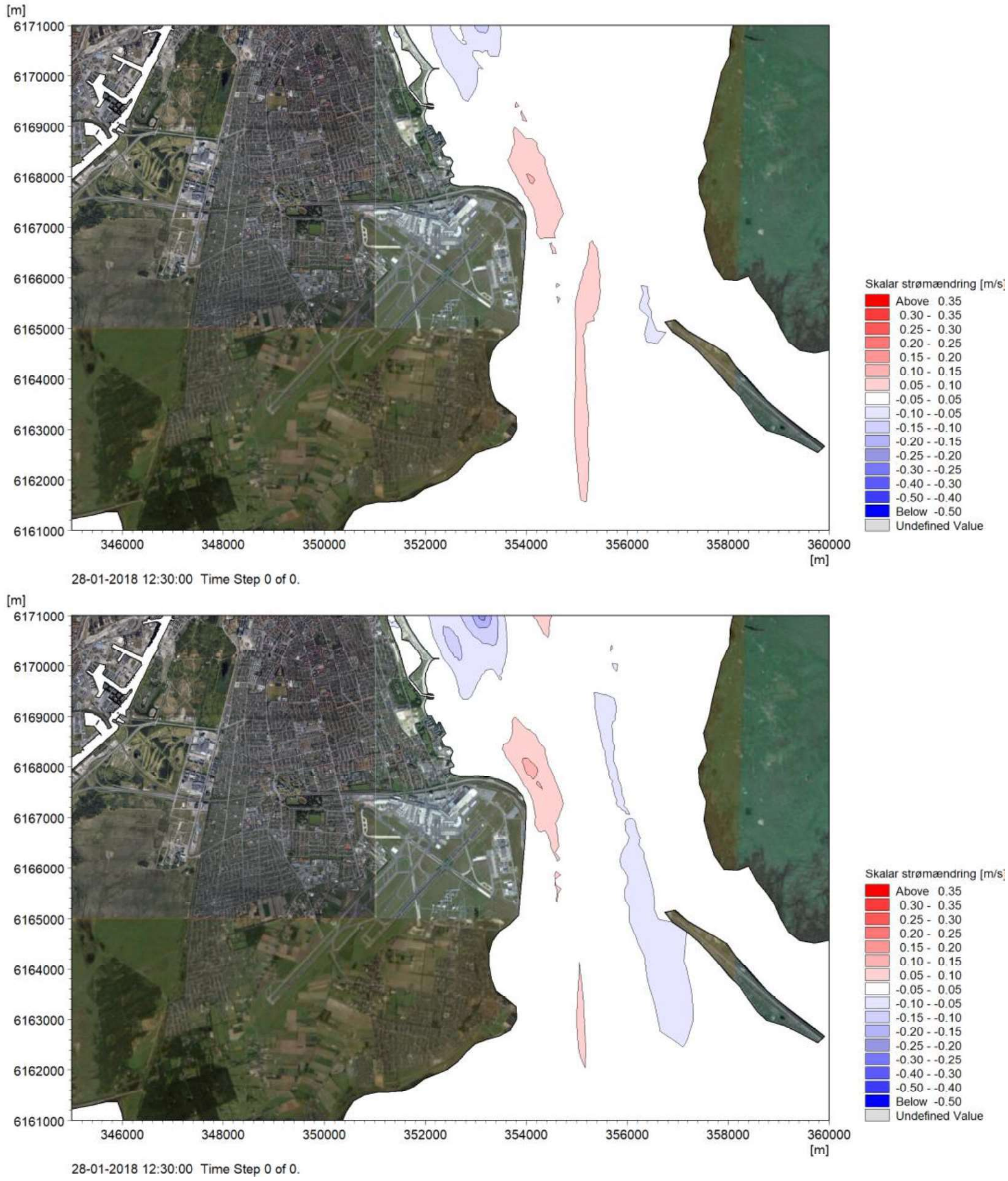


Figure 6-17 Scalar calculated current change in the area south of the reclamation. Top: Reclamation without coastal landscape, Bottom: reclamation with coastal landscape.

Figure 6-18 shows bottom velocities for the same event with a southbound current for existing conditions and a Lynetteholm reclamation without a coastal landscape, and in Figure 6-19 with a coastal landscape. Due to bottom friction, the bottom velocities are lower than the depth-averaged velocities, so the impact appears to be relatively smaller. To better understand the current pattern, a plot of the water depths has been inserted again.

Future changes in current conditions are shown in Figure 6-20 and Figure 6-21 for a Lynetteholm reclamation, without and with a coastal landscape along the eastern perimeter, respectively. These plots also show that the current through Kongedybet is cut and instead is led east of the reclamation across Middelgrunden and via Hollænderdybet.

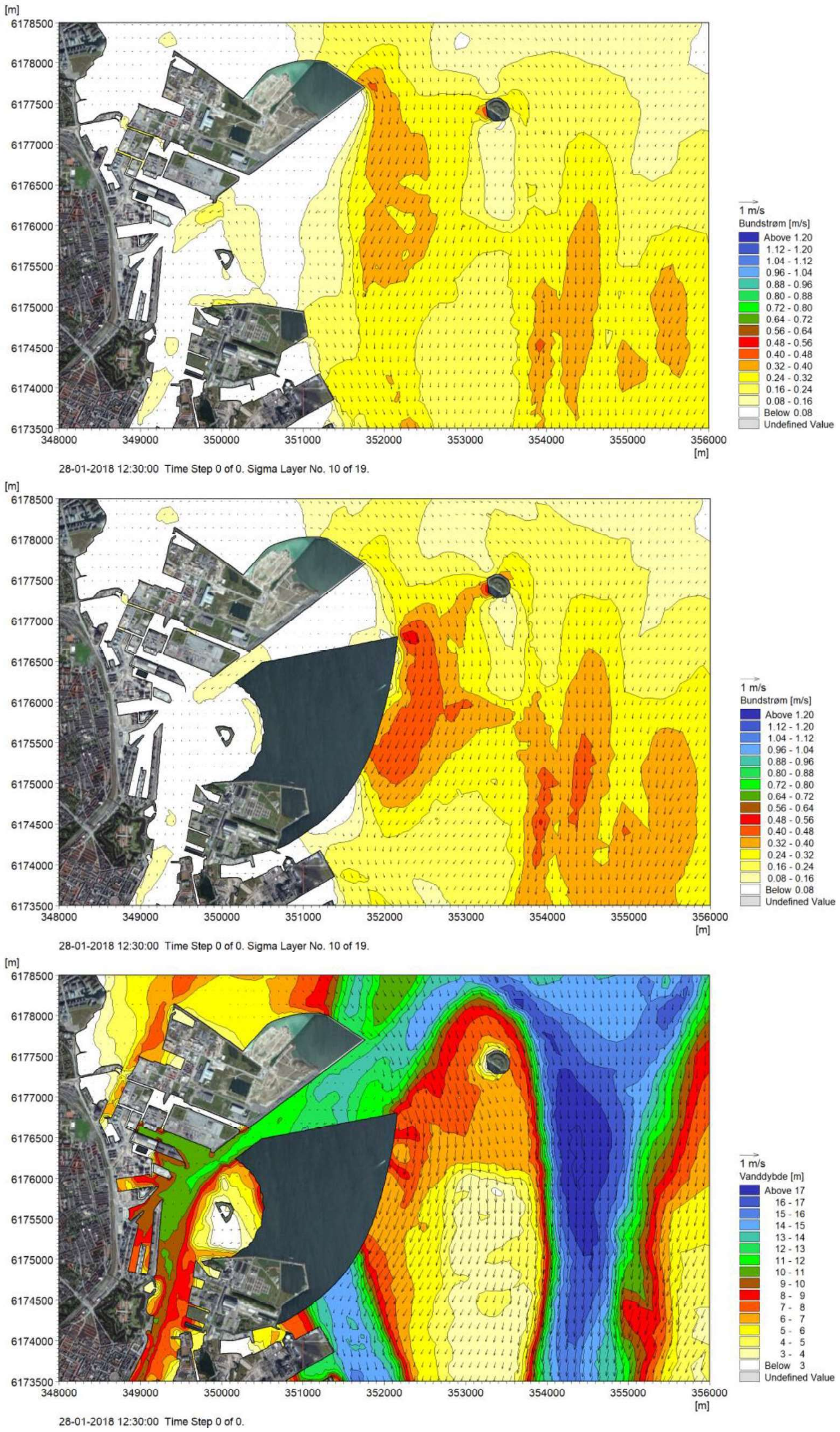


Figure 6-18 Bottom velocity for conditions with strong southbound current. Top: Existing conditions, Middle: Lynetteholm without coastal landscape, Bottom: Water depths superimposed with depth-averaged current vectors for conditions with strong southbound current and water depth.

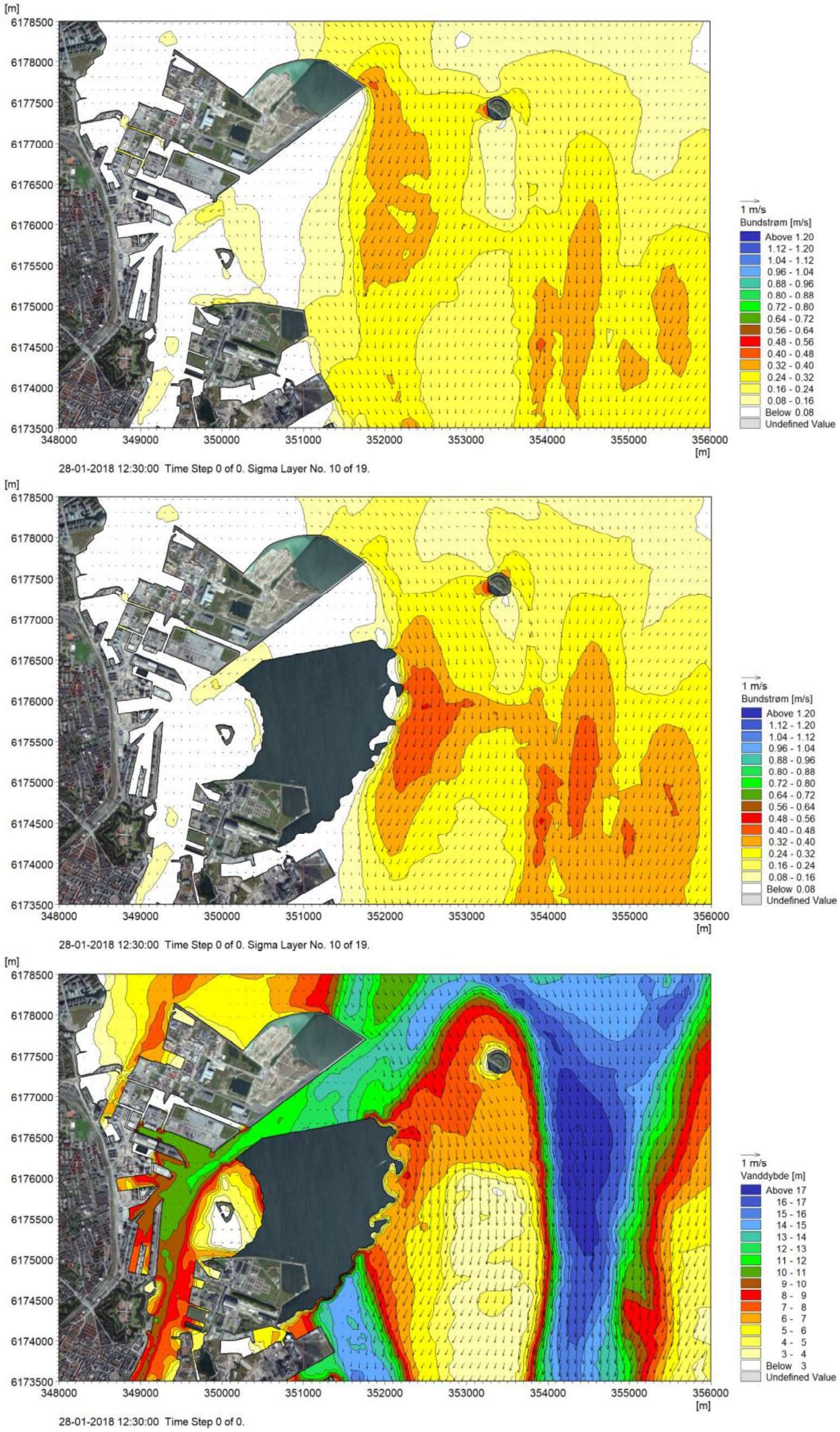


Figure 6-19 Bottom velocity for conditions with strong southbound current. Top: Existing conditions, Middle: Lynetteholm with coastal landscape, Bottom: Water depths superimposed with in-depth-averaged current vectors for conditions with strong southbound current and water depth.

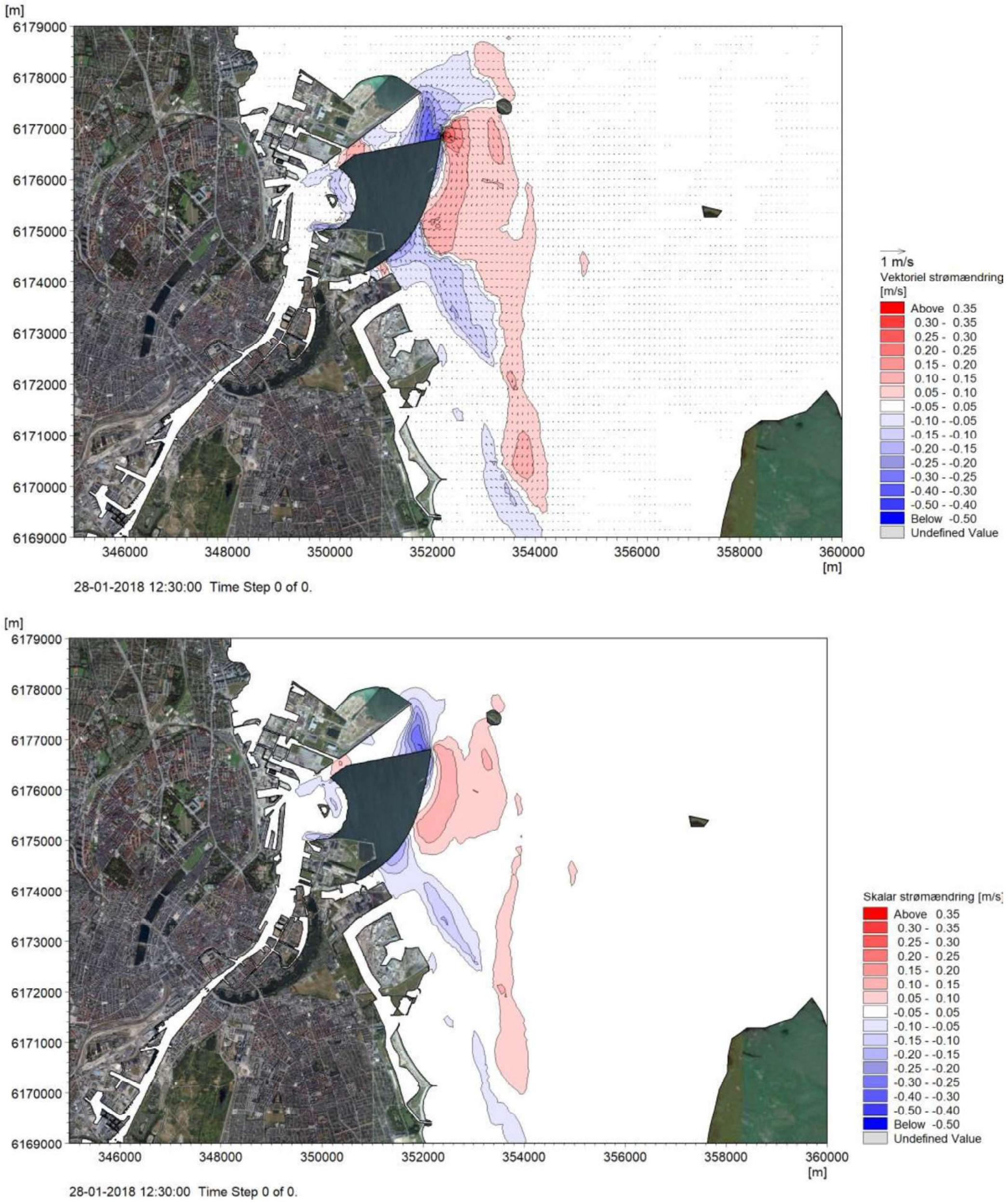


Figure 6-20 Vectorial (top) and scalar (bottom) calculated change of bottom current for conditions with strong southbound current and Lynetteholm reclamation without coastal landscape.

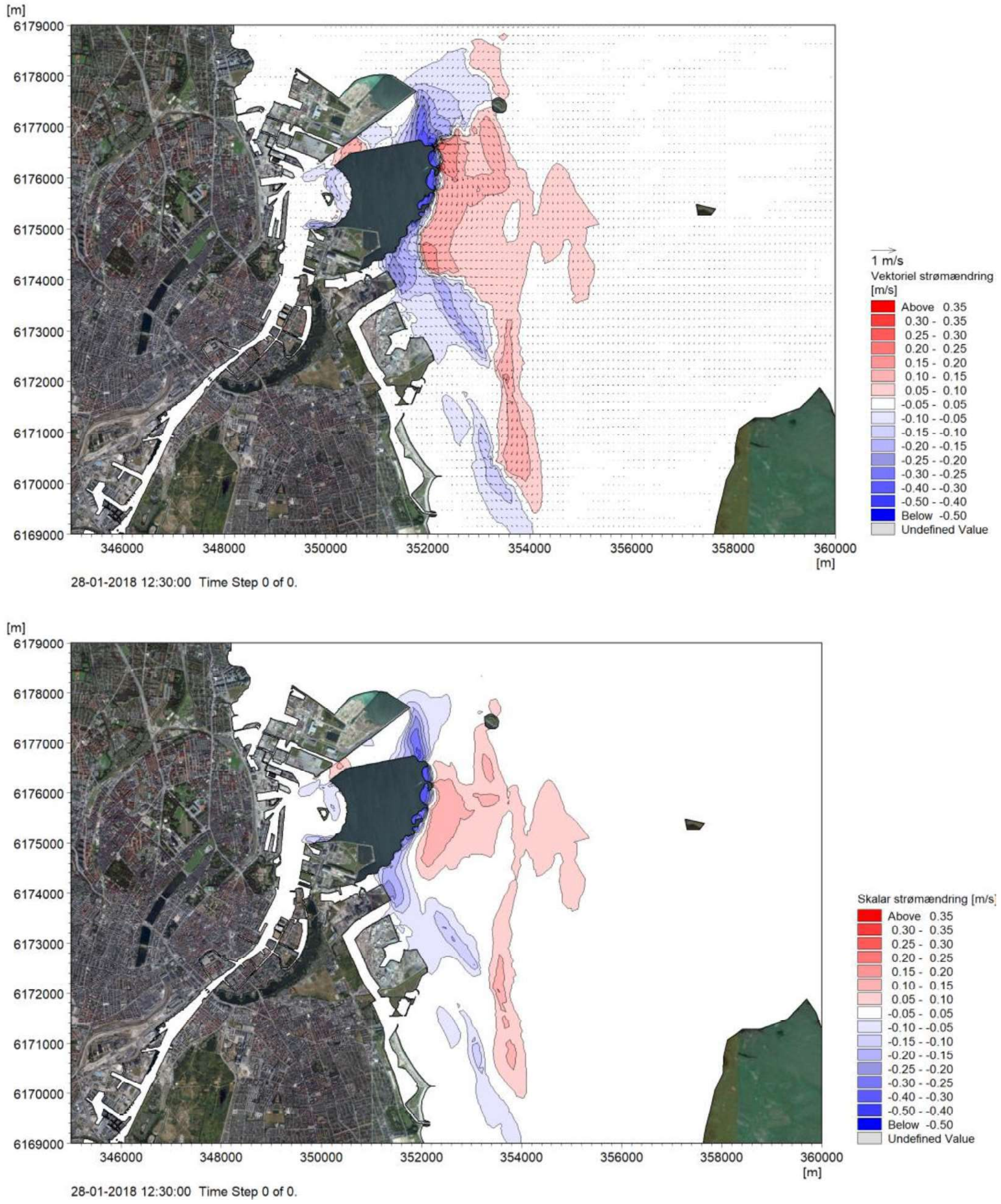


Figure 6-21 Vectorial (top) and scalar (bottom) calculated change of bottom current for conditions with strong southbound current and Lynetteholm reclamation with coastal landscape.

6.1.2.2 Conditions with a strong northbound current

The Lynetteholm reclamation affects the local flow conditions both with and without a coastal landscape along the eastern perimeter. This section highlights the impact of a situation with a solid northbound current. With the closure of Kongedybet, the current from Drogden will be forced further east so that the current weakens in the remaining part of Kongedybet and is reinforced along large parts of Lynetteholm's eastern perimeter as well as in the Hollænderdybet east of Middelgrunden.

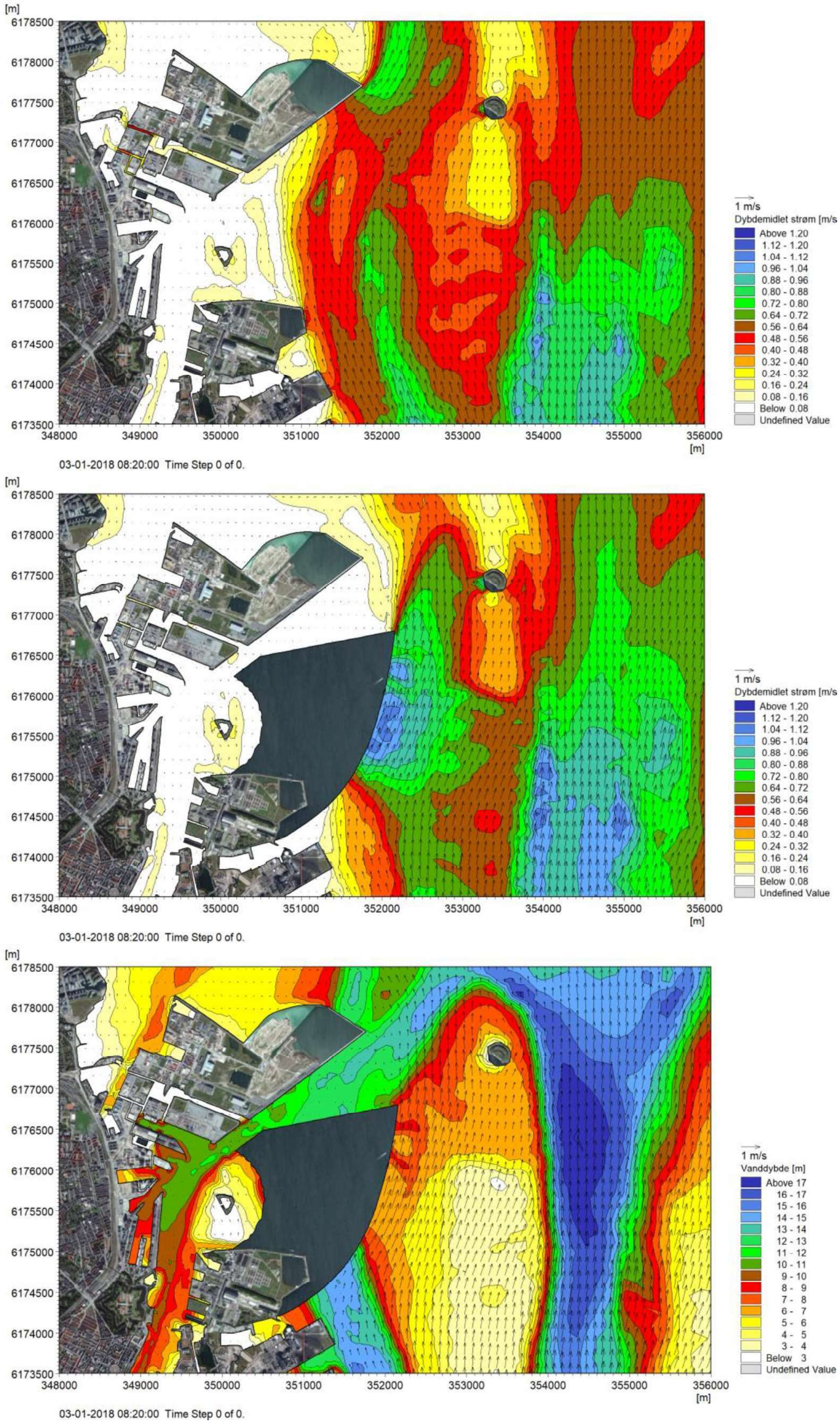


Figure 6-22 Depth-averaged current speed and water depths for conditions with strong northbound currents on 3 January 2018. Top: Existing conditions, Middle: Lynetteholm without coastal landscape, Bottom: Water depths superimposed with current vectors.

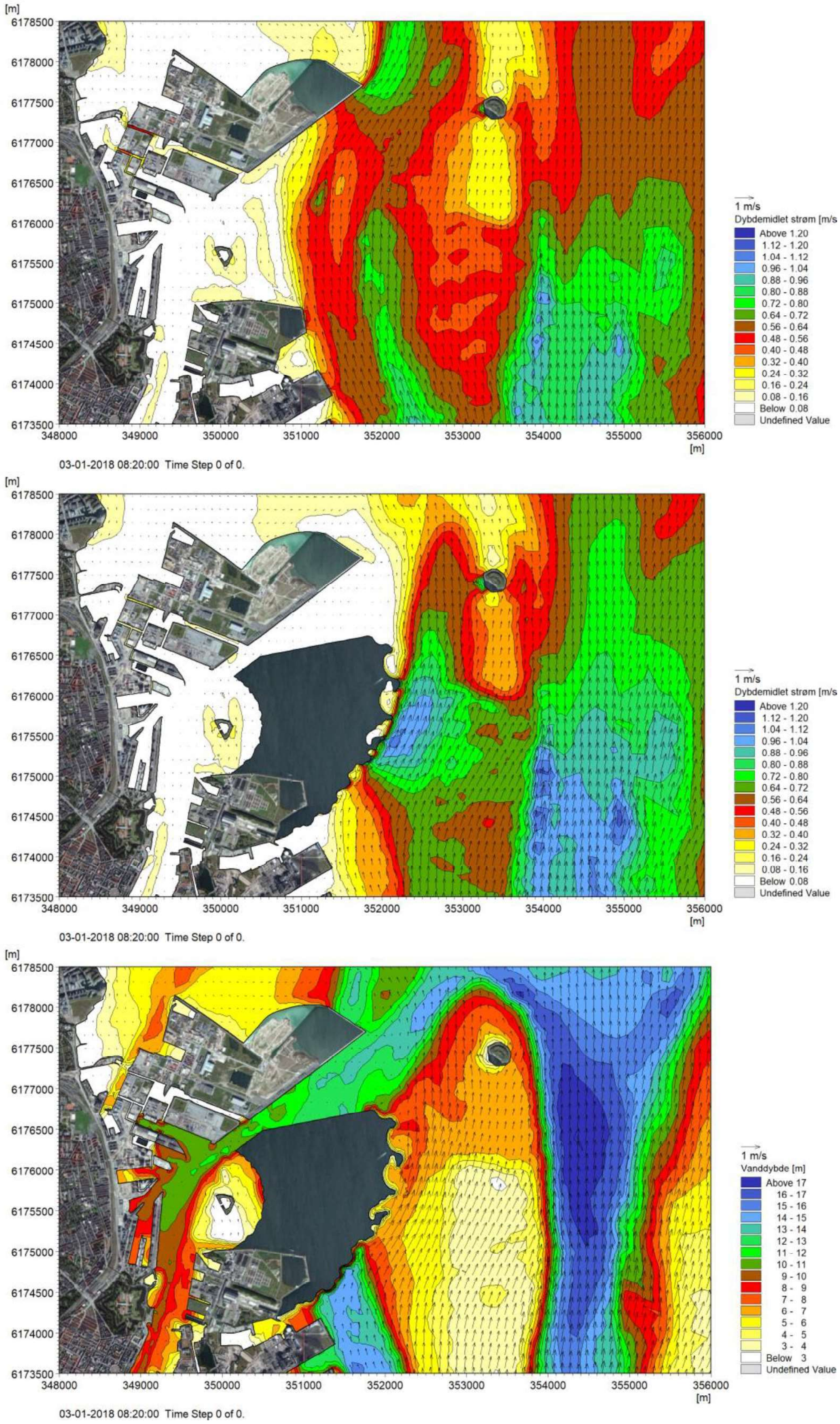


Figure 6-23 Depth-averaged current speed and water depths for conditions with strong northbound currents on 3 January 2018. Top: Existing conditions, Middle Lynetteholm with coastal landscape, Bottom: Water depths superimposed with current vectors.

Based on existing conditions Figure 6-22 (top) shows a depth-averaged current field for a situation of a strong northbound current (3 January 2018). The corresponding situation with Lynetteholm without a coastal landscape is shown at the bottom of the figure. Similarly, Figure 6-23 shows the current conditions with a coastal landscape. The current velocities during this northbound event are somewhat higher than during the southbound event described above.

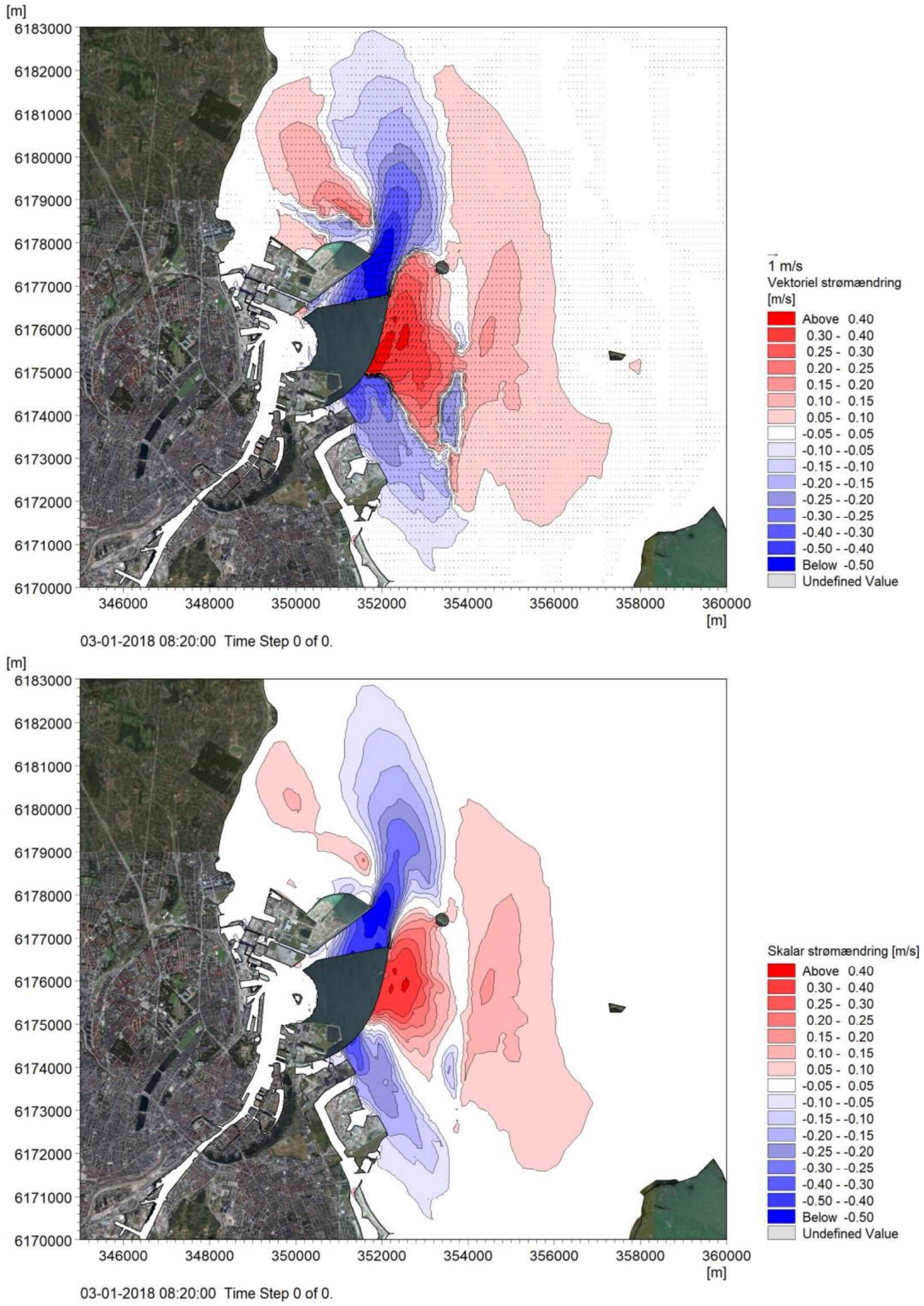


Figure 6-24 Vectorial (top) and scalar (bottom) calculated change of depth-averaged current for conditions of strong northbound current and reclamation coastal landscape.

It can be seen that a current increase occurs along with large parts of the eastern perimeter, but that the current weakens east of the Nordhavn tip and in Kongedybet off Amager power station as well as the Prøvestenen south of Lynetteholm. There is a current shelter in the concave pockets where beaches are established in the layout with a coastal landscape. The pockets with current shelters ensure safe bathing conditions. Outside the pockets, on the other hand, the current will often be strong, and bathing must therefore be discouraged in these areas. A plot of the water depths has been inserted at the bottom to better understand the current image at the time in question.