Fehmarnbelt Fixed Link (coast-coast)

TRANSBOUNDARY ENVIRONMENTAL IMPACT ASSESSMENT

Documentation for
the Danish Espoo Procedure

Femern Sund≈Bælt

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1 SUMMARY

1.1 INTRODUCTION TO THE FEHMARNBELT FIXED LINK

This report, hereafter the Espoo Report, constitutes the transboundary environmental impact assessment for the Fehmarnbelt Fixed Link to be used for the consultation of the Baltic Sea countries and Norway in accordance with the Espoo Convention on Environmental Impact Assessment in a Transboundary Context, hereafter "the Espoo Convention" or "the Convention".

The Fehmarnbelt Fixed Link is a joint Danish and German transport infrastructure project across the Fehmarnbelt. The project has been planned in accordance with the 2008 Treaty between the Kingdom of Denmark and the Federal Republic of Germany for a fixed link across the Fehmarnbelt.

The Kingdom of Denmark is responsible for the planning, construction, and operation of the Fehmarnbelt Fixed Link. In order to carry out this task, the government of Denmark has established the company Femern A/S, which is 100 % owned by the Danish State, represented by the Danish Ministry of Transport.

The Fehmarnbelt Fixed Link has been planned as a consequence of Denmark and Germany recognising that the transport infrastructure between the two states must be improved in order to promote the European and regional transport of goods and people.

A fixed link across the Fehmarnbelt would lead to an appreciable improvement in the transport of goods and people between the two countries, and also between continental Europe and Scandinavia, as well as to a promotion of rail traffic and a strengthening of integration, vitality, competition, and development in the regions.

FIGURE 1.1 **The Fehmarnbelt Region**

The fixed link across Fehmarnbelt will extend to stretch across the 18 kilometre wide Fehmarnbelt between the Danish island of Lolland and the German island of Fehmarn in the western part of the Baltic Sea.

The Fehmarnbelt Region is demarcated as the northern part of Germany, the eastern part of Denmark and the southern part of Sweden (Figure 1.1). The region has a population of almost 9 million, approximately 1.2 million in the Swedish part, 2.5 million in the Danish part and 5.2 million in the German part.

The Fehmarnbelt Fixed Link covers areas on Lolland (Denmark), Fehmarn (Germany) and a marine area (Denmark and Germany). The project crosses the national border between Denmark and Germany.

Construction work will take place within the national jurisdictions of both countries.

Femern A/S has investigated four technical solutions.

The Fixed Link is planned as an approximately 18 kilometre long immersed tunnel; because the investigations and planning indicate that an immersed tunnel is the best solution in terms of e.g. technical construction risks, construction investments, and environmental factors.

The four technical solutions investigated are: An immersed tunnel, a bored tunnel, a cable-stayed bridge, and a suspension bridge. For each technical solution, possible alignments have been investigated, and a comparison of the technical alternatives has been performed.

A summary of the investigations as well as background for the final selection of the technical solution is presented in this report. As the immersed tunnel is the project being applied for and hereby the preferred solution, focus in this report is on the immersed tunnel.

1.2 BACKGROUND FOR ESPOO PROCESS

The Fehmarnbelt Fixed Link is subject to a transboundary environmental impact assessment according to the Espoo Convention and the EU Directive 85/337/EEC, as the Fehmarnbelt Fixed Link can potentially cause transboundary environmental impacts.

The Espoo Convention's primary aim is to prevent, mitigate and monitor environmental damage by ensuring that explicit consideration is given to transboundary environmental factors before a final national decision is as to whether to approve a project.

In addition, the objective of the Espoo Convention is to identify and communicate potential transboundary impacts to stakeholders via an impact assessment.

According to Article 3 of the Espoo Convention, the Parties of Origin are responsible for the content and acknowledgement of receipt of notifications, and for the exchange of relevant information to/from the potentially affected countries.

For a transnational project such as the Fehmarnbelt Fixed Link Project, both Denmark and Germany are parties of origin.

In Denmark, the Danish Ministry of Environment is responsible for the above-mentioned exchange of relevant information to and from the potentially affected countries in connection with the Danish Espoo procedure.

According to Article 3 of the Espoo Convention, Germany and Denmark must notify affected parties. In relation to the Fehmarnbelt Fixed Link, the possible affected parties, apart from Denmark and Germany, could be countries around the Baltic Sea: Sweden, Poland, Finland, Estonia, Latvia, Lithuania, the Russian Federation and Norway.

The Espoo documentation is focused on providing sufficient background information, including baseline data, in order to facilitate the identification of transboundary impacts, but does not replicate all of the detailed material that is required of the national EIAs. The Espoo Report methodology corresponds to the Danish EIA report methodology, and therefore it describes the impacts expected from the project as well as mitigation measures.

According to the Espoo Convention all potentially affected parties are notified and invited to participate in the EIA procedure. Responses to this notification have been evaluated and taken into account by Femern A/S, the State Company for Road Construction and Transport of Schleswig-Holstein, and the Danish Ministry of the Environment, and are addressed in the Espoo Report.

1.3 PLANNING OF ALIGNMENT – IMMERSED TUNNEL

To find the most expedient location of the coast-to-coast project, the alignment has been decided on the basis of an environmental sensitivity analysis and an alignment analysis. The analyses were conducted in an early phase of the project, based on existing knowledge, and concentrated on the most significant differences between the alignment alternatives.

In both the marine area and on Lolland and Fehmarn, the environmental sensitivity analysis suggested that the eastern project corridor has a lower environmental impact than a western corridor, since it passes through fewer areas with a high conflict potential.

On the basis of the environmental sensitivity analysis, four approaches on both Lolland and Fehmarn were identified within the eastern and western corridors, giving a total of 16 different combinations of alignment for both a tunnel solution and a bridge solution.

An alignment analysis was prepared for each of the technical solutions to accommodate different interests and to allow for material goods in the seabed, such as submarine cables.

The identification of the alignment for the tunnel solution is based on two limitations: 1) the ferry operation between Rødbyhavn and Puttgarden must be operable during the construction and operation phase, and 2) the submarine cable, located below the seabed between Lolland and Fehmarn, must not be impacted. Due to these limitations, alignments which fully or partly make use of the harbour facilities, impact the submarine cable or intersect with the ferry route have been rejected.

Based on an environmental assessment, the alignment alternatives west of Rødbyhavn harbour and Puttgarden harbour for both the tunnel and bridge are considered less expedient and have been rejected, thereby reducing the number of alignment alternatives to two for both the tunnel and bridge solutions. The two preferred alternatives have an approach on Lolland either 1 or 1.5 km east of Rødbyhavn on Lolland and the same approach east of Puttgarden on Fehmarn. Comparison of the two alignments showed only minor differences, with a small advantage to the approach 1 km east of Rødbyhavn.

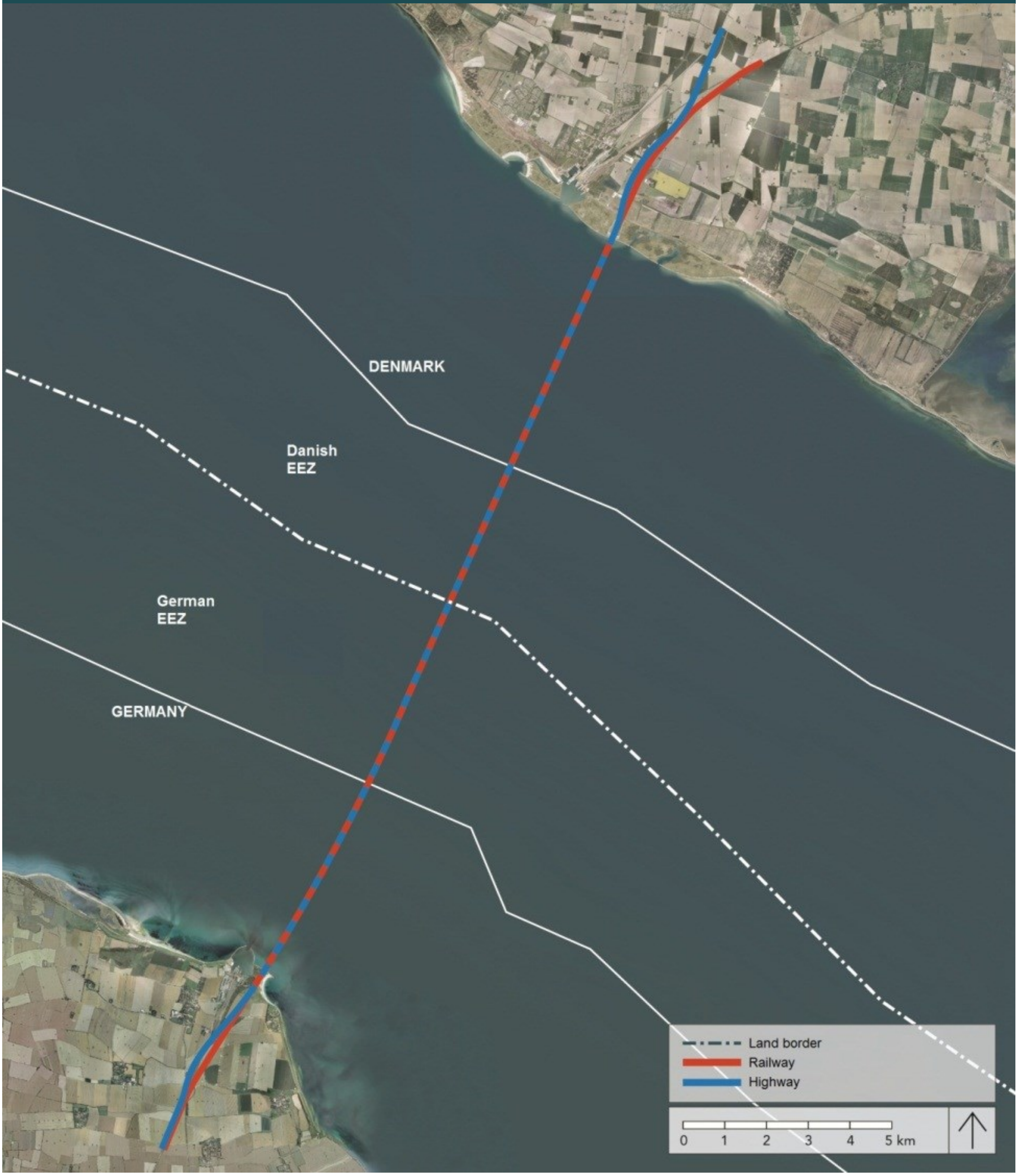
Based on these results, Femern A/S has concluded that the eastern corridor is the project corridor that has the lowest environmental conflict potentials. Furthermore, Femern A/S has presented its proposal for the alignment of the immersed tunnel which is located within the eastern corridor. After publication of proposals for the alignment in 2010, this has formed the basis of a continued planning process and dialogue with authorities and landowners.

1.4 IMMERSED TUNNEL – TECHNICAL DESCRIPTION

Based on investigations of different technical solutions, Femern A/S has chosen an immersed tunnel as the preferred technical solution for a fixed link between Lolland in Denmark and Fehmarn in Germany. From an early point in the project, analyses were carried out to define a project corridor and possible alignments with the least possible impact on the environment. Based on existing knowledge, the different alternatives and alignments were compared, and an immersed tunnel between land approaches east of Rødbyhavn and east of Puttgarden was chosen as the most expedient solution for a fixed link (Figure 1.2).

From coast to coast, the project comprises an approximately 18 km long immersed tunnel with a four lane motorway and dual track railway, as well as permanent and temporary structures in connection with the construction and operation of an immersed tunnel (Text box 1.1).

FIGURE 1.2 **Conceptual design of an immersed tunnel – Alignment for the fixed link across the Fehmarnbelt**



Text box 1.1

The main elements in the immersed tunnel solution as the fixed link between Fehmarn and Lolland are:

- A dual track railway and a four lane motorway link with emergency lanes in both directions in an immersed tunnel
- Cut-and-cover tunnels at each approach on the Danish and German sides, linking the immersed tunnel to the portal buildings
- Portal building at each tunnel mouth
- Ramps for the road and railway in connection with the tunnel
- Road and railway connections on both sides, linking the tunnel to existing infrastructure
- Land reclamation areas on both coasts
- Toll station - on the Danish side
- Facilities for operation and maintenance, including facilities for customs and emergency authorities
- Modifications to the surrounding secondary road network, including the construction of new local roads, etc.

The design speeds of the tunnel:

- Passenger train traffic: Maximum 200 km/h
- Goods train traffic: Maximum 140 km/h
- Road traffic: Maximum 130 km/h

1.4.1 Permanent structures

The planned immersed tunnel across the Fehmarnbelt will consist of a cut-and-cover tunnel at the two approaches and an immersed tunnel between the two approaches. The immersed tunnel will be placed in a tunnel trench and backfilled with sand and locking fill. The top of the immersed tunnel is planned to be covered with an approximately 1 meter thick layer of rocks. This top layer protects the immersed tunnel from marine activities such as sinking ships and anchors, and it is designed as an environmental optimisation in order to prevent impacts on the marine environment (Figure 1.3).

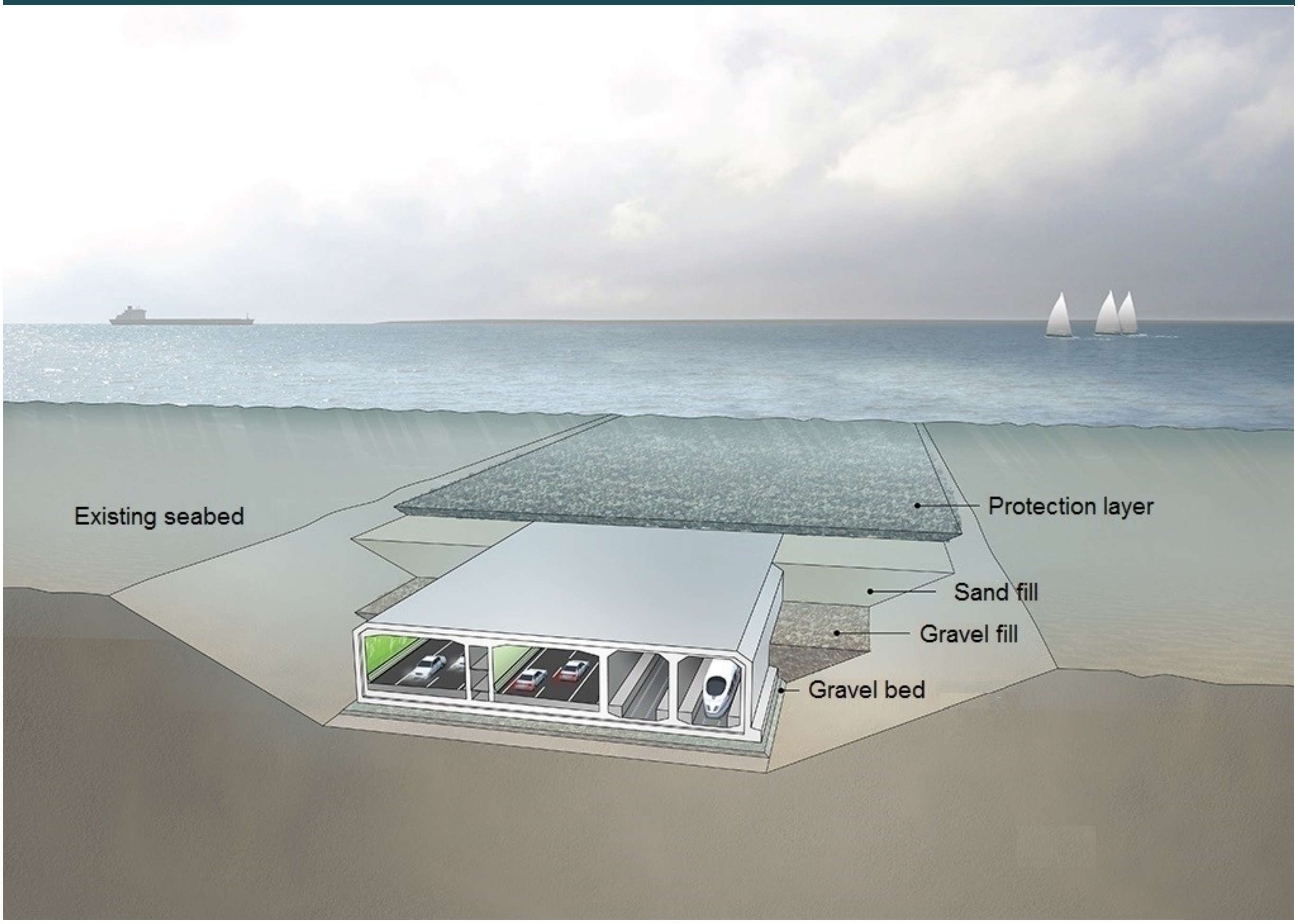
At both the Danish and German approach, a portal building is planned to be established on top of the cut-and-cover tunnel. Coastal protection in the form of dikes are planned to be placed around the portal and ramp with a height which will prevent flooding in the event of extreme high-water and wave conditions.

A toll station is planned to be located in accordance with the state treaty between Denmark and Germany on the Danish side. In the same place approximately 1 kilometre from the coastline, border control facilities and a technical supervision and communication centre will be placed.

A new drainage system for the immersed tunnel, motorway, railway, toll station etc. will be established on both the Danish and German side. Rainwater accumulated by the immersed tunnel and water from cleaning the immersed tunnel is planned to be collected in pump wells placed by each portal building. From here the water is pumped to existing water treatment plants in either Rødbyhavn or Puttgarden. Rainwater collected from the land works is planned to be led to rainwater basins, in order to treat run-off and contain any polluted spillages. From the basins the water will run through existing or altered channels to be discharged into Fehmarnbelt.

Furthermore the construction of a motorway requires diversion or alteration of some local roads and paths on both the Danish and the German side.

FIGURE 1.3 Conceptual design of an immersed tunnel – Cross section of dredged trench with tunnel element and backfilling



1.4.2 Land reclamation areas

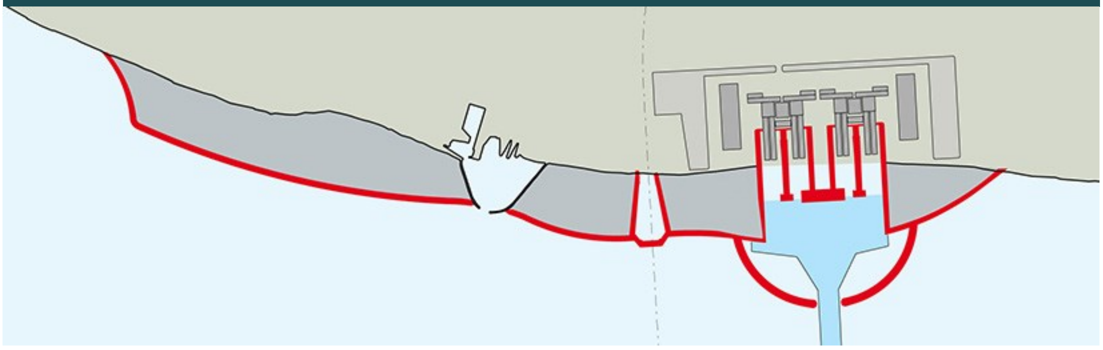
The conceptual design for the immersed tunnel solution includes the establishment of land reclamation areas at both Lolland and Fehmarn. The purpose of the reclamation is to utilise excess seabed material from the dredging of the tunnel trench and the work harbour for purposes which will add natural and recreational value to the local area. On Lolland, the area will also be used as the location for part of the replacement of nature areas which Femern A/S must establish, having appropriated nature areas on Lolland for the purpose of the project.

It is estimated that the dredging volume of marine sediment will be approximately 19 million m^3. Most of the sediment is planned to be used in the construction of the land reclamation area at Lolland (approximately 17 million m^3), while about 2 million m^3 will be used on German territory as new land reclamation or within the project.

The land reclamation area on Lolland is planned on each side of the work harbour and extends from this point approximately 3.5 km to the west and approximately 3.7 km to the east. The total area is approximately 330 ha (measured as area of seabed and including water areas inside the reclamation areas), and it will comprise both natural and recreational areas including beaches, dunes and salt meadows (Figure 1.4).

The planned land reclamation on the Fehmarn coast in Germany extends about 500 m along the existing coast east of the ferry harbour, and about 500 m from the existing coast line into the Fehmarnbelt. The total area is planned to be approximately 32 ha (measured as area of seabed and including water areas inside the reclamation areas). The land reclamation area is withdrawn from the tip of the jetties at the existing ferry harbour at Puttgarden to minimise the impacts on the marine environment. The area will comprise pastures and grassland as well as a new beach near Marienleuchte.

FIGURE 1.4 Placement of the tunnel portal production facility east of Rødbyhavn. Principle of establishment of the land reclamation area at Lolland with dikes around the landfill



1.4.3 The construction phase

First the cut-and-cover tunnels are planned to be established, beginning with dredging work, and then the tunnels will be cast in-situ and ultimately covered. On top of the cut-and-cover tunnels, the portal buildings on both the Danish and the German side will be constructed.

The immersed tunnel is planned to be constructed from prefabricated tunnel elements cast in an element factory. The tunnel elements are planned to be tugged from the production site by boat to the alignment, where they will be immersed and assembled in a dredged tunnel trench.

Production facility

An area east of Rødbyhavn in Denmark has been designated for the construction of a purpose-built casting factory at which the tunnel elements are to be produced. The production facility is partly located onshore and partly off the existing coastline (Figure 1.4).

Cut-and-cover tunnel and portal building at Lolland

The cut-and-cover tunnel on Lolland must be constructed in a dammed area just south of the existing coastline. Here dredging is planned to be performed in an initially dammed area of approximately 500 x 250 m. Then the cut-and-cover tunnel is planned to be cast in-situ and the first immersed tunnel element to be installed in continuation of the cut-and-cover tunnel. The portal building and the permanent coastal protection will then be established, and the cut-and-cover tunnel will be covered and the final terrain formed.

Cut-and-cover tunnel and portal building at Fehmarn

A work harbour is planned to be established at Puttgarden in Germany. As it was the case on Lolland, the cut-and-cover tunnel on Fehmarn is planned to be constructed in a dammed area just north of the existing coastline. Here dredging will initially be performed to approximately the level of the underside of the cut-and-cover tunnel. Then the cut-and-cover tunnel is planned to be cast in-situ, and the first tunnel element to be immersed in continuation of the cut-and-cover tunnel. The portal building, the ramp structures for road and rail, and the permanent coastal protection will then be established, the cut-and-cover tunnel will be covered and the final terrain formed.

Dredging of tunnel trench

The tunnel trench appropriates an area of the seabed of around 17.6 km * 110 m, and dredging of the tunnel trench is expected to last approximately 1.5 years. The overall dredging works, including backfilling of the tunnel trench, is in total expected to last approximately 4.5 years.

Construction estimate

The construction estimate for the immersed tunnel is calculated to approximately EUR 5.5 billion (2008 prices).

1.5 ALTERNATIVE TECHNICAL SOLUTIONS AND ALTERNATIVE ALIGNMENTS

Femern A/S has investigated four technical solutions for a fixed link over the Fehmarnbelt: An immersed tunnel, a bored tunnel, a cable-stayed bridge, and a suspension bridge. For all four technical solutions planning for possible alignments has been conducted and the preferred alignment selected. Based on the results of the technical investigations of the four solutions, the immersed tunnel is chosen as the preferred technical solution and the other solutions are deselected.

A 0-alternative has also been described for comparison of the immersed tunnel with reference conditions. The 0-alternative describes a situation where the fixed link across the Fehmarnbelt would not be constructed, where the ferry service Rødby-Puttgarden would continue and where consequently no Danish or German land works would be needed.

1.6 TRANSBOUNDARY IMPACT ASSESSMENT

It has been examined whether the construction and operation of an immersed tunnel under the Fehmarnbelt will result in transboundary impacts between Germany and Denmark (countries of origin), and between the countries of origin and third party countries.

This chapter summarises the transboundary impacts of the immersed tunnel during its construction and operation.

The investigations carried out show that the transboundary impacts of the Fehmarnbelt Fixed Link are only temporary, and mostly limited to the construction phase. The types of planned activities with potential impacts include dredging of the tunnel trench, seabed intervention works, all construction related vessel movements and anchoring, and operation of the tunnel.

Potential impacts from the construction and operation of the tunnel have been identified and assessed. In order to determine the significance of the potential impact on the environment, the impacts have been compared with the existing environmental conditions (the baseline conditions) in the Fehmarnbelt area and the conditions at the potential extraction sites at Rønne Banke and Kriegers Flak, where sand can be extracted for production of tunnel elements and for backfilling of the tunnel trench, respectively. Both potential extraction sites are located in the western part of the Baltic Sea.

Environmental and technical investigations have been carried out, allowing optimisation of the tunnel project during the design phase thereby avoiding and minimising some of the potential impacts caused by the construction and operation of the tunnel. Furthermore, the assessment includes proposals for mitigation measures in order to minimise possible impacts. These proposals can be found in the complete sections describing the respective components in this report.

Below is presented a summary of the results of the environmental assessment of transboundary impacts.

1.6.1 People and Health

An infrastructure project like the construction and operation of an immersed tunnel across the Fehmarnbelt might affect people and their health. This section looks at possible transboundary impacts on people and health.

The relevant project pressures for people and health are the following:

- Air pollution from construction activities on Lolland and Fehmarn and offshore
- Noise pollution from construction activities on Lolland and Fehmarn and offshore

Transboundary impacts
The potential transboundary impacts from these pressures are air pollution and noise, as all other pressures are of a local nature. Potential impacts on humans are assessed to be on construction workers offshore.

Air pollution
Because of the relatively low number of construction ships, the distance to land on both sides, and the generally good air circulation at both German and Danish sides and at sea, no transboundary impacts from air pollution on human health are expected as a consequence of the construction and operation of the immersed tunnel.

Noise
Noise from construction activities undertaken on Lolland and Fehmarn cannot have transboundary impacts, because of the distance to the opposite coast. Only construction activities in the middle of the Fehmarnbelt can be of a transboundary nature. However, because of the distance, it is assessed that the noise levels will not be heard far away. The only persons close to the middle of the Fehmarnbelt will be construction workers. The construction workers working offshore will be wearing hearing protection (among other protective gear) and will not be affected by high noise levels, should they occur. It is therefore concluded there will be no transboundary impacts from noise on human health as a consequence of the construction and operation of an immersed tunnel.

Transboundary impacts between Germany and Denmark
The investigations show that during construction and operation of an immersed tunnel, the project pressures on people and health on the Danish side will not cause any significant impacts for these on the German side, and vice versa.

Conclusion
The investigations and the environmental assessment show that there will be no transboundary impacts on people and health from the construction and operation of an immersed tunnel. The project pressures on the Danish side will not cause any impacts on people and health on the German side, and vice versa.

1.6.2 Hydrography

The hydrography of the Fehmarnbelt and adjacent water areas are very important, as the water flow, physical property and wave action set the frame for a number of environmental factors. The Baltic Sea is classified as an "estuary", due to its waters, which are a combination of fresh water runoff from its catchment and saline water from the North Sea. The Baltic Sea is one of the largest estuaries in the world.

The marine structures of the tunnel project may affect the hydrographical conditions in the Baltic Sea through two mechanisms, which are considered as project pressures: 1) Project structures potentially cause a blocking of the exchange flow between the North Sea and the Baltic Sea and thereby may impact the salinity and water quality in the Baltic Sea; 2) Project structures potentially causing additional mixing between the lower (high salinity) and upper (low salinity) layers of water in the Fehmarnbelt and thereby having an effect on the salinity and stratification of waters in the Baltic Sea. In relation to these hydrographical conditions, factors such as water exchange flows, current speeds, water levels, salinity, temperature and stratification have been investigated in German and Danish territories and transboundary waters.

Transboundary impacts

The results of the investigations show that the blocking of the water exchange flow with the Central Baltic Sea in the construction period is estimated to be -0.01%, which is similar to the permanent conditions after the construction period. This indicates that the work harbour and production facility impacts, which are project pressures during the construction period on the water exchange, are negligible. This also implies that there is no significant impact on the hydrography of the Central Baltic Sea in the construction period. The small blocking percentage is due to the minimal impact of the project structures on the flow through the Fehmarnbelt.

The impacts of construction and operation of the immersed tunnel on hydrography are therefore considered small or non-existing.

Transboundary impacts between Germany and Denmark

The changes in other hydrographical parameters such as water levels, salinity, temperature and stratification have also been assessed to be negligible. It is assessed that the hydrographical changes in the Danish waters do not cause any subsequent changes in the German waters, and vice versa.

Conclusion

The investigations and assessment show that construction and operation of an immersed tunnel have an insignificant impact on the hydrography (water level, salinity/temperature and stratification) in the Baltic Sea and all transboundary territorial waters. For Norway, the investigations show that there are no impacts. Concerning water exchange at Dars Sill, there are no impacts in Norway, Germany or Denmark, while the other countries around the Baltic face an insignificant impact.

It is assessed that the hydrographical changes in the Danish waters do not cause any subsequent changes in the German waters, and vice versa.

1.6.3 Water Quality

The water quality is reflecting environmental quality in a broad sense and can be seen as the essential condition for the existence of aquatic organisms and for bathing water quality. The water quality is affected by natural conditions, such as hydrography, nutrients introduced from adjacent waters and land, as well as the exchange of substances with the seabed and the atmosphere.

The project pressures, which could affect the water quality parameters in the Fehmarnbelt and thereby potentially impact the transboundary territorial waters of the Baltic Sea, are: 1) discharges of wastewater; 2) release of organic material, nutrients and contaminants from dredged materials; 3) enhanced vertical mixing of the upper and lower layers of water in the Fehmarnbelt, which could change the stratification in the Baltic Sea and redistribute nutrients and dissolved oxygen; and 4) impacts on the bathing water quality.

Transboundary impacts

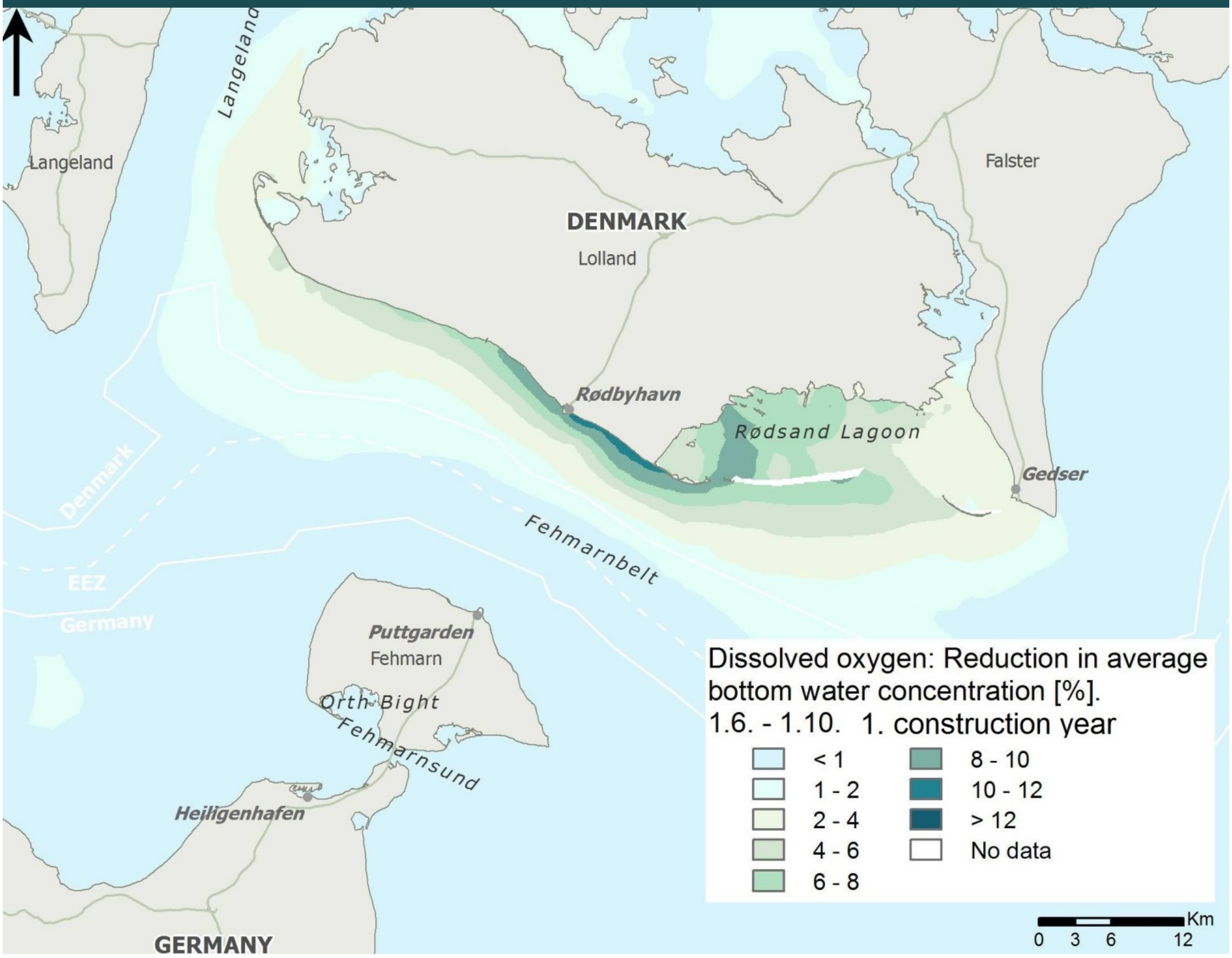
Discharges of wastewater

According to the conceptual design of the immersed tunnel the total discharge of waste-water from construction-related activities will not exceed 1 m^3/s on average, and the specific outlets will be positioned offshore to ensure sufficient mixing and dilution within German and Danish territories. The investigations show that no transboundary impacts from wastewater are expected outside German and Danish territories. The effluents have been assessed to have no impacts on the salinity and general hydrography close to the source, or on a larger scale, taking into account the normal variation in salinity in the affected areas (9 – 25 psu) and the efficient flow. The discharges could also include reject water from a desalination plant, if that solution is chosen as water supply for the construction. The reject water is very salty, but because the dilution is very large, it would not cause any adverse impacts if discharged into Fehmarnbelt. The results of the investigations indicate that the impacts will be very local and will not detectably spread to the central parts of Fehmarnbelt area or have any detectable transboundary impacts outside Danish and German territories.

Releases from dredged materials

Organic material: In areas with the largest reduction in oxygen concentration such as in Rødsand Lagoon (located east of the tunnel on Danish territory) the concentration of oxygen does not decrease below 6 mg O2/l as a result of the release of organic material from the dredged materials. Hence, using a critical level of 4 mg O2/l, reduction in oxygen levels caused by dredging will not constitute an additional pressure on benthos; therefore, impairment of indirect oxygen reductions caused by release of organic material is considered to be insignificant. As there is only an insignificant impact on the oxygen concentration in local waters, it is assessed that the release of organic material from dredging will not affect the oxygen content of any transboundary waters outside Danish and German territories (see Figure 1.5).

FIGURE 1.5 Oxygen reduction in the bottom water (%, June – October of first construction year) in relation to an immersed tunnel



Nutrients (Nitrogen and phosphorus): A daily demand for (and assimilation of) nitrogen and phosphorus by phytoplankton within a 100 m wide zone along the entire alignment can be calculated to 553 kg N and 35 kg P. For nitrogen, the daily uptake is 3 orders of magnitude higher than the estimated average release from dredged materials, while for phosphorus the demand is about 15 times higher than the average release and 7 times higher than the maximum release. Thus, the release rates are negligible compared with the natural demand and impacts from nutrient release can be ruled out. In conclusion, there will be no transboundary impacts of nutrients outside German and Danish waters from the release of nutrients during dredging operations.

Heavy metals: Regarding release of heavy metals during dredging of sediments, previous studies with sediment from the Fehmarnbelt have shown that release of heavy metals from sediments when suspended will typically be 1% of the sediment concentration. Because of the very low concentrations of heavy metals in the sediment, it can therefore be concluded that the heavy metals released during dredging in the Fehmarnbelt will not affect benthic or pelagic organisms. Hence, there will be no transboundary impact outside German and Danish waters from the release of heavy metals during dredging operations.

Persistent organic pollutants: Except for one sample the concentration of PCB in surface sediments was well below the lower values of the Danish and German standards. It is therefore assessed that there will be no impacts related to the release of PCB during dredging and subsequent settling of PCB on the seabed. As with other recently introduced pollutants, DDT is confined to the upper 10 - 15 cm of sediment. Below 10 cm depth PAHs reach background concentrations which are on average 10 times lower than surface concentrations. Being a recently introduced pollutant, TBT reaches zero (background concentration) below 10 cm sediment depth. It is therefore concluded that there will be no impacts of persistent organic pollutants related to spill or disposal of dredged sediment.

Enhanced vertical mixing: The modelling studies showed that neither in the construction nor in the operation of the immersed tunnel the marine structures will have any significant impact on the stratification of the waters in the Fehmarnbelt or the Central Baltic Sea. Therefore it can be concluded that the impact of enhanced vertical mixing is negligible and will have no transboundary impact outside German and Danish territories.

Impacts on bathing water quality: Dredging; changed discharges and movements of the discharge points may potentially affect the transparency and numbers of faecal bacteria at the different beaches and result in deterioration of the bathing water quality.

The discharge will be done in such a manner and at such a distance from the coast that it meets the current requirements and compared with existing conditions, the Fixed Link project will only cause insignificant impacts on bathing water quality in the Fehmarnbelt area. However, during the construction phase the dredging and land reclamation activities might affect the quality of the transparency of the water along minor parts of the coast, which might affect the use of one of the beaches (Bredfjed on Lolland). All impacts will be local and will not cause transboundary impacts.

Transboundary impacts between Germany and Denmark

The project pressures, which could affect the water quality parameters and thereby potentially impact the Danish and German territorial waters, are as mentioned above primarily local and only insignificant. The conclusion is that project pressures on water quality on the Danish side will only cause insignificant impacts on water quality on the German side, and vice versa.

Conclusion

The investigations and assessments of water quality show that discharges of wastewater, releases from dredged materials, enhanced vertical mixing, sediment spill, and impacts on bathing water quality from construction and operation of an immersed tunnel will have no transboundary impacts on the water quality of the countries outside German and Danish territories.

Concerning transboundary impacts between Germany and Denmark the project pressures on water quality on the Danish side will only cause insignificant impacts on water quality on the German side, and vice versa.

1.6.4 Sediment and Seabed forms

The project pressures on sediment and seabed forms related to an immersed tunnel are determined by:

- Permanent structures, which occupy a part of the seabed, such as land areas and the protection layer on top of the tunnel
- Dredging and backfilling of the tunnel trench, which result in removal of seabed forms, resuspension of sediments and sedimentation, as a result of spills from the dredging and filling works
- Dredging of access channels for production facilities on Lolland, which results in deepening of the seabed and dredging of natural seabed
- Construction of working harbours at Lolland and Fehmarn, which temporarily occupies/changes a part of the seabed
- Possible dredging at Kriegers Flak for sand for backfilling of the trench
- Possible dredging on Rønne Banke for sand for the concrete for the tunnel elements

The impacts caused by the pressures of the project can basically be divided in two types: impacts caused by the footprint and temporary structures with no potential for transboundary impacts, and another group of impacts related to the sediment spill caused by the dredging operations. Below, the different transboundary impacts are outlined.

Transboundary Impacts

Impacts by the footprint and temporary structures

The assessment of the impacts on the seabed morphology shows that the impacts will affect an area of 1,471 ha within the local zone. The impacts are partly the loss of an area of approximately 350 ha of ”other seabed”, meaning without special seabed forms, and partly temporary impairments of a total area of 1,115 ha with and without special current-dependent seabed forms. The permanent loss of seabed of approximately 350 ha corresponds to 0.9% of the total seabed within the area 10 km from the alignment (near zone + local zone). The seabed within the lost area has no special importance for the seabed morphology in the Fehmarnbelt area, and the loss is assessed as being insignificant.

Likewise, the temporary impacts in the area without special seabed forms are assessed to be insignificant. The area corresponds to approximately 126 ha, which will be naturally re-established within 15 – 20 years after the construction period. Impacts will occur on 989 ha with special current dependent seabed forms, hereof 984 ha with crescent-shaped seabed forms and 5 ha with sand waves. Of these, the impacts on approximately 890 ha are assessed to be of small or medium scale.

The affected area collectively corresponds to 6.1 % of the area of the existing 16,293 ha with special seabed forms (sand waves, crescent-shaped seabed forms and other current related seabed forms) found at a distance of up to 10 km from the alignment. All the impacts on the seabed forms are temporary. Most of the changes (90%) are solely related to a temporary change of the size of the seabed forms. In the remaining area (103 ha), corresponding to less than 1% of the area with special seabed forms within 10 km from the alignment, the seabed forms will be temporarily eliminated. In most parts of this area, the seabed forms will be fully re-established within a maximum of 15 - 28 years.

In an area of 5 ha with sand waves, which earlier were used for sand extraction and deposition of dredged materials, the regeneration of the seabed forms takes longer time, up to approximately 30 - 40 years.

According to applied assessment criteria, temporary changes in the geometry of sea bed forms are assessed to be a small to medium impairment. Based on the relatively limited area of affected seabed forms within the Fehmarnbelt, and the character of the changes, the impacts on the seabed forms from construction and operation of an immersed tunnel are assessed to be insignificant for the seabed morphology.

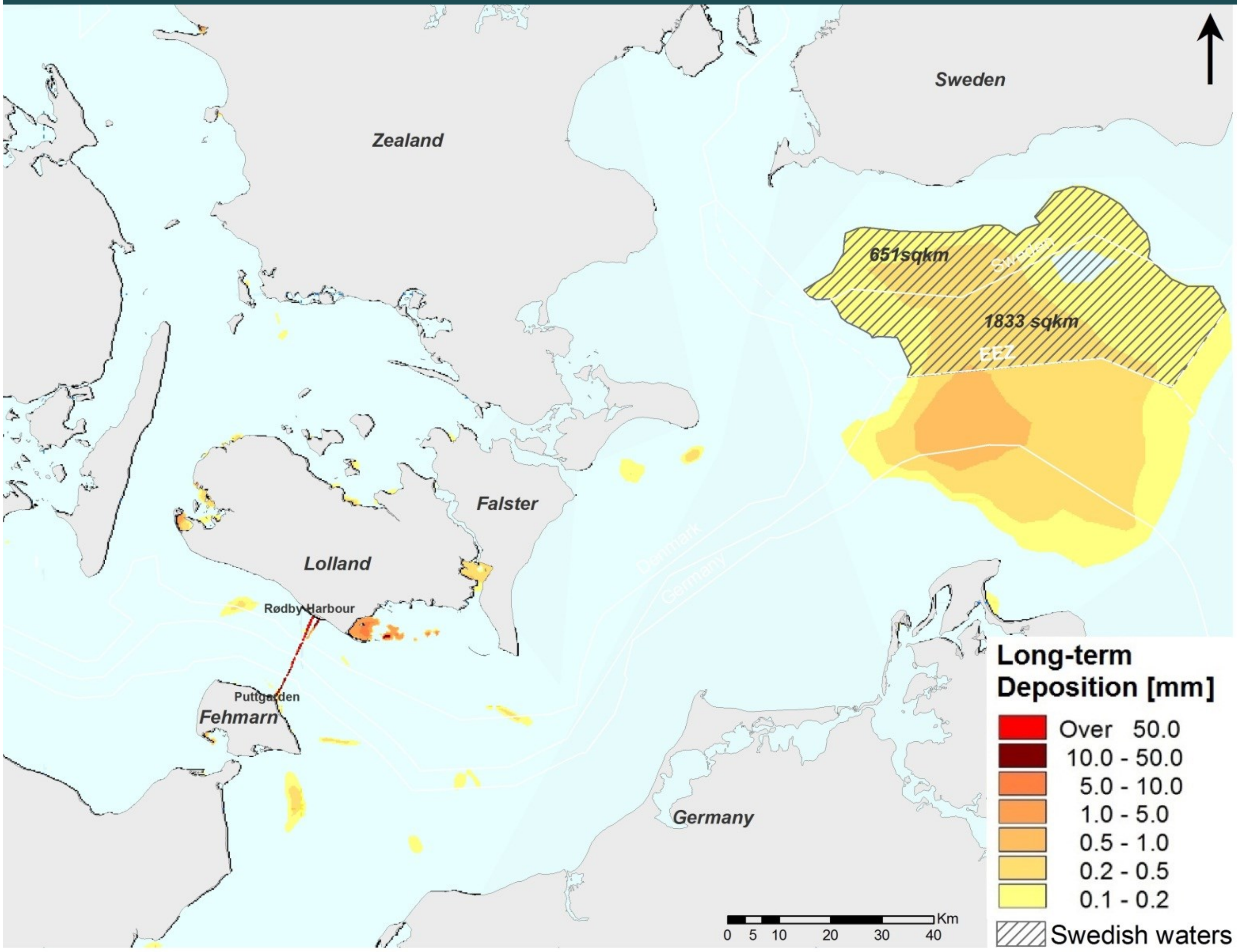
All impacts are located within the local zone and therefore no transboundary or regional impacts are expected.

Impacts related to the sediment spill

Plume patterns from dredging
The sediment plumes from the marine works at the Fixed Link site are assessed to be local and have no transboundary impacts outside German and Danish territories. At Kriegers Flak and Rønne Banke, which are both located within Danish territorial waters, the visible plumes are located around the dredger and do not extend to transboundary waters. This is mainly due to the low fine sediment content of the sand deposits in both areas.

Exceedence of sediment concentration
The visible surface plumes will only be seen in German and Danish waters, and at any given time during the construction the suspended sediment concentration will not exceed the physical threshold value for visibility (2 mg/l) outside German and Danish territories. Similar results for Kriegers Flak and Rønne Banke can be found in the summer period, when the currents are less powerful, and the plume will not extend far away from the dredger. Transboundary territories outside Germany and Denmark will therefore not be affected by sediment spill at the extraction sites or the work areas.

FIGURE 1.6 Deposition of sediment spill from construction activities after the end of the construction period, excluding dredging at Kriegers Flak and Rønne Banke



Deposition of spilled sediment

The deposited sediment will be resuspended until final sedimentation in areas with the right physical conditions. The results of the modelling show that final resting places for the sediment spill are the Arkona Basin, the deeper waters in the Southern Lillebælt between Als and Ærø, Rødsand, and the edges of the Bay of Mecklenburg, where also natural deposition of fine-grained material takes place. Therefore, the deposition only occurs in the Danish, German and Swedish waters, and not into the rest of the transboundary territories (see Figure 1.6).

The deposits from the project in the Arkona Basin are less than 1 mm, which compared to the natural yearly deposition of approximately 10 mm, represents an excess deposition of 10%. The sediment deposition from the project, which only takes place in natural deposition environments, is therefore assessed not to affect sand banks, sediment stability or sediment movements in Fehmarnbelt or in transboundary waters.

At Rønne Banke and Kriegers Flak, which can be used for extraction of raw material, there will only be small areas with deposition of fine sediments of between 0.5 and 2 mm south and south-east of the dredging areas. The small deposition is due to the limited sand suction and the small content of fine sediments in the sand. All depositions from sand extraction at Rønne Banke and Kriegers Flak are assessed to occur only within German and Danish national waters and therefore have no transboundary impact.

The total deposition of fine sediments from the construction works in transboundary waters is less than 1 mm, which is less than 10 % of the natural annual deposition in the Arkona Basin, and the impact on deposition is therefore assessed to be insignificant.

Transboundary impacts between Germany and Denmark
Due to the highly variable hydrographical conditions in the Fehmarnbelt, smaller parts of the sediment spilled in Danish waters may spread to German waters and vice versa. However, the modelling does show that the areas potentially impacted by the suspended sediments are close to the coasts of Lolland and Fehmarn and are caused by the dredging activities near the coasts. It is therefore assessed that the sediment spill on the Danish side will only have a minor and insignificant impact on the seabed morphology on the German side and vice versa.

The possible sand extraction in the Danish part of Rønne Banke may give rise to a temporary and very small dispersal of spilled sediment into German waters. The effect is temporary and will not lead to significant impacts on the environment.

Conclusion
The investigations show that there will be no transboundary impacts outside German and Danish territories, except on Swedish waters, where there is expected to be insignificant transboundary impacts from sediment spill as a result of deposition of sediment from the dredging works of the construction of an immersed tunnel.

1.6.5 Coastal Morphology

Coastal morphology concerns changes to a coastline and the adjacent seabed in terms of erosion and accretion. Such developments along a coast are caused primarily by the waves breaking at the coast.

Three pressures can affect the coastal morphology locally by: 1) reclamations at the coasts of Lolland and Fehmarn; 2) protection reefs over the tunnel near the coasts; and 3) the dredged approach channel for the work harbour on Lolland. The impacts on the coasts of Lolland and Fehmarn are caused by the reclamations, including new beaches occupying part of the original coastline and blocking the natural transport of sediment along the coast. The effect of these structures is to interrupt the natural transport of sand along the coasts – the so-called littoral drift The littoral drift is predominantly a function of the wave climate which is a function of the wind conditions. The wind conditions are not affected by the project. The reclamations and protection reefs, but also the access channel to the production facilities on Lolland will cause changes to the near-shore wave field and thereby changes to the sediment transport along the coasts of Lolland and Fehmarn. However, no transboundary impacts are expected from this project pressure.

The only project activities which potentially could affect the coasts of transboundary waters, are the possible dredging at Kriegers Flak and Rønne Banke, where sand extraction is planned to take place during construction. The changes in water depths at the two sites could change the wave conditions, and if the wave changes reach the nearby coasts, there could be an impact on the coastal morphology.

Transboundary Impacts
Sand extraction in the extraction area at Kriegers Flak will, on the average, lower the seabed by about 1 m, i.e. from a depth of about 20 to 23 m to about 21 to 24 m. This approximately 5% increase in the water depth over the dredging area of 10 km^2 will have an insignificant impact on the wave conditions in the deepened area and absolutely no impact on the wave conditions at the nearest coasts, more than 20 km away from the sand extraction area. The wave conditions will therefore not be changed along the closest coasts of Møn, Rügen and southern Sweden; it can thus be concluded that the dredging at Kriegers Flak does not change the coastal morphology along these coasts. Therefore, there will be no transboundary impacts outside German and Danish territories from activities at Kriegers Flak.

Sand extraction in the extraction area at Rønne Banke will, on the average, lower the seabed by maximal 1 m (but will most likely be 0.5 m), i.e. from a depth of about 17 to 21 to about 18 to 22 m. The approximately 5% increase in the water depth over the extraction area at Rønne Banke of 9 km^2 will have an insignificant impact on the wave conditions in the deepened area and absolutely no impact on the wave conditions at the nearest coasts, 30 km away from the sand extraction area. Therefore, there will be no transboundary impacts outside German and Danish territories near Rønne Banke.

Transboundary impacts between Germany and Denmark

The Lolland reclamation area has been assessed to cause significant erosion of the coastline to the east of the reclamation, and effective mitigation measures in the form of beach nourishment have been included in the project. The Fehmarn reclamation area may give rise to a small potential erosion of the coast south of Marienleuchte (Germany) and also here mitigation measures will be implemented. Under no circumstances will the reclamations on the Danish side cause changes to the coastal morphology on the German side, and vice versa.

Conclusion

The investigations show that there is no impact from construction and operation of an immersed tunnel on coastal morphology in the transboundary region.

The land reclamations on the Danish side will cause no transboundary impacts on the German side, and vice versa.

The possible sand extraction at Kriegers Flak and Rønne Banke will have no impact on the coastal stability along any transboundary coasts.

1.6.6 Plankton

Plankton populations are generally not considered sensitive to disturbances from construction activities in coastal areas, because of their short generation times, fast population changes in relation to environmental changes and the large exchange of water with adjacent areas. Nevertheless, phytoplankton and zooplankton serve as the base of the food chain, supporting fish, sea-floor life and other marine organisms. All fish and most invertebrates depend on plankton for food during their larval phases, and some species such as mussels continue to consume plankton their entire lives.

Four pressures are related to the construction and operation of an immersed tunnel in relation to plankton within transboundary waters: 1) suspended sediments; 2) sedimentation; 3) release of contaminants; and 4) loss of habitats. During construction, spill from dredging operations will influence light penetration and the transparency of sea water (measured as Secchi depth) that, in turn, affects primary production, phytoplankton biomass and composition, and zooplankton production. Furthermore, suspended sediments can bury resting eggs of copepods and potentially affect recruitment of copepods, affecting the composition of the zooplankton community.

Transboundary Impacts

Suspended sediment and sedimentation

The modelled reductions of phytoplankton biomass correspond to a low and negligible degree of impairment, because reductions in waters of special importance for plankton (depths > 6m) are below 5 % in all years during construction. Direct impacts on zooplankton will be very low because the concentration of suspended sediment is low in those areas, where zooplankton biomass is high.

Release of contaminants

Under maximum dredging intensity of one dredger (5000 m^3/d) concentration of persistent organic pollutants (PCB, DDT, PAH, TBT) and heavy metals are not predicted to exceed the environmental quality standards set to protect the marine environment, not even in the sediment plume near the vessel. The impact of toxic substances released from the sediments is therefore assessed as insignificant for plankton living in transboundary waters.

Loss of habitats
Permanent impacts of the immersed tunnel relate to loss of pelagic habitats for plankton. The volume lost constitutes approximately 0.03% of the total pelagic volume (0 - 20 m) in the Fehmarnbelt and adjacent waters. Such low proportion, along with the fact that loss is mainly confined to waters where importance for plankton is low, leads to the conclusion that impairment caused by the loss of habitats is negligible. Overall, the assessment showed that minor impacts on plankton will only appear in German and Danish territories, and therefore no transboundary impacts are expected to occur for plankton organisms.

Transboundary impacts between Germany and Denmark
Concerning transboundary impacts between Germany and Denmark, there are no local impacts on phytoplankton or zooplankton in Danish waters from the project with a potential for having impacts in Germany and vice versa.

Conclusion
The investigations show that there will be no transboundary impacts outside German and Danish territories on plankton from construction and operation of an immersed tunnel.

There will be no transboundary impacts between Germany and Denmark.

1.6.7 Benthic Flora

Benthic vegetation is a valuable part of the coastal ecosystem due to its function as a three-dimensional habitat as well as a nursery, breeding and/or feeding ground for invertebrates and fish. The habitat function of vegetation is dependent on the complexity and longevity of their key species as well as the size and coverage of the habitat itself.

Eight project pressures have been determined to have a potential impact on the benthic flora in the Fehmarnbelt during construction and operation of the immersed tunnel, and some of them can also have impacts on the benthic flora in transboundary waters. The pressures are:

- Suspended sediments
- Sedimentation
- Release of contaminants
- Nutrients
- Construction vessels and imported material
- Additional solid substrate
- Land reclamation and tunnel footprint
- Drainage

Transboundary Impacts

Suspended sediments and sedimentation
During construction, an increased concentration of suspended sediment in the water reduce light availability for photosynthesis and growth of benthic flora, while sedimentation leads to physical stress as sediment reduces the active surface area for photosynthesis and nutrient uptake. The model simulations predict that the response of benthic flora to increased concentrations of suspended sediment is highest in the first and second years of the construction phase of the immersed tunnel. During the following years, the benthic flora recovers to a state close to that for

the reference situation with no sediment spill. The maximum thickness of sediment layers persisting > 10 days is 8 cm and occurs directly at the alignment area as well as in the Rødsand lagoon. Time series for the Rødsand Lagoon showed that the sediments are re-suspended from time to time, and that the overall thickness of deposited sediments will therefore be reduced.

Release of contaminants, nutrients, and introduction of non-indigenous species
Furthermore, benthic flora can be influenced, if dredging activities are resulting in concentrations of contaminants in the water column exceeding environmental quality standards (EQS) for seawater, or if the nutrient loading is increased. During construction increased ship traffic and imported material also increase the risk of an introduction of non-indigenous species. Impacts from these pressures are assessed to be non-existing, because of the low content of contaminants or nutrients in the dredged materials and the low risk of introducing non-indigenous species. Therefore the benthic flora in the transboundary region will not be affected during the construction phase or the operational phase of the immersed tunnel.

Construction vessels and imported materials
The additional ship traffic related to the construction works corresponds to a minor pressure compared with the very intense existing traffic through Fehmarnbelt, where approximately 38,000 ships from other water areas pass every year. Furthermore, the additional ships and the new materials are expected to come from areas with comparable benthic flora, so there is only a negligible risk of introducing non-indigenous (invasive) species into Fehmarnbelt.

Additional hard substrate with risk of introducing non-indigenous species, and footprint and land reclamation on top of existing macroalgae communities
Other pressures of relevance during operation of an immersed tunnel are additional solid substrate, which can impact benthic flora communities in three ways: 1) introduction of hard-bottom macroalgae communities to areas previously dominated by soft-bottom communities, 2) increased risk of introducing non-indigenous species, and 3) loss of seabed due to footprint and land reclamation on top of sites with existing macroalgae communities.

Overall, an immersed tunnel affects 298 ha of benthic flora; 218 ha are affected by structure-related and 80 ha by construction-related impacts. Nearly all of the lost area occurs in Danish national waters and EEZ waters (298 ha). In German waters, 0.22 ha are lost: 0.22 ha in German national waters and none in EEZ waters.

Out of the eight identified macro-algae communities, only one community has been assessed to be affected significantly due to loss of habitat caused by the footprint of the immersed tunnel. However, the impact is only assessed to be significant for the hard bottom macro-algae *Furcellaria* community (Red Seaweed) along Lolland's coastline. The *Furcellaria* community is common in the whole Baltic Sea area and is dominant or occurring frequently from the Skagerrak to the Bothnian Sea. Therefore, the loss will not threaten the existence or function of the community in the Baltic Sea and no transboundary impacts will occur. In all other benthic flora communities the impacts are assessed as insignificant and not transboundary.

Drainage
Freshwater outlets coming from the accumulation of water from the project structures during operation can result in an increased pressure on benthic flora. However, the additional discharge of rainwater runoff from structures of the immersed tunnel, water from cleaning and maintenance of the inside of the immersed tunnel, and possible fire fighting are not assessed to be more than 3,500 m^3 per year. The normal discharge from the wastewater treatment plant and dewatering by the pumping stations by the same water mains will ensure sufficient dilution, even before the mixing and dilution with the Fehmarnbelt water. No transboundary impacts are therefore expected on the benthic flora as a result of freshwater discharges.

Benthic Flora at the extraction sites at Rønne Banke and Kriegers Flak
The observations did not detect any macro algae, seagrasses or visible concentrations of microalgae (at the seabed surface) in the affected area at the sampling stations at Rønne Banke;

only very limited quantities of macroalgae were present in the affected area at Kriegers Flak or in the vicinity, and the impacts on macroalgae at the extraction sites are assessed to be negligible. The observed green thin layer, consisted most likely of deposited algae and benthic microalgae, and it will be lost, when the sand at the seabed is extracted. The growth rate of small microalgae is very fast (hours-days), and the algae will hence recolonize very fast after the extraction has ended. Hence, the impact on the microalgae is very limited at Rønne Banke and Kriegers Flak.

Transboundary impacts between Germany and Denmark
Concerning transboundary impacts between Germany and Denmark, there are local impacts on the benthic flora in the Danish waters from the land reclamations, but they have no potential for having impacts in German waters and vice versa. The local impacts are anyway much larger in Denmark than in Germany.

Conclusion
The investigations show that there will be no transboundary impacts outside German and Danish territories on benthic flora from construction and operation of an immersed tunnel.

There will be no transboundary impacts between Germany and Denmark.

1.6.8 Benthic Fauna

The benthic fauna communities in the Fehmarnbelt are important components of the marine ecosystem, since benthic fauna functions as a key link between primary producers and the higher trophic levels, and many benthic fauna communities also contribute to the creation of the substrate that actively shapes their surroundings.

In the Fehmarnbelt and transboundary waters, only the following two pressures, out of eight identified, have been determined to have a potential impact on the benthic fauna, as these have magnitudes of pressure that may exceed natural levels. The pressures are:

- Suspended sediments
- Sedimentation

Increased ship traffic and import of new materials such as sand, gravel and stones that will be introduced to the area in the construction phase may increase the risk of introduction of non-indigenous species. However, this is perceived as a minimal pressure in relation to the benthic fauna, as the construction and filling materials are primarily introduced from adjacent sea areas, which means that no non-indigenous species will be introduced.

Transboundary Impacts

Suspended sediment
The modelling shows that approximately 57,942 ha of benthic fauna communities in the Fehmarnbelt will be affected by suspended sediment from the construction phase. Up to 99% of the area shows a minor degree of impairment, while 1% is impaired to a medium degree, mostly in the Dendrodoa community. The maximum decrease in mussel biomass is estimated to be 10% within small local areas along the coasts of Lolland and Fehmarn. However, the impact of suspended sediment has no transboundary impact outside German and Danish territories on benthic fauna.

Sedimentation
The impact from sedimentation is distributed across all fauna communities, but the Arctica community is affected most in terms of area (16 ha). The impact is located largely around the tunnel trench (within 500 m from the tunnel trench) and in the Rødsand Lagoon east of the tunnel trench. The maximum accumulation of sediment is modelled to 7 cm near the tunnel trench. In other areas, sedimentation rates are typically below 1 mm per day. However, the impact is local

and therefore no transboundary impact on benthic fauna caused by sedimentation is expected outside German and Danish territories.

Benthic Fauna at the extraction sites at Rønne Banke and Kriegers Flak
The impact from suspended sediment and sedimentation from dredging at Kriegers Flak and Rønne Banke is not considered to have an impact on the adjacent areas, since the deposits are very thin, less than 1 mm. In comparison the natural deposition in the Arkona basin is approximately 10 mm during the construction period, and thus the effect of the immersed tunnel represents an excess deposition of 10 % The deposition in these areas therefore does not influence benthic fauna outside German and Danish territories.

Transboundary impacts between Germany and Denmark
Regarding suspended sediment, approximately 60,000 ha of benthic fauna communities are affected from the construction phase. Up to 99% of this area is affected to a minor degree, while 1% is affected to a medium degree, mostly in the Mytilus community. Most of the impacts are observed in the shallow waters along the Lolland coast, while a smaller area is observed along the northern and eastern coast of Fehmarn. The degree of the impact is largely minor and not significant.

Concerning sedimentation, 11,871 ha of benthic fauna communities will be affected according to the analyses. In 85 % of this area there is no impact for the benthic fauna, nearly 15 % of the area is affected insignificantly and 16 ha are affected significantly. The impact is located largely around the tunnel trench (in the near zone) and in the Rødsand Lagoon.

A total of 584 ha of benthic fauna communities are affected by the footprint. Most of the impacts are from the permanent loss due to reclamation areas at Lolland and Fehmarn and from temporary loss due to the tunnel trench. All temporary impacts are expected to be recovered within 5 – 22 years, depending on the location and the affected community. The transboundary impact from temporary loss of area is assessed to be not significant.

Concerning additional solid substrate, 149 ha of solid substrate are added due to the structures of the immersed tunnel, mainly (85 %) due to the protection layer on top of the tunnel elements. Their transboundary impact is not significant.

The conclusion is that in the Fehmarnbelt itself the impacts are very local, and none of the impacts in Danish waters, which are graded overall as not significant, have any transboundary impacts on German territory, and vice versa.

Conclusion
The investigations show that the impact from construction and operation of an immersed tunnel will have no transboundary impacts outside German and Danish territories on benthic fauna.

None of the impacts in Danish waters, which are overall assessed as being not significant, have any transboundary impacts on German territory and vice versa.

1.6.9 Fish Ecology

The Fehmarnbelt plays a key role in the water exchange system of the Baltic Sea and is an important passage for migrating cod, herring and silver eel, as well as a spawning area for a number of fish species, including cod and flatfish.

The following pressures were identified as relevant to fish, in relation to construction and operation of an immersed tunnel in the Fehmarnbelt.

- New land reclamations (permanent or temporary loss of habitats)
- Changes in the hydrographical regime
- Sediment spill

- Noise and vibrations
- Changes/impairments of fish habitats (indirect pressures).

Transboundary Impacts

Land reclamations
The new land reclamations will affect the shallow part of the near zone, including the redlisted sea stickleback. The temporary seabed reclamation will, in addition, affect benthic species at greater depths, including the red listed snake blenny, along the tunnel trench. However, the new land reclamations and temporary seabed reclamation are very local and do not extend into transboundary areas outside German and Danish territories.

Changes in the hydrographical regime
No transboundary impacts are expected outside German and Danish territories on fish as a result of changes to the hydrographical regime caused by the construction and operation of an immersed tunnel.

Sediment spill
The possible direct transboundary effects are mainly caused by sediment plumes and re-suspension of sediment. Apart from the Fehmarnbelt the central areas of the Mecklenburg and Arkona Bight will be affected by sediment spill. A medium level of sedimentation is expected in these bights of maximum 0.5 mm of sediment deposition the first three years of the construction period. The Mecklenburg and Arkona Bight are important spawning areas for flatfish and particularly for cod. A temporary impairment of eggs and larvae of these species cannot be excluded, although the natural background level of suspended sediment is considered a much more severe pressure.

Changes/impairments of fish habitats and noise/vibration
During the construction phase a barrier effect caused by dredging of the tunnel trench and immersing the tunnel elements is expected for anadromous fish species that spend most of their adult lives at sea, but return to fresh water to spawn, and also for fish species with long term migrations (cod, whiting, herring and sprat). These species avoid areas with a high intensity of sediment plumes and noise/vibration. Thus, the migratory fish species might not reach areas of importance (spawning and feeding areas) in adjacent waters.

Sediment spill and noise can cause a temporary local impact on the migration of the Rügen herring from the spawning grounds at Rügen to the feeding areas in the Skagerrak. This can potentially have a theoretical impact on the stock in Norwegian and Swedish waters. The construction of the immersed tunnel may also affect the spawning migration of cod and the survival of eggs and larvae locally, which might theoretically affect the cod recruitment in Swedish and Polish waters. Impacts on the migration of whiting from nursery areas in the Baltic, back to the North Sea, might affect the whiting stock outside the project area, while impacts on sprat migration only imply local impacts. The impacts are all temporary and generally of very low intensity, and therefore only insignificant transboundary indirect impacts are expected outside the German and Danish areas. There are no such impacts on the fish ecology in the operation of the immersed tunnel.

The impacts on sprat are only local.

Fish Ecology near Rønne Banke and Kriegers Flak
Due to the low intensity of direct impacts by sedimentation at Rønne Banke and Kriegers Flak the potential transboundary effects for these areas are classified as insignificant. The overall conclusion is that there will be no impact on fish within the extraction areas due to extraction of sand. Outside the mined areas, the impact is very limited. Furthermore, the impacts in the extraction area are temporary and do not have significant impacts on the environment of the Baltic Sea region.

Transboundary impacts between Germany and Denmark
Overall only insignificant or minor impacts are expected outside the near zone. In the near zone most impacts are expected to be due to loss of seabed, where land reclamation in both German and Danish shallow waters reduces nursery areas/grounds for cod and flatfish and habitats of shallow-water species.

Transboundary effects between Germany and Denmark at the operational phase of the immersed tunnel are of minor importance and insignificant (noise emission, sediment spill and barrier effect).

Most impacts on all fish species are in the near zones in Germany and Denmark, thus having no transboundary impacts. Only fish species migrating to other waters will be affected, e.g. cod, whiting, and herring. The impacts on these species will be small and insignificant.

The conclusion is that project pressures on fish ecology on the Danish side will only cause insignificant impacts on fish ecology on the German side, and vice versa.

Conclusion
The investigations shows that there are insignificant transboundary impacts outside German and Danish territories on some fish species (cod, herring, whiting) as a result of the construction and operation of an immersed tunnel.

Project pressures on fish ecology on the Danish side will only cause insignificant impacts on fish ecology on the German side, and vice versa.

1.6.10 Commercial Fishery

An infrastructure project like the construction and operation of an immersed tunnel across the Fehmarnbelt might affect fish stocks and the access to fishing areas, which may have economic consequences for the commercial fishery.

The project pressures relevant to the commercial fisheries and their resources (commercial fish species) have been assessed to concern:

- Land reclamation
- Sediment spill
- Noise and vibration
- Changes in hydrographical regimes
- Other pressures potentially causing avoidance responses and loss of fish habitats. The magnitude of pressure derived from light, electro-magnetic fields and contaminants are assessed as insignificant

Transboundary Impacts
A number of the commercial fish species present in the Fehmarnbelt migrate over large distances between spawning grounds, nursery areas and feeding grounds. During these migrations and residency periods, these commercial species pass through or reside in national waters of other countries and international waters and fishermen of other countries will fish for the same species. Thus, it is therefore recognised that the commercial fisheries in other countries are indirectly impacted, if shared commercial fish stocks are affected by the establishment of the immersed tunnel.

Land reclamation
Results of the investigation show that there will be no impacts on trawl fishing, gill net fishing or seine net fishing in the Fehmarnbelt during construction activities, operation, or due to reclamation of areas/footprints, as this type of fishing takes place in deeper waters. As the migration behaviour of fish (e.g. herring, cod and eel) is not affected, no impacts on distant

subpopulations and on distant fishing of the fish species occurring in the Fehmarnbelt are foreseen. Thus, in the case of commercial fishing, no transboundary impacts outside German and Danish territories will occur.

Sediment spill and noise/vibration

There are no impacts on pound net fishing in the Fehmarnbelt during construction or operation activities. Sediment plumes will be greatest along the coastal areas of Lolland and may have an impact in short time intervals, but the impact on pound net fishing is only relevant on a local scale, and there will be no restrictions on the fishing activities outside German and Danish territories. In general, the impacts from the tunnel pressures such as sediment spills, noise and vibrations are only minor or insignificant in all cases.

Changes in the hydrographical regime and other pressures

Hydrographical changes such as land reclamations and construction at the seabed may have an impact on the yield of the fishing, by causing avoidance reactions or changed distribution of commercial fish species. It can also be a consequence of e.g. changes of seabed substrates.

Impacts from the construction, operation and structures of the immersed tunnel were low to medium on all commercial fish stocks that have extended geographical distribution. Significant impacts were only registered in the near vicinity of the fixed link i.e. they are classified as local and can therefore be considered insignificant in relation to potentially affecting transboundary fish ecology.

Commercial Fishery at Rønne Banke and Kriegers Flak

Impacts on commercial fishery from the dredging at Kriegers Flak and Rønne Banke (fishery here is only undertaken with trawl) are restricted to loss of fish within the dredged area, due to loss of food sources for the fish. This impact is only expected to occur within a 5 year period, hereafter a re-colonisation of the benthic infauna and epifauna is expected. Furthermore, the fishing can be affected due to fishery restrictions during dredging activities. However, the impact is low (days) and only temporary within dredging periods. The fish can also be re-distributed to other areas due to increased sediment deposition, and this will cause a low impact on the trawl fishery in the area. This impact is, however, temporary and will be negligible after a few months.

The impact on the trawl and net fishing at Kriegers Flak within the extraction period (days) is only minor, because fish move to other areas, from where they can be fished. An impact on the undertaking of fisheries is only short-term (during the extraction period). In connection with the sand extraction, the fishery will be affected during the sand extraction periods. Because of the risk of collision, there will be zones around the extraction sites, where fishery is not possible. This impact is only expected over a short time period (hours).

Transboundary impacts between Germany and Denmark

The fishing with trawl, gill nets, pound nets, and Danish seine nets will only be affected locally due to the construction and operation of an immersed tunnel. Apart from gill nets that locally will be affected significantly, all other types of fishery will only be affected insignificantly.

There are no transboundary impacts on commercial fishery between Germany and Denmark as a result of the pressures from the construction and operation of an immersed tunnel.

Conclusion

The investigations show that the construction and operation of an immersed tunnel will have temporary impacts on commercial fishery in the construction phase, which do not reach beyond German and Danish territories.

At Rønne Banke and Kriegers Flak the impact on the fishery is negligible, since impact primarily occurs within the extraction area, where fishing cannot take place in shorter periods of time.

Overall, the investigations show that there will be no transboundary impacts outside German and Danish territories regarding commercial fishery from the construction and operation of an immersed tunnel.

The project pressures on commercial fishery on the Danish side will not cause any impacts on commercial fisheries on the German side, and vice versa.

1.6.11 Marine Mammals

In the Fehmarnbelt and the Baltic Sea three species of marine mammals, which are top predators of the food chain, occur regularly:

- the harbour porpoise, a small cetacean, which is widely distributed in the western Baltic Sea and the North Sea
- the harbour seal, with haul-out sites in the Rødsand lagoon, holding a substantial proportion of the small subpopulation in the western Baltic Sea
- the grey seal, which has its only and most southern breeding site at Rødsand Lagoon

Five project pressures, which may impact marine mammals, have been identified from the construction and operation of an immersed tunnel:

- Noise from construction-related activities
- Habitat loss and change
- Contaminants
- Barrier effects
- Suspended sediment

Transboundary Impacts

Of the three species of marine mammals occurring in the Fehmarnbelt, only the harbour porpoise may be directly affected by the project. The seals seldom forage in the near-zone of the planned alignment, and their haul-out places are located at least 8.5 km from the alignment and therefore, they cannot be affected, except indirectly by barrier effects and suspended sediment.

Noise

Investigation results show that only 3 - 7 individuals of porpoise are expected to be affected at a time by noise in winter and summer, disturbing a maximum of 0.45% of the local Fehmarnbelt study area population and less than 0.1% of the population of the Belt Sea and Western Baltic. The number of harbour porpoises, which maximally will be affected by under-water noise are 3 from the dredging works and 4 from sheet piling. Therefore, the impact is insignificant at the population level (<1% of both the Fehmarnbelt study area population and the Belt Sea and Western Baltic population) for the occurrence (staging) and nursery areas of harbour porpoise.

Habitat loss and change

Investigation results show that in relation to habitat loss 1 - 2 porpoises are expected to be affected by construction works, with a maximum disturbance of 0.1% of the local Fehmarnbelt study area population and less than 0.1% of the estimated population in the Belt Sea and Western Baltic. Moreover, less than one porpoise is expected to be affected by habitat loss during the operation phase, with a maximum disturbance less than 0.1 % of the local Fehmarnbelt study area population. The impact is therefore insignificant for the population in the Belt Sea and Western Baltic Sea.

Contaminants

The analyses of sediment samples for contaminants in the Fehmarnbelt study area show levels at or below the lowest sediment quality criteria (Action Level). It is therefore concluded that contaminants released as a result of the project will have no adverse impacts on marine mammals in the Fehmarnbelt area or for the populations in the Belt Sea and Western Baltic Sea, living in transboundary waters.

Barrier effects
Given the fact that less than 30 % of the alignment across Fehmarnbelt will be affected by the project at the same time and thereby resulting in barrier effects during construction, it has been concluded that there will be no local impact from barrier effects during construction, as the animals will easily be able to move around each dredging section. It has therefore also been assessed that the populations of marine mammals in the Belt Sea and Western Baltic Sea will not be affected by this pressure. Likewise, there will be no impact of the immersed tunnel during operation, as animals will be able to pass over the top of the immersed tunnel, once it is constructed.

Suspended sediment
The sediment spill from the dredging of the tunnel trench and the temporary working harbours will increase the amount of suspended matter in the water. Harbour porpoises, which orient themselves with the help of echolocation, are adapted to conditions with a high degree of turbidity, and seals locate prey using whiskers, vibrissae, and thus to some extent do not depend on vision. Therefore, no impacts on marine mammals are expected as a result of construction-related sediment spill.

Marine Mammals at the extraction sites at Rønne Banke and Kriegers Flak
The planned sand extraction activities on Rønne Banke will have little impact on harbour porpoises and seals in the area. There are few animals in these areas, and the sound levels are not assumed to affect the animals except at very close range. The impact on marine mammals is assessed to be insignificant. Considering the results of the sediment spill modelling, sediment plumes are not expected to cause any direct impact on seals and porpoises near the sites. The impacts on availability of prey, especially juvenile fish are assessed as minor. However, since the affected areas are expected to be very small compared to the total area available to the animals on Kriegers Flak and as the duration of the impact is short, no significant negative impact due to sediment dispersal are expected near the sites.

In summary, the impacts from raw material extraction at Kriegers Flak and Rønne Banke lead to mainly temporary impacts, which do not reach beyond the German and Danish territories, and thus do not pose an impact on marine mammals living in transboundary waters.

Transboundary impacts between Germany and Denmark
There are no significant impacts on harbour porpoise, but there will be a small area with noise levels from the construction work that might cause avoidance behaviour. In a worst-case scenario the dredging will cause a continuous noise barrier above 144 dB re 1μPa^2s stretching about 5,3 km, which corresponds to less than the 30 % of the total length of the alignment.

As described for the transboundary impacts, the severity of impairment from the sediment spill, footprint, change of habitat, and reduction in food availability are assessed as being negligible for the transboundary impacts between Denmark and Germany.

Conclusion
The investigations show that there will be no transboundary impacts outside German and Danish territories on marine mammal species from the construction and operation of an immersed tunnel.

The severity of impairment from the sediment spill, footprint, change of habitat, and reduction in food availability is assessed as being negligible for the transboundary impacts between Denmark and Germany.

1.6.12 Birds

In the Fehmarnbelt the bird community is dominated by non-breeding water birds, which use the area for moulting, staging or wintering. In addition, a variety of bird species pass through the area on migration. More than 200 bird species have been assessed during the investigations of the potential impacts of an immersed tunnel on the environment. However, only those species where a potential transboundary impact might occur are included in the assessment.

Four main pressures with respect to birds have been identified from the construction and operation of an immersed tunnel:

1 Habitat loss and change

2 Barrier effects and disturbance from construction vessels

3 Reduced light conditions in the water column caused by sediment spill

4 Collision risk with construction vessels

The project will have no impacts for birds during the operation phase.

Transboundary Impacts

Breeding water birds
Loss of habitat: The overall assessment of the severity of habitat loss from the footprint of an immersed tunnel across the Fehmarnbelt has been assessed to be minor for all breeding waterbird species.

As such, the impact of the habitat loss by the tunnel footprint has been assessed to be only relevant for birds breeding in the northern part of Fehmarn, in the south of Lolland and partly for birds breeding in the western part of Rødsand Lagoon, which might commute between the impact zone and the breeding area. Cormorants breeding in the western part of Fehmarn and birds of other breeding colonies within the German Special Protection Areas (SPAs) are mostly expected to use marine areas close to their colonies and not regularly visit the affected project area.

Since the impact from habitat loss has been assessed to be insignificant for all breeding water birds on a local scale, there will be no transboundary impact for those living outside German and Danish territories.

Non-breeding water birds
Sediment spill: Based on model calculations it is estimated that there will be impacts on 8,300-8,800 Common Eider and 950 - 990 Red-breasted Merganser the first two winters of the construction period within the investigation area, due to sediment spill, which leads to reduced light in the water column. This impact is expected to cause a displacement of foraging areas. The food availability is not affected significantly.

In total, the resulting impact of the sediment spill is expected to be a reduction in the number of diving water birds in the affected areas within German and Danish territories. The impact is estimated to be temporary and confined to the first two years of the construction phase. An increase in density of the Common Eider means a doubling of the mortality rate to 1,200 individuals. This extra mortality of 600 individuals corresponds to less than 0.1 % of the biogeographic population and is far below the natural variation in mortality (which is 17,500 p.a. equal to 7 % of the total bio-geographical population). Thus, there will be a theoretical transboundary impact, but the possible higher mortality will not be measurable in the breeding area of the Common Eider in the Eastern Baltic.

Redistribution of 950 - 990 Red-breasted Mergansers the first two winters of the construction period, which equals approximately 0.6% of the bio-geographical population, is below the internationally recognized criteria of 1%. The impact is therefore assessed as insignificant for the transboundary region, and as being local.

Disturbances and barrier effects from vessel traffic: It is estimated that 1,500 Eurasian Widgeon, 700 Pochard and 7,000 Tufted Duck will be displaced due to disturbances from service vessels and marine works during construction. In addition, calculations show that 4,100 Common Eiders will be displaced due to these pressures. This is less than 1 % of the bio-geographical population of all four species, and there are thus no transboundary impacts outside German and Danish territories on these species. Furthermore, the impact is temporary for those species since it will be confined to parts of the construction phase.

The impact on the above-mentioned bird species consists of a local displacement of sensitive water birds on the Danish and German territories, mostly on stretches along the Lolland coast which means that the impacts are local. A consequent redistribution of water birds within the Fehmarnbelt area leads to statistically minor increased mortality.

No transboundary impacts outside German and Danish territories are expected for non-breeding water birds due to disturbances and barrier effects from vessel traffic.

Impacts on birds near Rønne Banke and Kriegers Flak

The impacts (due to sediment spill and vessel traffic/light) from the extraction at Rønne Banke and Kriegers Flak on the non-breeding water birds and the migrating birds are assessed as being insignificant and with minor impact, respectively. There are no breeding birds at Rønne Banke or Kriegers Flak.

Despite the fact that the planned dredging site at Rønne Banke is located within 5 km distance from the SPA Pommeranian Bay holding the largest concentration of water birds in the German EEZ of the Baltic Sea, it is assessed with certainty that there cannot be any significant impacts on the conservation objectives of this Natura 2000 site or on the conservation objectives of any other Natura 2000 site.

All other potential impacts from habitat displacement, collision risks, and sediment dispersal impacting foraging conditions have been assessed to cause a minor impact for birds in the extraction areas, and no transboundary impacts outside German and Danish territories are expected.

Transboundary impacts between Germany and Denmark

The indirect impact of sediment spill is among the highest pressures on birds within the German and Danish project area. The highest levels of impact are predicted to occur along the Lolland coast and within Rødsand Lagoon, which are both within Danish territory.

The indirect impacts from sediment spill will cause displacement of birds, which is significant to Eider ducks only. It is estimated, that on both sides of the German and Danish project area the reduction in the population of Eider ducks will be in the order of magnitude of 8,300-8,800 birds (corresponding to approx. 1.09 - 1.16 % of the bio-geographic population) in the first two winters during the construction phase, where the most intensive dredging works take place.

A reduction in the light conditions in the water column due to sediment spill has thus been assessed to have a large local impact on Common Eider and a medium local impact on Merganser. 1.2% of the bio-geographic population of Common Eider is displaced during the construction period and 0.6% of the bio-geographic population of Merganser is displaced, due to this indirect impact from the sediment spill.

Individual-based modelling on Common Eider duck shows that the impact from reduced light conditions in the water column does not reduce the food resources significantly. Hence, the mortality rate caused by the displacement is not expected to be significantly higher than under existing conditions, and the impact from the sediment spill is hence assessed as insignificant for Eider ducks.

The conclusion from the impacts on birds within the German and Danish project area are therefore assessed as minor for Common Eider and insignificant for Tufted Duck, Merganser, Pochard and Wigeon. Concerning transboundary impacts between Germany and Denmark, there are minor impacts on Common Eider. For other non-breeding water birds, breeding water birds, and migrating birds there are insignificant impacts.

Conclusion
The investigations show that there will be insignificant transboundary impacts on birds outside German and Danish territories from the construction and operation of an immersed tunnel.

Concerning transboundary impacts between Germany and Denmark, there are insignificant impacts on Common Eider. For other non-breeding water birds, there are also insignificant impacts across the border between Germany and Denmark.

1.6.13 Migrating Bats

As part of the transition area between Scandinavia and the middle European mainland, the Fehmarnbelt (and the Belt Sea) is passed by migratory bats.

The main pressures during construction (temporary) and the potential impacts identified are:

- Working areas, equipment, facilities and physical structures of the fixed link including land approaches and work areas at sea
- Collision risk with construction vessels
- Barrier effects from construction vessels
- Habitat change at tunnel entrances/land approaches

Potential effects induced by the presence of the (permanent) physical structures and associated facilities of the fixed link or related to the operation of the fixed link:

- Habitat loss and/or change
- Traffic-related collision risks of bats
- Habitat change at tunnel entrances/land approaches

Transboundary Impacts
Only three bat species (Soprano Pipistrelle, Nathusius' Pipistrelle, and Noctule) are assessed to be relevant for the EIA of the fixed link, because of their migratory behaviour.

Most of the potential pressures concerning bats were assessed to cause no impacts on the relevant bat species during their migration phase. Therefore, these potential pressures were not assessed any further. Only the pressure 'Traffic-related collision risks for bats' was assessed to be relevant.

Traffic collisions at the tunnel entrances have been assessed as the only relevant pressures with an impact on bats. The collision risk for migrating bats is assessed to be medium for Soprano Pipistrelle and Nathusius' Pipistrelle and low for Noctule.

The overall degree of impact in the project area is assessed to be minor. A medium collision risk between bats and traffic is present at the tunnel entrances at Rødbyhavn and Puttgarden. Accordingly, the magnitude of impact on bat migration is insignificant in the Fehmarnbelt and no transboundary impacts are expected outside German and Danish territories.

Transboundary impacts between Germany and Denmark
Only traffic related collision risk is assessed to be relevant for the impact assessment. Traffic-related collision risk is assessed as a medium impairment to migratory *Pipistrelle* species in the area of the tunnel entrances. Traffic collisions and the tunnel entrances have been assessed as the only relevant pressures. The estimated traffic volume with regard to operation of a fixed link was estimated to be between 8,000 and 9,450 vehicles on an average day. The collision risk of migrating bats near the tunnel entrances at Rødbyhavn and Puttgarden is assessed to be medium for Soprano Pipistrelle and Nathusius' Pipistrelle and low for Noctule. However, the

impact is insignificant, even though these bat species are migrating. Therefore, transboundary impacts on migrating bats from Germany to Denmark are considered to be insignificant and vice versa.

Conclusion

The investigations show that there are no transboundary impacts outside German and Danish territories on bats from the construction and operation of an immersed tunnel.

Transboundary impacts on migrating bats from Germany to Denmark are considered to be insignificant and vice versa.

1.6.14 Strictly Protected Species

The construction and operation of the immersed tunnel will potentially impact strictly protected species (as defined by the Habitats Directive) on land and in the marine area.

Pressures as a result of construction and operation of an immersed tunnel are treated separately for each species and include the following pressures: Area occupation and loss of habitat, barrier effects, and kills by traffic.

Other pressures, such as lighting, noise, vibrations, ground water lowering, nitrogen deposition and pressures resulting from exposure to contaminants are also included, when they are considered relevant.

The protected species which could potentially be impacted are: amphibians (on Lolland and Fehmarn), birds (Appendix I in the Bird Directive), bats, fish and marine mammals. Impacts on the different protected species are assessed in the chapters with the relevant environmental component.

Conclusion

The investigations show that with the implementation of planned mitigation and compensation measures there will only be insignificant local impacts on amphibians and bats, and limited to Denmark and Germany.

Furthermore, it is assessed that a minor impact could occur on Common Eider in the trans-boundary waters between Denmark and Germany because of displacement from construction vessels and sediment spill, but this impact is insignificant in other transboundary waters. No transboundary impacts are expected on the other protected bird species.

No significant impacts on marine mammals are expected either in Danish, German or trans-boundary waters.

Overall, the impact assessment shows that with the implementation of planned mitigation and compensation measures no significant transboundary impacts are expected on strictly protected species from the construction and operation of an immersed tunnel.

1.6.15 Natura 2000

For the project in Fehmarnbelt, the impact assessment of Natura 2000 is based on the screening report of 16 Natura 2000 areas, eight in Denmark and eight in Germany. Furthermore, in connection with the Natura 2000 assessments of the possible sand extraction at Krieger’s Flak and Rønne Bank, a preliminary assessment (screening) has been made of the possible impacts by the extraction activities on additional three Natura 2000 sites in Denmark and five in Germany.

Transboundary Impacts

The two Swedish marine Natura 2000 sites, which are the closest sites to the area, where final deposition takes place in the Arkona Basin, Falsterbo-Foteviken (SE0430002) and Falster-bohalvön (SE0430095), can be considered as potentially affected sites. However, both areas lie outside the deposition area (closest distance is 6.6 km) and neither direct, nor indirect impacts are expected for these sites.

Excess sediment concentrations in the water column as well as the expected amount of deposited sediment in Swedish waters are low compared to the natural background level in the Arkona Basin.

All other countries further east, i.e. Finland, Poland, Estonia, Latvia, Lithuania and Russia as well as Norway, and other sites in Sweden, will only receive non-measurable sediment deposition, and thus their Natura 2000 sites have not been included in the screening.

Transboundary impacts between Germany and Denmark

For six out of the eight Natura 2000 sites in Denmark the conclusion from the screening phase shows that significant impacts with certainty are not present, and that an appropriate Natura 2000 assessment should not be conducted.

For the remaining two areas, “SCI 006X238 Hyllekrog-Rødsand” (Smålandsfarvandet North of Lolland, Guldborg Sund, Bøtø Nord and Hyllekrog-Rødsand) and “SPA DK 006X083 Coastal Zone Hyllekrog-Rødsand”, the conclusion is different, however, as the screening indicates that an appropriate Natura 2000 assessment should be conducted for the immersed tunnel. Both areas lie within the Natura 2000 area nr. 173 (Smålandsfarvandet north of Lolland, Guldborgsund, Bøtø Nor and Hyllekrog-Rødsand). The rationale behind this judgment is, that it cannot be excluded that the expected amounts of sediment during the construction phase within the Rødsand Lagoon will affect benthic communities of habitat type 1160 (shallow bays and inlets), and 1170 (reefs) through light attenuation and sediment deposition. Sediment spill may also affect food resources and feeding possibilities of breeding and staging birds. The Natura 2000 assessment of area no. 173 concludes that the fixed link over Fehmarnbelt neither in the construction phase nor in the operation phase affects the nature types or species, which the area has been appointed to conserve, or is in conflict with the conservation objectives of the areas.

For five out of the eight Natura 2000 sites in Germany the conclusion from the screening shows that significant impacts on the designation basis of the sites and conservation objectives can be excluded, and that an appropriate Natura 2000 assessment should not be conducted.

For the remaining three areas, SCI DE-1332-301 “Fehmarnbelt”, SPA DE 1631-392 “Meeres-gebiet der östlichen Kieler Bucht”, and SPA DE 1633-491 “Ostsee östlich von Wagrien” the screening indicates that a significant impact on the conservation objectives cannot be excluded. An appropriate Natura 2000 assessment is therefore required for these sites.

All potential impacts in the German Natura 2000 areas are related to the construction phase. Relevant pressures to be considered are related to construction of harbours and other dredging operations, with their resulting sediment spill and subsequent spreading of sediment over a large area.

The possible sand extraction activities on Kriegers Flak and Rønne Banke may by their sediment spill, noise and other disturbances during the extraction and transportation potentially affect Natura 2000 sites located in the influence area of the sand extraction sites.

Concerning the sand extraction at Krieger’s Flak a preliminary Natura 2000 screening shows that for the two Natura 2000 sites, which by the nature and spread of the pressure could be affected (”Klinteskov og Klinteskov Kalkgrund” on Møn (DK990000254) and the German site ”Kadetrinne” (DE1339301)), it can be excluded that there should be any significant impact on the designation basis or conservation objectives.

Concerning the sand extraction at Rønne Banke the preliminary Natura 2000 screening shows that a significant impact can be excluded on the two Danish and the four German Natura 2000 sites. Both the sediment spill as well as the other pressures are considered to be negligible, and there will be no significant impacts in the Danish habitat sites ”Adler Grund og Rønne Banke” (DK00VA261) and ”Bakkebrædt og Bakkegrund” (DK00VA310), in the German habitat sites ”Adlergrund” (DE1251301), ”Westliche Rönnebank” (DE1249301) or ”Pommersche Bucht mit Oderbank” (DE652302) or in the German bird protection site ”Pommersche Bucht” (DE1552401).

Conclusion
The appropriate assessment of the Danish Natura 2000 area no. 173 (Smålandsfarvandet north of Lolland, Guldborgsund, Bøtø Nor and Hyllekrog-Rødsand) concludes as mentioned that the Fehmanbelt Fixed Link will neither in the construction nor in the operation phase affect the species or habitats, which the area has been designated to conserve, nor is the project in conflict with the conservation objectives of the areas.

In Germany the appropriate assessment of the three relevant Natura 2000 areas SCI DE-1332-301 "Fehmarnbelt", SPA DE 1631-392 "Meeresgebiet der östlichen Kieler Bucht", and SPA DE 1633-491 "Ostsee östlich von Wagrien" concludes that the Fehmanbelt Fixed Link will neither in the construction nor in the operation phase affect the Natura 2000 areas, the nature types or species, which the areas have been designated to conserve, nor is the project in conflict with the conservation objectives of the areas.

In the Kattegat and further outside of the Baltic transition area, also including the possible sand extraction areas at Krieger's Flak and Rønne Banke, the impacts are assessed to be negligible, and the construction and operation of an immersed tunnel is therefore assessed to result in no impacts in the Kattegat and the Central Baltic Sea.

On the basis of the implemented Natura 2000 assessments, including both an assessment of the possible distribution of the overall pressures by the project, as well as a Natura 2000 screening of 24 Natura 2000 sites and an appropriate Natura 2000 assessment in two Danish and three German Natura 2000 sites it can be concluded that the project, including possible sand extractions on both Krieger's Flak and Rønne Banke, neither in the construction phase nor in the operation phase will affect any Natura 2000 sites.

1.6.16 Cultural Heritage and Marine Archaeology

It is possible to find ship wrecks from all historic periods in the Fehmarnbelt on both German and Danish marine territory. It is also possible to discover findings from habitations, fishing sites and minor findings of the way of life of prehistoric hunter-gatherer societies.

The following main pressures with respect to cultural heritage and archaeology have been identified from the construction of an immersed tunnel:

- Impacts from anchors, anchor wires and handling of anchors
- Erosion due to changing current conditions caused by the changing seabed after dredging and backfilling of the tunnel trench
- Changing seabed in the project area caused by e.g. sediment spill after dredging and backfilling of the tunnel trench, and establishment of the land reclamation (especially along the coast of Lolland)

Transboundary Impacts
The location of the shipwrecks on Danish and German territory can potentially be affected by construction ships, anchor blocks and anchor wires during construction.

The project pressures identified for marine archaeology from the construction and operation of an immersed tunnel have no transboundary impacts outside the German-Danish EEZs. Therefore, no transboundary impacts on marine archaeology induced by project pressures are expected during construction and operation of an immersed tunnel.

Marine archaeology at Rønne Banke and Kriegers Flak
As the baseline study did not observe any wrecks in the extraction area at Rønne Banke, no assessment has been found relevant for the site. Similarly, settlements have not been registered in the area.

Within the extraction area at Kriegers Flak, three ship-wrecks are registered in a database held by the Danish Heritage Agency. Actions should be taken to provide information of wreck positions to the captain of the dredger to avoid destruction due to dredging activities. However, all three wrecks are located outside the area recommended for extraction.

Ship wrecks outside the extraction area will not be affected by the project, as no activities influencing the seabed will take place here. Furthermore, settlements have not been registered, nor will they be at risk of being affected by the sand extraction due to the deep layer of sand, which has been deposited on the seabed. No impacts are therefore expected for marine archaeology in the extraction area.

Transboundary impacts between Germany and Denmark
Because all impacts on marine archaeology are assessed to be local, no transboundary impacts are expected from project pressures in Denmark on marine archaeology in Germany, and vice versa.

Conclusion
The investigations show that there are no transboundary impacts outside German and Danish territories on marine archaeology from the construction and operation of an immersed tunnel.

No transboundary impacts are expected from project pressures in Denmark on marine archaeology in Germany, and vice versa.

1.6.17 Recreation and Tourism

The tourism and recreation industries in the Baltic Sea area are likely to be dependent on the state of the marine environment. A fixed link between Germany and Denmark may have different impacts on the marine environment that can indirectly affect the tourism and recreational areas in the Fehmarnbelt area. Recreation activities include kite-surfing, water-skiing, kayaking, windsurfing, recreational fishery, and recreational boating.

The following project pressures, in relation to recreation and tourism on Fehmarn and Lolland, have been identified from the construction and operation of an immersed tunnel:

- Habitat loss and changes of recreational habitats also due to the new land reclamation (construction and operation)
- Physical and visual barrier effects of recreational areas and fragmentation of the landscape (construction and operation)
- Air, noise and light pollution of recreational areas (construction and operation)
- Sedimentation in the water column, which impacts the bathing water quality (construction)

Transboundary Impacts
Tourists and other visitors may be temporarily affected by the construction works offshore and near-shore. This applies mainly to recreational boaters who pass the Fehmarnbelt area and for tourists visiting Lolland and Fehmarn. The possibility for practicing recreational activities offshore in the Fehmarnbelt area is assessed to be affected to a minor degree, as there are many places where such activities can take place without disturbances. As such, the offshore construction activities only occupy a minor area within the Fehmarnbelt near shore, and most of the recreational activities take place near shore.

The barrier effect caused by offshore construction works and increased traffic intensity in the Fehmarnbelt will influence the area to a minor degree, but it is assumed that people using the Fehmarnbelt for recreational activities are already used to heavy ship traffic in the area, because there are 52 ferry passages between Rødby and Puttgarden per day.

Concerning transboundary impacts for recreation and tourism, all potential project pressures induced by the immersed tunnel are local, and hence there are no transboundary impacts.

Transboundary impacts between Germany and Denmark
Concerning transboundary impacts for recreation and tourism, all potential project pressures induced by the immersed tunnel project are assessed to be non-existing, as they are all local. No transboundary impacts are expected from project pressures in Denmark on recreation and tourism in Germany, and vice versa.

Conclusion
The investigations show that there are no transboundary impacts outside German and Danish territories on recreation and tourism from the construction and operation of an immersed tunnel.

No transboundary impacts are expected from project pressures in Denmark on recreation and tourism in Germany, and vice versa.

1.6.18 Material Assets

The project pressures identified as relevant in relation to impacts on material assets from the construction and operation of an immersed tunnel are all related to the project area activities and material assets within or in the vicinity of the project area.

Transboundary Impacts
There are no material assets at the extraction sites at Rønne Banke and Kriegers Flak. Therefore no transboundary impacts on material assets outside German and Danish territories are expected.

Project pressures that extend into transboundary areas i.e. more than 10 km from the alignment (such as sediment spill) during construction works offshore, are assessed not to affect planned or existing material assets.

Transboundary impacts between Germany and Denmark
As mentioned, impacts on material assets from the construction and operation of an immersed tunnel are all related to the project area activities and material assets within or in the vicinity of the project area. Therefore, impacts on material assets in Denmark will only be of a local character and not affect German territory, and vice versa.

Conclusion
The investigations show that there are no transboundary impacts on material assets outside German and Danish territories from the construction and operation of an immersed tunnel.

The project pressures on material assets on the Danish side will not cause any impacts on material assets on the German side, and vice versa.

1.6.19 Raw Materials and Waste

In this chapter the environmental impacts of raw material consumption and disposal of waste generated during construction and operation of the immersed tunnel are assessed separately.

Raw materials
The main raw material consumption, i.e. concrete, steel and gravel have been calculated for the project including the tunnel, the land reclamation, and connecting railroad and highway.

Concerning import of raw materials, the dredged materials from the tunnel trench is planned to be used as filler in the land reclamations at Fehmarn (1 million m^3) and Lolland (15 million m^3). Thus, a maximum of 1 million m^3 of sediment will be imported from Danish territorial waters to Germany and up to 7.5 million m^3 of sediment will be imported from German territorial waters to Denmark. The total amount of dredged materials from the tunnel trench and cut-and-cover tunnel corresponds to 15 million m^3.

Transboundary Impacts of raw materials
Chemical analyses show that the hazardous substances are below national and international criteria, except for one sample. In this sample PCB exceeded the Danish LAC but not HAC. All contaminants are limited to the upper 10 cm of the sediment. Therefore, no transboundary impacts from raw materials are foreseen.

The consumption of raw materials will only cause insignificant transboundary impacts on the environment. The majority of resources will potentially come from Kriegers Flak and Rønne Banke. The environmental assessment is integrated in this report.

Sediment from the Fehmarnbelt can be exported from Denmark to Germany and vice versa, as the sediment generally contains low background levels of contaminants.

Waste
It is assumed that all waste from the project is handled and disposed of properly in accordance with applicable legislation. The total waste generation and the amount of potentially recyclable materials generated during the project are relatively small compared to waste generation at the national level.

Waste from the project will be handled in compliance with the Danish provisions of source separation, authorisation and review of construction and demolition waste. This will ensure that the vast majority of concrete, metal, sand/gravel and asphalt waste will be recycled. If the excavated volumes cannot be reused directly on site, the material will be sent to sorting facilities for reprocessing/recycling.

Transboundary Impacts of waste
It is assessed that disposal of waste can be handled without problems in Germany and Denmark, and that there are no cross-border implications of waste.

Transboundary impacts between Germany and Denmark
As indicated above, there will be no transboundary impacts due to consumption of raw materials or generation of waste, between Germany and Denmark during the construction or operation of an immersed tunnel. The potential import of sediment dredged from the tunnel trench from Germany to Denmark, or vice versa will not result in any transboundary impacts either.

Conclusion
There are no transboundary environmental impacts identified by consumption of raw materials or generation of waste between Denmark and Germany and vice versa.

1.6.20 Air Quality and Climate

Construction of the immersed tunnel involves a number of activities on land and offshore, which will result in emissions of pollutants into the air.

The construction and operation of the immersed tunnel will also result in emission of greenhouse gasses (GHGs), either directly (such as exhaust from heavy equipment) or indirectly (such as electricity consumption and in the production of steel and cement used for the construction of the immersed tunnel).The greenhouse gasses will be released to the atmosphere and therefore add to the global emission of greenhouse gasses. The GHGs are irrelevant to air quality, but are relevant for climate change.

The emissions from marine activities, that is, from dredgers, tug boats and construction vessels, are considerable, and air quality will be locally affected. This is based on calculations of fuel consumption, and because for marine works there are fewer regulations for emissions from machines than on land. Since the activities will take place far away from residential areas and in a large area, where the air circulation is good, it is not expected that the threshold values for air quality inland will be exceeded during the construction phase.

With regard to PM_{10} and NO_2 concentrations, calculations of dispersion show that on shore around the tunnel opening and up to approximately 200 m in the direction away from the tunnel opening there will be elevated concentrations of these substances, exceeding current air quality threshold values for residential areas. However, there will be no permanent habitation is these areas, and the public will not have access to the areas, where the concentration is above the threshold values.

Project activities emitting GHGs during the construction and operation phases are: 1) construction of the fixed link, including production of tunnel elements and building materials, the main structures and construction works, temporary work sites and approach links for rail and road; 2) operation of the link, excluding traffic; and 3) traffic.

Transboundary Impacts
Emissions of air pollutants from the marine activities are of a local character and are not expected to affect the air quality offshore. Likewise, the emissions of PM_{10} and NO_2 inland are of a local character.

The assessment of calculated CO_2 emissions during construction of an immersed tunnel shows that CO_2 equivalent emissions of approximately 2.0 million t will be emitted compared with the situation of not establishing a fixed link across the Fehmarnbelt. Over the lifetime (120 years) of the immersed tunnel assuming the same emission and emission factors a total of 0.7 million t of CO_2 equivalents will be emitted during the operation.

The immersed tunnel will also result in savings of CO_2 emissions in the operation phase. The larges saving will be the result of the expected closure of the ferry line between Rødby and Puttgarden. In addition, there will also be a reduction of emissions from freight transport on road and rail. The reason for this is an expected transfer of road freight to rail and a decrease in travel distance for the rail freight. In its lifetime, the immersed tunnel will save over 22,000,000 t of CO_2 compared to a situation with continued ferry service, which is considered a positive impact for the climate.

The emission of GHGs from the construction and operation of the immersed tunnel is overall a small contribution compared to the national and global GHGs emission.

Transboundary impacts between Germany and Denmark
Emissions from the marine activities are as mentioned of a local character and not expected to affect the transboundary air quality. Likewise, the emissions of PM_{10} and NO_2 inland are of a local character, and emissions in Denmark will not affect the air quality in Germany and vice versa.

The emissions of GHGs are assessed as being of no relevance for the air quality on Lolland and Fehmarn.

Conclusion
The Fixed Link project is assessed not to result in significant transboundary impacts outside German and Danish territories as a result of emissions from construction works and the operation of an immersed tunnel. However, over time there will be a minor positive impact from the expected closing of the ferry line between Puttgarden and Rødby and the expected transfer of freight from road to rail.

The conclusion regarding transboundary impacts between Germany and Denmark is that emissions on the Danish side from marine construction activities and emissions of PM_{10} and NO_2 inland will not have impacts on air quality on the German side and vice versa.

1.6.21 Ship Traffic and Navigation

Construction of an immersed tunnel involves a number of marine activities, which will affect the ship traffic in the Fehmarnbelt from adjacent areas.

The project pressures in relation to ship traffic are:

- The offshore construction works
- Exclusion zones
- Work areas offshore
- Barrier effects from construction works

The offshore construction related traffic is estimated to cause 130,000 movements in total during the four years it takes place (approximately 32,000 p.a. which corresponds to the present scenario of the movements of the ferries that sail between Puttgarden and Rødbyhavn). About half of those movements are bound to cross the international T- route in the Fehmarnbelt.

Transboundary Impacts

The offshore construction works, exclusion zones and work areas offshore

The majority of the dredging is related to dredging of a trench across the Fehmarnbelt where the immersed tunnel will be placed, but the works also include dredging for work harbours, access channels to work harbours, and dredging for portals and ramps near the coast associated with the construction of the immersed tunnel. The dredging is planned to be done by backhoe dredgers and trailing suction hopper dredgers, and the sediment will be transported to the reclamation areas with barges. Guard ships will be placed close to the dredging areas on both sides of the trench.

The tunnel elements will be towed from the work harbour to holding areas in the vicinity of the tunnel alignment by tug boats. The tunnel elements are stored in holding areas until they are moved into position and immersed.

Barrier effects from construction works

There will be a barrier effect from the offshore construction works, but since all types of ship traffic can still pass the Fehmarnbelt during the construction phase, this is not assessed as a significant impact.

However, the impacts from construction of an immersed tunnel lead to mainly temporary local impacts, which do not extend beyond the German and Danish Exclusive Economic Zones (EEZ), and thus in the case of ship traffic, no significant transboundary impacts occur. This is mainly due to the effective mitigation measures such as the VTS system and the guard ships, as well as the WVC centre, which all will be in operation during the construction phase. A permanent VTS system has already been put in place in Travemünde by the German authorities, which takes care of the German part of the T-route. These measures ensure that all types of traffic in the Fehmarnbelt can continue as usual during the construction phase. During operation there will be no impacts for ship traffic with an immersed tunnel.

Impacts on Ship traffic at Rønne Banke and Kriegers Flak

Only a smaller amount of ship traffic (135 - 670 passages) passes Rønne Banke and Kriegers Flak (approximately 800-1,400 passages are expected during the construction phase). The extraction activities might cause the changing of sailing routes during the extraction period due to approximately 135-670 expected passages of construction-related traffic. The impact is regarded as minor.

Transboundary impacts between Germany and Denmark

As mentioned, the impacts from construction and operation of an immersed tunnel is assessed to lead to temporary local impacts in the Fehmarnbelt, which do not extend beyond the German and Danish Exclusive Economic Zones (EEZ), and thus in the case of ship traffic and navigation, no significant transboundary impacts occur. There are also no transboundary impacts between Germany and Denmark, as all impacts are considered local and not significant.

Conclusion
The investigations show that the impact from construction and operation of an immersed tunnel is assessed to have no significant impact on the ship traffic in the Fehmarnbelt, Rønne Banke or Kriegers Flak and the transboundary region. This is mainly, because the traffic is allowed to operate during the construction phase, and because the implementation of the different risk reduction measures (mitigation) continuously secures the on-going traffic.

The project pressures on ship traffic and navigation on the Danish side will not cause any impacts on ship traffic and navigation on the German side, and vice versa.

1.6.22 Cumulative impacts

When several planned activities/projects within the same geographical area have an impact on environmental factors at the same time, cumulative impacts may occur. The potential for transboundary cumulative impacts associated with an immersed tunnel in the Fehmarnbelt has thus been assessed. The assessment only includes planned offshore projects of the countries of origin (Germany and Denmark) of the immersed tunnel, as no planned offshore projects/activities of third parties have been identified.

Transboundary impacts
The potential cumulative transboundary impacts have been assessed by analysing impacts from a number of projects, which are mostly offshore wind farms, as well as the replacement of a bridge across the Storstrøm in Denmark. All projects are either German or Danish owned, and they are all planned within German and Danish territories.

The assessment shows that the planned offshore wind farms Arkona-Becken Südost, EnBW wind farm Baltic 2, Wikinger wind farm and the planned wind farm at Kriegers Flak all lie more than 100 km from the project area of the immersed tunnel. Potential cumulative impacts in relation to these projects are sediment spill and displacement of habitat. Regarding sediment spill, no cumulative impacts are expected to occur because of either the large distances, or - for the wind farm at Kriegers Flak - because the sediment spill from the dredging activities overlapping with the project area of the wind farm will consist only of fine sediments, which will be re-suspended and thereby will cause no significant cumulative impacts on the marine environment. Concerning habitat displacement, the immersed tunnel will theoretically affect a number of water birds within a two year period during the construction phase. Since all wind farms lie more than 100 km from the project area it is assessed that the construction of an immersed tunnel will not cause any transboundary cumulative impacts in relation to replacement of habitat.

Concerning the wind farm Rødsand II, a potential cumulative impact on the coastal morphology (erosion) may occur. Rødsand II has been incorporated in the hydrodynamic modelling, which forms the basis for the assessment of impacts on hydrography and coastal morphology from the immersed tunnel. Rødsand II has also been incorporated in the individual-based model (IBM) in relation to the assessment of impacts on Common Eider and other bird species. No significant cumulative impacts on birds in this respect are expected. Concerning cumulative impacts on coastal erosion, mitigation measures in the form of beach nourishment will prevent such impacts, and Rødsand II's contribution in relation to this pressure is assessed as insignificant.

Concerning the wind farm GEOFReE, in order for any cumulative impact to occur, there will have to be an overlap between the dredging works of this project and the two years during which the intensive dredging works of the construction phase of the immersed tunnel are taking place. This is not the case, as the timing of the two projects is different. Regarding displacement of habitat, an immersed tunnel causes a theoretical displacement of habitat for a number of water birds within a two year period. As a consequence of the distance between GEOFReE and the project area, and this limited period of time, it has been assessed that there will be no cumulative impacts concerning displacement of habitat between these two projects.

Regarding extraction of raw materials at Kriegers Flak and Rønne Banke, the assessment concludes that given the very limited and local range of the sediment plumes near the extraction site and the distance of more than 130 km from these to the work areas where the construction of an immersed tunnel takes place, cumulative transboundary impacts are unlikely to occur. Only an assessment of potential cumulative impacts between the sand extraction at Kriegers Flak and the construction phase of the wind farm at Kriegers Flak is relevant, since the time schedule of these two projects are expected to overlap. However, since the exact timing of the work activities in relation to the construction of the wind farm is not known, it has not been possible to assess to what extent cumulative impacts may occur.

Concerning a planned new Storstrøm Bridge, it has not been possible to assess potential transboundary cumulative impacts, because the EIA for the Storstrøm project has not been completed yet. However, it has been assessed that disturbance and loss of habitat will only cause local impacts from the two projects, and no cumulative impacts are expected. Since the old Storstrøm bridge will be dismantled and replaced with a new bridge, no increased barrier effects are expected from the Fehmarn Belt Fixed Link, and no significant cumulative barrier effects are thus expected in regard to the replacement of the Storstrøm Bridge.

Transboundary impacts between Germany and Denmark

As can be concluded from the above, all planned offshore wind farms, and the replacement of the Storstrøm Bridge, are either German or Danish owned, and they are all planned within German and Danish territories. No cumulative transboundary impacts are expected from Denmark to Germany or vice versa.

Conclusion

For the wind farms Arkona Becken Südost, EnBW Baltic 2, and Wikinger, no transboundary cumulative impacts have been identified. Concerning the Rødsand II and GEOFReE wind farms, which both lie closer to the work areas of the immersed tunnel, no transboundary impacts have been identified either.

In relation to the planned wind farm at Kriegers Flak, no cumulative transboundary impacts are expected, even though the construction of the wind farm overlaps with the period of the extraction activities at the site. However, since the exact range and type of work activities in relation to the construction of the wind farm are not known, it has not been possible to assess other potential cumulative impacts.

The construction and operation of a new Storstrøm bridge is not expected to have any significant transboundary cumulative impact.

Overall, no transboundary cumulative impacts have been identified in relation to the construction or operation of an immersed tunnel.

1.6.23 Summary

The investigations of the environmental impact assessment show that for two environmental components there will be a physical transboundary impact beyond the borders of Germany and Denmark.

Firstly, there will be a globally non-significant impact as a result of the emissions of greenhouse gases. Secondly, there will be deposition of suspended sediments from the sediment spill in the Arkona Basin as a result of the dredging activities of the Fehmarnbelt Fixed Link. Regarding the sediment spill, it is assessed that the amounts of deposited sediment on Swedish territory are very small and have a non-significant impact on the marine environment. Project-related transboundary impacts from temporarily increased concentrations of sediment and deposition rates on Swedish territory are very small and have insignificant impacts on the marine environment.

In addition to the mentioned physical impacts, there may be impacts on migratory bird and fish species. The impacts on fish take place in the near zone in Denmark or Germany without transboundary impacts. Only fish that migrate to other regional waters such as cod, whiting and herring may theoretically be affected and only with an insignificant impact.

Similarly, there will in general be no transboundary impacts on birds, but there may be a theoretical impact on Common Eider in areas belonging to Sweden, Finland, Russia, Estonia, Latvia, Lithuania, and Poland, because of a temporary and impact on this bird species in the local area of the project.

Concerning ship traffic and navigation, the insignificant impact of national and international ship traffic in the Fehmarnbelt will be temporary and limited to a period of four years, which is the time; the offshore construction works have been estimated to last. Based on that it is assessed that there will be insignificant transboundary impacts on ship traffic and navigation.

1.7 CONTROL AND MONITORING PROGRAMME

Femern A/S has decided to develop an inspection and monitoring programme for the construction and operation of the Fehmarnbelt Fixed Link. This is not a formal requirement from the EIA Executive Order, but customary practice if a project entails impacts, which impacts and development cannot be inspected or monitored solely on the basis of requirements and threshold values already prescribed by public authorities.

The purpose of the programme is:

- to verify that the project is compliant with prevailing standards, requirements and threshold values for construction and operation
- to monitor that any project pressures are as assumed in the environmental impact assessments
- to monitor that mitigation and compensation measures function as assumed
- to be able to implement corrective actions, if necessary

Therefore the programme will only be carried out for activities, where the impact is assessed as significant or insignificant in the EIA. For activities assessed as having no impact, or where the impact is so minor it is assessed as being of no consequence whatsoever, no inspection or monitoring will be carried out.

The monitoring programme will be based on self-regulation, where the requirements for the contractor's documentation of compliance with conditions, requirements, etc. will be set contractually.

The findings of the programme will be reported to the authorities at regular intervals, and interested groups, especially affected parties and the general public, will have access to monitoring data and results. The programme of parts hereof will be implemented at latest at the initiation of construction activities and is expected to be completed during the operation phase, depending on the type of parameter monitored.

The monitoring programme will be organised as part of an environmental management system, which will also set out guidelines and procedures indicating what is to be inspected and monitored, by whom, when and how.

The monitoring programme will be based on four main component packages:

1. Requirements for inspections at the construction site in compliance with statutory environmental requirements. This relates to e.g. emissions, handling of oil and chemicals, waste management, effluent discharge, raw materials consumption, etc.
2. Requirements for spillage control of dredged sediment in compliance with contractually stipulated requirements. The contractor of marine construction works will be responsible for inspecting sediment spillage from all relevant sources at sea and for reporting to Femern A/S in compliance with the guidelines
3. Monitoring of implemented mitigation and compensation measures in order to ensure that the projected ecological functionality is achieved

4 Monitoring of selected biological/chemical components in order to verify basic model assumptions and to document the actual environmental status by means of selected parameters (e.g. Natura 2000 area designation basis and Marine Strategy Framework Directive's requirements for good qualitative status).

2 INTRODUCTION TO THE FEHMARNBELT FIXED LINK

This report, hereafter the Espoo Report, constitutes the transboundary environmental impact assessment for the Fehmarnbelt Fixed Link to be used for the consultation of the Baltic Sea countries and Norway in accordance with the Espoo Convention on Environmental Impact Assessment in a Transboundary Context (hereafter "the Espoo Convention" or "the Convention").

The Fehmarnbelt Fixed Link is a joint Danish and German transport infrastructure project across the Fehmarnbelt (Figure 2.1). The project has been planned in accordance with the 2008 Treaty between the Kingdom of Denmark and the Federal Republic of Germany for a fixed link across the Fehmarnbelt. The Kingdom of Denmark is responsible for the planning, construction, and operation of the Fehmarnbelt Fixed Link. In order to carry out this task the government of Denmark has established the company Femern A/S, which is 100% owned by the Danish State, represented by the Danish Ministry of Transport.

The Fehmarnbelt Fixed Link has been planned as a consequence of Denmark and Germany recognising that the transport infrastructure between the two states must be improved in order to promote the European and regional transport of goods and people. A fixed link across the Fehmarnbelt would lead to an appreciable improvement in the transport of goods and people between the two countries and also between continental Europe and Scandinavia.

Furthermore, the two countries wishes to strengthen the transport links between the two states and thereby create the necessary conditions for a more intensive cultural and economic cooperation to the benefit of the European Union, the two states, and the regions bordering the Fehmarnbelt.

A fixed link across the Fehmarnbelt will promote rail traffic between Germany and Denmark and also between continental Europe and Scandinavia and strengthen the integration and vitality in the regions as well as promote competition and development in the regions.

The fixed link across the Fehmarnbelt will extend to stretch across the 18 kilometres wide Fehmarnbelt between the Danish island of Lolland and the German island of Fehmarn in the western part of the Baltic Sea.

The Fehmarnbelt region is demarcated as the northern part of Germany, the eastern part of Denmark and the southern part of Sweden. The region has a population of just under 9 million, approx. 1.2 million in the Swedish part, approx. 2.5 million in the Danish part and approx. 5.2 million in the German part.

The Fehmarnbelt Fixed Link covers areas on Lolland (Denmark), Fehmarn (Germany) and a marine area (Denmark and Germany). The project crosses the national border between Denmark and Germany.

Construction works will take place within the national jurisdictions of both countries.

FIGURE 2.1 **The Fehmarnbelt Region**

The four technical solutions investigated are a cable-stayed bridge, a suspension bridge, an immersed tunnel and a bored tunnel. For each technical solution possible alignments are investigated, and a comparison between the technical alternatives has been performed.

The fixed link is planned as an 18 km long immersed tunnel because the investigations and planning indicate that an immersed tunnel is the best solution in terms of e.g. technical construction risks, construction investments and environmental factors.

A summary of the investigations and background for the selection of the technical solution is presented in this report. As the immersed tunnel is the project being applied for and hereby the preferred solution, focus in this report is on the immersed tunnel.

2.1 READING GUIDE

The Espoo Report is structured along the broad lines of conventional EIA Reports as set out below.

- *Chapter 1* is a summary which aims to provide a summary of the Fehmarnbelt Fixed Link and the environmental components and possible impacts.
- *Chapter 2* gives an introduction to the Fehmarnbelt Fixed Link and its background.
- *Chapter 3* describes the legal basis for the Espoo consultation and the planned consultation process.

- *Chapter 4* provides the reader with an understanding of the environmental and technical argumentation for determining the alignment of the immersed tunnel.
- *Chapter 5* is a thorough technical description of the preferred solution – the immersed tunnel.
- *Chapter 6* describes other investigated technical solutions and alignments and the reason for deselecting these.
- *Chapter 7* presents the transboundary environmental impact assessment, including the baseline conditions, transboundary impacts, impacts between Germany and Denmark, level of significance and mitigation measures.
- *Chapter 8* gives a description of the strategy for the future control and monitoring programme.

2.1.1 Transboundary assessment approach

The approach adopted for the assessment of transboundary impacts presented in this report is based on a number of premises:

During construction of an immersed tunnel in the Fehmarnbelt the environment will to some extent be impacted. Some pressures are associated with the construction phase; others are linked to the operational phase, and some to both phases. In addition, some pressures are temporary and others are permanent.

The presented assessment takes into account both the type of impact, the level of impact and the proximity of the impact to the Exclusive Economic Zone (EEZ) of other countries.

Therefore, the Espoo Report addresses both impacted and non-impacted components in order to address all concerns in nearby countries around the Baltic Sea. The components described are:

- People and human health
- Hydrography
- Water quality
- Sediment and seabed forms
- Coastal morphology
- Plankton
- Benthic flora
- Benthic fauna
- Fish ecology
- Commercial fisheries
- Marine mammals
- Birds
- Migrating bats
- Strictly protected species
- Natura 2000
- Cultural heritage and marine archaeology
- Recreation and tourism
- Material assets
- Raw materials
- Climate and air quality

- Ship traffic and navigation
- Cumulative impacts

The chapters concerning impacts on the different components have the following structure: First the baseline investigations will be presented, then the pressures of the project on the component, then the transboundary impacts on the component, then the transboundary impact on the component between Germany and Denmark, and then the significance of the transboundary impact. Finally, possible mitigation measures are presented.

The aggregated impacts of the pressures by the project and possible cumulative impacts in relation to existing pressures are part of the environmental assessment of the different components. Aggregated pressures such as the pressures on the benthic flora and fauna by increased amounts of suspended sediment concentrations in the water and accompanying increased sedimentation are treated as part of the impact assessment. The assessment does also include, where relevant, the existing pressures as part of the baseline conditions to elucidate the total anthropogenic impacts on the assessed component. Cumulative transboundary impacts in relation to future planned projects will be treated in a separate chapter 7.24.

The construction of Fehmarnbelt Fixed Link will require large amounts of sand, gravel and crushed stone. In the environmental impact assessment it is assumed that the extraction of sand will take place at Kriegers Flak and Rønne Banke in the Baltic Sea, northeast and east of the Fehmarnbelt. These two extraction places are included in the transboundary impact assessment.

3 ESPOO CONSULTATION AND BACKGROUND

3.1 LEGAL FRAMEWORK

The Fehmarnbelt Fixed Link is subject to a transboundary environmental impact assessment according to the Espoo Convention on Environmental Impact Assessment in a Transboundary Context (hereafter "the Espoo Convention" or "the Convention") and EU Directive 85/337/EEC as the Fehmarnbelt Fixed Link can potentially impose transboundary environmental impacts.

The Espoo Report is to serve the objectives and comply with the requirements of the Espoo Convention.

The Espoo Convention's primary aim is to prevent, mitigate and monitor environmental damage by ensuring that explicit consideration is given to transboundary environmental factors before a final national decision is made as to whether to approve a project.

In addition, the objective of the Espoo Convention is the identification and communication of potential transboundary impacts to stakeholders via the application of an impact assessment.

3.1.1 Parties of Origin

According to Article 3 of the Espoo Convention, the Parties of Origin are responsible for the content and acknowledgement of receipt of notifications, and for the exchange of relevant information to/from the potentially affected countries.

For a transnational project such as the Fehmarnbelt Fixed Link Project, both Denmark and Germany are parties of origin.

In Denmark, the Danish Ministry of Environment is responsible for the above-mentioned exchange of relevant information to and from the potentially affected countries in connection with the Danish Espoo procedure.

3.1.2 Possible Affected Parties

According to Article 3 of the Espoo Convention, Germany and Denmark must notify affected parties. In relation to the Fehmarnbelt Fixed Link, the possible affected parties, apart from Denmark and Germany, could be countries around the Baltic Sea Sweden, Poland, Finland, Estonia, Latvia, Lithuania, and the Russian Federation and Norway.

Furthermore, since Fehmarnbelt Fixed Link is a transnational project, the parties of origin (Denmark and Germany) are also considered possible affected parties.

3.2 ESPOO AND NATIONAL ENVIRONMENTAL IMPACT ASSESSMENTS

3.2.1 National Environmental Impact Assessments

According to the Treaty between the Kingdom of Denmark and the Federal Republic of Germany, the necessary approval procedures for the part of the fixed link across the Fehmarnbelt that is situated on German territory shall be carried out according to German law and according to Danish law for the part of the fixed link across the Fehmarnbelt that is situated on Danish territory.

It is common to both the Danish and the German Environmental Impact Assessments (EIAs) that they describe and assess the environmental impacts for the entire project area and that both are based on the same environmental data generated and orchestrated by Femern A/S.

In Denmark the environmental impact assessment is presented in one document, the Danish VVM report (Vurdering af Virkninger på Miljøet). The VVM report describes the immersed tunnel and alternative technical solutions, and assesses the immersed tunnel, including design optimisation and mitigation and compensation measures.

In Germany the environmental impact assessment is presented in two documents, the UVS (Umweltverträglichkeitsstudie) and the LBP (Landschaftspflegerischer Begleitplan). The UVS assesses the immersed tunnel, a bored tunnel solution and a cable-stayed bridge. The LBP focuses solely on the immersed tunnel and defines all mitigation and compensatory measures and other arrangements for the equalisation of the project's impact on the environment.

Due to different laws, guidelines and practices on assessing impacts with and without design optimisation and mitigation and compensation measures, the conclusions in the VVM/UVS/LBP can have different nuances. However, the conclusions of the VVM are similar to the conclusions of the UVS and the LBP together.

3.2.2 The Espoo Documentation

The present report constitutes the Fehmarnbelt Fixed Link documentation for the Danish authority Espoo procedure, focusing on transboundary environmental impacts, including a summary of these.

For practical reasons, the Espoo Report does not replicate all of the detailed material that is required in the national EIAs (such as national legislative provisions and detailed country-specific baseline descriptions), and is focused instead on providing sufficient background information, including baseline data, for facilitating the identification of transboundary impacts. The assessment includes design optimisation as well as mitigation and possible compensation measures. As the focus is on the transboundary impacts the conclusions therefore have different nuances compared to the national EIA reports.

The Espoo report is written in English and the summary will, for information, be translated into German, Finnish, Polish, and Swedish.

3.3 ESPOO CONSULTATION PROCESS

3.3.1 Notification

According to Article 3 of the Espoo Convention, Germany and Denmark on 21 June 2010 sent a notification to the countries that are regarded as potentially Affected Parties. The notified countries are Sweden, Poland, Finland, Estonia, Latvia, Lithuania, the Russian Federation and Norway.

In the notification, Germany and Denmark invited the notified countries to participate in the EIA procedure for the Fehmarnbelt Fixed Link and, as part of the notification, included the Scoping Report - proposal for an environmental investigation programme for the Fehmarnbelt Fixed Link (coast-to-coast).

Responses have been received from Estonia, Finland, Latvia, Lithuania, Norway, Poland and Sweden.

Finland, Poland, Norway and Sweden responded that they wish to participate in the EIA documentation process and are therefore invited to participate in the Espoo consultation process.

The notification comments are published on the Femern A/S website, www.femern.com.

3.3.2 Handling of Notification Comments

All countries wishing to take part in the Espoo consultation process commented on the Scoping Report and the subsequent EIAs and Espoo Report.

Comments from notified parties have been evaluated and taken into account by Femern A/S, the State Company for Road Construction and Transport of Schleswig-Holstein and the Danish Ministry of the Environment, and they are addressed in the Espoo Report.

Most of the comments from the notification of the project and associated Scoping Report were centred on possible impacts from a bridge solution. The preferred solution for the project is an immersed tunnel and because of this a large number of comments are therefore no longer relevant.

In addition a number of the comments were regarded as out-of-scope in relation to both the EIA and the Espoo Report, such as overall energy planning and CO_2 assessment in the region and related socio-economic consequences.

3.3.3 Consultation Process

The Fehmarnbelt Fixed Link has a large number of both local and regional stakeholders. As a result, Femern A/S has conducted hearings and consultations, as well as supplying the local community with information about the project in order to involve all relevant parties and stakeholders in the further development of the project. Femern A/S will continue these information activities while the project is being developed.

Hearings and consultations are being performed in line with legal requirements and, in addition, other means of information have been used, including web information, local meetings and participation in conferences.

The comments, remarks and ideas received will, where possible, be incorporated in the project and the project design.

4 PLANNING OF ALIGNMENT – IMMERSED TUNNEL

During the planning of the Fehmarnbelt Fixed Link, Femern A/S examined alternative alignments for all the investigated technical solutions. In this chapter both the process of choosing the project corridor and the alignment alternatives for the immersed tunnel are described. The alignment alternatives are subsequently compared and one alignment for the immersed tunnel is selected as the preferred choice. For information about the alignment alternatives for the technical solutions not selected, see Chapter 6.

Femern A/S has chosen predominantly to follow the German planning act (Richtlinien für die Erstellung von Umweltverträglichkeitsstudien im Strassenbau RUVS-Entwurf 2008, Merkblatt zur Umweltverträglichkeitsstudie in der Strassenplanung MUVS 2001) for the planning of the alignment of the coast-to-coast project. The method consists of first identifying a project corridor based on an assessment of environmental conflict potentials in the study area – a so-called environmental sensitivity analysis. The purpose of this approach is to determine, right from the start of the project, whether the project is feasible and, if so, which general conditions and environmental conflict potentials in terms of impacts could exist.

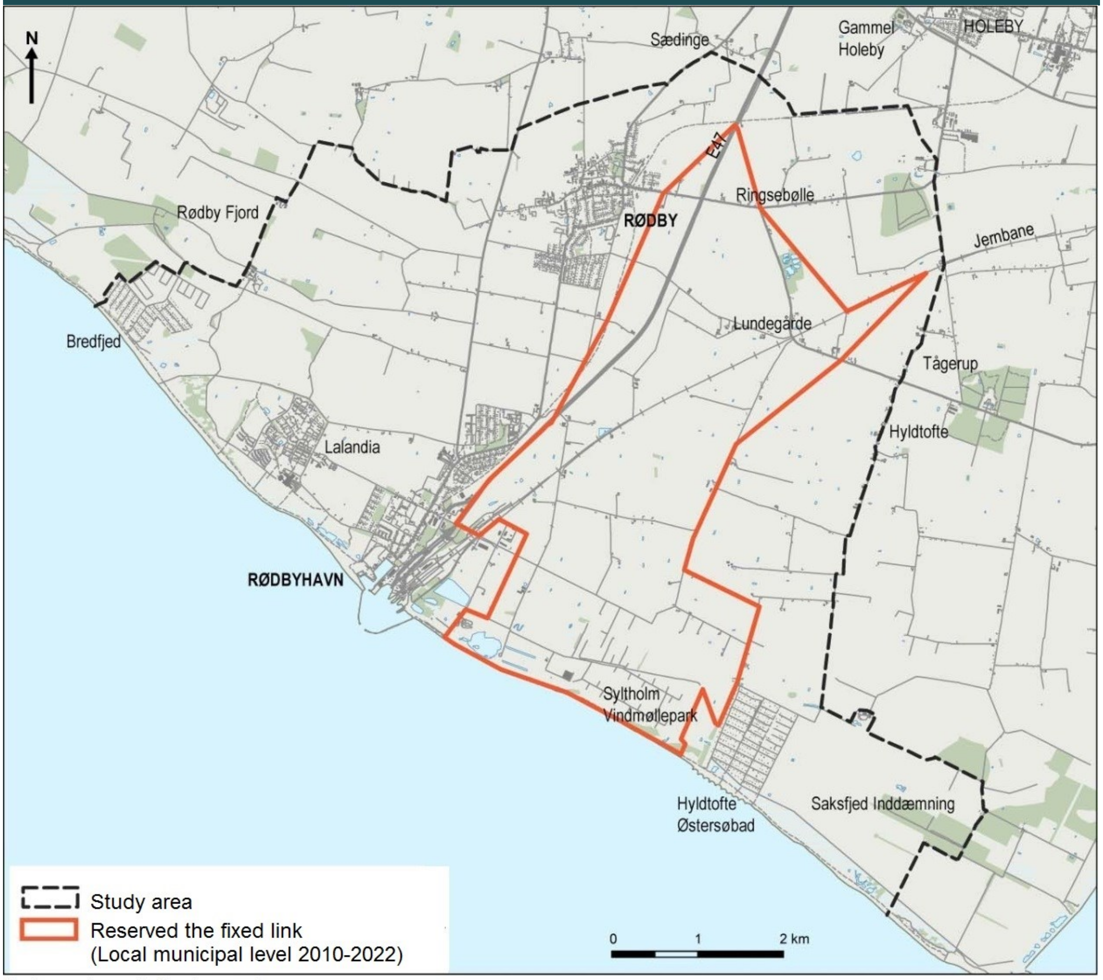
On the basis of the environmental sensitivity analysis and technical and safety considerations, Femern A/S has identified the preferable alignment. The alignment was identified on the basis of a so-called alignment analysis. The basis of the identification of alignments was:

- The Treaty of 3 September 2008 between the Kingdom of Denmark and the Federal Republic of Germany on a Fixed Link across the Fehmarnbelt
- Act on the planning of the Fixed Link across the Fehmarnbelt with associated hinterland infrastructure in Denmark (Act no. 285 of 15 April 2009)
- The 2010 - 2022 urban area development plan (Lolland Municipality, 2011), in which an area reservation has been designated for the Fixed Link east of Rødbyhavn (Figure 4.1)
- The study area defined in the Scoping Report where the detailed environmental investigations have been initiated
- Existing information about the area as well as preliminary environmental investigations (landscape, nature and cultural heritage) conducted by Femern A/S from April 2009.

After finalisation of the environmental sensitivity analysis, Denmark has implemented the EU Directive 2000/60/EC (establishing a framework for community action in the field of water policy) and initiated a number of water programmes. The water programme for the area around Rødbyhavn has been taken into account in the selection of alignment.

This chapter gives an account of the results of the environmental sensitivity analysis and the alignment analysis and includes a description of the possible alignment alternatives for the immersed tunnel.

FIGURE 4.1 Area reserved for the project in the development plan of Lolland Municipality 2010 - 2022



Background map @ Geodatastyrelsen

4.1 DETERMINATION OF A PROJECT CORRIDOR

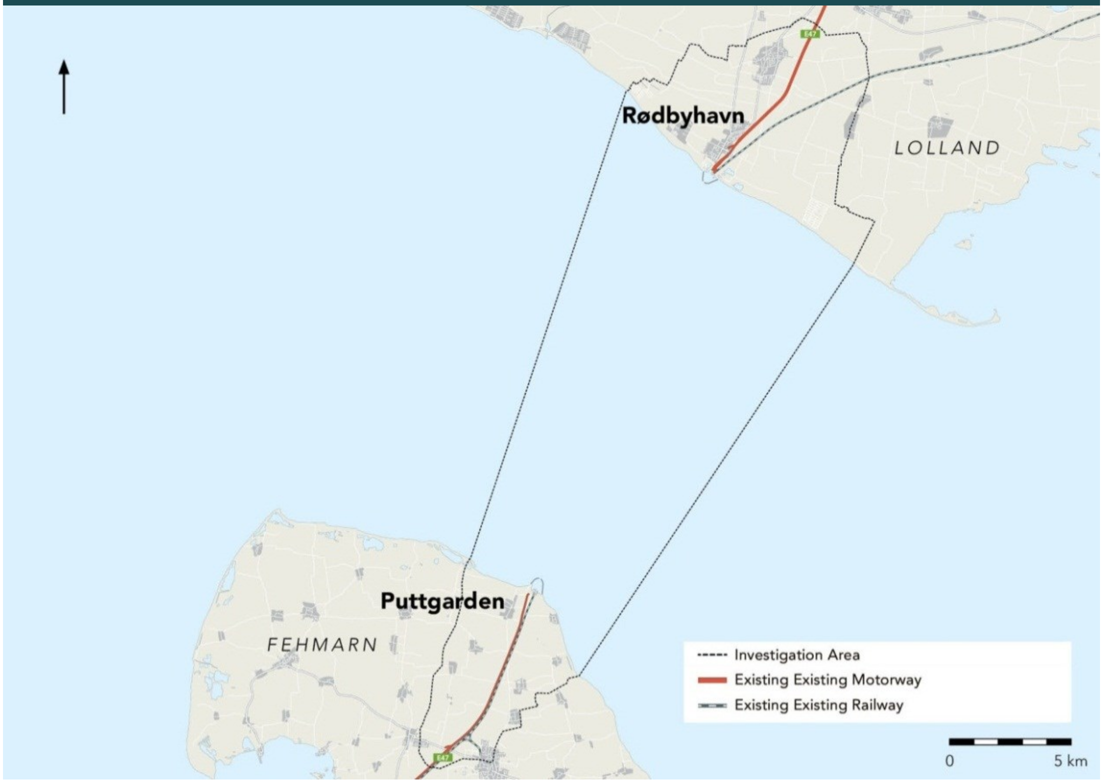
The purpose of the environmental sensitivity analysis is, at an early stage, to identify the project corridor for the coast-to-coast project that has the least possible conflict potential for the environment.

The analysis covered a defined geographical area around Rødbyhavn and Puttgarden, (Figure 4.2) and was based on existing knowledge. It is considered inexpedient to place the project corridor outside the defined area, as this would mean a longer link across the Fehmarnbelt, and it would require more extensive road and railway installations onshore to connect to the existing road and railway networks.

In the environmental sensitivity analysis, the study area is divided into areas of varying sensitivity, which are understood as having different conflict potentials between the Fixed Link and environmental interests. The sensitivity of the areas is divided into three categories: high, medium and low conflict potential.

The sensitivity is assessed for the following environmental factors: landscape, soil, population, flora and fauna, cultural heritage, material assets, surface water, groundwater and air. The sensitivity assessment includes both planning commitments, material assets such as pumping stations, wind turbines and the like.

FIGURE 4.2 **Study area for project corridors and alignments**



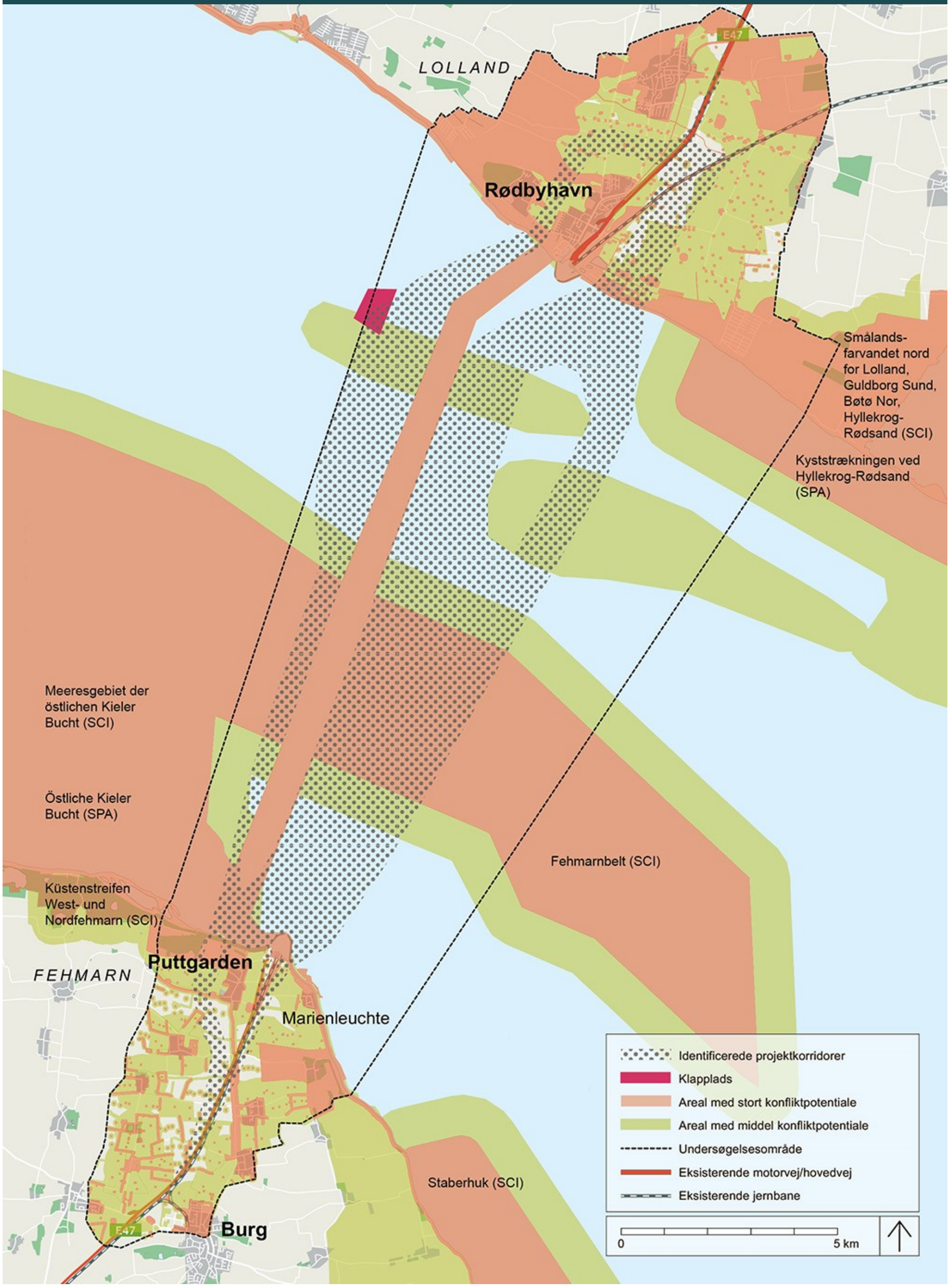
For example, an area that is part of a Natura 2000 area will be classified as an area with high conflict potential, while buffer zones designated by Femern A/S around Natura 2000 areas will be classified as areas with medium conflict potential. The sensitivity of the areas is illustrated in Figure 4.3.

On the basis of the identification of the conflict potential of the areas within the study area, the project corridor with the lowest conflict potential has been identified (Figure 4.3). Furthermore, the following prioritisations were made in relation to identifying the project corridor:

- The project corridor must bypass the central parts of the ferry facilities at Rødbyhavn and Puttgarden because the ferry link must be operable during the construction and operational phases of the coast-to-coast project. To a limited extent, areas in the periphery, such as parking areas, areas for storage of goods, etc. were included.
- The project corridor must avoid a large submarine cable located under the seabed between Rødbyhavn harbour and Puttgarden harbour.
- Project corridors which imply a markedly longer coast-to-coast connection are deselected.

Consequently, the project corridor has been divided into a western and an eastern corridor.

FIGURE 4.3 Conflict potential between the coast-to-coast project and environmental interests. Areas without a coloured sign were assessed as having low conflict potential



4.1.1 Corridors in the marine area

Based on the location of the submarine cable, a western and an eastern corridor have been identified in the marine area. On the Danish side, the eastern corridor is divided in two (Figure 4.3).

The eastern corridor is, in its western geographical range defined by the submarine cable, and in its eastern geographical range the corridor is defined by a buffer zone designated on the Danish side in relation to the Natura 2000 area 'Smålandsfarvandet north of Lolland, Guldborgsund, Bøtø Nor, Hyllekrog-Rødsand' (SCI) and the coastal section at Hyllekrog-Rødsand (SPA). On the German side, the definition was based on the coastal area east of Puttgarden, which has high protection status under the German Nature Protection Act.

To the west, the western corridor is defined on the German side by the Natura 2000 areas, BSG DE 1530-491 ‘Östliche Kieler Bucht’ and GGB DE 1631-392 ‘Meeresgebiet der östlichen Kieler Bucht’, which are located just off the coast.

In the marine area, the following environmental conflict potentials have been identified:

- Approx. 1 km off the coast of Lolland, an area was identified with sand waves having a geomorphology that differs from the general seabed in the Fehmarnbelt. The sand waves are classified as having medium conflict potential because of their protection status under German law, not because of their ecological function. The sand waves do not have any special protection status in Danish waters. Both the western and eastern corridors pass through the sand wave area.
- On the German side and in the middle of the Fehmarnbelt, both corridors pass by the German Natura 2000 area 'Fehmarnbelt' (SCI). The western corridor extends furthest into a nature protection area, and its width on parts of the section has therefore been reduced to approx. 500 m, so as to keep clear of as large a part as possible of the inshore German Natura 2000 areas. This includes the areas BSG DE 1530-491 ‘Östliche Kieler Bucht’ and GGB DE 1631-392 ‘Meeresgebiet der östlichen Kieler Bucht’ and West and North Fehmarn sections of coast (SCI).

In the marine area, the environmental sensitivity analysis suggests that an eastern corridor has a lower environmental impact than a western corridor, since it passes through fewer areas with high conflict potential.

4.1.2 Corridors on Lolland

On Lolland, two corridors have been identified, a western and an eastern corridor (Figure 4.3). The areas with the highest conflict potential are:

- The residential areas at Rødby and Rødbyhavn
- The holiday resort Lalandia west of Rødbyhavn
- The holiday cottage areas at Bredfjed and Hyldtofte Østersøbad to the east of Rødbyhavn

The western corridor passes by the coast between Rødbyhavn and Lalandia at a distance of approx. 200 - 500 m from buildings on both sides. A couple of km from Rødbyhavn it turns east where it passes between Rødbyhavn and Rødby at a distance of approx. 500 m to both residential areas. At the existing motorway, the corridor turns north-east up to the connection to the existing road and railway network.

The eastern corridor is approx. 1 km wide and has a straight course up to the connection with the existing motorway and railway.

In the coastal area, both corridors affect sensitive areas in connection with the dike and the area behind the dike. The area behind the dike consists of recreational areas and habitats of plants and animals as well as areas with landscape and cultural values. There are also minor nature protected areas and individual properties in the open land.

On Lolland, the environmental sensitivity analysis suggests that an eastern corridor has a lower conflict potential than a western corridor.

4.1.3 Corridors on Fehmarn

On Fehmarn, three corridors have been identified: one corridor just east of Puttgarden harbour, one corridor just west of Puttgarden harbour and one corridor further to the west (Figure 4.3).

On Fehmarn, the following areas have the highest conflict potential:

- The residential areas Puttgarden, Todendorf, Hinrichsdorf (west of the existing road and railway network), and Presen (east of the existing road and railway network)
- The northern coast west of Puttgarden harbour with protected nature areas
- The coastal area both east and west of Puttgarden harbour with beaches and dikes.

The corridor west of Puttgarden harbour extends along the areas of the harbour and with its connection to the existing road and railway network. In the coastal area, the corridor affects areas with high and medium conflict potential, e.g. harbour facilities, a farm and a hotel. At Puttgarden, the corridor also passes through residential areas. After Puttgarden, the corridor passes through areas with low conflict potential.

The most western corridor is divided in two from the coast and approx. 1 km inland. The corridor extends from the coast and approx. 2 km inland in areas with high or medium conflict potential, e.g. the buffer zone to the Natura 2000 area West and North Fehmarn section of coast (SCI) and a salt meadow area. Both areas are of great importance to flora and fauna and as recreational areas. After that, the corridor passes west of a residential area in Puttgarden.

The corridor east of Puttgarden harbour follows the existing road and railway network. In the coastal area, the corridor affects areas with high and medium conflict potential, among other things, harbour facilities, a beach and a salt meadow with two small ponds. After that the corridor passes by areas with low conflict potential.

Of the three corridors, the eastern corridor is the one that passes by fewest areas with high or medium conflict potential.

4.1.4 Summary – the preferred project corridor

On the basis of the environmental sensitivity analysis, the eastern corridor is considered to be the preferred project corridor based on the level of environmental impact.

In the marine area the eastern corridor is the preferred corridor as it intersects a smaller part of the Natura 2000 site and it is placed further away from the coastal part of this protected site.

On Lolland, the eastern corridor is the preferred corridor as it does not affect the urban areas, Rødbyhavn and Rødby, and the holiday resort Lalandia. In the eastern corridor, biological interests will primarily be affected, but this may be prevented by replacing the impacted biological interests.

On Fehmarn, the eastern corridor is also the preferred corridor because it follows the existing road and railway network and in contrast to the western corridors does not affect the residential areas west of the road and railway network and the northern coast with protected nature areas.

The result of the environmental sensitivity analysis was published in December 2010 on www.femern.com.

4.2 DETERMINATION OF ALIGNMENT

The alignment of the coast-to-coast project was decided on the basis of an alignment analysis, in accordance with German practice and methods. The purpose of the alignment analysis was to find the preferred location of the coast-to-coast project, based on both technical, environmental, construction logistics and safety criteria.

The alignment analysis was conducted within the same study area as the environmental sensitivity analysis (Figure 4.2). The results of the environmental sensitivity analysis were used for the rejection of alignments based on environmental arguments.

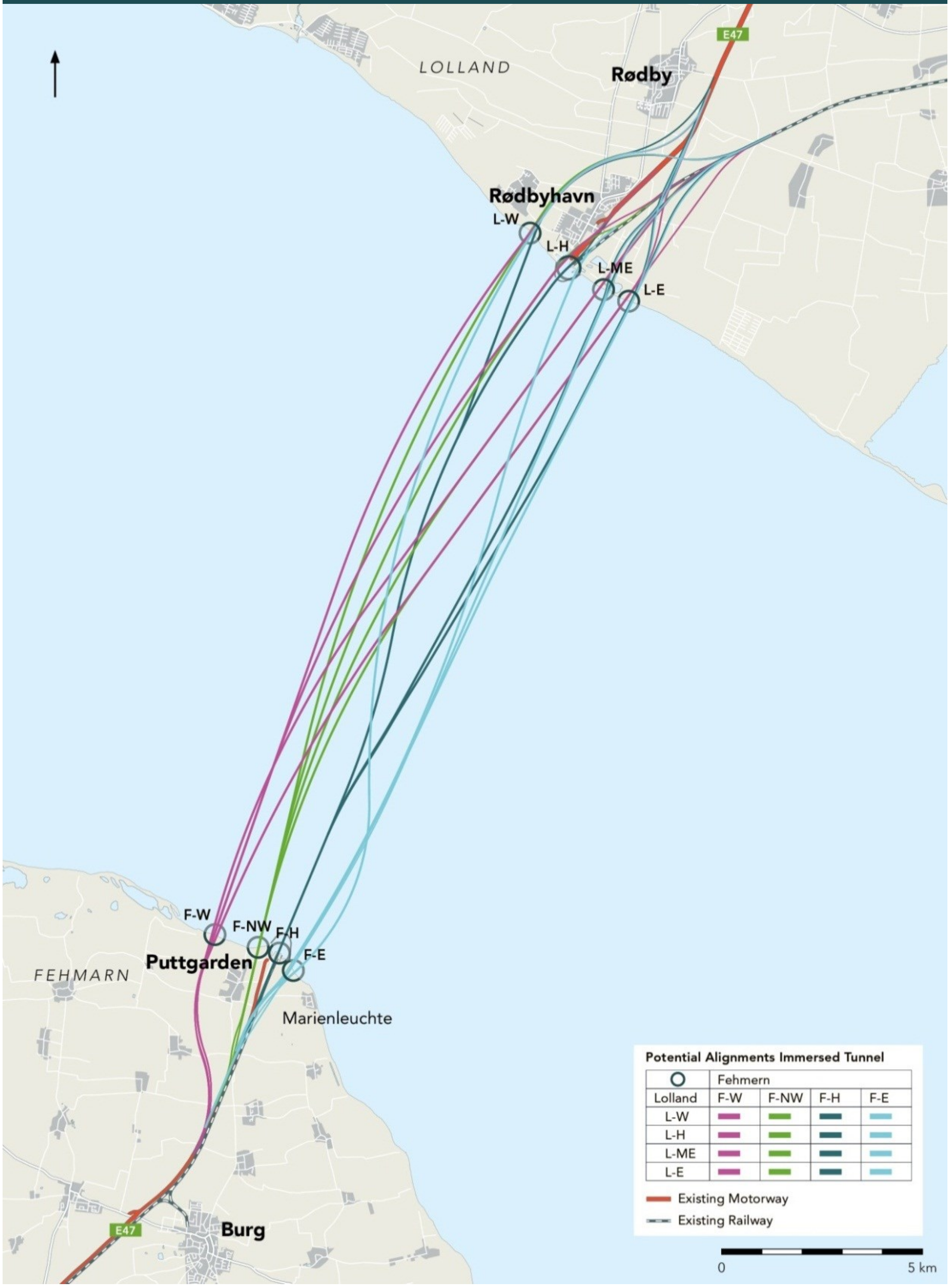
Similar to the environmental sensitivity analysis, the alignment analysis was conducted in an early phase of the project and was based on existing knowledge.

The alignment analysis concentrates on the most significant differences between the alignment alternatives.

4.2.1 Identification of alignment alternatives

On the basis of the environmental sensitivity analysis and the identified project corridors, four approaches on Lolland and Fehmarn were identified within the eastern and western corridors. This gives 16 different combinations of alignment alternatives for the immersed tunnel (Figure 4.4).

FIGURE 4.4 Alignment alternatives for a tunnel solution



Identification of the alignment of the coast-to-coast project is subject to the following limitations:

- The ferry operation between Rødbyhavn and Puttgarden must be allowed to be operable in a safe way during the construction phase of the coast-to-coast project.
- The submarine cable, which is located below the seabed between Lolland and Fehmarn west of the two ferry harbours, cannot be impacted (particularly relevant in relation to a tunnel solution).

On the basis of the above limitations, alignments which fully or partly make use of the harbour facilities in the Rødbyhavn and Puttgarden harbours have been rejected, i.e. alignment alternatives with approach at either Rødbyhavn harbour (L-H) or Puttgarden harbour (F-H) (Table 4.1).

Alignments impacting the submarine cable have been rejected, i.e. alignments with approach west of Rødbyhavn harbour (L-W) or west of Puttgarden harbour (F-W).

Because the western project corridor is less expedient than the eastern project corridor, based on an environmental assessment, all western alignment alternatives have been rejected.

TABEL 4.1 Final alignment alternatives for the immersed tunnel

Lolland / Fehmarn	L-W	L-H	L-ME	L-E
F-W	~~W→W~~	~~W→H~~	~~W→ME~~	~~W→E~~
F-NW	~~NW→W~~	~~NW→H~~	~~NW→ME~~	~~NW→E~~
F-H	~~H→W~~	~~H→H~~	~~H→ME~~	~~H→E~~
F-E	~~E→W~~	~~E→H~~	**E→ME**	**E→E**

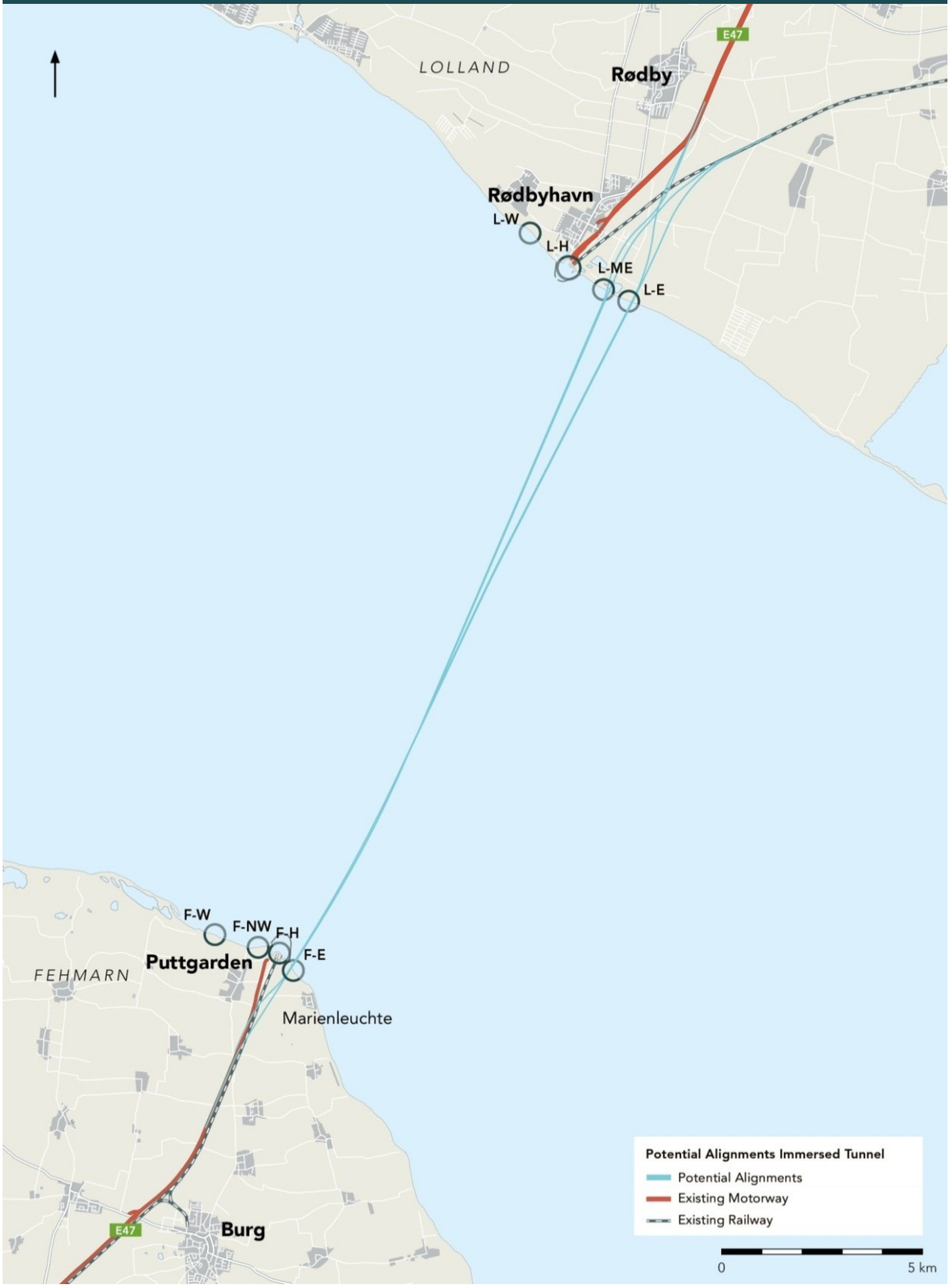
The number of alignment alternatives is thus reduced to two (Figure 4.5):

- L-ME → F-E: Alignment extending from east of Rødbyhavn harbour to just east of Puttgarden harbour
- L-E → F-E: Alignment extending from further east of Rødbyhavn harbour to just east of Puttgarden harbour

Due to technical optimisation of the project, it is expedient to have a straight tunnel alignment. This implies that the tunnel will intersect the area of the Danish part of the Fehmarnbelt, which in the environmental sensitivity analysis had been rejected on the basis of the presence of sand waves. As sand waves do not have any special protection status in Denmark, and because sand waves are able to re-establish themselves on top of a tunnel to a certain extent, onshore interests have been weighted higher in relation to the approaches.

In the following sections, the two remaining alignment alternatives have been compared in relation to technical and environmental advantages as well as disadvantages. Since the two alignment alternatives have the same approach on Fehmarn, the comparison is only relevant for Lolland.

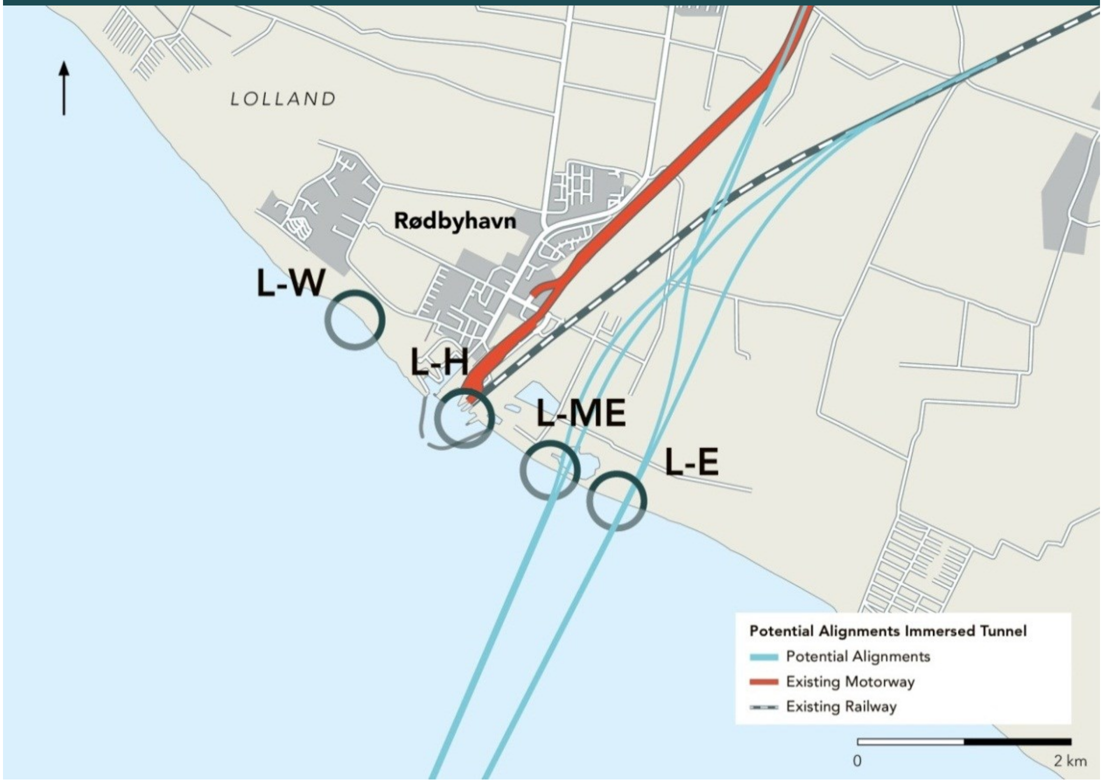
FIGURE 4.5 Potential alignment alternatives for the immersed tunnel



4.2.2 Determination of alignment for the immersed tunnel

The two alignment alternatives for the immersed tunnel differ by having their landing point L-ME approx. 1 km east of Rødbyhavn harbour or L-E approx. 1.5 km east of Rødbyhavn harbour (Figure 4.6).

FIGURE 4.6 **Alignment L-ME and L-E for the immersed tunnel, Lolland**



Alignment L-ME
L-ME's landing point on Lolland is approx. 1 km from the existing harbour facilities and approx. 3 km from Hyldtofte Østersøbad and the neighbouring holiday cottage area.

The primary impact from L-ME is on the lake Strandholm Sø, which is located east of Rødby harbour behind the sea dike. Strandholm Sø is protected under the Danish Nature Protection Act and covers an area of approx. 8 ha. Strandholm Sø is of both recreational and environmental value. No Annex IV species, which are protected by the Habitats Directive, are present. Despite Strandholm Sø being a characteristic landscape element, it is an artificial lake, and it is assessed that impacts on the lake can be compensated for by establishing replacement nature areas.

The tunnel element production for the immersed tunnel is expected to be located at Rødbyhavn off the coast, allowing the tunnel elements to be towed by boat to the tunnel trench in the Fehmarnbelt. With the alignment alternative L-ME, the production facility at Rødbyhavn will have the most optimal location, seen from an environmental perspective, just east of L-ME's approach, where the distance to both the holiday cottage area at Hyldtofte Søbad and Rødbyhavn minimises lighting and noise pollution from the production facility. In addition, a nature protected area with a major population of the Lesser Butterfly-orchid, which is protected in Denmark, will remain undisturbed.

Alignment L-E
L-E's landing point on Lolland is approx. 1.5 km from the existing harbour facilities and approx. 2.5 km from Hyldtofte Østersøbad and the neighbouring holiday cottage area.

The landing point of L-E is further towards the connection to the existing motorway than L-ME, and therefore the footprint is greater for L-E than for L-ME. Additionally, the landing point of L-E is further east of the existing motorway than L-ME, which results in a major division of the landscape (several plot divisions) and leaves a large area between the Fixed Link and Rødbyhavn harbour, which is planned to be isolated and thus have a limited number of potential uses.

The environmental comparison of L-ME and L-E is summarised in Table 4.2. Based on the alignments alone, the environmental comparison of the two alternatives shows that none of them has a clear advantage over the other.

Including the decision on placing the production facility next to Rødbyhavn in the comparison, the L-E alternative is technically more difficult and environmentally more inappropriate than L-ME. This is due to limited space for the production facility next to the L-E alternative, which means that it will have to be placed closer to either the town of Rødbyhavn or Hyldtofte Søbad.

According to a technical assessment, the alignment alternative L-ME has a smoother course than the alternative L-E, which will be important for the comfort on the railway connection. In summary, Femern A/S considers L-ME to be the preferred alignment for the immersed tunnel, and the alternative alignment L-E is therefore deselected.

TABEL 4.2 Assessment of alignment L-ME and L-E in relation to environmental criteria, Lolland, Immersed tunnel

Tunnel	L-ME	L-E
People	Crosses dike with recreational path Affects an area of recreational interest (among others, Strandholm Sø) Near Rødbyhavn	Crosses dike with recreational path Affects a relatively small area of recreational interest Relatively further from Rødbyhavn
Flora and fauna	Crosses dike Red-backed shrike and marsh harrier have been observed in the area around Strandholm Sø Affects an area with a salt meadow which is nature protected Affects an area, L-014 with two Danish red-listed beetle species Affects wetland area L-16 with high values for two species of Annex IV amphibians and the red-listed bird species Garganey	Crosses dike Affects area with a salt meadow which is nature protected Affects a wetland, L-16 of great value for jumping frog and green toad (which is protected) and the Danish red-listed Garganey.
Soil	Crosses a low-lying area at the coast	Crosses a low-lying area at the coast Longer alignment
Water	Crosses Strandholm Sø, which is nature protected Crosses 2 watercourses (Kirkenorsløbet, which has high biological value, and Næsbæk, which has medium biological value)	Crosses 2 watercourses (Kirkenorsløbet, which has high biological value, and Næsbæk, which has medium biological value) Crosses pumping station
Landscape	Crosses the Danish coast protection line Closer to the existing transport infrastructure and therefore less division of the landscape	Crosses the Danish coast protection line A little further from the existing infrastructure and therefore more division of the landscape
Cultural heritage and material assets	Crosses an old extraction area and dike	Crosses an old extraction area and dike Affects an area of archaeological cultural heritage Crosses pumping station

4.2.3 Landing point on Fehmarn (F-E)

The alignment has its landing point on Fehmarn just east of Puttgarden harbour. After the approach, the alignment is divided for the motorway and railway. Both the motorway and the railway run close to the existing motorway and railway (up to 250 m from the existing structures). The motorway is located furthest to the west and crosses the existing railway approx. 1.5 km from the coast via a bridge, which is established as part of the coast-to-coast project.

The location of the landing points allows for the continuance of harbour activities and is also located as far from the residential areas in Marienleuchte as possible.

4.2.4 Summary

In December 2010, Femern A/S published the result of the environmental sensitivity analysis, which concluded that the eastern corridor is the project corridor that has the lowest environmental conflict potentials. At the same time, Femern A/S presented its proposal for the alignment for the immersed tunnel which is located within the eastern corridor.

Following publication of the proposals for the alignment, this has formed the basis of the company's continued planning process and dialogue with authorities and landowners.

5 IMMERSED TUNNEL – TECHNICAL DESCRIPTION

5.1 THE LOCATION OF THE PROJECT

This chapter describes the technical solution – the immersed tunnel. The description is based on a conceptual design. It should be noted that project modifications may occur as part of the further development of the project, first as a tender project and later as the contractors' detailed project. Modifications may include dimensions of the various construction elements, execution methods and set-up of temporary work stations. The contractors' proposals may be different from the proposals in this document.

From coast to coast, the project comprises an approx. 18 km long tunnel between Lolland on the Danish side and Fehmarn on the German side, as well as permanent and temporary structures in connection with the construction and operation of the immersed tunnel (Text Box 5.1).

Text Box 5.1

The main elements in the immersed tunnel solution as the fixed link between Fehmarn and Lolland are:

- A dual track railway and a four lane motorway link with emergency lanes in both directions in an immersed tunnel
- Cut-and-cover tunnels at each approach on the Danish and German sides, linking the immersed tunnel to the portal buildings
- Portal building at each tunnel mouth
- Ramps for the road and railway in connection with the tunnel
- Road and railway connections on both the Danish and the German side, linking the tunnel to existing infrastructure
- Land reclamations at both the Danish and the German coasts
- Toll station – on the Danish side
- Facilities for operation and maintenance, including facilities for customs and emergency authorities
- Modifications to the surrounding secondary road network, including the construction of new local roads, etc.

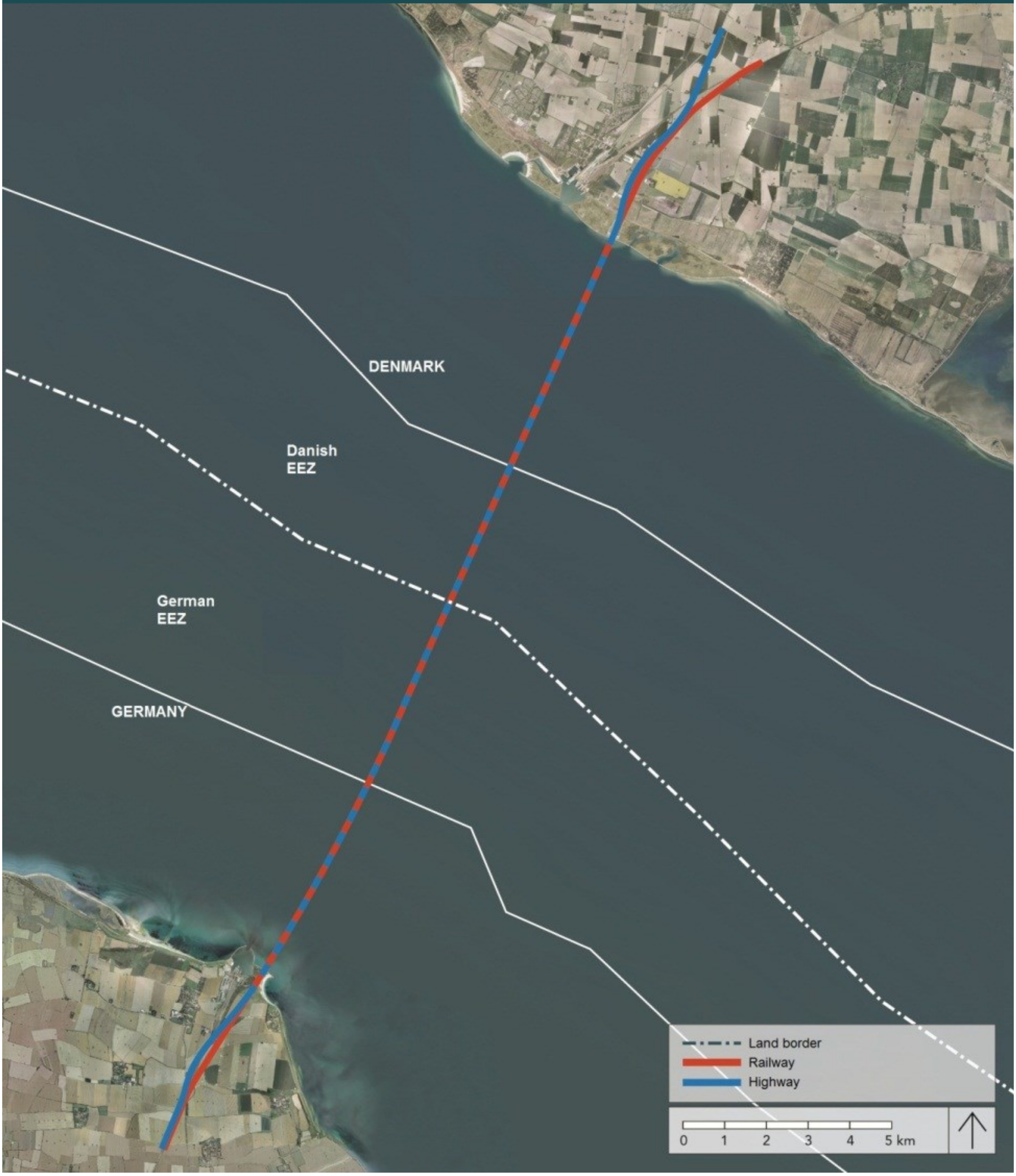
The maximum design speeds of the tunnel:

- Passenger train traffic: Maximum 200 km/h
- Goods train traffic: Maximum 140 km/h
- Road traffic: Maximum 130 km/h

5.2 ALIGNMENT

The alignment and the approaches of the immersed tunnel have been determined based on a process assessing environmental, technical, and safety factors. This process was described in Chapter 4, and the determined alignment for the conceptual design is shown in Figure 5.1.

FIGURE 5.1 Conceptual design of an immersed tunnel – Alignment for the fixed link across the Fehmarnbelt



Note: The exclusive economic zone (EEZ) is a sea zone prescribed by the **United Nations Convention on the Law of the Sea** over which a **state** has special rights over the exploration and use of **marine resources**, including energy production from water and wind. It stretches from the baseline out to 200 **nautical miles** from its coast. The state also has the right to enforce their environmental legislation within the zone, where the state has the full jurisdiction. its coast. The state also has the right to enforce their environmental legislation within the zone, where the state has the full jurisdiction.

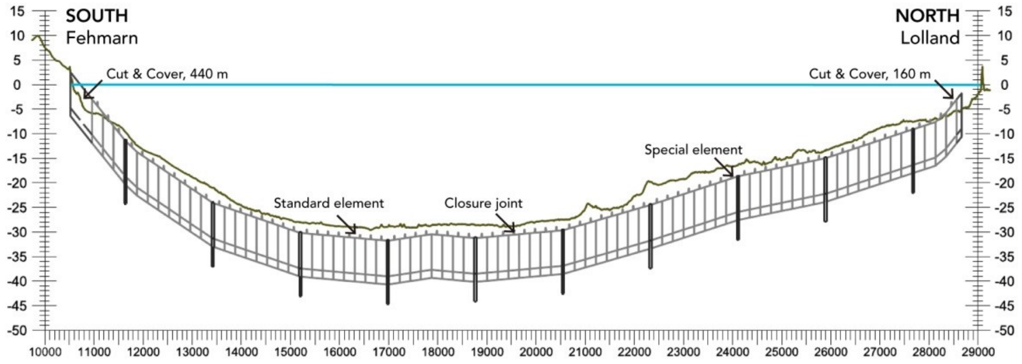
5.3 TUNNEL DESIGN

The planned tunnel across the Fehmarnbelt will consist of a cut-and-cover tunnel at the two approaches and an immersed tunnel between the two approaches. The cut-and-cover tunnel forms the transition in the marine area between the ramp structures and the immersed tunnel. A cut-and-cover tunnel in this part is necessary in order to be able to install the first immersed tunnel element, since this requires a certain water depth (Figure 5.2). On the Danish side the cut-and-cover tunnel is about 0.2 km long and on the German side it is about 0.4 km long.

When establishing the cut-and-cover tunnels, dredging work will first be carried out, and a tunnel element will then be cast in-situ and ultimately covered. The portal building is planned to be constructed on top of the cut-and-cover tunnel.

The immersed tunnel will be constructed from prefabricated tunnel elements cast at an element factory. Subsequently, the tunnel elements will be towed by boat from the production site to the alignment, where they will be immersed and assembled in a dredged tunnel trench.

FIGURE 5.2 Conceptual design of an immersed tunnel – Longitudinal profile of the alignment showing the depth beneath the surface of the sea



5.3.1 Tunnel elements

The conceptual design features two types of immersed tunnel elements: Standard elements and special elements.

All elements consist of two road tubes, each with two lanes and an emergency lane as well as two railway tubes, each with one set of railway tracks (Figure 5.3). Between the two road tubes, a gallery will be established which can be used for technical installations and as a place of temporary refuge in the event of evacuation from one road tube to the other.

The immersed tunnel part is planned to consist of 79 standard elements (measuring 9x42x217 m) and approx. 10 special elements (measuring 13x45x39 m), which are to be located approx. every 1.8 km (Figure 5.2). The special elements differ by being taller and wider as they must accommodate equipment rooms for, among other things, mechanical and electrical equipment to be used in connection with the tunnel operation systems. Via the western road tube, access is provided to a lower level from which maintenance staff have access to all road and railway tubes, regardless of traffic.

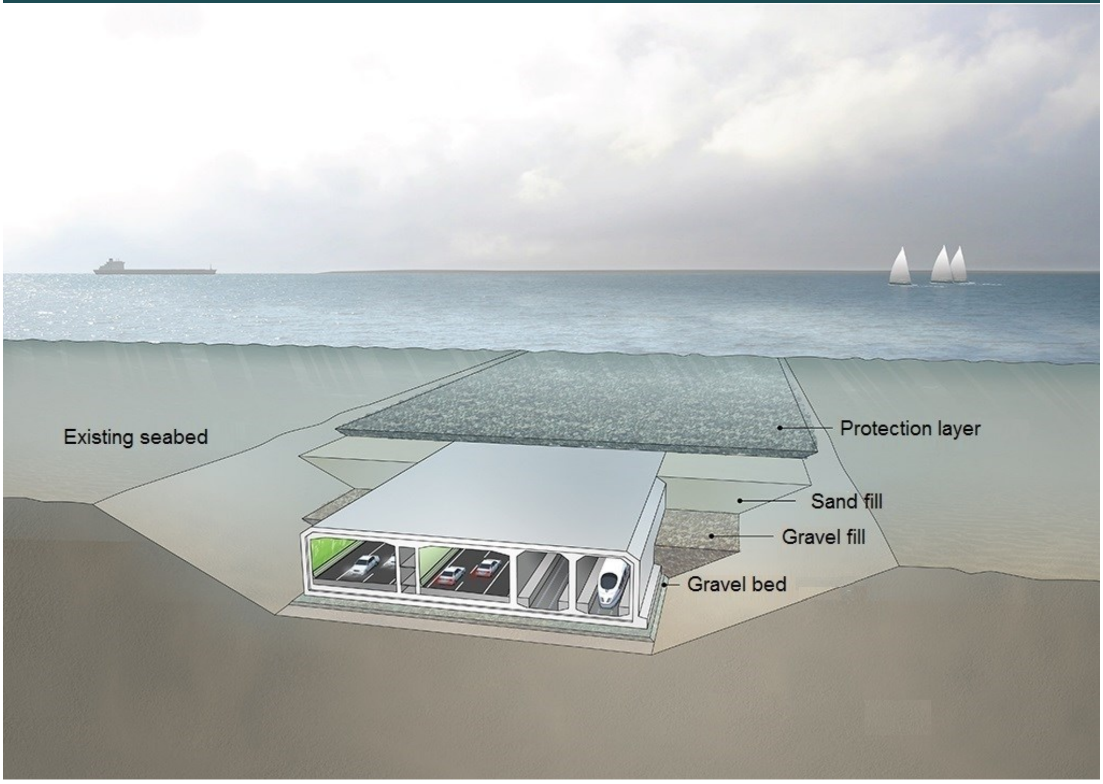
The standard elements are cast in concrete, while the special elements may also be cast in concrete or made as steel frameworks which are filled with concrete.

The tunnel elements will be placed on a layer of crushed rock laid out at the bottom of the trench to form the foundation for the elements. After installation of the tunnel elements, sand and locking fill will be backfilled along the sides, while at the top a protection layer of rocks of approx. 1 m thickness will be placed. The function of the bottom part of the sand and locking fill is to ”lock” the tunnel element into position in the trench and prevent any movement from taking place due to hydraulic loads or from placement of the remaining sand fill. The protection layer on top protects the tunnel elements from any sinking ships or anchors that are dragged along the seabed or lost by a ship.

The tunnel is located at such a depth that the rock protection layer is below the existing seabed level. The natural eastward and westward movement of sand is expected to fully re-establish the seabed above the tunnel within a few decades. However, this does not apply to the areas closest to the coast at Lolland and Fehmarn, where the top of the tunnel is above the existing seabed, and raised protective reefs will be established in order to protect the tunnel approaches. The protective reefs will have a height of 3-4 m above seabed closest to the coast of Lolland, and a height of 4-5 m above seabed closest to the coast of Fehmarn. The height of the reefs decreases gradually with the distance from the coasts, until they reach the existing seabed level.

The immersed tunnel will be designed to withstand potential tremors from earthquakes of the magnitude possible for this region.

FIGURE 5.3 Conceptual design of an immersed tunnel – Cross section of dredged trench with tunnel element and backfilling



5.3.2 Technical installations and safety issues

Air quality and emergency control

During normal operation, the immersed tunnel is planned to be self-ventilating due to the piston effect of vehicles and trains dragging air through the immersed tunnel. In addition, the road and railway tubes is planned to be provided with a system of impulse fans to assist ventilation when necessary. Emissions from the vehicles, which may be hazardous to health, are monitored continually with the concentrations of, e.g. CO, NO_2 as well as visibility (as a measure of dust concentration) being recorded. The concentration of these substances helps decide when to start the impulse fans.

The expected concentration of CO and NO_2 and the visibility has been estimated for the first 20 years of operation of the immersed tunnel based on expected traffic density. The results show that the air quality will at all times, except during traffic jams, be well below the threshold values for all substances. Traffic jams are planned to be prevented by modern traffic survey systems and control of approaching traffic at both entrances of the immersed tunnel.

Traffic, together with the function of technical installations, is planned to be monitored from a control and supervision centre placed adjacent to the toll station on the Danish side. From here traffic can be regulated in the case of emergencies. The railway system is monitored by the German and Danish railway control centres.

Electricity

A number of high-voltage cables with transformers are planned to be installed in the immersed tunnel with the option of power supply to the entire infrastructure of the immersed tunnel from both Danish and German sources of supply. During ordinary operation, it is planned for power to be sourced from the Danish side. In the case of a power cut, illumination is planned to be powered by an emergency power supply.

Drainage system

Rainwater accumulated by the immersed tunnel and water from cleaning the immersed tunnel is planned to be collected in pump wells placed by each portal building. From here the water is pumped to existing water treatment plants in either Rødbyhavn or Puttgarden. The expected water volume being pumped from the immersed tunnel is up to 3.500 m^3 per year.

5.3.3 Traffic in the operation phase

The estimated traffic for the operation of the Fehmarnbelt Fixed Link is based on a traffic prognosis worked out in the ”Fehmarn Belt Forecast 2002 Final report” (2003) by the Fehmarnbelt Traffic Consortium (FTC) for the Danish and German Ministries of Transport.

The traffic prognosis entails different scenarios for the increase in traffic, and the environmental assessments are based on the scenario with a high growth rate in traffic, which ensures the most precautionary assessments of impacts from e.g. noise and emissions (FTC Base Case B - High).

The results of the traffic prognosis for trains, cars, trucks and busses in 2025 are shown in Table 5.1, both as concerns the Fehmarnbelt Fixed Link operation and the 0-alternative.

TABLE 5.1 Expected traffic in year 2025 for the operation of the Fehmarnbelt Fixed Link and the 0-alternative

Passages per day	2025	0-alternative (2025)
Passenger trains	40	8
Goods trains	78	0
Cars	9,700	6,700
Trucks	1,850	1,550
Busses	150	150
Vehicles total	**11,700**	**8,400**

Note: Expected traffic in 2025 is based on the traffic scenario with high growth rate (Base Case B - High) from the "Fehmarn Belt Forecast 2002 Final report". The 0-alternativ is based on the reference scenario in "Fehmarn Belt Forecast 2002 Final report". Number are rounded off

5.4 PERMANENT LAND WORKS

In addition to the immersed tunnel itself, the establishment of a fixed link between Fehmarn and Lolland also comprises permanent land works, including a new motorway and railway on both Lolland and Fehmarn to connect with the existing motorways and railways.

5.4.1 Permanent land works in Denmark

The immersed tunnel's approach in Denmark is planned to be approx. 1 km east of Rødbyhavn ferry harbour on Lolland (Figure 5.4), and the permanent works in the area are described below.

FIGURE 5.4 Conceptual design of an immersed tunnel – Land works on Lolland

Portal building

The portal building is planned to be established on top of the cut-and-cover tunnel outside the existing coastline. As coastal protection, dikes will be established around the perimeter of the portal and ramp and will have a height of 5.75 m, in general, and 6.25 m, seawards, and will protect the portal against flooding in the event of extreme high-water and wave conditions (Figure 5.5).

FIGURE 5.5 **Conceptual design of an immersed tunnel – Visualisation of the portal building in Denmark seen from south-west**

New motorway and railway

On the Danish side, the existing motorway and railway will be extended up to the toll station with a section at ground level or on a low embankment. After the toll station, the motorway will be elevated on an embankment before the portal and tunnel ramp. The motorway embankment will be established partly to give the users of the link a view of the tunnel portal and the Fehmarnbelt before the tunnel ramp, and partly to safeguard the tunnel in the event of extreme high-water situations.

The new motorway will cross the existing railway at ground level, which means it will not be possible to continue the railway operation to Rødbyhavn after the establishment of the link.

Toll station and border control facilities

A toll station is planned to be located on the Danish side. The area of the toll station will also include a tunnel control and supervision centre as well as operation and maintenance facilities.

Alteration of local roads

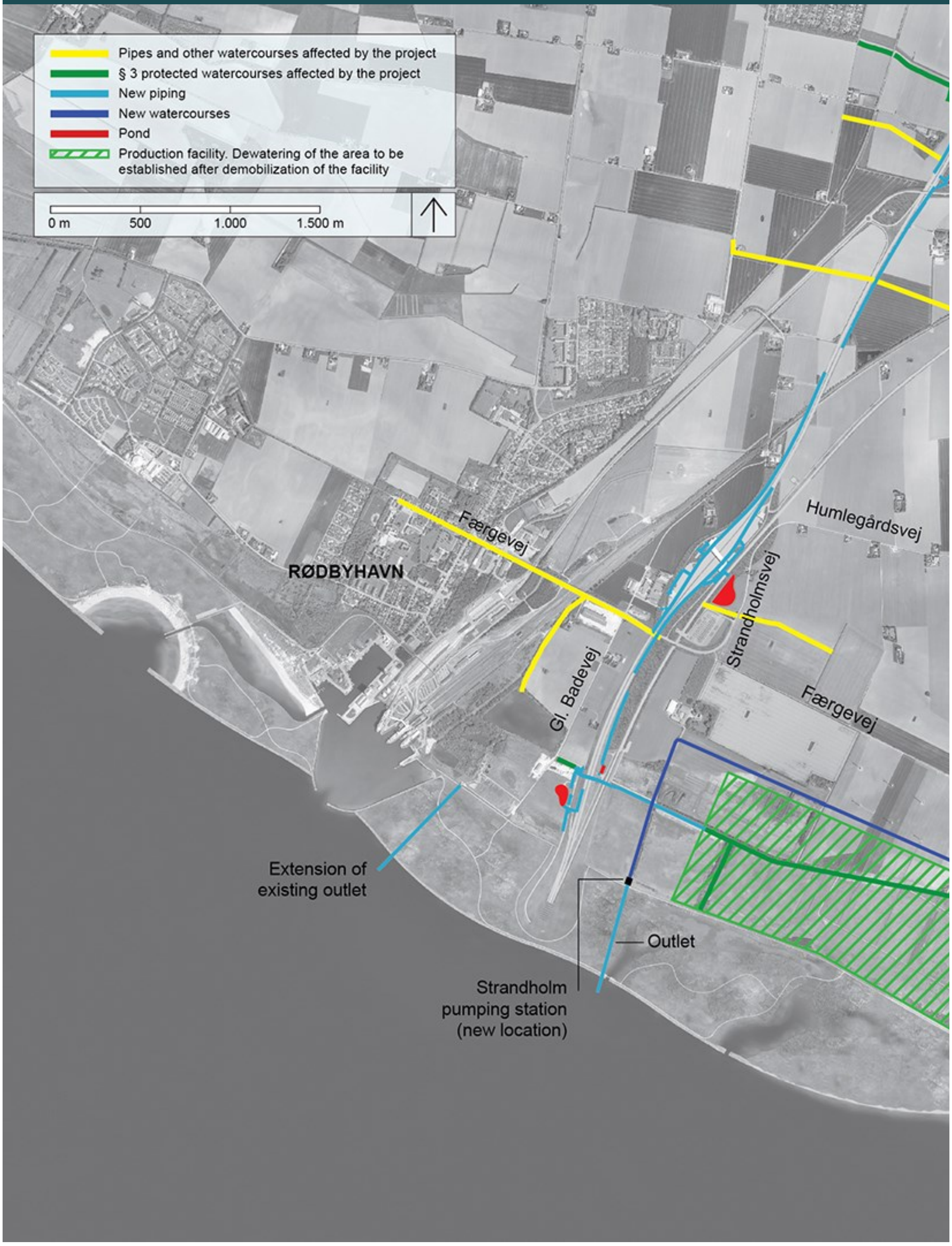
The construction of the motorway requires diversion or alteration of some local roads and paths, and in a few locations new bridges will have to be established across the new motorway and railway.

Drainage system

Drainage systems for the motorway, railway, toll station, and other permanent land works are planned to be established, and the collected water is planned to be led to new rainwater basins (Figure 5.6).

At the same time, part of the existing drainage culverts are planned to be altered to ensure that the existing drainage structure and the ecological function in the local area are maintained.

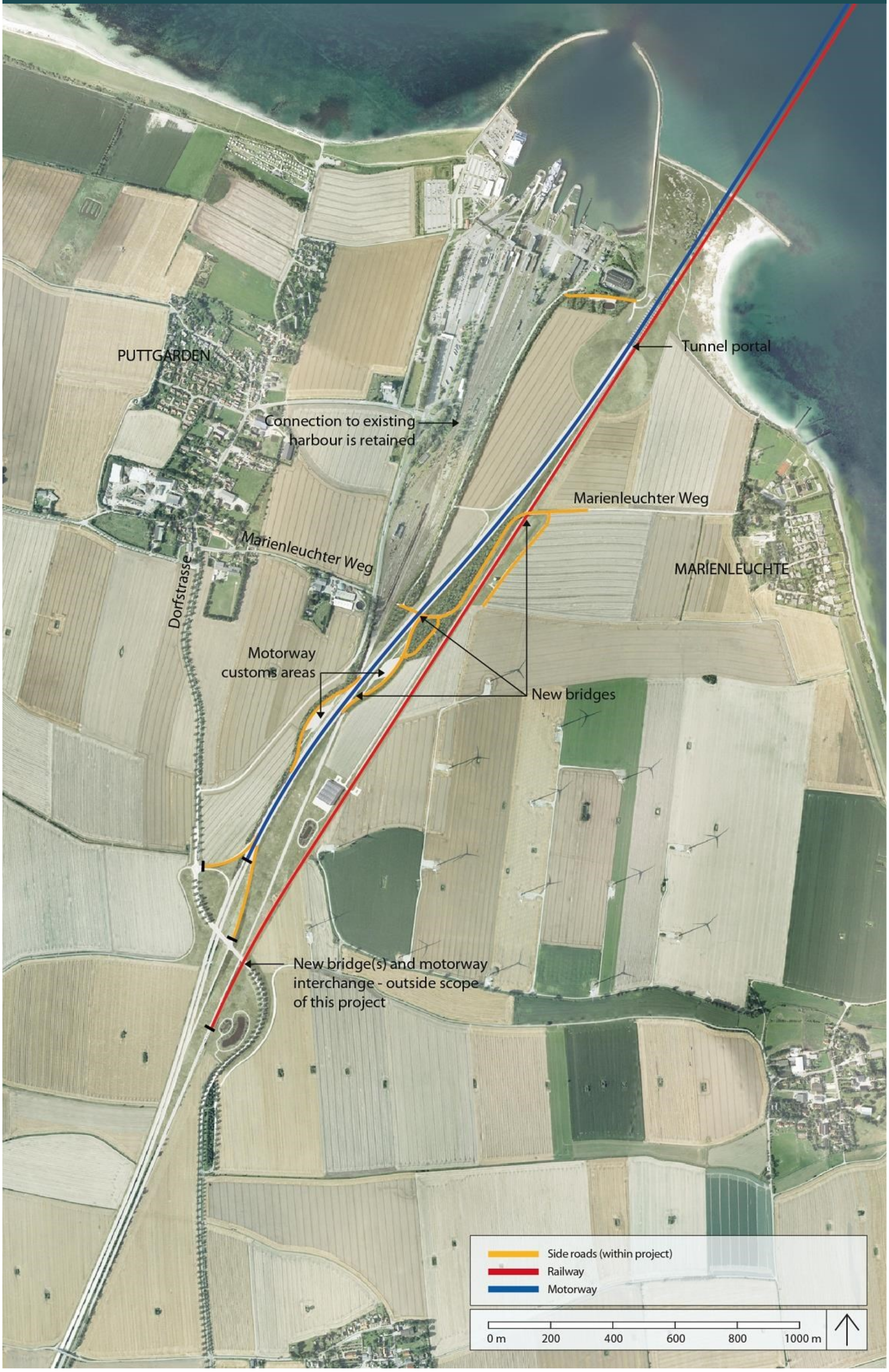
FIGURE 5.6 Conceptual design of an immersed tunnel – Suggested design of the drainage system for permanent land works and production facility in Denmark



5.4.2 Permanent land works in Germany

The tunnel approach on Fehmarn in Germany is located just east of Puttgarden harbour (Figure 5.7) and the permanent land works in the area are described below.

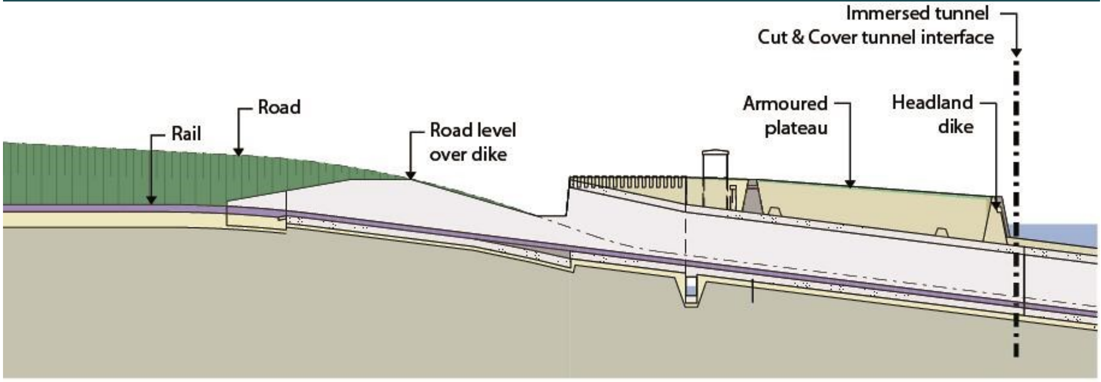
FIGURE 5.7 **Conceptual design of an immersed tunnel – land works on Fehmarn**

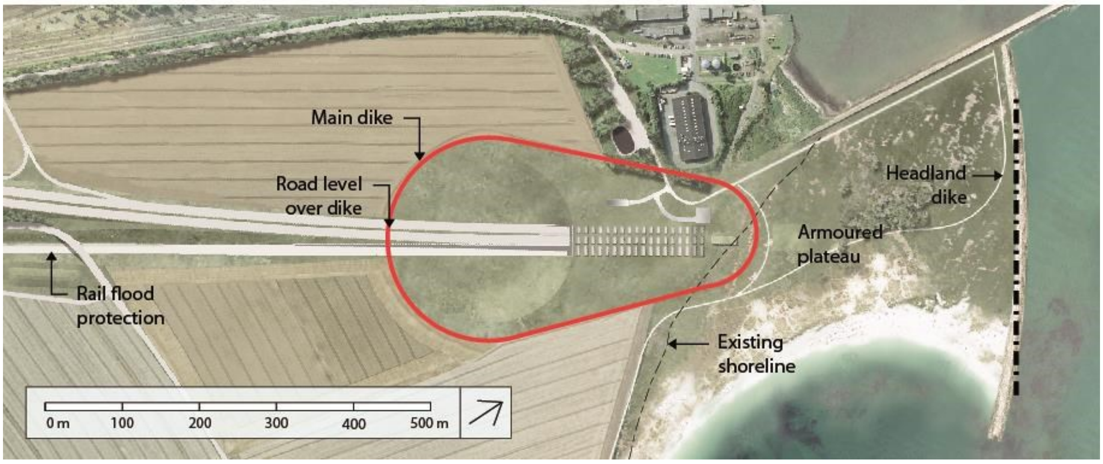


Portal building

It is planned for the Fehmarn tunnel portal to be located behind the existing coastline within a bowl in the landscape. The protection of the immersed tunnel against flooding consists of a closed ring of dikes surrounding the portal and ramp structures (Figure 5.8). The railway intersects the dike around the portal and ramp structure, and in the event of extreme storm surge, barriers can be installed across the railway.

FIGURE 5.8 Conceptual design of an immersed tunnel – Tunnel portal, ramp structures and dikes on Fehmarn in Germany





New motorway and railway

A new four-lane motorway is to be constructed on Fehmarn on a section of approx. 3.5 km south of the tunnel portal. This new motorway will rise out of the immersed tunnel and pass over an embankment across the existing harbour railway. Towards the southern end of the motorway, a new approach area is planned to be built to connect to the existing local road system.

A new electrified, twin track railway is to be constructed on a section of approx. 3.5 km south of the tunnel portal. A new point switch is planned to be constructed approx. 2.5 km from the tunnel portal to provide access for the trains to both the existing harbour railway and the immersed tunnel.

Alteration of local roads

Construction of the landside motorway and railway will require some diversion or alteration of local roads.

Drainage system

A drainage system handling water from the permanent land works is planned to be established as rainwater basins provided with oil separators and sand traps, in order to treat run-off and contain any polluted spillages. From the drainage basins, the water is planned to be led to the Fehmarnbelt via local watercourses or pipes.

In addition, separate drainage systems are planned to be required within the dike for storm surge protection, where the area is acting as a drainage basin in itself. At the northern section of the alignment, nearest the portal but outside the dike, the run-off is planned to be discharged into the Fehmarnbelt. Retention basins and sedimentation basins will therefore also be provided here in order to treat run-off and contain any polluted spillages.

5.5 LAND RECLAMATION AREAS

The conceptual design for the immersed tunnel includes the establishment of land reclamation areas at both Lolland and Fehmarn. The purpose of the reclamation is to utilise excess seabed material from the dredging of the tunnel trench and the service port for purposes that will add natural and recreational value to the local area. Lolland, with its appropriate nature areas, will also host the replacement of nature areas, which Femern A/S must establish as compensation.

It is estimated that the dredging volume of marine sediment arising from the project will be approx. 19 million m^3. Most of the sediment is planned to be used in the construction of the land reclamation area at Lolland (approx. 17 mil m^3), while about 2 million m^3 is planned to be used on the German land areas.

5.5.1 Land reclamation area at Lolland in Denmark

On the Danish side at Lolland, a land reclamation area will be established by backfilling dredged seabed material in an area extending parallel with the existing coast and the dike behind it, from Hyldetofte Østersøbad east of Rødby to Dragsminde Sluse west of Rødby. Material is planned to be backfilled approx. 500 m into the Fehmarnbelt until approx. the same distance from the coast as the jetties to the existing ferry harbour at Rødbyhavn. It will also be streamlined at the ends towards north-west and south-east to minimise the environmental impact on the marine environment (Figure 5.9).

The land reclamation area is planned on each side of the harbour and extends from this point approx. 3.5 km to the west and approx. 3.7 km to the east. The total area is approx. 330 ha.

On the major part of the section, the existing dike will remain intact, but it is planned to be intersected by the new motorway and railway. When constructing a dike around the tunnel portal, the dike's function as a storm surge dike will be secured.

The proposal for the design of the land reclamation area includes:

- West of Rødbyhavn harbour: A nature area with salt meadows, grasslands, and ponds as well as a recreational area with sandy beaches.
- East of Rødbyhavn harbour: A nature area with a lagoon, pasture areas as well as salt meadows.
- Sections around the tunnel ramp are protected with rocks from granite quarries (rock size approx. 1 - 3 t).
- Adjacent sections of coast will be protected against the impacts of the sea by rocks.
- The area to the east is terminated by a clay-till cliff, where erosion is allowed, releasing sand to the section east of the land reclamation area. This section is designed as a steady course along the existing beach at Hyldtofte Østersøbad.

FIGURE 5.9 **Conceptual design of an immersed tunnel – Design proposal for a land reclamation area on Lolland in Denmark**

Terrain

The land reclamation area is planned to be a varied terrain, providing the possibility of having both areas that are exposed to the wind and sheltered areas. The area to the west consists of a rolling terrain between elevations of approx. +3 m and +5 m, and with a few tops up to +7 m, having reference to the existing overgrown coastal dunes west of Rødby-havn. High areas will be avoided in the areas off the harbour and off a water park area (Lalandia).

The area to the east also consists of a rolling terrain, although with a softer character. This landscape feature especially applies to the coastal cliff furthest to the east, gradually rising from an elevation of approx. +2.5 m at the existing dike up to an elevation of +7 m on the Fehmarnbelt side. The wetland and nature areas just east of the portal are planned to be designed as relatively flat coastal areas, allowing the natural flow of water and the tide to interact with the landscape and the plantation.

The above described terrain of the land reclamation area is subject to some uncertainties. These uncertainties are, among other things, related to the actual volume of dredged material, the bulking of the sediments, the level of the existing sea bottom as well as the degree to which the dredged material can be used in motorway and railway embankments.

Nature areas and recreational green areas

In the proposal, the land reclamation area west of Rødbyhavn is designated as a nature area and recreational area. Two new sandy beaches are planned to be established: one to the west and one in a semi-circular lagoon towards the sea. An interior lagoon will be established around the existing sandy beach at Rødbyhavn (Figure 5.10). The beaches are planned to be designed to be stable in relation to the coastal morphology conditions in the area, eliminating the need to establish coast protection or add new sand to the beaches after establishment. Due to natural erosion, the western beach is planned to be maintained naturally.

Just behind the lagoon beach, a zone with dunes will be established. Besides acting as a natural transition between the individual landscape elements, the dunes provide the possibility of distinctive vegetation and shelter for visitors.

FIGURE 5.10 Conceptual design of an immersed tunnel – Visualisation of lagoon beach seen from the west, Denmark

A network of footpaths and cycle paths as well as minor paths will intersect the land reclamation areas, and allow access around the portal area. This system of paths is integrated with the existing footpaths and cycle paths and public parking areas in the local area, and a new parking area is planned to be established in connection with the lagoon beach, including access for the disabled to the area.

The proposal for the land reclamation area east of the tunnel portal includes a coastal lagoon with two openings towards the sea, which allows the water to flow the entire way to and along the existing dike (Figure 5.11). The lagoon is designed with wetlands in the transition between water and land as well as two islands. One of these islands is planned to be designated as a nature area without public access, thereby making it possible to establish undisturbed birdlife. The other island is planned to be linked to the nearby areas via two bridges, which are part of the overall path system.

It is the intention to let vegetation develop naturally in the wetland and nature areas in order to obtain a biodiversity of natural species.

FIGURE 5.11 Conceptual design of an immersed tunnel – Visualisation of wetland in the eastern part of the land reclamation area in Denmark

5.5.2 Land reclamation area at Fehmarn in Germany

The planned land reclamation on the Fehmarn coast in Germany extends approx. 500 m along the existing coast east of the ferry harbour, and about 500 m from the existing coastline into the Fehmarnbelt (Figure 5.12). The total area is planned to be approx. 32 ha (measured as area of seabed and including existing water areas inside the reclamation areas). The land reclamation area is withdrawn relative to the tip of the jetties at the existing ferry harbour at Puttgarden to minimise the environmental impacts on the marine environment. The land reclamation will not come into contact with the protected area at Grüner Brink or the coast at Marienleuchte to the southeast.

The reclamation area is designed as an extension of the existing terrain, with the natural hill between Puttgarden and Marienleuchte turning into a plateau behind a coastal protection dike. The plateau is designed as an enclosed pasture and grassland habitat with an elevation of 3-5 m. In the design proposal, the land reclamation is designed as an extension of the existing coastline and must allow space for a new beach near Marienleuchte. To protect the land reclamation area against the impacts of the sea, revetments are planned to be established on the northern side of the land reclamation area.

FIGURE 5.12 **Conceptual design of an immersed tunnel – Design proposal for a land reclamation area on Fehmarn in Germany**

5.6 ACTIVITIES IN THE CONSTRUCTION PHASE

For the construction phase, temporary structures must be established that will be removed after the construction phase. Temporary structures include the tunnel element factory, work harbours and work areas both in Germany and in Denmark.

The immersed tunnel consists of prefabricated concrete elements, which, according to the project assumptions, will be produced at a tunnel element factory at Rødbyhavn. The elements will be prefabricated by reinforced concrete. The work harbour on Lolland is included as part of the tunnel element factory. In addition, a separate temporary work harbour is planned to be established on Fehmarn in Germany.

The construction work will begin with the establishment of the production area for the construction of the tunnel elements, establishment of accommodation facilities (campsite) and the early phases of dredging, including construction of the work harbours.

5.6.1 Production facility at Rødbyhavn

An area east of Rødbyhavn in Denmark has been designated for the construction of a purpose-built casting factory at which the tunnel elements are to be produced. The production facility is partly located onshore and partly off the existing coastline (Figure 5.13). The total area needed for the production facility, temporary storage of dredged seabed materials and other temporary work facilities is approx. 187 ha. The reason for choosing Rødbyhavn in Denmark as the production site is apparent in Text Box 5.2.

Text Box 5.2

Designation of Rødbyhavn in Denmark as production site

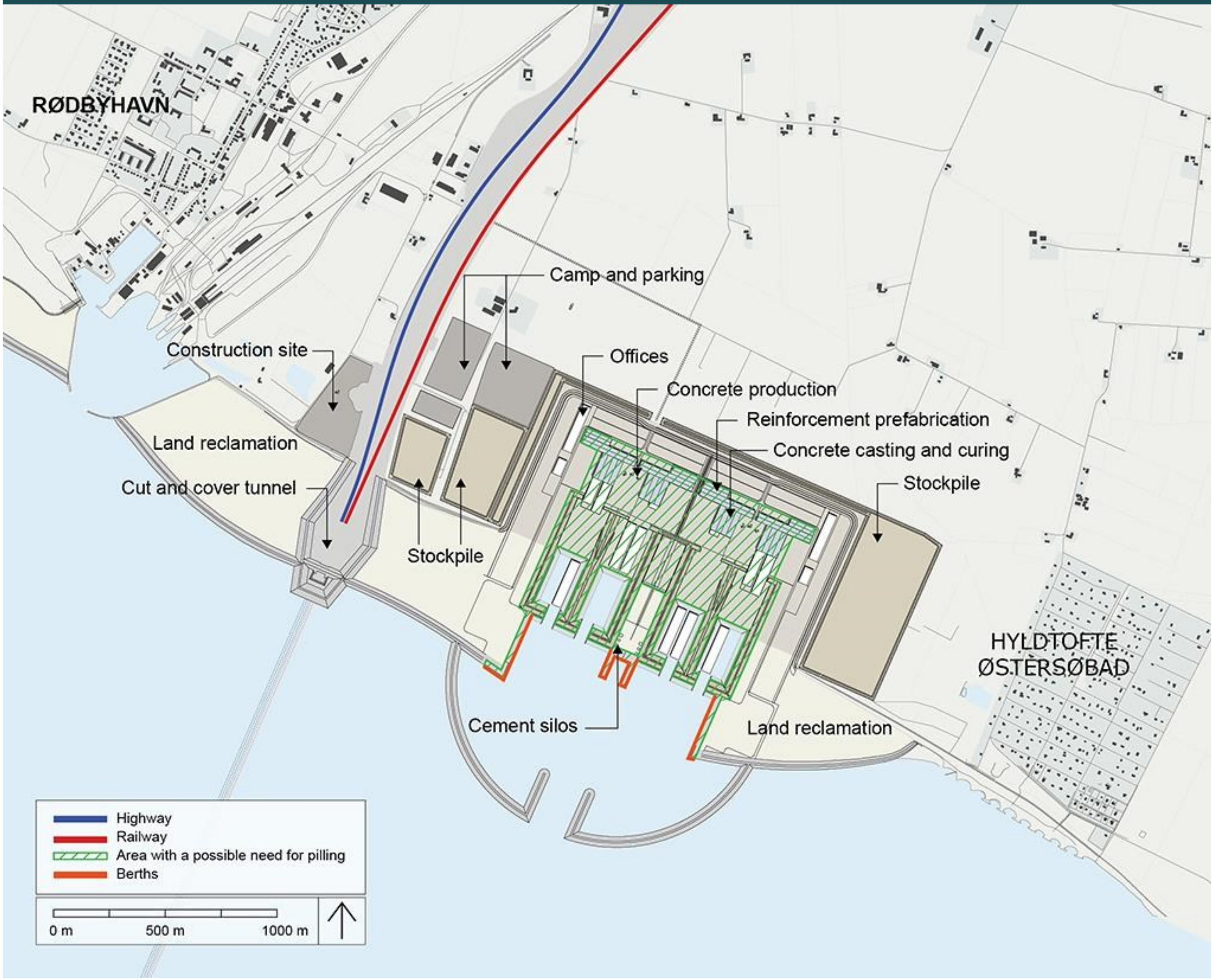
Femern A/S has analysed information from about 20 locations, which during spring 2011 expressed an interest in making sites available for a production facility for the production of tunnel elements. The determination of location placed emphasis on the following parameters:

- Technical suitability,
- Environmental impacts,
- Implications in terms of time and
- Risks.

Among the possible locations, Femern A/S is of the clear opinion that Rødbyhavn is the most expedient location for the production facility. This opinion is based upon the following:

- Rødbyhavn meets all the technical requirements. Thus, it is possible to establish eight production lines in the area based on industrial production, and the only requirement is to excavate a relatively short disembarkation channel
- Femern A/S has all the necessary environmental data to allow it to integrate the production site into the EIA report as the company has carried out its environmental investigation in the area
- Rødbyhavn entails the fewest risks and provides the best monitoring opportunities for the company. A location in the immediate vicinity of the alignment minimises the transport risks. Additionally, Rødbyhavn has the maximum possible level of certainty with regard to environmental data as Femern A/S itself has obtained this data. A location next to the alignment means a smaller risk of appeal cases as there would only be a limited expansion of the group of people and organisations affected by the project, and similarly the authorities involved at both local and national levels would, to the extent possible, remain the same

FIGURE 5.13 Conceptual design of an immersed tunnel – Production area Rødbyhavn in Denmark for tunnel elements and tunnel portal



The production facility is dimensioned to be able to produce both standard elements and special elements for the immersed tunnel. It is planned to produce the standard elements on identical production lines, while special elements can be produced on a separate production line.

In connection with the establishment of the production facility, the following buildings and structures must be established:

- Office buildings
- Parking spaces
- Staff facilities
- Halls for the prefabrication of reinforcement (one for each production line)
- Halls for casting the concrete elements (one for every second production line)
- Concrete mixing facilities (one for every second production line)
- Concrete storage silos
- Storage halls

- Area for temporary storage of removed top soil

In the production area buildings and surfacing are expected to cover approx. 40% of the area. Halls in the area are planned to be up to 30 m high, and the concrete storage silos may be up to 50 m high. According to the conceptual design, a shallow launch basin and a deep launch basin are located in front of the casting halls, which have access to the Fehmarnbelt through a floating gate. In front of the outer launch basin, breakwaters must be established to protect the work harbour and the launch basins against wave impacts.

In connection with the work harbour, approx. 1,000 m of quay is planned to be established for the ships that deliver construction materials. The harbour as well as a shipping lane for the transportation of tunnel elements as well as shipping of materials for the concrete production will be dredged after the same principles as described for the tunnel trench. The depth of the harbour is determined by the size of the tunnel elements and will be approx. 12 m.

It is a possibility that the special elements are not produced at the production facility at Rødbyhavn. In that case, the special elements will have to be transported to the production facility at Rødbyhavn for finishing works, before they can be towed to the tunnel trench. If the special elements are not produced at Rødbyhavn, the production area and work harbour may be optimised. For example, the dredging volume in the access channel and work harbour could be reduced as the height of the standard elements is smaller than the special elements.

Terrain

In connection with the establishment of the production area the terrain will be elevated to a level above mean sea level. Elevation of the terrain is planned to be performed with dredged material.

Temporary groundwater lowering

In connection with the establishment of the production area, it is necessary to construct skidding beams on which the tunnel elements rest when they are pushed from the production hall to the upper launch basin. Because of the weight of the elements and the requirements for minimum deformations in the production of the elements, it will be necessary for these beams to be founded upon intact clay-till or to construct pile foundations below the beams.

In connection with direct foundation it may be necessary to establish temporary groundwater lowering in an area of approx. 1,000 m x 350 m. Such groundwater lowering is expected to last for up to one year.

Pile driving/sheet piling

If the skidding beams described above in relation to the production facility are constructed using pile foundations, it will be necessary to drive in a large number of concrete piles. Similarly, in connection with the work harbour, it will be necessary to drive in sheet piles when establishing quay sections.

The work on driving in piles and sheet piles is expected to last up to one year and will only be performed during the daytime.

Temporary drainage system

As described above, buildings and surfacing are planned to be established on a large part of the production area. It is therefore necessary to collect rainwater in a drainage system in the form of a temporary rainwater basin (this will be planned in detail in a later phase). The basin is planned to be provided with oil separators and sand traps in order to treat surface water and contain any polluted spillages. Hereafter, the collected rainwater will be discharged into Fehmarn Belt.

Piping

Water for the production area is planned to be delivered from Lolland Vand A/S in Denmark. For the concrete production, water will possibly also come from desalination of sea water or from other sources transported by vessels. A buffer tank is planned to be established at the production facility, continuously collecting water, ensuring sufficient amounts of water during peak periods, e.g. during production of concrete in connection with casting.

Electricity for the production facility is planned to be supplied by SEAS-NVE. As part of the final operation situation, it is planned to establish a new transformer station near the toll station.

A sewage system, primarily connected to office buildings and staff facilities, is planned to be established at the production facility. Femern A/S is planning to connect this sewage system to the existing sewage system in the area.

Femern A/S is planning to discharge surplus water from concrete production and from drainage of the production area to the sea after the water has been through oil separators and sand traps and undergone pH adjustment in order to contain any polluted spillages.

Casting process

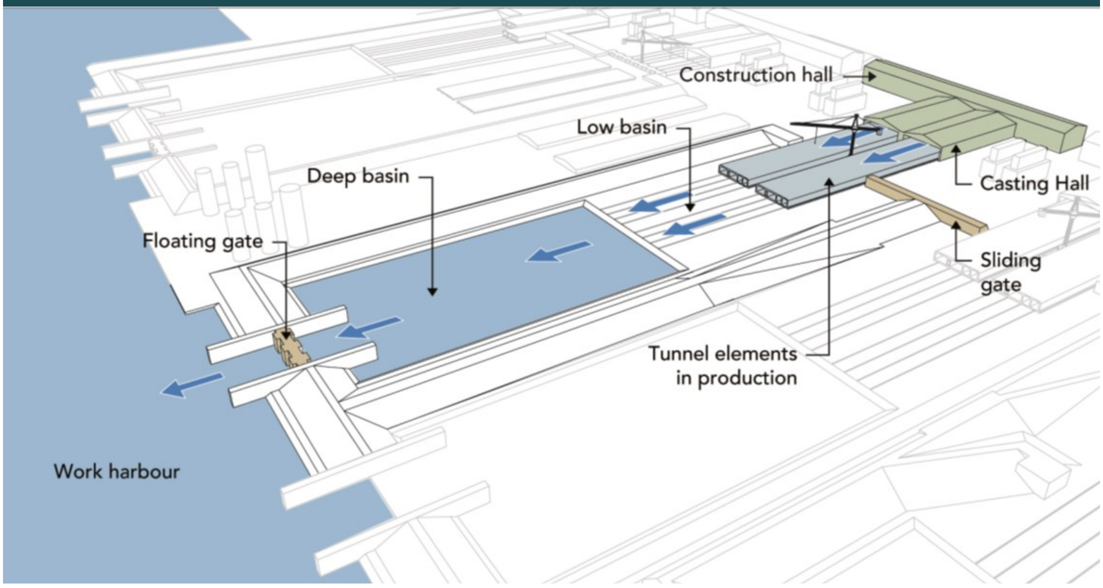
Each tunnel element is cast in short sections known as segments. Each element consists of approx. nine segments. One segment is expected to be cast at each production line every 7 - 8 days.

Reinforcement mesh for the segments is planned to be prefabricated in halls. When the re-inforcement has been tied together and completed, it is planned to be pushed into the casting hall in a form on a solid casting base. The segment is cast and after a short hardening period, the form will be removed and the segment released from the casting base (to be moved horizontally) by means of hydraulic jacks to allow casting of the next segment. This process will be repeated until an entire tunnel element has been fully cast.

Once a complete tunnel element has been produced, it will be pushed into the shallow launch basin, which is then cut off from the production area by a sliding gate and from the sea by a floating gate. Here, the element will be prepared for transportation and equipped with watertight bulk-heads at each end.

Subsequently, the tunnel elements will be towed into the deep launch basin, after which the water level will be lowered to the same level as the Fehmarnbelt. From the deep basin, the elements will be towed to a designated holding area next to the tunnel trench, ready for immersion (Figure 5.14).

FIGURE 5.14 Conceptual design of an immersed tunnel – Illustration of production method for the tunnel elements



Environmental nuisances
The production of tunnel elements is expected to generate dust from site roads and the handling of materials. The nuisances are planned to be reduced by surfacing a large part of the area of the production facility and by irrigating during dry periods. Moreover, the majority of the materials stored will be covered.

The production of tunnel elements and the handling of materials are also expected to generate noise. To reduce the nuisance, noise protection is planned to be established in the form of embankments between the production facility and the surroundings.

As the production of tunnel elements is expected to take place 24 hours a day, the production area is planned to be illuminated during this period. To reduce the nuisances, lighting will be shielded where necessary.

Closure of the production facility
The production facility is planned to be closed when all tunnel elements have been completed and immersed into the tunnel trench. Buildings, silos, storage halls, surfacing and other constructions will be removed. The work harbour in front of the production facility and the launch basins are planned to be backfilled with seabed material from the tunnel trench.

On existing land, backfilled material will be removed, and the removed top soil, which has been stored in two top soil deposits, will be put back so as to re-establish the terrain in its original form to the extent possible.

In the reclamation area, the landscape will be established as described in chapter 5.6.7.

5.6.2 Work site at portal and ramp on Lolland in Denmark

The cut-and-cover tunnel on Lolland is planned to be constructed in a dammed area just south of the existing coastline. The bulk of the construction materials is planned to be delivered by sea to the harbour and further on to the site.

Initially, dredging is planned to be performed to the level of the underside of the cut-and-cover tunnel, after which temporary waterproof dikes will be established around the area (500 x 250 m), and the dammed area is planned to be emptied of water by pumping the water into the sea. This groundwater lowering is expected to last for up to two years and entail approximately 140,000 m^3 water per year.

The cut-and-cover tunnel will be cast in-situ, and the waterproof embankment at the outside of the cut-and-cover tunnel is removed, allowing for the first tunnel element to be immersed in continuation of the cut-and-cover tunnel.

Finally, the ramps for road and rail, the portal building and the permanent coastal protection will be established, and the cut-and-cover tunnel covered and the final terrain formed.

The temporary work site area for the portal and ramp construction (Figure 5.13) will include the following buildings and structures:

- Office buildings
- Parking spaces
- Staff facilities
- Concrete batching plant for production of portal, ramp and cut-and-cover tunnel
- Storage silos and halls

In addition, a new access road is planned to be constructed from the work harbour to the work site. The staff for this work site will be using the same campsite as the production facility, but the two worksites at Lolland are expected to be operated by different contractors.

5.6.3 Work site at portal and ramp on Fehmarn in Germany

A work harbour will be established at Puttgarden in Germany (Figure 5.15). The bulk of the construction materials to the harbour will be delivered by sea. The work harbour on Fehmarn is planned to be established in an area where dredging and subsequent backfilling work is not required, and the harbour will be removed when the tunnel construction work has been completed.

The cut-and-cover tunnel on Fehmarn is planned to be constructed in a dammed area just north of the existing coastline. The bulk of the construction materials for the structures are expected to be delivered by sea.

Initially, dredging is planned to be performed to approx. the level of the underside of the cut-and-cover tunnel. Then temporary waterproof dikes are planned to be established around the area, and the dammed area is planned to be emptied of water by pumping the water into the sea. Thereafter final excavation will take place in the dry.

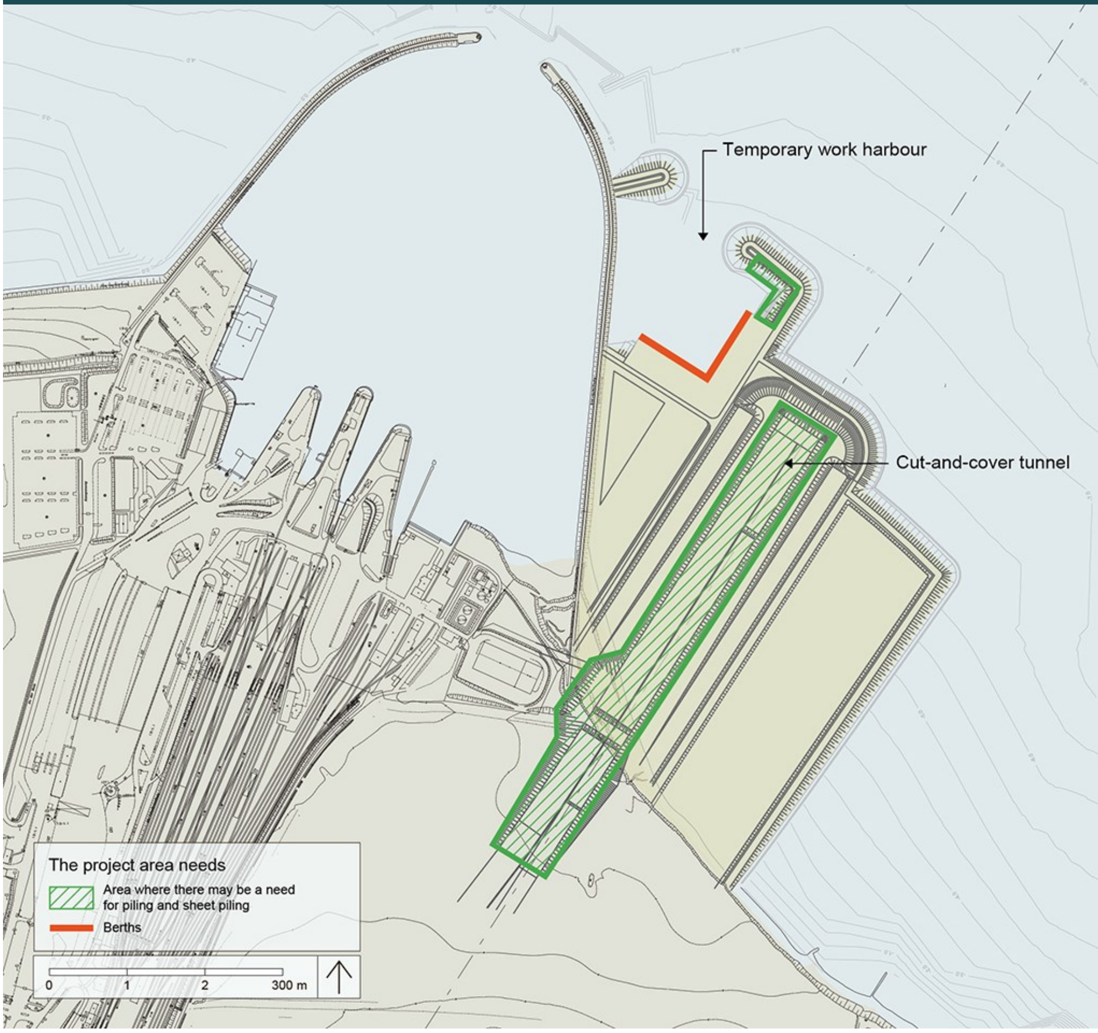
The cut-and-cover tunnel is planned to be cast in-situ, and the waterproof embankment outside the cut-and-cover tunnel to be removed, allowing for the first tunnel element to be immersed in continuation of the cut-and-cover tunnel.

Finally, the portal building, the ramp structures for road and rail and the permanent coastal protection will be established, the cut-and-cover tunnel will be covered and the final terrain formed.

The temporary work site area for the portal and ramp construction will include the following buildings and structures:

- Office buildings
- Parking space
- Concrete batching plant for production of portal, ramp and cut-and-cover tunnel
- Storage silos and halls

FIGURE 5.15 **Conceptual design of an immersed tunnel – Temporary work harbour on Fehmarn**



5.6.4 Other work sites

In connection with the establishment of the toll station as well as bridges across the motorway and railway, a number of small work sites shall be established. These work sites will mainly be located within the area of the permanent works, but at some locations also in areas closely connected to that area.

Based on the planned alignment, approx. 3 m on each side of the motorway and of the railway are expected to be used for temporary work areas.

Work sites will also be established in connection with the establishment of the electrical and mechanical installations in the immersed tunnel and in connection with the railway-technical installations.

Construction works on these sites will be on-going during the entire construction period of the project.

5.6.5 Dredging of tunnel trench

In connection with the establishment of the immersed tunnel, a trench is to be dredged, into which the tunnel elements can be immersed. The tunnel trench appropriates an area of the seabed of approx. 17.6 km * 110 m and dredging of the tunnel trench is expected to last approx. 1.5 years, while the overall dredging work, including backfilling of the tunnel trench, is expected to last approx. 4.5 years.

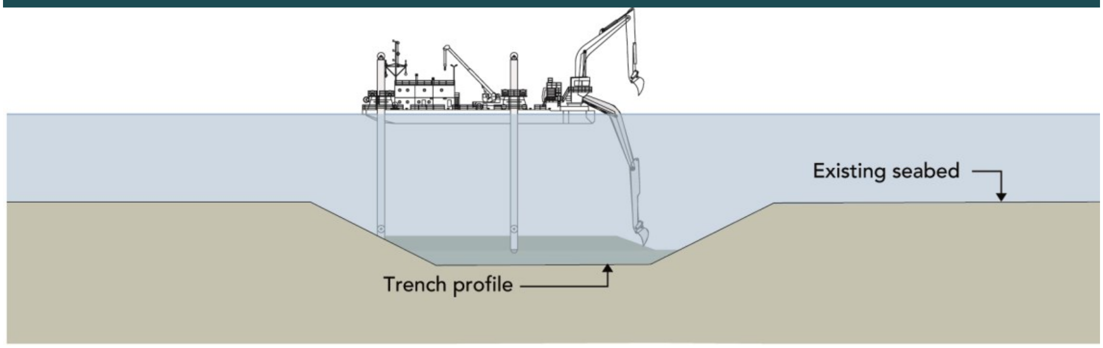
The dredging must be planned with regard for the following factors:

- The geological conditions, because dredging must be performed in different materials, including hard clay-till.
- Depth, because dredging is to be performed down to approx. 46 m below the sea surface.
- Existing navigational conditions, because the construction work must be organised with regard for traffic in the international channel.
- Location and design of the incorporation areas.
- Environmental conditions, because sediment spillage from dredging operations must be limited.

In the dredging scenario of the conceptual design, the majority of the dredging is planned to be performed by means of backhoe dredgers and grab dredgers. Backhoe dredgers are mounted on barges provided with anchoring support and anchors. They load the dredged material onto transport barges that are moored alongside (Figure 5.16). A backhoe dredger uses a backhoe back-acting bucket with a bucket size of up to approx. 20 m^3. Grab dredgers use a similar method and have a bucket size of up to 10 m^3.

Backhoe dredgers are expected to remove any material down to 25 m below the sea surface, whereas the grab dredgers remove the majority of the seabed material below this level. Some of the deeper seabed layers are planned to be pre-treated by ripping the hardest soil with a Trailing Suction Hopper Dredger (TSHD). This is planned to be provided with a drag head which ploughs and thus loosens the top seabed layers at depths of 30 - 40 cm.

FIGURE 5.16 Conceptual design of an immersed tunnel – Dredging of the tunnel trench using backhoe dredgers



Barges with dredged seabed material will sail between these work areas in the Fehmarnbelt and the land reclamation areas in both Denmark and Germany. The work areas will change location as the dredging works progress. Principles for the marine works are described in chapter 7.23 on ship traffic and navigation.

A total of 19 million m^3 of materials is to be dredged and distributed over the tunnel trench, the access channel to the work harbour and the work harbour at the production facility (Table 5.2). The material will be transported and incorporated into the land reclamation areas off Rødbyhavn and Puttgarden. The dredging work involves a potential risk that sediment spillage could result in a transboundary environmental impact. The total sediment spillage is estimated at approx. 0.75 million m^3, of which the greater part originates from the dredging of the tunnel trench.

TABEL 5.2 Conceptual design of an immersed tunnel – Estimated volumes of dredged material divided on sediment types

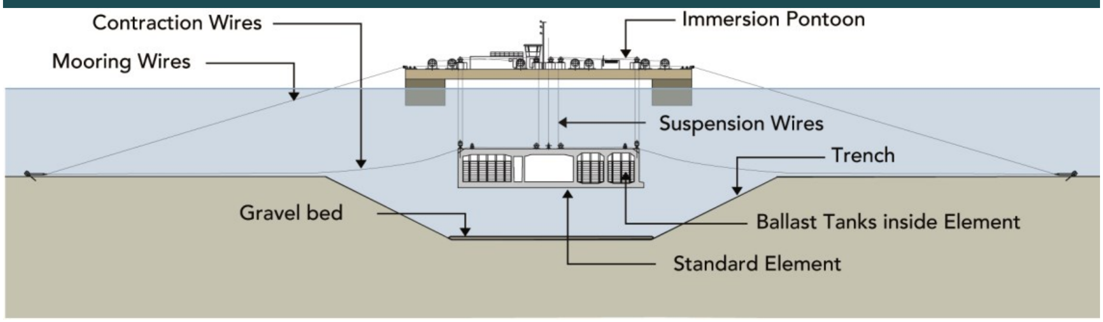
Sediment type	Expected volume (m^3)
Moraine clay	12,400,000
Clay	3,200,000
Silt/sand	1,400,000
Sand	700,000
Organic silt	700,000
Palaeogene clay	500,000
Melt-water sand	100,000
Total	19,000,000

In the dredging scenario of the conceptual design, it is assumed that two large backhoe dredgers, five large grab dredgers, one Trailing Suction Hopper Dredger, approx. 25 barges, six tug boats, and boats for marine measurements, staff transport and mechanical service will be used. In total about 50 return trips between the dredging area and the incorporation area are expected per day.

5.6.6 Immersion and installation of the tunnel elements

The tunnel elements are planned to be immersed by placing immersion pontoons on each element. The element will be positioned above the tunnel trench and fixed by anchors weighing approx. 1 - 3 t. The immersion starts with the ballast tanks being filled with sea water to make the element sink. During the immersion operation, the tunnel element is controlled by the two immersion pontoons by means of suspension wires (Figure 5.17). Subsequently, the ballast tanks and the steel bulkheads that separate the tunnel elements will be removed and, at the same time, permanent ballast concrete shall be laid. The joints between the tunnel elements will be completed, and ballast concrete to be cast along the full length of the tunnel floor, thereby securing the elements against buoyancy.

FIGURE 5.17 Conceptual design of an immersed tunnel – Immersion of an element from an immersion pontoon



Two independent work areas are planned to be present at the same time in the Fehmarnbelt from which immersion of elements takes place. One starts from the Danish coastline, the other from the German coastline, and both work towards the middle of the Fehmarnbelt.

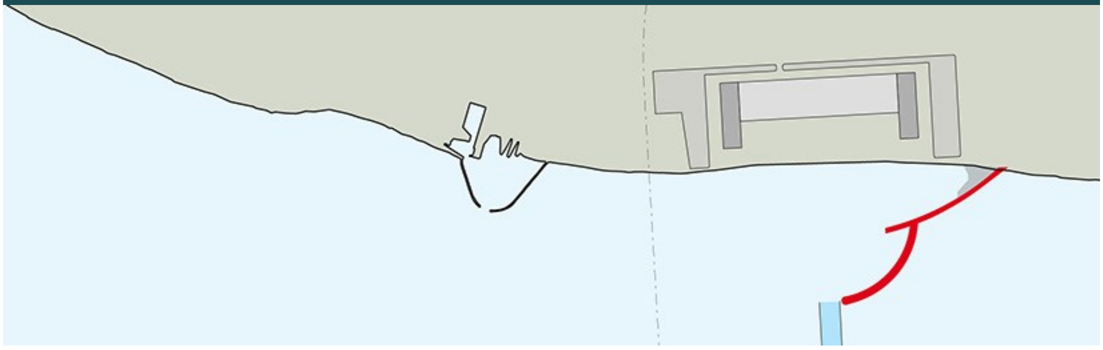
The locking fill for ”locking” elements to the tunnel trench is planned to be supplied from a barge via a downpipe. The rest of the fill on the sides of the elements will be sand, which by means of a Trailing Suction Hopper Dredger is placed on the sides of the elements. The rock protection layer above the tunnel elements will be positioned by a grab. All filling material will be shipped to the working site without temporary deposit.

5.6.7 Establishment of land reclamation area

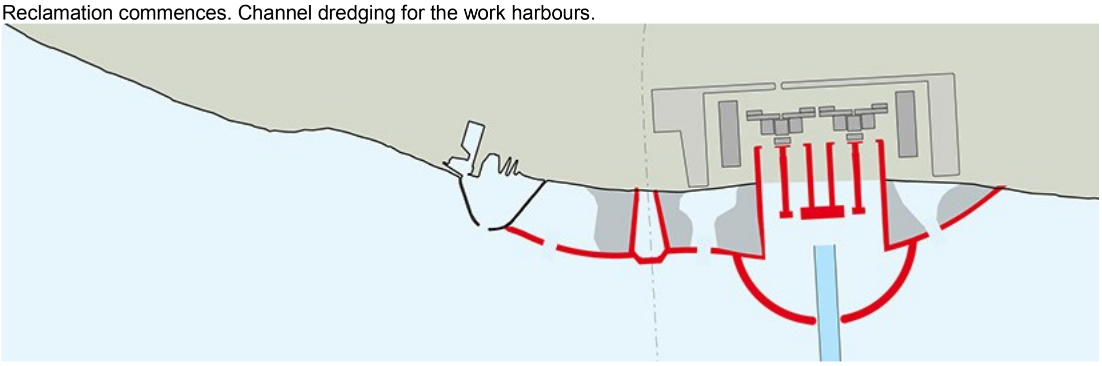
Material dredged from the tunnel trench is planned to be incorporated into land reclamation areas in both Denmark and Germany. The method of incorporation and the use of the dredged material have been chosen with a view to reducing the amount of sediment spillage as much as possible during incorporation.

It is planned that the land reclamation areas will be established by first constructing a containment dike around the reclamation areas. This dike is planned to be built from selected parts of the seabed materials and will be protected against wave impact from the Fehmarnbelt by an embankment. The dredged materials will subsequently be incorporated in the reclamation areas behind the containment dikes. Figure 5.18 illustrates the principle of the establishment of the land reclamation area on Lolland.

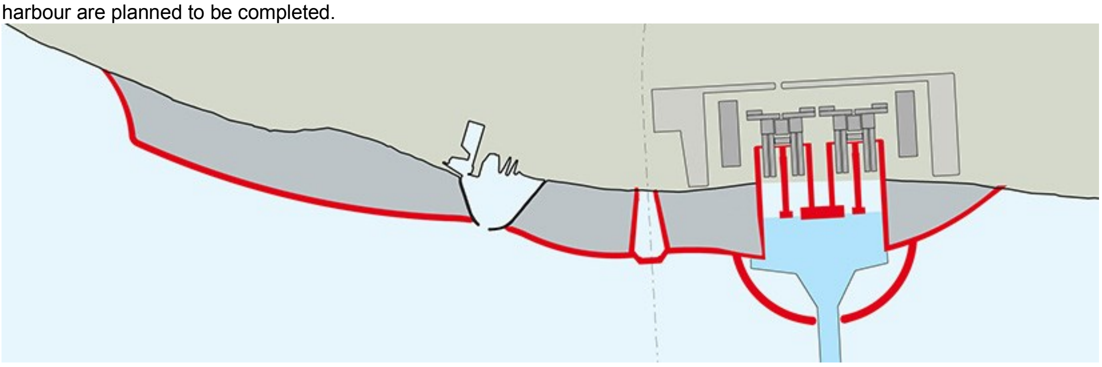
FIGURE 5.18 Conceptual design of an immersed tunnel – Principle of the establishment of land reclamation on Lolland, DK



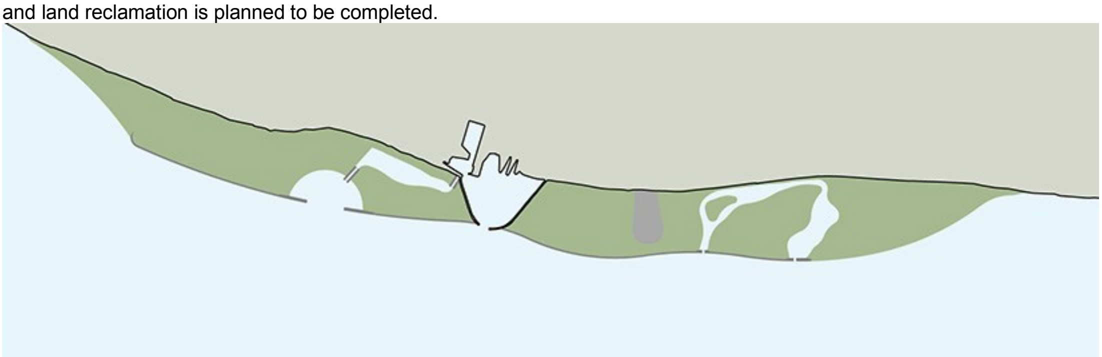
Note: Construction phase year 0: Establishment of the tunnel element production facility starts in the east with the establishment of temporary containment dikes (including an embankment) around the reclamation area and work harbour. Reclamation commences. Channel dredging for the work harbours.



Note: Construction phase year 1: Establishment of the production facility is planned to be completed. Establishment of temporary containment dikes (including an embankment) around the reclamation area is in progress. Dredging of the work harbour is planned to be completed. Land reclamation is in progress. Temporary containment dikes around the work harbour are planned to be completed.



Note: Construction phase year 1-2: Establishment of temporary containment dikes (including and revetments) around the reclamation area are planned to be completed. Production of tunnel elements will commence. Dredging of the tunnel trench and land reclamation is planned to be completed.



Note: The two last years of the construction phase: Production facility and work harbour are planned to be demobilised. Land reclamation and revetments are planned to be developed to its final form.

As the production facility at Rødbyhavn is located within the area that is included in the eastern part of the land reclamation area, this part of the land reclamation area cannot be established until the tunnel element production is completed and the production facility removed.

It is therefore necessary to store parts of the seabed materials to be used for backfilling of the work harbour. Some of the materials is planned to be placed around the production facility, which will give rise to soil deposits of up to approx. 10 m, serving as a noise barrier. The remaining part is planned to be placed in the reclamation areas around the work harbour or in the reclamation area west of the ferry harbour.

After the second year of the construction phase the coast west of Rødbyhavn is planned to be barred to swimmers for a period of two years.

5.6.8 Soil balance and resource consumption

This chapter describes the overall resource consumption and soil balance in the construction phase.

Offshore dredging

The marine dredging works are expected to involve dredging of approx. 19 million m^3 of sediment consisting of sand, clay-till and organic silt of varying grain sizes. Dredging of the tunnel trench, cut-and-cover tunnel and ramps is expected to involve a dredging volume of approx. 15 million m^3. Dredging for the production facility and work harbour, including the channel at Rødbyhavn, is expected to involve a dredging volume of approx. 4 million m^3. The total volume of dredging material to be handled during the construction phase on Lolland is estimated at approx. 18 million m^3 and on Fehmarn approx. 1 million m^3.

In total, the dredging volume on Danish territory is expected to be approx. 11 million m^3 and on German territory approx. 8 million m^3. Within the overall scope (approx. 17 million m^3 on Lolland and approx. 2 million m^3 on Fehmarn) it is the responsibility of the contractor to decide how to handle the dredge sediment. Therefore, a maximum of 8 million m^3 sediment from German territory is handled on Lolland and maximum 1 million m^3 from Danish territory is handled on Fehmarn.

The majority of the dredged seabed material is planned to be used to create the reclamation area on Lolland, but the material may also be used for other purposes within the construction work, as shown in Table 5.3.

TABEL 5.3 Conceptual design of an immersed tunnel – Estimated offshore soil balance

Activity	Volume (million m^3)
Dredging, tunnel trench and cut-and-cover tunnel	15
Dredging, production facility	4
Dredging in total	**19**
Establishment of dikes around land reclamation areas – Lolland	1
Ramps and backfilling around structures – Lolland	1
Reclamation, Lolland east of the ferry harbour	9
Reclamation, Lolland west of the ferry harbour	6
Ramps and backfilling around structures – Fehmarn	1
Reclamation, Fehmarn	1
Reclamation in total	19

Onshore dredging
In connection with the establishment of the various onshore facilities, some dredging will have to be performed. The dredged materials will be loaded onto dumpers and transported to other parts of the work areas or the reclamation areas.

Contaminated soil
Part of the coast-to-coast project on Lolland will have to be located within an area which is classified by Lolland Municipality as slightly contaminated. Soil is planned to be analysed according to an agreement with Lolland Municipality, and relocation of soil within the classified area will be notified to Lolland Municipality in accordance with applicable rules.

Contaminated soil is not expected on the German side of the project area, as the soil here is generally classified as LAGA Z 0 (class defined by not being more contaminated than the natural soil). If contaminated soil is observed during the construction phase on the German side, it will be handled in accordance with the applicable rules on the disposal of contaminated soil.

Resource consumption
An estimate of the major resource requirements for the construction phase of the coast-to-coast project is given in Table 5.4.

Besides these resources, it is expected that there will be a fuel consumption of approx. 100,000 m^3, mainly for the works in the marine area.

TABEL 5.4 Conceptual design of an immersed tunnel – Estimated resource requirements in the construction phase

Activity and resource (origin)	Estimated volume
Tunnel production	
Concrete for tunnel elements (Sand possibly from Rønne Banke)	2,500,000 m^3 total
Reinforcing steel	300,000 t total
Ballast concrete (Sand possibly from Rønne Banke)	400,000 m^3 total
Concrete for portal, ramps and cut-and-cover (Sand possibly from Rønne Banke)	200,000 m^3 total
Crushed rock for foundation for tunnel elements	800,000 m^3 total
Sand and locking fill around tunnel elements (Possibly from Kriegers Flak)	3,600,000 m^3 total
Rocks in the protection layer above tunnel elements	2,000,000 m^3 total
Land reclamation areas DK and DE	
Dredged material from the tunnel trench, access channel and work harbour	approx.19. million m^3 total
Rocks for revetments	400,000 m^3 total
Sand for beaches (Possibly from Kriegers Flak)	500,000 m^3 total
Sand fill for temporary constructions (Possibly from Kriegers Flak)	1,000,000 m^3 total
Permanent land works	
Gravel for railway and road construction	200,000 m^3 total
Concrete for railway	75,000 m^3 total
Iron for railway	10,000 t total
Granite for railway	80,000 t total
Asphalt for roads	200,000 t total
Supplies	
Water for concrete production and staff facilities	1,350,000 m^3 total
Electricity including heating	130 million kWh total
Wastewater from staff facilities	4,500 PE per year in peak periods
Possible discharge of reject water from desalination of seawater	410,000 m^3 per year

Note: Sand fill for temporary constructions is primarily for elevating the terrain in the area of the production facility but also for other work areas where material of a higher quality than the dredged seabed sediment is needed

Raw material extraction

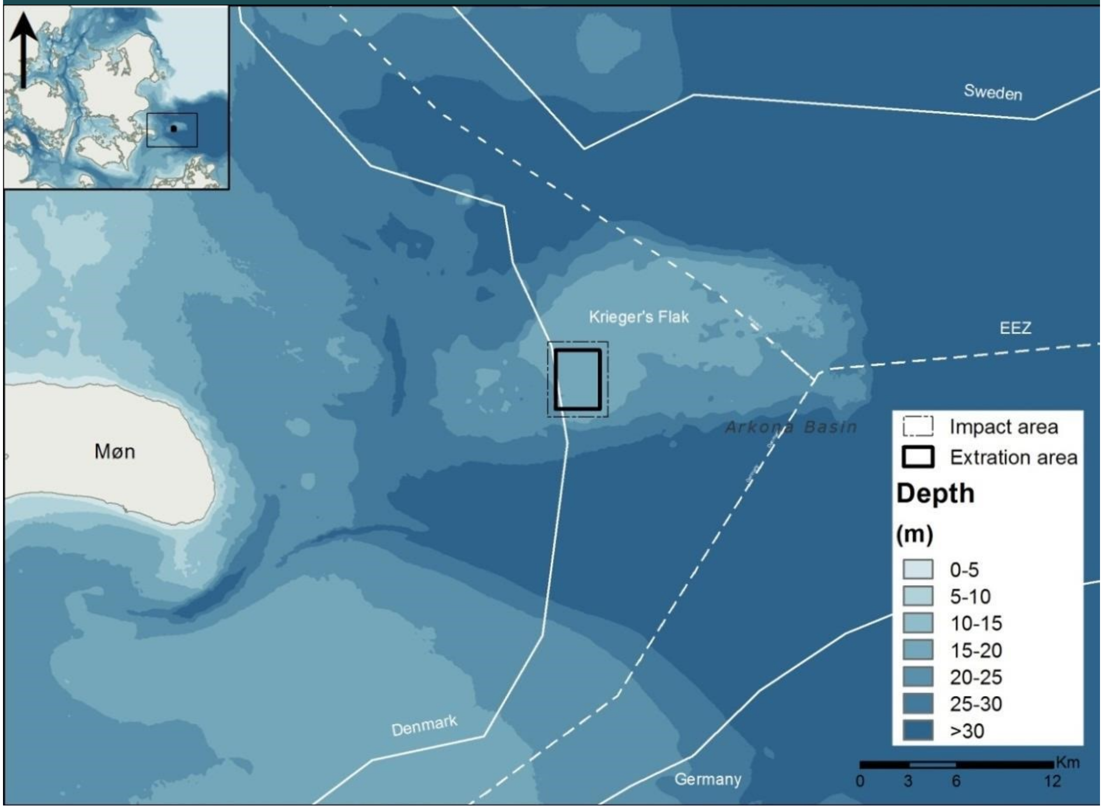
Table 5.4 shows an estimate of the most important resources required for the construction of a permanent immersed tunnel across Fehmarnbelt. The planned construction of the fixed link across the Fehmarnbelt (coast-to-coast) will require large volumes of sand and gravel. Femern A/S has designated two possible areas for sand extraction, both of which are in Danish waters: Kriegers Flak and Rønne Banke.

Kriegers Flak is located approx. 30 km east of the Danish island of Møn and approx. 120 km from the project area in the Fehmarnbelt (Figure 5.19). An EIA has been prepared for the extraction of up to 6 million m^3 sand. The sand extraction is planned to take place regularly over a period of 2.5 years. In the EIA, the environmental impact is assessed to be:

- Loss of seabed (approx. 10 km^2). Physical and biological traces from the extraction are estimated to be eliminated within 5 - 10 years

- Increased concentration of suspended matter. Suspended matter and sediment is not expected to exceed a limit above which it may impact aquatic and seabed fauna
- Emission and air pollution from the sand extraction and transportation of sand to and from the construction areas in the Fehmarnbelt. The emission of CO_2 is estimated at approx. 26,600 - 42,000 t
- The extraction is not estimated to have any transboundary environmental impact

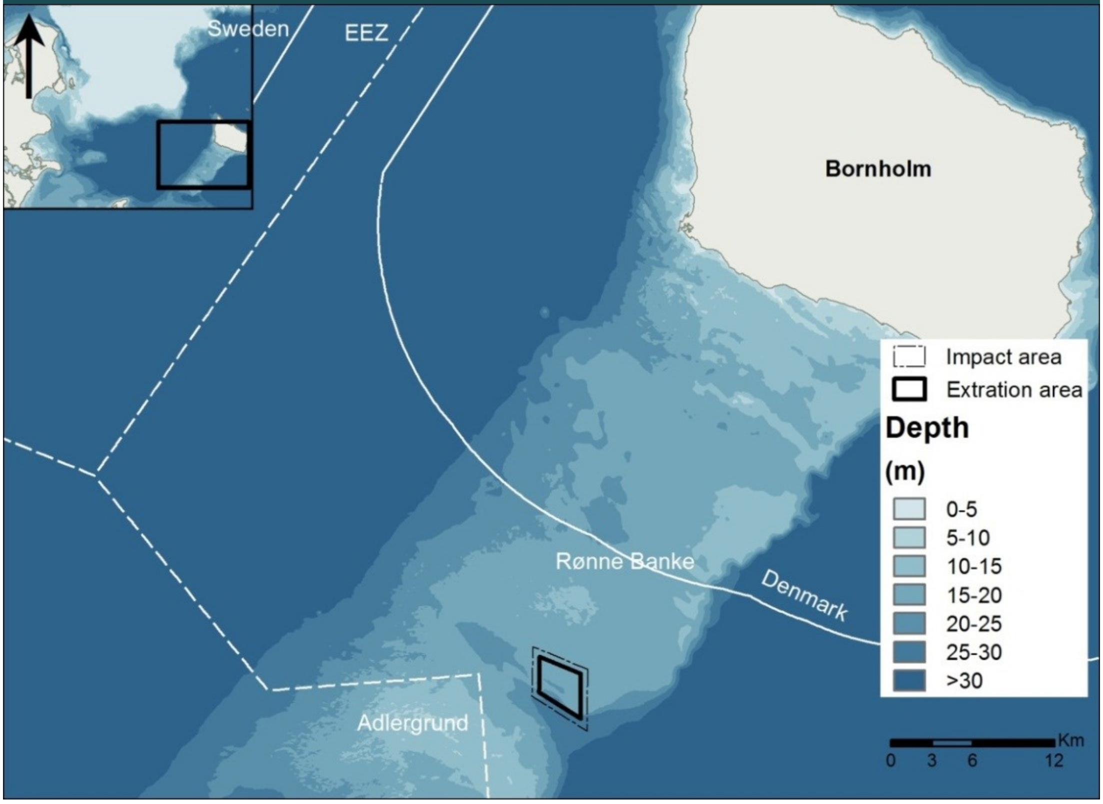
FIGURE 5.19 **Conceptual design of an immersed tunnel – Location of Kriegers Flak, a possible area for sand extraction**



Rønne Banke is approx. 30 km south-southeast of Bornholm and approx. 220 km from the project area in the Fehmarnbelt (Figure 5.20). An EIA has been prepared for the extraction of 1 million m^3 sand for the purpose of concrete casting. The sand extraction is planned to take place regularly over a period of 1 - 1.5 years. In the EIA, the environmental impact is assessed to be:

- Loss of seabed (approx. 2 km^2). Physical and biological traces from the extraction are estimated to be eliminated within 3 - 5 years
- Increased concentration of suspended matter. Suspended matter and sediment are not expected to exceed a limit above which it may impact aquatic and seabed fauna.
- Emission and air pollution from the sand extraction and transportation of sand to and from the construction areas in the Fehmarnbelt. The emission of CO_2 is estimated at approx. 7,400 - 11,600 t
- The extraction is not estimated to have any transboundary environmental impact

FIGURE 5.20 **Conceptual design of an immersed tunnel – Location of Rønne Banke, a possible area for sand extraction**



Femern A/S will let the contractors who are performing the construction works decide how to deliver the raw materials for the tunnel project. If the contractors choose to collect raw materials from a different approved raw material area, the existing EIA reports and applications for extraction permits for Kriegers Flak and Rønne Banke will not be used.

Water

The production area on Lolland is expected to require a maximum of 450,000 m^3 water per year for concrete production as well as sanitary purposes. The water requirement will be largest in the years, where the tunnel elements are produced.

Water is projected to be supplied from Lolland Forsyning A/S and will be of drinking water quality. The EIA of the fixed link between Fehmarn and Lolland also investigates a scenario for the water supply to the concrete production based on desalination of seawater.

Water for the concrete production is to be supplied to the production facility as well as to the work area for the portal and ramp production. Buffer tanks are planned to be established in order to secure water supply at peak demands.

5.6.9 Waste

This chapter provides an estimate of the expected waste quantities, mainly as a result of the construction phase of the fixed link project. Expected amounts of waste generated during the production of the immersed tunnel, household waste generated in the construction phase, and demolition of the production facility and existing wind turbines on Lolland is given in Table 5.5.

TABEL 5.5 Conceptual design of an immersed tunnel – Expected volumes of waste from the construction phase

Waste from the tunnel production	Amount	Treatment
Concrete from tunnel elements	40,000 m^3	Recovery
Ballast concrete, total	6,000 m^3	Recovery
Concrete from portals, ramps and cut-and-cover	3,000 m^3	Recovery
Steel	150 t	Recovery
Reinforcement steel	2,000 – 5,000 t	Recovery
Household waste		
Household waste – Lolland	1,200 t per y	Incineration
Household waste – Fehmarn	60 t per y	Incineration
Demolishing of production facility		
Steel, Reinforcement iron	20,000 t	Recycling
Steel and metal, framework of canopy	25,000 t	Recycling
Concrete constructions	150,000 m^3	Recycling
Demolishing of wind turbines on Lolland		
Steel	3,100 t	Recycling
Composites from wings, cabins etc.	775 t	Disposal
Concrete foundations	150 m^3	Recycling

During the production of the immersed tunnel, construction waste is generated from spillage and disposal of various building materials. The expected waste quantities from the concrete and reinforcing steel are 1.5% and 0.5-1.5% respectively, based on experience from other major infrastructure constructions (Øresundsforbindelsen).

Construction waste also consists of cable scrap from electrical installations, packaging waste, wood waste and other combustible waste. In addition, waste is generated from the service and repair of machinery and other equipment on site. A small proportion of the waste is expected to consist of hazardous waste and will be handled according to the national rules for hazardous waste in Denmark and Germany respectively. This applies, for example, to waste oil, glue and sealants, tar asphalt, and paint residues.

Concrete waste will mainly be demolished and reused in the project. Steel and other construction waste will be shipped on the returns of the ships delivering materials for the production or transported on trucks. Disposal of construction waste is expected to entail traffic of approx. 1,000 trucks during the years 1 - 4 of the construction period.

When all tunnel elements have been produced and immersed in the tunnel trench, the production facility is planned to be demolished. Installations such as concrete mixing plant, silos, buildings, etc. will be the contractors' estate, and are expected to be reused on other projects. Buildings that cannot be reused elsewhere, along with concrete foundations, are planned to be crushed down and disposed of to an approved recipient.

Disposal of household waste from the camp is expected to entail traffic of up to 1,000 trucks per year in the peak time of the construction period (year 2 - 4).

5.6.10 Traffic and employment during the construction phase

During the construction phase, additional ship traffic and road traffic is expected in the form of commuter traffic and heavy traffic with materials to and from the construction site. The commuter traffic is expected to take place 24 hours a day, while trucks are only expected to access the area during the daytime. The generation of traffic in the construction phase is estimated on the basis of the current expectations for work processes and time schedules.

Direct employment in the construction phase is estimated to create workplaces corresponding to approx. 19,700 man-years. The majority of the employees will be working at the production facility at Lolland, and it is estimated that during peak construction periods there will be approx. 3,000 workers in the camp at Lolland.

With regard to commuter traffic, it is expected that most of the employees will be transported between the work site and main traffic junctions by bus. Assuming a work schedule of seven days on the tunnel work areas and three days off, this will result in a traffic of 1,200 car passages on average per day and 70 bus passages on average per week to and from the work site (number of passages is calculated as twice the number of cars/busses, assuming that the vehicles are going both to and from the work site the same day/week, Table 5.6). It is expected that staff for the campsite (200 persons) will commute from the local area on a daily basis.

TABEL 5.6 Estimated traffic during the construction phase of the Fixed Link on Lolland

	Production area Rødbyhavn	Camp	Work area – tunnel portal	I alt
Cars per day	500	400	300	1.200
Trucks per day	150	20	120	290
Busses per week	10	50	10	70

Note: In the analysis number of passages is calculated as twice the number of cars/busses, assuming that the vehicles are going both to and from the work site the same day/week

Truck traffic to/from the work area is estimated at 290 trucks/day including delivery of materials to the production facility and supplies to the campsite.

Ship traffic with materials to the element production is estimated at an average of 15 ships per week with a load of up to 5,000 t and 5 ships per week with a load of up to 2,000 t. The number of ship transports during the marine construction period of four years is expected to be approx. 130,000, which equals the average of the existing intensity of ship traffic from the ferry line Rødby-Puttgarden.

5.6.11 Time schedule

The presumed time schedule for the construction phase for an immersed tunnel is based on a construction period lasting approx. 6.5 years. The time schedule in Table 5.7 shows activities from the start-up in the last six months of year 0 until the end of the construction phase 6.5 years later.

It is presupposed that construction work will be carried out non-stop. Some activities, however, generate a large amount of noise, and these activities will therefore only be carried out during the daytime.

TABLE 5.7 Conceptual design of an immersed tunnel – Expected time schedule for the construction phase

5.6.12 Construction estimate of the immersed tunnel

The construction estimate for the immersed tunnel is calculated to approx. EUR 5.5 billion (2008 prices, Table 5.8). The estimate includes the total costs of planning and implementing the technical solution as well as consultancy costs and client costs.

The construction estimate is to be considered the best possible estimate based on the available information at the present stage of the project. It cannot be excluded that new information, demands from authorities, or delays because of complaints etc. will cause changes in the project or in the project time schedule, thereby affecting the cost estimate. Finally, it will be the tenders of the contractors that determine a large part of the construction costs.

The Fehmarnbelt Fixed Link is a priority project in the EU TEN-T programme (Priority axis No 20, Fehmarn belt railway axis). The project therefore gains subsidies for both the planning of the project as well as for the construction works. Since the frames for the coming subsidy period are not yet set, it is not possible to give a precise estimate of the total EU subsidy to the Fixed Link project. In Act on the planning of the Fixed Link across the Fehmarnbelt (Act no. 285 af 15/04/2009) it is assumed that the project will granted 50 % of the costs eligible for subsidies in the planning phase and 10 % of the costs eligible for subsidies in the construction phase.

TABEL 5.8 Construction estimate of the Fehmarnbelt Fixed Link

2008 prices	EUR
Gross construction cost	5.46 billion
Projected EU subsidies[1]	0.63 billion
Net construction cost	4.83 billion
Annual operating and maintenance cost and reinvestment	73.3 million

Note: 1) EU subsidies are estimated at 50% in the planning phase and 10% in the construction phase
2) Reinvestment is calculated as an annual average for 40 operation years

6 PLANNING OF ALIGNMENT AND TECHNICAL DESCRIPTION OF ALTERNATIVES

Femern A/S has investigated and developed conceptual designs for four technical solutions for a fixed link across the Fehmarnbelt: An immersed tunnel, a bored tunnel, a cable-stayed bridge, and a suspension bridge. In addition, Femern A/S has investigated alternative alignments for the two tunnel and bridge solutions.

In November 2010, Femern A/S recommended to the Danish Minister for Transport that the immersed tunnel should be included in the continued work as the preferred solution. The recommendation is published at www.femern.com. The recommendation was based on the company's assessments of the conceptual designs for the technical solutions and a provisional environmental assessment based on existing data.

Chapter 4 contains the reasoning for the selection of alignment for the immersed tunnel and Chapter 5 contains the technical description of the immersed tunnel.

The present chapter contains a description of the investigated alignments for the alternative technical solutions as well as a technical description of the alternative technical solutions. Arguments are given, first for the selection of the bridge solution. The investigated alignments and reasoning for selection of alignment for the bored tunnel solution are the same as for the immersed tunnel which is given in Chapter 4. Second, the technical description of the bridge solutions and the argumentation for the selection of the bridge alternative is given. Third, a description of the bored tunnel and arguments for the selection of the tunnel alternative are set out. Finally, the argumentation for the preferred technical solution – the immersed tunnel – is presented.

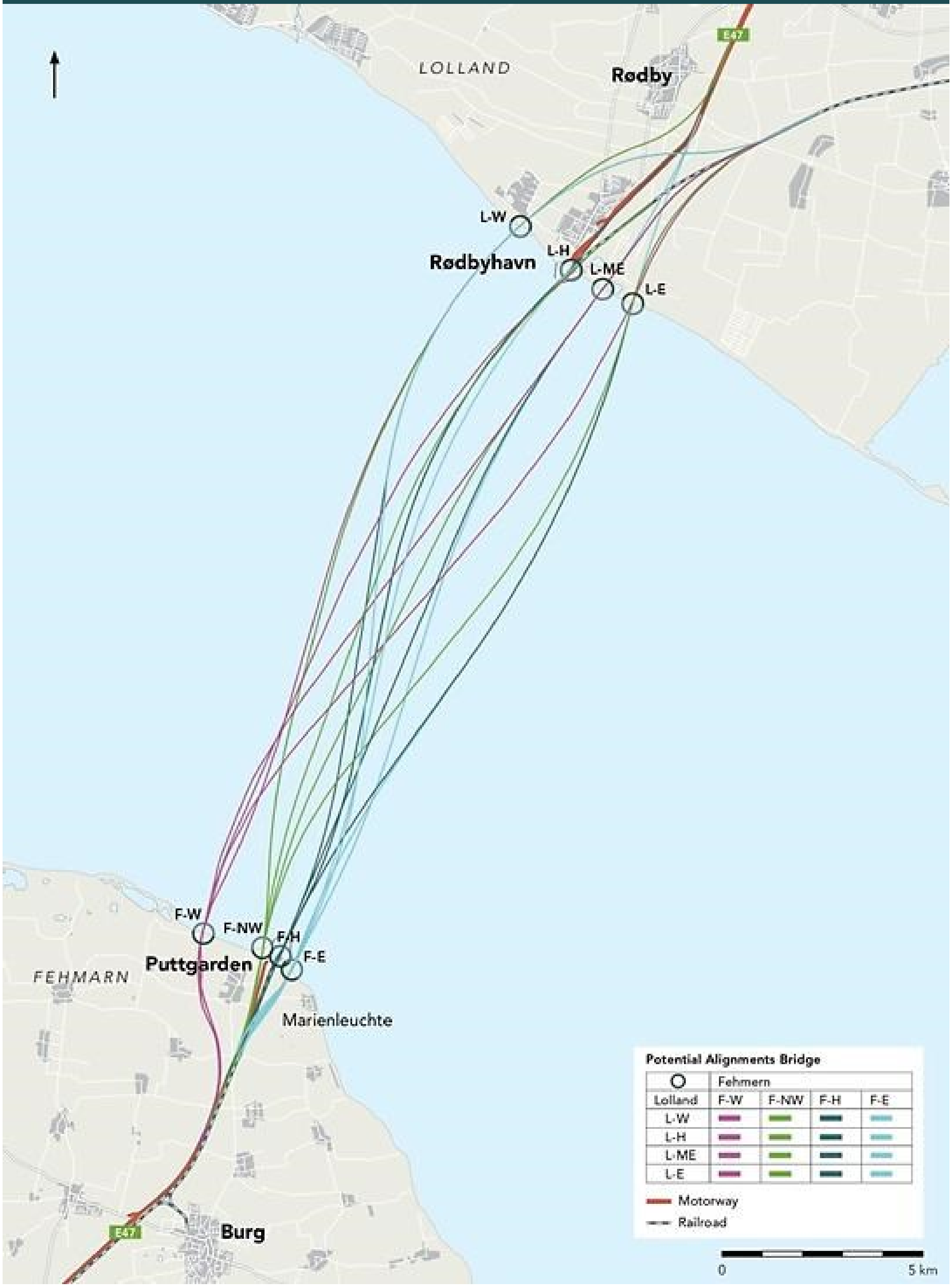
The descriptions of all the technical solutions are based on their conceptual designs, which are described in further detail in the Consolidated Technical Report from 2011, which can be downloaded from www.femern.com.

The chapter also contains a description of the 0-alternative which is used in the assessment of the environmental consequences of the immersed tunnel solution (see Chapter 7).

6.1 ALIGNMENT ALTERNATIVES FOR BRIDGE SOLUTIONS

On the basis of the environmental sensitivity analysis, four approaches on Lolland and Fehmarn were identified within the eastern and western corridors. This gives 16 different combinations of alignment alternatives for the bridge solutions (Figure 6.1).

FIGURE 6.1 **Alignment alternatives for the bridge solutions**



For the bridge solutions, the following has been taken into account:

- The ferry operation between Rødbyhavn and Puttgarden must be operable during the construction and operational phase of the coast-to-coast project.
- An alignment with an S-shape will give motorists a good view across the entire bridge.
- An alignment which intersects perpendicularly with the ship traffic route (the T route) will give ship traffic the best possible view.

On this basis, alignments which fully or partly make use of the harbour facilities in the Rødbyhavn and Puttgarden harbours have been rejected, i.e. alignment alternatives with the approach at either Rødbyhavn harbour (L-H) or Puttgarden harbour (F-H) (Table 6.1).

Furthermore, alignments intersecting the ferry route between Rødbyhavn and Puttgarden have been rejected, i.e. alignments with approaches west of Rødbyhavn harbour (L-W) and east of Puttgarden harbour (F-E) and alignments with approaches east of Rødbyhavn (L-ME and L-E) and west of Puttgarden harbour (F-W).

Because the western project corridor has fewer potential environmental conflicts than the eastern project corridor, based on an environmental assessment, all western alignment alternatives have been rejected.

TABEL 6.1 Final alignment alternatives for the bridge solutions

Lolland Fehmarn	L-W	L-H	L-ME	L-E
F-W	~~F-W→L-W~~	~~F-W→L-H~~	~~F-W→L-ME~~	~~F-W→L-E~~
F-NW	~~F-NW→L-W~~	~~F-NW→L-H~~	~~F-NW→L-ME~~	~~F-NW→L-E~~
F-H	~~F-H→L-W~~	~~F-H→L-H~~	~~F-H→L-ME~~	~~F-H→L-E~~
F-E	~~F-E→L-W~~	~~F-E→L-H~~	F-E→L-ME	F-E→L-E

The number of alignment alternatives is thus reduced to two (Figure 6.2):

- L-ME → F-E: Alignment extending from east of Rødbyhavn harbour to just east of Puttgarden harbour
- L-E → F-E: Alignment extending from further east of Rødbyhavn harbour to just east of Puttgarden harbour

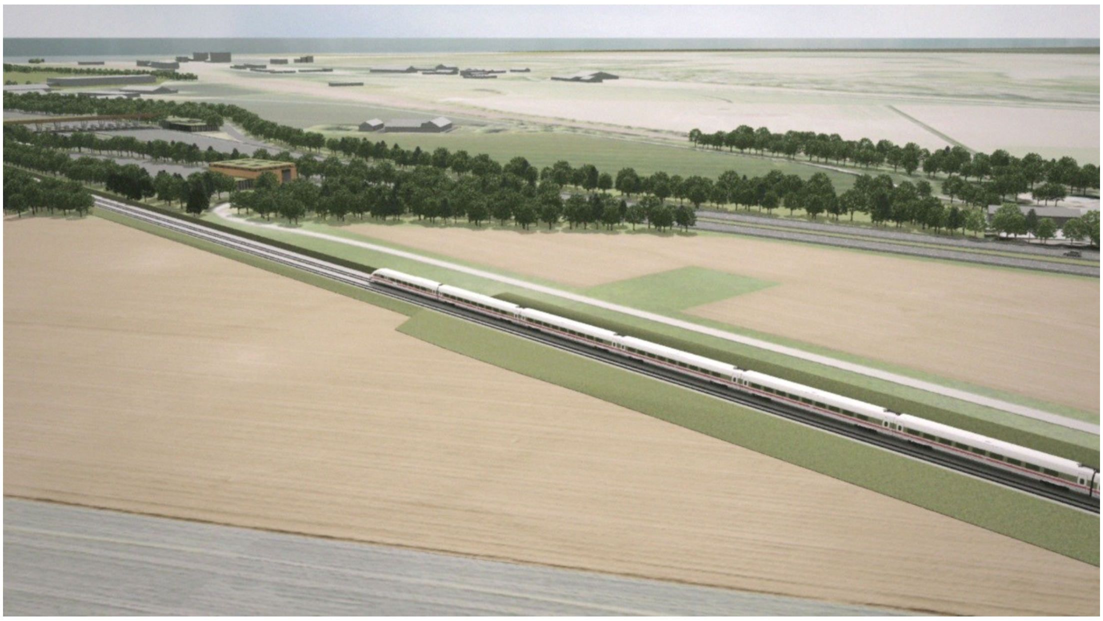
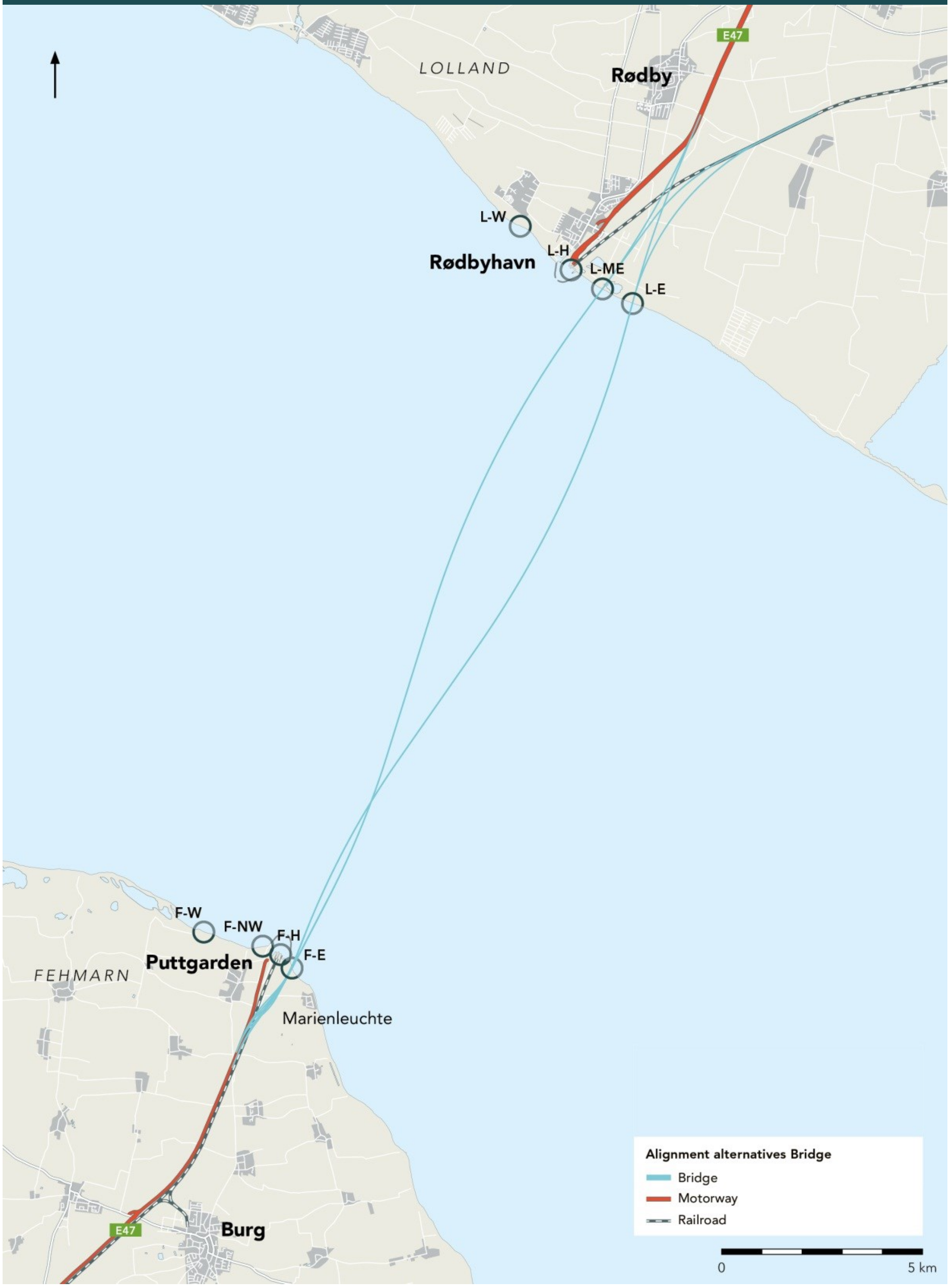


FIGURE 6.2 Final alignment alternatives for the bridge solutions



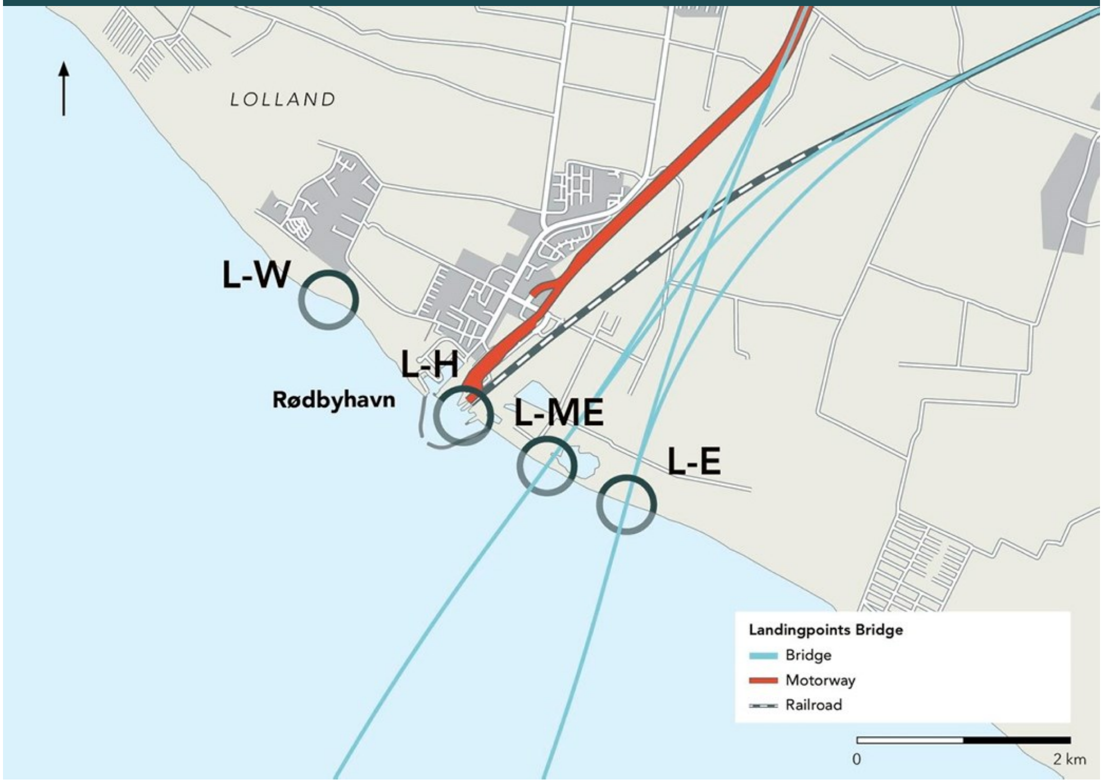
In the following sections, the two remaining alignment alternatives have been compared in relation to each of the environmental components: people, flora and fauna, soil, water, landscape as well as cultural heritage and material goods. As the two alignment alternatives have the same approach on Fehmarn, the comparison is only relevant for Lolland.

6.1.1 Determination of alignment for the bridge solutions

The two alignment alternatives for a bridge solution differ by having approach L-ME approx. 600 m east of Rødbyhavn harbour or L-E approx. 1.4 km east of Rødbyhavn harbour (Figure 6.3).

The approach on Fehmarn is identical with the approach described for the immersed tunnel (Chapter 4).

FIGURE 6.3 Alignment L-ME and L-E, Lolland



Alignment L-ME
L-ME's landing point on Lolland is approx. 600 m from the existing harbour facilities and approx. 3.5 km from Hyldtofte Østersøbad and the neighbouring holiday cottage area.

The primary impact from alternative L-ME is its location relatively close to the harbour, which reduces the manoeuvring space of the ferries and increases the risk of the ferries colliding with the bridge. Alternative L-ME also affects an area of recreational interest and bird habitats (Strandholm Sø).

Alignment L-E
L-E's landing point on Lolland is approx. 1.4 km from the existing harbour facilities and approx. 2.5 km from Hyldtofte Østersøbad and the neighbouring holiday cottage area.

L-E's landing point is further from Rødbyhavn harbour than L-ME and provides more manoeuvring space for the ferries.

The primary impact from the alignment alternative L-E consists in the landing point being located further from the connection to the existing motorway than L-ME, and the footprint is therefore greater. Additionally, L-E's location further to the east results in a larger division of the landscape (more plot divisions) and leaves a larger area between the Fixed Link and Rødbyhavn harbour, which is planned to be isolated and thus have a limited number of potential uses.

For the purpose of the production of bridge elements, a production facility would have to be established at Rødbyhavn. Only part of the bridge elements would have to be produced at Rødbyhavn, and the production facility will therefore be smaller for bridge elements than for tunnel elements. For alignment alternative L-E, it will be possible to locate the production facility just west of the alignment, between Rødbyhavn harbour and the approach. This means that the production facility will affect Strandholm Sø, but will be located as far from Hyldtofte Østersøbad and the holiday cottage area as possible.

The environmental comparison of L-ME and L-E is summarised in Table 6.2. The comparison shows that only minor differences exist between the two alignment alternatives. However, from a technical point of view, L-E has an advantage over L-ME, which will reduce the manoeuvring space of the ferries and increase the risk of the ferries colliding with the bridge.

In summary, Femern A/S considers L-E to be the most expedient alignment for the bridge solution.

TABEL 6.2 Assessment of alignment L-ME and L-E in relation to environmental criteria, Lolland, bridge solution

Bridge	**L-ME**	**L-E**
People	Crosses dike with recreational path Affects an area of recreational interest (among others, Strandholm Sø) Near Rødbyhavn	Crosses dike with recreational path Affects an area of recreational interest Relatively further from Rødbyhavn
Flora and fauna	Crosses dike Red-backed shrike and marsh harrier (Annex 1) have been observed in the area around Strandholm Sø Affects areas with a salt meadow which is nature protected Affects an area, L-014, with two Danish red-listed beetle species	Crosses dike Affects areas with a salt meadow which is nature protected Affects a wetland of great value for jumping frog and green toad (Annex IV) and the Danish red-listed Garganey.
Soil	Crosses low-lying area at the coast	Crosses a wide low-lying area at the coast Longer alignment and therefore greater footprint
Water	Crosses Strandholm Sø, which is nature protected Crosses two watercourses (Kirkenorsløbet, which has high biological value, and Næsbæk, which has medium biological value)	Crosses two watercourses (Kirkenorsløbet, which has high biological value, and Næsbæk, which has medium biological value)
Landscape	Crosses the coastal protection line Closer to the existing transport infrastructure and therefore less division of the landscape	Crosses the coast protection line A little further from the existing infrastructure and therefore more division of the landscape
Cultural heritage and material assets	Crosses an old extraction area and dike	Crosses an old extraction area and dike Affects an area of archaeological cultural heritage

6.2 CABLE-STAYED BRIDGE

The conceptual design for a cable-stayed bridge is described in the following sections (Figure 6.4).

FIGURE 6.4 Conceptual design of a cable-stayed bridge

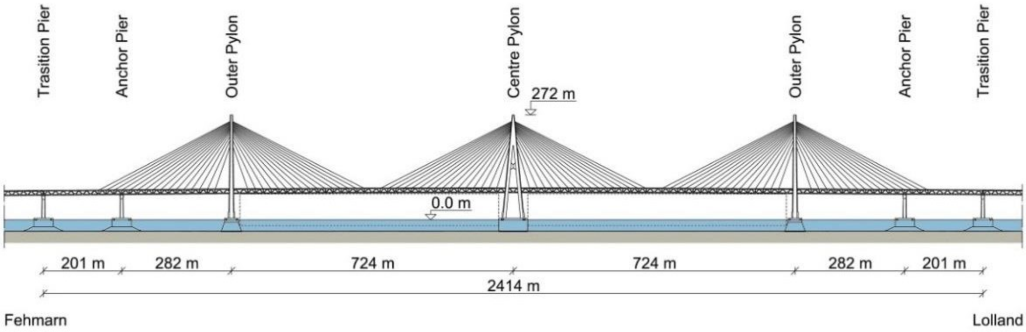
6.2.1 Bridge design

The conceptual design for a cable-stayed bridge consists of a main bridge and two approach bridges. The total length of the bridge is 17.6 km from landfall to landfall. The main bridge is designed with six bridge spans with a total length of 2,414 m. The approach bridges that link the main bridge to the coast are designed with a length of 9,412 m on the Lolland side and 5,748 m on the Fehmarn side.

The main bridge is designed with two main spans of 724 m each and navigation clearance above the surface of the sea of at least 66.2 m, while the approach bridge spans are primarily 200 m long (Figure 6.5). The height of the roadway rises from 20.9 m at the landfall on Lolland to 82.2 m at the central pylon, subsequently falling to 24.9 m at the landfall on Fehmarn.

The conceptual design for a cable-stayed bridge also comprises two reclaimed peninsulas off the coasts of Lolland and Fehmarn out to a water depth of 5 - 6 m, which connect the approach bridges to the coasts, as well as structures onshore which connect the motorway and railway to the existing infrastructure.

FIGURE 6.5 Conceptual design of a cable-stayed bridge - Schematic diagram of the main bridge in elevation



The bridge elements

The conceptual design comprises a main bridge with three pylons and two approach bridges with 74 bridge piers. The cable-stayed bridge consists of one bridge girder in two decks. The roadway is on the upper deck with a four-lane carriageway and emergency lanes. The lower deck has a two-track railway (Figure 6.6). The upper deck is designed as a closed steel box, with the stay cables anchored at the outer edge. A steel lattice girder structure connects the road deck to the underlying two-track railway in a closed steel box.

The superstructure of the approach bridges are as that of the main bridge, except that the bridge girder is a composite structure with an upper concrete deck, intermediate steel lattice structure, and a lower steel deck.

FIGURE 6.6 Conceptual design of a cable-stayed bridge – Schematic diagram of the main bridge in cross-section

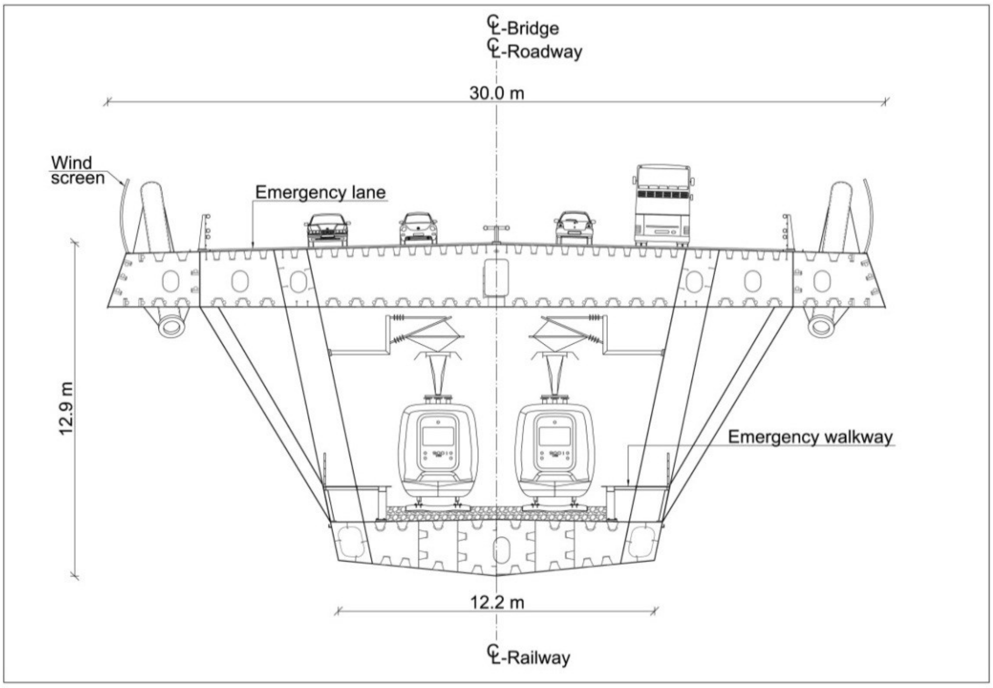
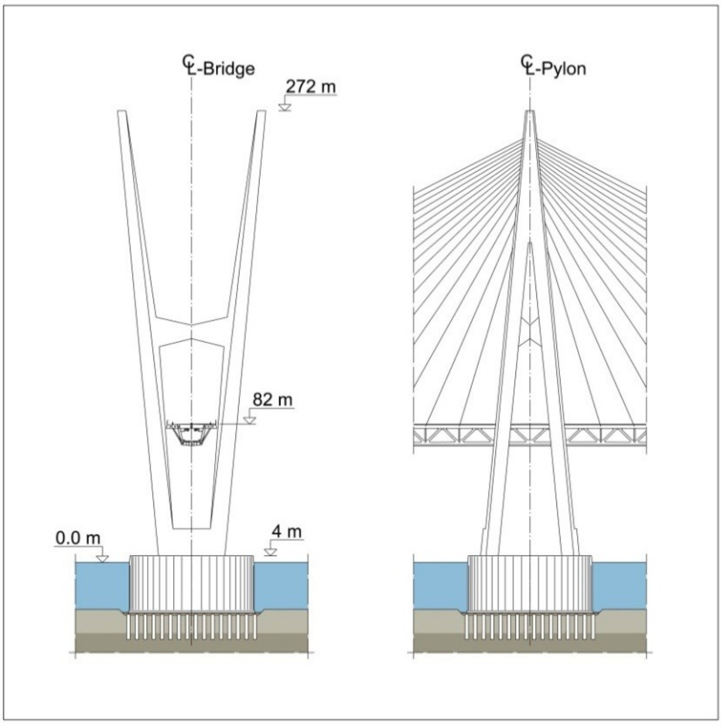


FIGURE 6.7 Conceptual design of a cable-stayed bridge – Schematic diagram of a centre pylon



According to the conceptual design, the three pylons consist of a centre pylon with four legs and two outer pylons with two legs each that anchor the stay cables. The centre pylon is V-shaped when viewed in the direction of the alignment and A-shaped when viewed from the side (Figure 6.7). The two legs in each A are separate under the cable anchoring zone from a height of 190 m downwards. The outer pylons are vertical when viewed from the side and V-shaped when viewed in the direction of the alignment. The pylons' height is 272 m.

Caissons are the foundations for the pylons and the piers of the main bridge. The caisson for the centre pylon is circular to ensure minimum impact on water flow (Figure 6.8). The outer wall of the caisson projects above the surface of the water so that it is visible to vessels and it has openings below the surface of the water to ensure water exchange behind the wall.

The outer pylons' caissons are elliptical and filled with sand so that they are able to resist the impact of vessel collision (Figure 6.9). Just as at the centre pylon, the outer wall projects above the surface of the water. The caissons for the anchor and transition piers as well as for the approach bridges are identical but smaller than those for the pylons (Figure 6.10).

FIGURE 6.8 Conceptual design of a cable-stayed bridge – Schematic diagram of a section of the centre pylon's caisson

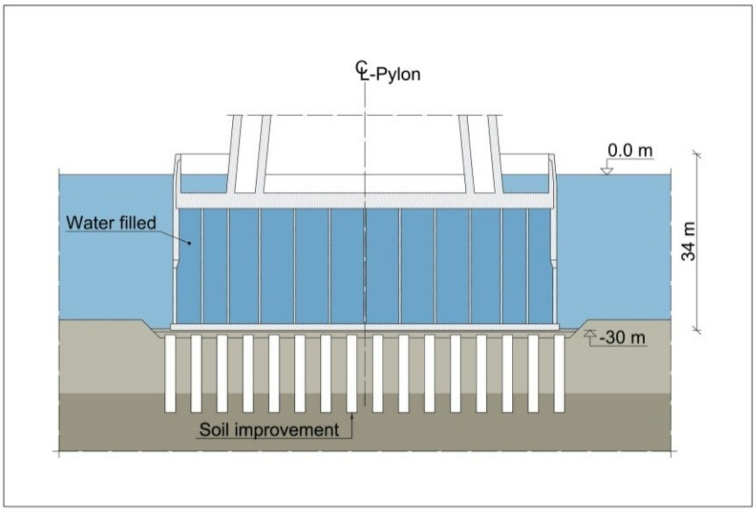


FIGURE 6.9 Conceptual design of a cable-stayed bridge – Schematic diagram of a section of the outer pylon's caisson

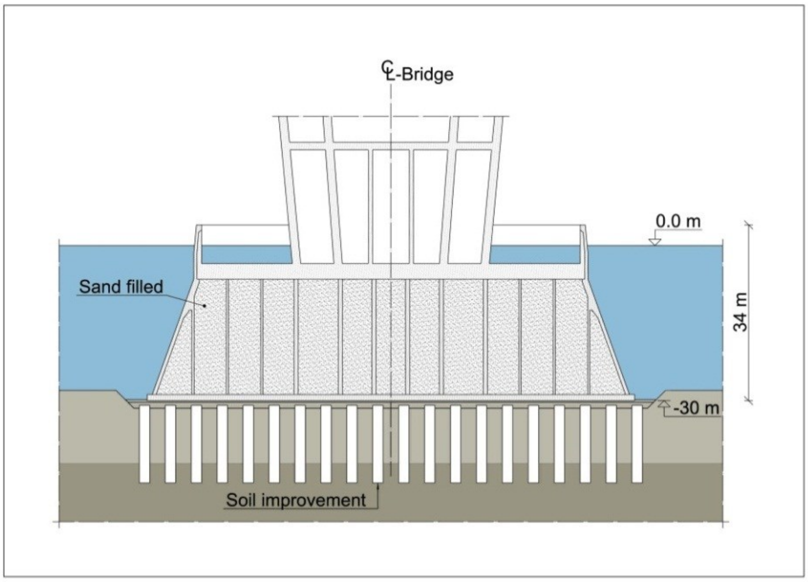
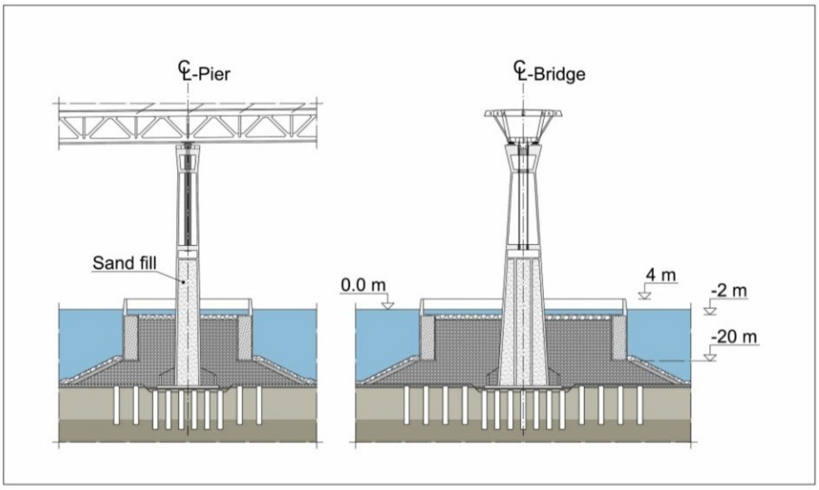


FIGURE 6.10 Conceptual design of a cable-stayed bridge – Schematic diagram of the design of the anchor piers



Technical installations and safety factors

The conceptual design assumes that the entire technical installation will be monitored 24 hours a day via a central control and monitoring centre on Lolland. Monitoring takes place via video monitoring of traffic conditions and active traffic control, as well as the operating status of important technical systems.

The railway deck is fitted with evacuation lighting (for each 25 m, there are arrows pointing towards the closest stairs to road level) and safety lighting on railings. The pylons are illuminated. According to the conceptual design, the lower side of the bridge girders and the pylons, plus the piers around the navigation channels, are illuminated to mark out the navigation opening for ship traffic. There is no general lighting on the road and railway decks.

According to the conceptual design, run-off from the road and railway will be collected and treated in combined oil separators and sand traps before being discharged into the sea.

Communication systems in the form of telephones and radios are installed so that emergency calls for assistance can be made in the event of fire or accidents. The conceptual design assumes that a road traffic management system is installed on the bridge to reduce the risk of accidents on the road and to help limit the extent of any accidents that do occur.

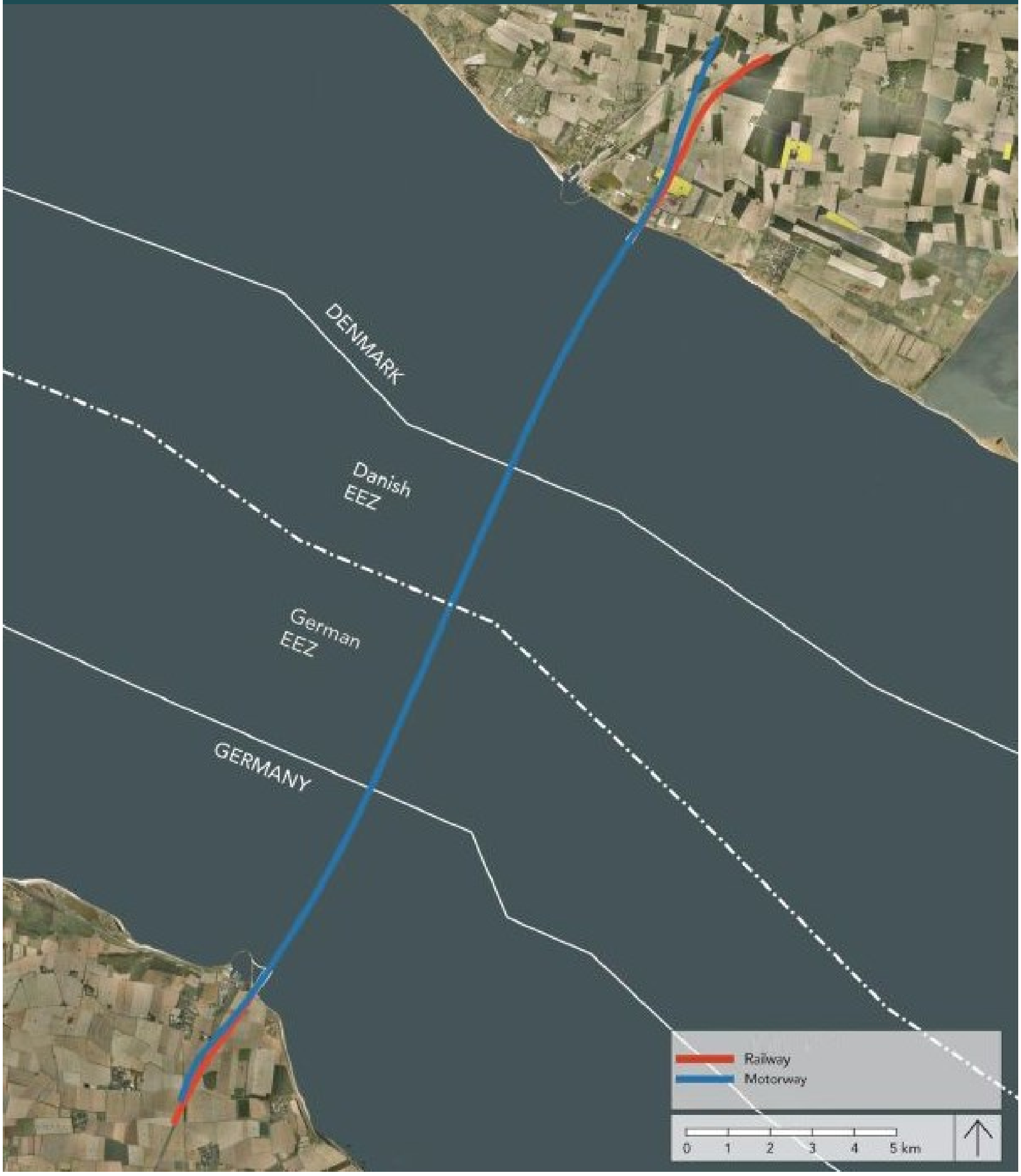
According to the conceptual design there will be stairs and lifts between the railway and the road deck every 400 m on both sides of the railway deck. These may, for example, be used in the evacuation of passengers from trains and for fire and rescue personnel.

According to the conceptual design, the fire service will fight fires on the bridge with trucks with water tanks. Risers between the road and railway deck are installed every 100 m. There will be facilities for filling water tanks at both ends of the bridge and there will be water for fire fighting at the emergency stop locations for trains at both ends of the bridge. There will also be systems for automatic fire fighting in technique rooms, where fire may occur in the electrical equipment.

Alignment

According to the conceptual design, the alignment is immediately east of Puttgarden harbour, crosses the Fehmarnbelt in a gentle S-curve and reaches Lolland approx. 1.5 km east of Rødbyhavn (Figure 6.11). The alignment and the landfall points were determined by a process that included environmental, technical and financial factors as described in Chapter 4.

FIGURE 6.11 **Conceptual design of a cable-stayed bridge – Outline proposal for horizontal alignment**



Note: An exclusive economic zone (EEZ) is the marine area in which a coastal state has a sole right to explore in the sea and on the seabed, to exploit the natural resources in the sea, on the seabed and in the subsoil and to any other economic exploitation. Coastal states are also entitled to enforce their own environmental legislation within the zone. A territorial water line is the limit of outer territorial waters. The coastal state has full jurisdiction between the coast and the territorial water line.

6.2.2 Permanent land works

In addition to the bridge itself, the conceptual design for a cable-stayed bridge also comprises permanent structures onshore on both Lolland and Fehmarn. The permanent structures are reviewed below.

Permanent structures on Lolland

The permanent structures on Lolland (Figure 6.12) comprise:

- Landfall on a new peninsula
- Diversion of or changes to some local roads and bridges
- Control and monitoring centre and toll station with appropriate areas for police and customs authorities
- Motorway approach

FIGURE 6.12 **Conceptual design of a cable-stayed bridge – Outline proposal for alignment for road and railway, Lolland**

New peninsula

According to the conceptual design, landfall is located on a new peninsula with a length of approx. 480 m off the existing coastline (Figure 6.13). At the landfall point, the road deck on the bridge is planned to be approx. 21 m above ground level and approx. 600 m from the existing coastline onshore. It is planned to be level with the existing terrain.

According to the design, the peninsula consists of dredged material from the dredging for the bridge foundations and recovered sand material. The peninsula is designed to be approx. 2 m above mean sea level and is surrounded by a dike with quarried rubble and an outer protection layer of large stones.

FIGURE 6.13 Conceptual design of a cable-stayed bridge – Schematic diagram of the peninsula off Lolland

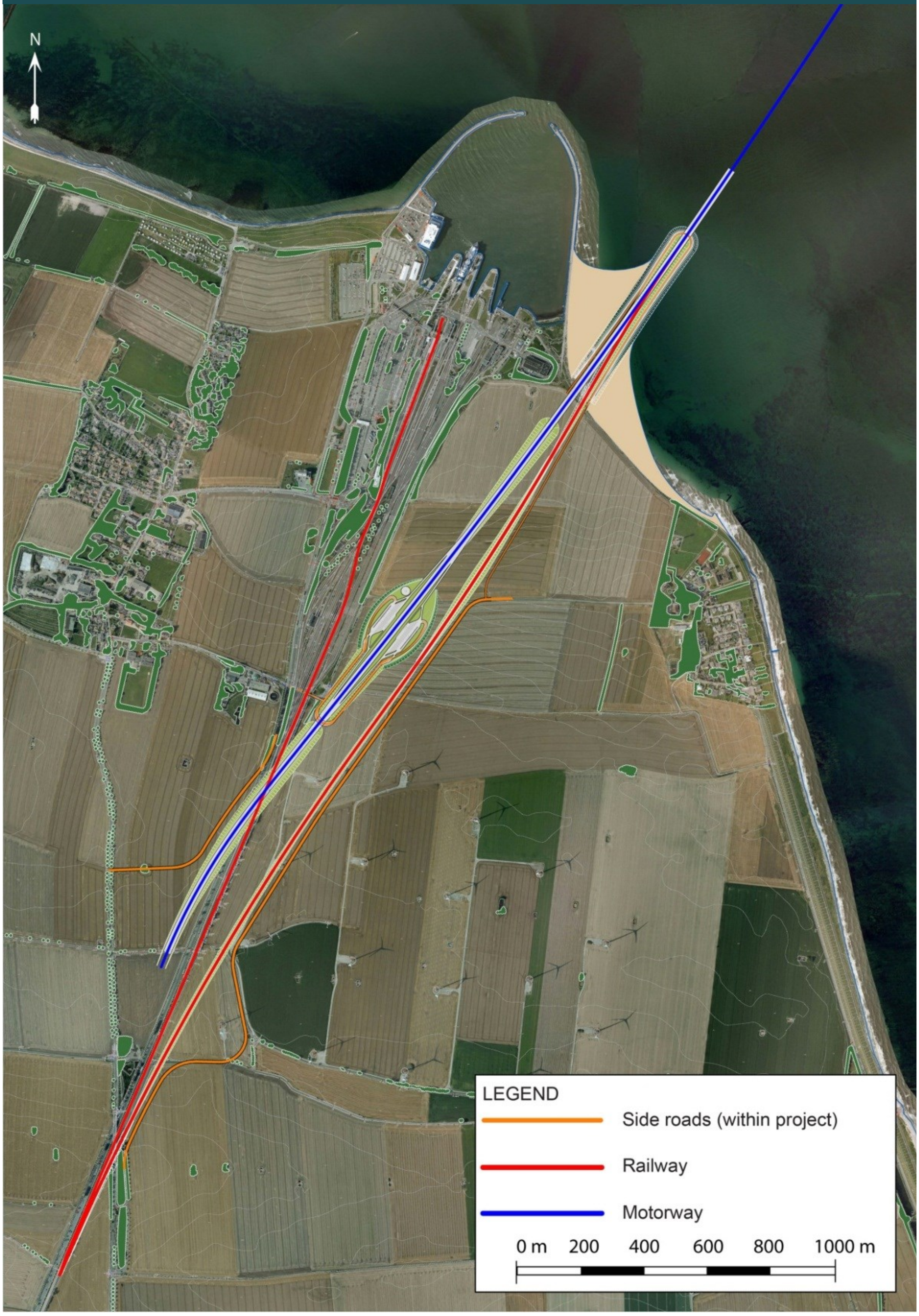
Toll station etc.
According to the conceptual design, the toll station, monitoring centre and secure area for public authorities, including customs and tax authorities and the police, are established on Lolland and can be accessed from the existing road as well as from a new road.

New motorway approach
The conceptual design includes a new motorway approach approx. 1,200 m north of the toll station. It will be possible, via the existing motorway and a new connecting road, to route future traffic to/from Rødbyhavn's ferry port.

Permanent structures on Fehmarn
The permanent structures on Fehmarn (Figure 6.14) comprise:

- Landfall on a new peninsula
- Diversion of or changes to some local roads

FIGURE 6.14 **Conceptual design of a cable-stayed bridge – Outline proposal for alignment for road and railway, Fehmarn**



New peninsula

According to the conceptual design, the bridge's landfall is located on a new peninsula with a length of approx. 580 m off the existing coastline (Figure 6.15). At the landfall point, the road deck on the bridge is planned to be approx. 25 m above ground level and approx. 600 m from the existing coastline onshore. It is planned to be level with the existing terrain.

The peninsula is established with dredged material from the dredging for the bridge foundations and recovered sand material. According to the conceptual design, the peninsula is designed to be approx. 2 m above mean sea level and is surrounded by a dike with quarried rubble and a protection layer of large stones.

The railway runs first on an embankment from the peninsula onto the shore and subsequently in a cutting up to the connection with the existing railway.

FIGURE 6.15 Conceptual design of a cable-stayed bridge – Schematic diagram of the peninsula

Changes to local roads
The conceptual design provides access to Marienleuchte via a new road with a connection to the road to Presen. The road runs east of the railway line and is extended to provide access to the peninsula and the landfall point for maintenance and operation purposes. The underpass to the existing road to Marienleuchte is retained in the design.

Land reclamation on Lolland and Fehmarn
Although the land works in the conceptual design are different on Lolland and Fehmarn, the principle and the construction method are similar, as described below.

According to the conceptual design, the peninsulas are planned to be constructed at an early stage as it will be necessary to have access via the peninsula and the embankment when the landfall point and the superstructure of the approach bridge are to be built. Therefore, a transition structure and viaduct are constructed on the peninsulas.

The conceptual design involves a toll station with facilities for police and customs control being constructed on Lolland, while a control system and a motorway flyover are constructed on Fehmarn.

According to the conceptual design, the new motorway on Lolland crosses the existing single-track railway behind Rødbyhavn at a distance of approx. 3 km behind the coastline. To maintain continued operation of the ferry port during the construction phase, the track will remain in operation until the bridge is opened, and gap of 20 m in the motorway connection therefore cannot be closed until then. According to the conceptual design, on account of the traffic in the construction phase, a level crossing with signal control is planned to be established across the railway. This is planned to be used as a diversion in the first few weeks after the bridge has been opened, when the existing railway line can be closed. At that time, the missing 20 m of motorway is planned to be constructed.

On account of the motorway flyover, a similar procedure is not necessary on Fehmarn.

6.2.3 Construction phase of the cable-stayed bridge

According to the conceptual design, the greater part of the bridge is planned to be prefabricated onshore at large element factories, from where the elements will be taken by sea to the bridge site and installed. Only the three pylons will be cast on site. It will be necessary to establish temporary work harbours on Lolland and Fehmarn.

The construction works on the seabed comprise soil improvement with bored concrete piles, dredging for and installation of rubble around the caissons, injection of mortar beneath the caissons and establishment of erosion protection. Structures for protection against vessel collision also involve construction work at sea in the form of filling with crushed rock beneath and within the caisson.

The dredging work for the caissons is planned to be carried out by dredgers with hydraulic grabs.

According to the conceptual design, the pylon legs are planned to be cast on site. During the construction of the pylons, the caissons function as working platforms and barges is planned to be used as an additional work area for floating concrete mixing plants. The concrete is pumped from the concrete mixing plant to the casting site. The work sites are planned to be supported from temporary work harbours on Lolland and Fehmarn.

The conceptual design includes the establishment of a vessel traffic system (VTS) in the construction phase which will inform vessels about the construction activities that are in progress in the Fehmarnbelt.

It is assumed, according to the conceptual design, that the filler for the embankment on the peninsula and for the road onshore and the railway embankment is primarily supplied to the work harbours in barges and small bulk carriers and transported from there to the work sites with dumpers. The total volume of filler for the embankments is estimated to be approx. 200,000 m^3. Approx. 100 shipments are expected via the harbour if all material is supplied via the harbour. The peak period for shipments via the harbour is estimated to involve eight shipments a month.

Production area on Lolland
Caissons and pier shafts for the approach bridges' substructure, anchor piers and transition piers, and structures for protection against vessel collision for the main bridge are expected to be produced in a new production area east of Rødbyhavn (Figure 6.16).

According to the conceptual design, the production site in Rødbyhavn is combined with the work harbour on Lolland for the construction of the bridge and the land works on Lolland. The plan is for a production area of approx. 370,000 m^2. An area located between the existing ferry port at Rødbyhavn and the alignment is planned to be reserved for the establishment of production and auxiliary facilities for this.

When the construction work in connection with the bridge has been completed, the production site will be shut down, according to the conceptual design.

According to the conceptual design, a work harbour will be established within the production area. The harbour will be dredged to a depth of 6 - 7.5 m. The volume of dredged material at the site is estimated to be 850,000 m^3. It is expected that the dredged material will be incorporated in the peninsula off the coast of Lolland.

Production plant for caissons and pier shafts
The conceptual design's production plant consists of two production lines, one for the production of caissons and one for the production of pier shafts. Each line consists of a number of identical plants operating in parallel. The caisson lines require the establishment of 10 individual casting positions, and the casting of pier shafts requires the establishment of 12 casting positions. Each line is serviced by a workshop for prefabrication of reinforcing cages. The finished caissons and pier shafts are transported by sea to the construction corridor in the Fehmarnbelt.

Both production lines are serviced by two concrete mixing plants. A total of approx. 270,000 m^3 of concrete is expected to be used for caissons, pier shafts, anchor piers, etc., which is planned to be cast over a period of approx. 30 months. According to the conceptual design, the concrete mixing plants also produce ready-mixed concrete for casting joints between caissons and pier shafts, etc. in the bridge line. For this purpose, the concrete is transported in concrete mixing vehicles that are driven on board shuttle ferries and then sailed to the work site.

Loading and unloading facilities
According to the conceptual design, materials are primarily delivered to the production area by vessel and secondarily by truck. In the temporary work harbour, it is assumed that a quay is built for small bulk carriers (DWL ≤ 4,000 t) for unloading cement and aggregate for concrete production. The materials are transported on a belt conveyor to the aggregate store from the quay. Reinforcing steel (approx. 55,000 t) is also expected to be delivered to the production area by vessel. The reinforcement is transported by truck to the reinforcement workshops from the quay. Alternatively, the reinforcement can be delivered by truck via the existing access roads.

The prefabricated elements are transported from the construction site by a floating crane directly to the bridge's alignment for installation. To allow the floating crane to grab the elements, two landing piers are planned to be built, one for caissons and one for pier shafts.

FIGURE 6.16 Conceptual design of a cable-stayed bridge – Schematic design of production area, Rødbyhavn

P Prefabrication of approach bridge substructure
P1 Caisson production line – step 1
P2 Caisson production line – step 2
P3 Load out pier – caissons
P4 Storage formwork / rebar cages
P5 Rebar prefabrication – caissons
P6 Pier shaft production line
P7 Load out pier – pier shaft
P8 Storage formwork / Rebar cages
P9 Rebar prefabrication – pier shafts
P10 Batching plant
P11 Aggregate storage
P12 Load in – aggregates
P13 Load in – material and equipment
P14 General storage
P15 Workshop
P16 Site office
P17 Parking
P18 Idle position

AS Support for the construction of the approach bridge superstructure
AS1 Site office, laboratory and parking
AS2 Ancillary works
AS3 Workshops and storage
AS4 Batching plant, rebar fabrication and storage
AS5 Storage and equipment parking

M Support for the construction of the main bridge
M1 Site offices, laboratory and parking
M2 Workshop and storage
M3 Storage
M4 Rebar fabrication and storage

L Support for the construction of landworks
L1 Site offices, laboratory and parking
L2 Workshop and storage
L3 Rebar fabrication and storage and storage of equipment

C Camp
C1 Parking
C2 Accommodation
C3 Canteen

G General facilities
G1 Passenger terminal

Notes:
1. Area for temporary depositing of dredged material not shown. To be decided after revision of total earth balance.
2. Establishment of final routing of Østersøvej to be done after demolition of affected production site area.
3. Dewatering trench at east side and pumping station remain in operation; they are not affected by the production site.
4. Main elevation:

Top of dyke	+3.60 m
Skidding beam	+3.50 m
Quay area	+2,00 m
General site area	+0,50 m

Traffic in the construction phase on Lolland
Material for e.g. filler for embankments and aggregate, which, according to the conceptual design, is to be used for concrete production, is assumed mainly to be supplied by vessel to the construction site via the temporary work harbour. The volume of heavy traffic on public roads near the construction site is, therefore, expected to be relatively moderate during the construction phase. According to the conceptual design, the number of trucks to and from the construction site is expected to be 10 - 30 a day over four years.

Access to the production area on Lolland is primarily via Østersøvej, and it is expected that the capacity of this road will be increased. Asphalted roads are planned to be built within the production area for internal transportation of materials, equipment and personnel. The roads are generally 15 m wide and built so they can carry heavy goods vehicles. The traffic will primarily consist of cars and coaches, transporting personnel to and from the construction site.

Production area on Fehmarn
For the handling of materials to and from the work site on Fehmarn, the conceptual design provides for the construction of a temporary harbour with appropriate loading and unloading facilities. The work harbour is also used to transport personnel and, to a limited extent, materials for the approach and main bridges.

To reduce the extent of the quay along the coast, the quay is designed at an angle so that part of it is located along the peninsula. The intention is for smaller vessels such as working boats, both for personnel transportation and tug boats, to be moored at a light jetty located perpendicular to the coast along the pier opposite the peninsula. The quays are planned to be built with sheet piles. The jetty for mooring smaller vessels can be built as a pontoon jetty.

The harbour and the access channel are planned to be dredged to a depth of 6 m. The volume of dredged material at the site is estimated to be 260,000 m^3. It is expected that the dredged material can be used as filler in the quays in the piers and in the peninsula on Fehmarn.

Traffic in the construction phase on Fehmarn
The conceptual design indicates that the volume of traffic on public roads near the construction site will be relatively moderate in the construction phase because materials, including filler for embankments and aggregate for concrete, will primarily be delivered to the construction site via the harbour. The traffic will, therefore, be dominated by cars, transporting personnel to and from the construction site.

The number of trucks to and from the construction site is expected to be 10 - 30 a day. This number is expected to be higher if the contractor for the land works prefers to have some of the filler for the embankments delivered to the construction site in trucks from a gravel pit in the local area.

When the construction work in connection with the bridge has been completed, the temporary structures are planned to be removed.

6.2.4 Production plant

According to the conceptual design, the superstructure of the cable-stayed bridge and approach bridges is assumed to be produced in existing shipyards or equivalent, for example Lindø Industripark A/S / Odense Havn, and the caissons for the three pylons are assumed to be prefabricated in existing dry docks. The floating concrete mixing plants to be used at a later time for the construction of the pylons in the Fehmarnbelt are also used to produce concrete for the caissons in dry dock plants.

It is assumed in the design that the production of the steel structures for the main bridge will be able to take place at Lindø Industripark A/S / Odense Havn, and that the steel plates are produced by a European steelworks and delivered to the construction site by boat. Reinforcing steel, cement and aggregate for concrete are assumed to be delivered to the construction site by boat.

The finished bridge girders for the approach bridge are transported by barge to the bridge line in the Fehmarnbelt.

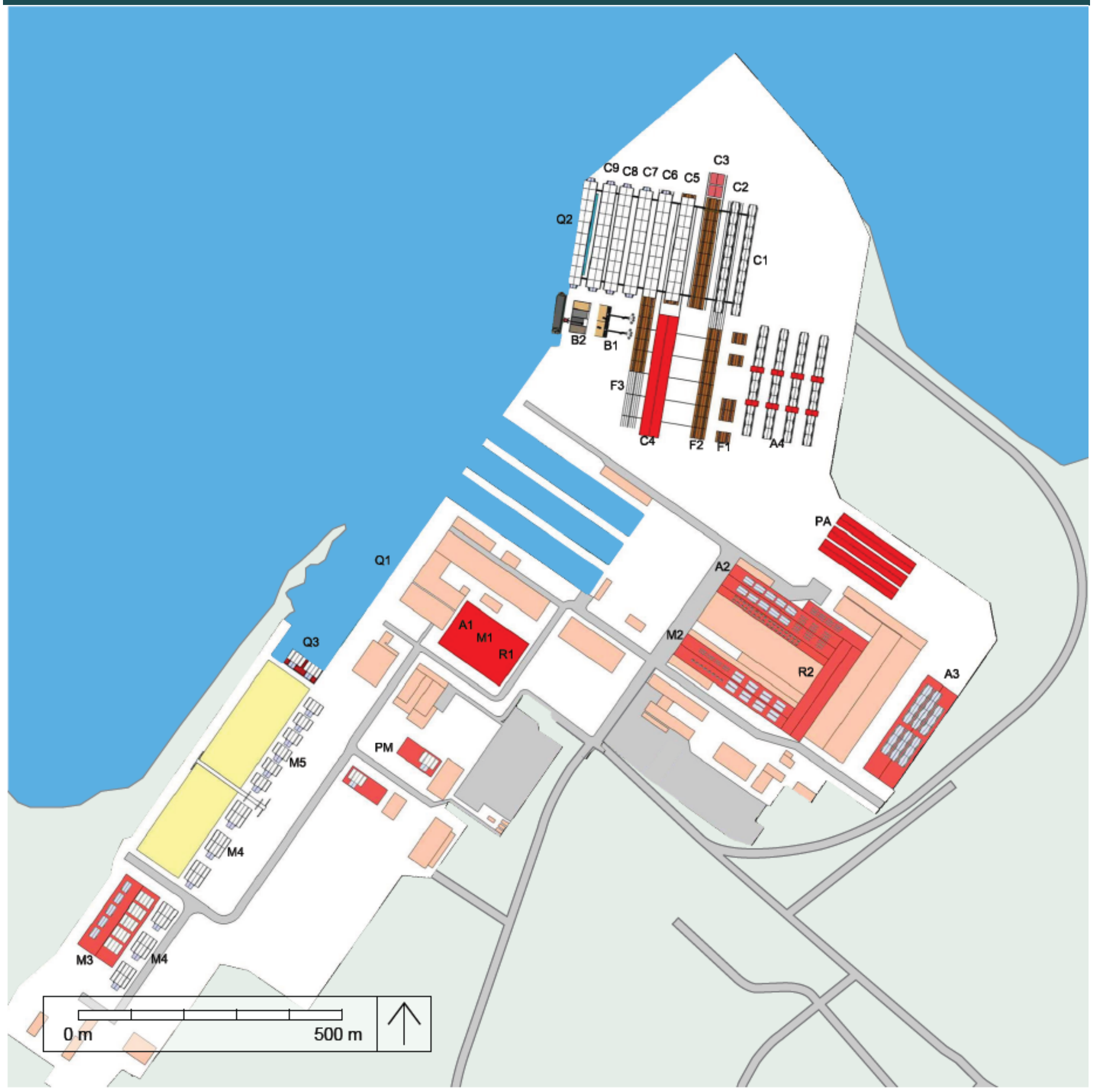
It is assumed in the design that the existing external infrastructure at the production plant, including supply of electricity and water and sewage treatment, is adequate.

Traffic in the construction phase at Lindø Industripark A/S / Odense Havn

According to the conceptual design, the internal roads at the construction site are adequate for most transport activities on the site. However, the area at Odense Havn must be prepared for the production of bridge girders for the approach bridges and there will be a need for internal roads to transport bridge girders and bridge girder segments with self-propelled multi-axle trucks (Figure 6.17).

It is expected that the external infrastructure is adequate for the production of the structures for the bridge. An increase in heavy traffic on the public roads is not expected during the construction phase, because nearly all materials to be used, including steel plates, concrete aggregate, reinforcing steel, etc., are delivered to the construction site by boat.

FIGURE 6.17 Conceptual design of a cable-stayed bridge – Schematic diagram of production area, Lindø Industripark A/S / Odense Havn



A Approach bridge steel assembly lines
A1 Storage area for steel elements after load-in
A2 Steel assembly positions
A3 60 m and 80 m assembly positions
A4 200 m assembly positions and painting of joints

M Main bridge steel assembly lines
M1 Storage area for steel elements after load-in
M2 Steel assembly positions
M3 Steel box assembly positions
M4 20 m assembly positions
M5 Storage area for completed 20 m elements

PA Paintshops for approach bridge
PM Paintshops for main bridge

R Reinforcement cage prefabrication line
R1 Storage area for rebar
R2 Prefab and storage area for rebar cages

C Concreting line
C1 Storage position for stel girder
C2 Installation of inner and outer formwork
C3 Installation of rebar cages
C4 Movable protection cover for the casting position
C5 Casting of the deck
C6 Prestressing and removal of formwork
C7 Finishing and preparation for shipment
C8 Storage until sufficient strength is reached
C9 Storage until sufficient strength is reached

Q Load-in / out quays
Q1 Load-in quay
Q2 Load-out quay approach bridge girders
Q3 Load-out of main bridge girder segments

F Formwork line
F1 Storage positions for formwork elemenets
F2 Formwork cleaning and preparation
F3 Formwork striking and removal

B Concrete batching plant
B1 Batching plants
B2 Storage area for concrete raw materials

6.2.5 Resource and personnel requirements

Table 6.3 shows the conceptual design's estimate of the most important material resources required for the construction of a permanent cable-stayed bridge across the Fehmarnbelt.

TABEL 6.3 Conceptual design of a cable-stayed bridge – Estimated resource requirements

Material	Quantity
Structural steel	283,000 t
Painted area on steel structure	1,133,000 m^2
Stay cables	6,100 t
Prestressed reinforcement	5,100 t
Reinforcing steel	158,000 t
Concrete piles for soil improvement	110,000 t
Structural concrete	790,000 m^3
Dredging work and filling	1,400,000 m^3
Sand filler for caissons and filling around caissons	305,000 t
Crushed rock for caissons and filling around caissons	444,000 t
Erosion protection stones	257,000 t
Large stones for dikes	125,000 t
Filler for peninsulas and embankments	829,500 m^3

Direct and indirect employment in the construction phase is estimated to create workplaces corresponding to approx. 32,000,000 man-hours overall.

Time schedule for construction work
According to the conceptual design, the construction period for a cable-stayed bridge across the Fehmarnbelt is assessed to be approx. six years.

Please refer to a more detailed description of the cable-stayed bridge in the background report "Consolidated Technical Report, 2011", which is published at www.femern.com.

6.3 SUSPENSION BRIDGE

In this section the conceptual design of the suspension bridge is described briefly, focusing on the features that set the suspension bridge apart from the cable-stayed bridge.

6.3.1 Bridge design

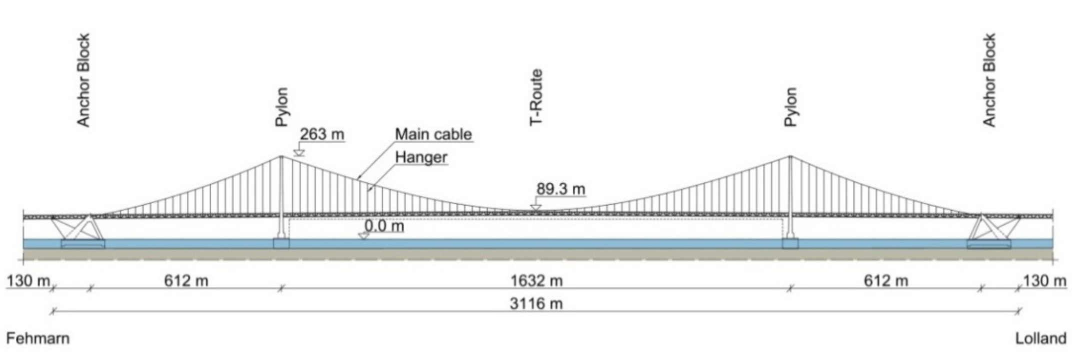
According to the conceptual design, the suspension bridge consists of the following features: a main bridge with five spans and a total length of 3,116 m and two approach bridges connecting the main bridge with the coasts, with lengths of 5,388 m on the Fehmarn side and 9,072 m on the Lolland side. Approach bridge spans are usually 200 m. The suspension bridge has a main navigation span of a length of 1,632 m and minimum clearance from the sea surface of 66.2 m. The conceptual design includes two reclaimed peninsulas at the Fehmarn and Lolland coasts out to water depths of 5 - 6 m. These connect the approach bridges to the coasts and land works connecting the road and railway with the existing infrastructure.

The total bridge length is approx. 18 km between the abutments of the approach bridges with a total of 71 piers, plus two pylons and two anchor blocks for the main bridge. The pylon height is 263 m.

The main bridge
The main bridge is a suspension bridge with two pylons and a main span of 1,632 m (Figure 6.18). The pylons and anchor blocks are designed for the structural loads and ship impact forces

as well as for aesthetic aspects. The anchor block supports the superstructure at two points 130 m apart, in order to achieve a rigid end span up to the expansion joint.

FIGURE 6.18 Conceptual design of a suspension bridge – Illustration of main bridge elevation



Superstructure

The superstructure of the suspension bridge consists of a double deck girder with the dual carriageway road traffic running on the upper deck and the dual track railway traffic running on the lower deck. The upper roadway deck is constructed as a closed steel box with the hangers anchored at the edge. A truss structure under the road deck carries the dual track railway. Emergency walkways are placed inside the trusses along with cable trays for various services including electricity, communication etc.

FIGURE 6.19 Conceptual design of a suspension bridge – Illustration of a pylon

Pylon design

The pylons reach a height of 263 m above sea level. The pylon has polygonal tapering legs connected by only one cross beam placed at the top of the pylon (Figure 6.19). At the base, a cross beam of similar height is provided to match the upper cross beam. It also protects against ship impact and distributes the concentrated load from the pylon legs more evenly to the caisson.

At the bottom, the legs have a trapezoidal cross section, which gradually transforms to a quadratic cross section at the top, solely by using plane surfaces. The pylon legs have rounded corners to reduce wind load. Structurally, the upper cross beam needs to be of a considerable height in order to provide adequate stiffness against wind load perpendicular to the bridge.

The pylon legs are buried into the seabed by means of caissons that work as the pylon foundation.

Anchor blocks
The upper part of the anchor blocks features a large frame structure comprising the splay chambers, the legs supporting the splay saddles and a cross beam at the top connecting these elements and supporting the bridge girder. In addition to this frame, a huge ballast chamber is provided leaning backwards to support the girder as well (Figure 6.20). This design provides an excellent opportunity to balance the entire anchor block by placing a heavy ballast fill in the backward-leaning chamber to counteract the large overturning moment from the main cables. The top of the anchor block is visible above the water line.

The rectangular caisson for the anchor block has adequate capacity to transfer the large horizontal forces from the main cables to the ground, but no spare capacity to take up ship impact loads. Surrounding the anchor blocks, a circular ring structure was developed. This ring structure protects the main bridge and can be repaired without restrictions to the traffic on the bridge.

FIGURE 6.20 **Conceptual design of a suspension bridge – Illustration of an anchor block**

Approach bridges
The design of the main bridge is connected to the coasts by two approach bridges. The southern approach bridge is 5,388 m long and consists of 27 spans and 26 piers. The northern approach bridge is 9,072 m long and has 46 spans and 45 piers.

6.3.2 Construction phase of the suspension bridge

Pylon caissons and bases
The pylon caissons comprise the prefabricated caissons and a solid 3 m thick plinth cast in-situ at the top of the prefabricated caisson. The pylon bases comprise the cellular structures from the plinth where the pylon starts and will also be cast in-situ. It is anticipated that the bottom parts of the two pylon caissons are planned to be prefabricated in an existing dry dock at Lindø Industripark A/S. After completion of the bottom part of the caissons, the dry dock is flooded and the partly completed caissons are towed to an intermediate site where the caissons can be finished to their full height of 34 m in floating condition.

The intermediate construction site should be at a location close to the shore with a minimum water depth of 15 m. The site could be located near Puttgarden harbour east of the bridge alignment and the construction activities could be supported by the temporary construction harbour on Fehmarn or Lolland.

After completion of the outer walls, the caissons are towed to the final location at the bridge site and lowered by controlled water ballasting to rest on three pre-installed landing pads, followed by under-base grouting of the void between the caisson bottom slab and the excavated soil profile.

The plinth on top of the caisson is cast in-situ and is followed by the pylon base. Concrete batching plants and other site facilities are planned to be provided on barges moored to the caissons, and support to the offshore sites are planned to be provided from the temporary work harbour on Lolland or Fehmarn.

Pylon construction
The pylon legs are assumed to be cast in-situ using jump forms with a lift height of approx. 4 m. All pylon legs are constructed in parallel. During the construction of the pylons, the caissons are used as working platforms; and barges are used for providing additional work space and storage area as well as for the floating concrete batching plants. The concrete is pumped from the batching plants to the casting level. Support to the sites is provided from the temporary construction harbour on Lolland or Fehmarn.

Anchor blocks construction
The caissons for the two anchor blocks are constructed in the same dry dock as the pylon caissons after these have been completed. The construction time for the anchor blocks is shorter than for the pylons. Towing out, completion of the caissons at an intermediate site, placing and in situ casting of the top part are performed in a similar way as for the pylon caissons.

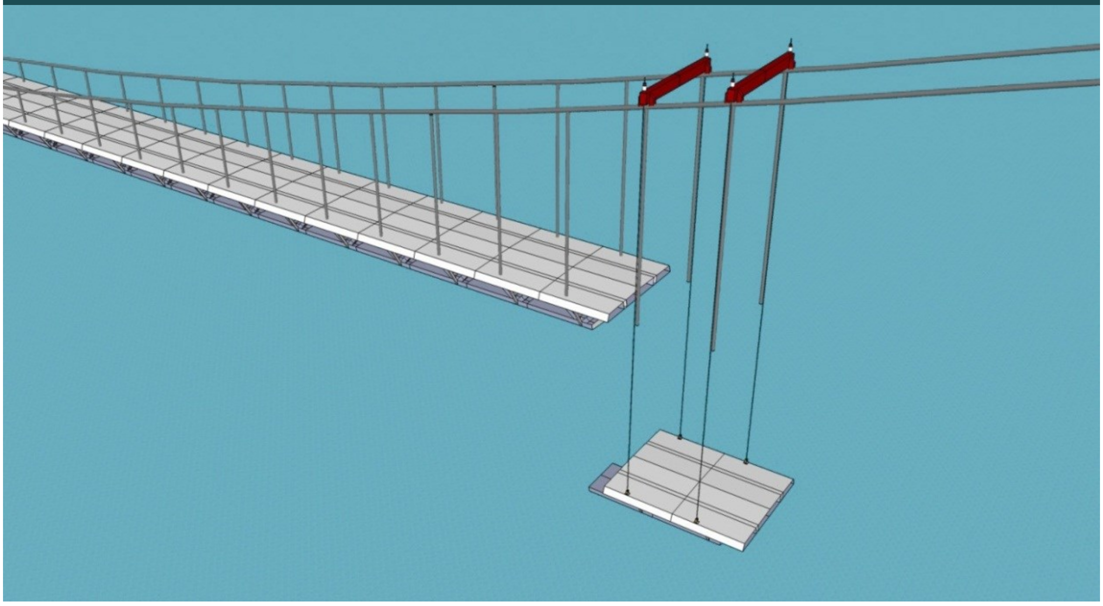
Ship collision protection rings
Ship collision protection structures are provided around the anchor blocks and the first approach span piers. The protection rings for the anchor blocks are constructed in eight segments in order to keep the weight of each segment below 3,500 t. Otherwise, the construction is similar to the one used for the cable stayed bridge.

Erection of cables
Once the pylons and anchor blocks are completed, the main cables are erected, using one of two methods:

- Preformed parallel wire strands (PPWS), where each strand comprises 127 No. 5.3 mm diameter wires, or
- Aerial spinning (AS), where individual 5 mm wires are assembled on site by pulling from one anchor block to the other over the pylon saddles.

The preformed parallel wire strands method is preferred in Japan, whereas aerial spinning is most commonly used in Europe and America. Aerial spinning was used for the Storebælt's East Bridge and is the presupposed method for this project.

FIGURE 6.21 **Conceptual design of a suspension bridge – Illustration of erection of a 40 m girder section**



Construction of main bridge superstructure

Girder prefabrication

The main bridge girders are made up of 40 m long sections with a weight of 1,000 to 1,200 t. It is expected that the fabrication of the steel structures for the main bridge will take place at Lindø/Odense harbour.

Transport and load out of the completed girder sections is performed with hydraulic trailers. The girder sections are loaded onto a barge for transport to the bridge site. It is expected that two 20 m sections are planned to be delivered to the site for each voyage of the barge.

Erection of girders

The bridge girder is erected beginning at the centre of the main span. The 20 m long girder segments are hoisted from a barge to the bridge deck level with temporary hangers from the main cable (Figure 6.21). At the pylons and at the anchor blocks, bridge girder segments are erected with a floating sheer leg crane.

After mounting of the bridge girders the joints of the road deck, the railway deck and the diagonals are planned to be welded together. There will be platforms for the welding to secure access to all joints. The permanent vertical hangers are then erected and finishing works on the bridge deck will be performed including:

- Paint repair at the joints
- Application of the final coat of paint
- Installation of safety barriers, wind screens and guard rails
- Surfacing
- Installation of M&E equipment

Personnel

The total number of working hours needed to construct a suspension bridge across the Fehmarnbelt is estimated at 35,000,000 man-hours.

Time Schedule for the Construction

The estimated time schedule for the construction of the suspension bridge is 6.5 years from contract formation with selected contractors to the opening of the bridge.

Please refer to a more detailed description of the suspension bridge in the background report "Consolidated Technical Report, 2011" (Femern A/S, 2011) which is published at www.femern.com.

6.4 SELECTION OF BRIDGE ALTERNATIVE

The cable stayed bridge and the suspension bridge were compared on the following factors at an early stage: 1) environment, 2) navigational safety, 3) technical risks, 4) time schedule and 5) finances. On the basis of the comparison the suspension bridge was rejected. The arguments for rejecting the suspension bridge are summed up below.

6.4.1 Environment

The environmental assessment of the conceptual design for a suspension bridge is based on a comparison with the provisional assessment of the conceptual design for a cable-stayed bridge prior to Femern A/S' recommendation of November 2010 to have the immersed tunnel included in the continued work as the preferred solution.

The environmental assessment shows that the impacts of a suspension bridge are equivalent to the environmental impacts of a cable-stayed bridge. The primary impacts of a bridge as a fixed link across the Fehmarnbelt are related to water flow (hydrography) and the fact that there is uncertainty about whether a bridge solution impedes free bird migration in the area.

It is assessed that the large anchor blocks of the suspension bridge and rings around the anchor blocks that protect against vessel traffic will entail larger permanent impacts on water flow (hydrography) compared with the impacts of a cable-stayed bridge.

Navigational safety

Due to the large spans of the main bridge, a suspension bridge is planned to be less of an impediment to navigational safety than a cable-stayed bridge. However, the difference between the two bridge solutions in terms of navigational safety is minimal.

Technical risks

A major reason for rejecting the suspension bridge is that a deflection (movement) of up to 4 - 5 m occurs on the bridge when two goods trains pass each other. The deflection will be a major impediment to the other traffic on the bridge. Such deflection does not occur on a cable-stayed bridge.

Moreover, it is difficult to construct the large anchor blocks of the suspension bridge at a water depth of approx. 30 m and with relatively poor soil conditions.

Finances

The costs of constructing a suspension bridge are considerably higher than for a cable-stayed bridge with a price difference of approx. 10 %. In addition, there is a risk of unforeseen costs due to the challenging construction of the suspension bridge anchor blocks.

Comparable construction estimates and profitability calculations were not prepared for the suspension bridge as it was established early in the process that the costs of the suspension bridge would be significantly higher than for the cable stayed bridge.

Time schedule

The construction period for a suspension bridge is estimated at 6.5 years, which is six months longer than the construction period for a cable-stayed bridge.

Summary
Based on the above comparison of the suspension bridge and the cable-stayed bridge Femern A/S finds a cable-stayed bridge to be a better and cheaper technical solution for a bridge forming a fixed link across the Fehmarnbelt. The cable-stayed bridge is therefore the preferred bridge alternative.

As will be described in section 6.6, the bridge alternative was subsequently rejected and the immersed tunnel selected as the preferred technical solution.

6.5 BORED TUNNEL

In this chapter the conceptual design of the bored tunnel solution is described briefly, focusing on the features that set the bored tunnel apart from the immersed tunnel (Chapter 5).

6.5.1 Tunnel design

The conceptual design of a bored tunnel consists of three circular tunnels: one tunnel with space for two railway links and two tunnels that each accommodates a one-way motorway link with emergency lanes in each direction. The railway tunnel has a total length of 21.2 km while the road tunnels have a length of 19.6 km.

On Fehmarn the physical interface of the motorway with the existing roads on land is identical to that of the immersed tunnel project, while the railway interface with the existing railway is 2 km further inland on Fehmarn in relation to the immersed tunnel project. On Lolland the physical interface with the existing motorway is approx. 250 m further inland, and the interface with the existing railway is approx. 700 m further inland in relation to the immersed tunnel project. This is because the portals are deeper for the bored tunnel than for the immersed tunnel and because they are located further inland.

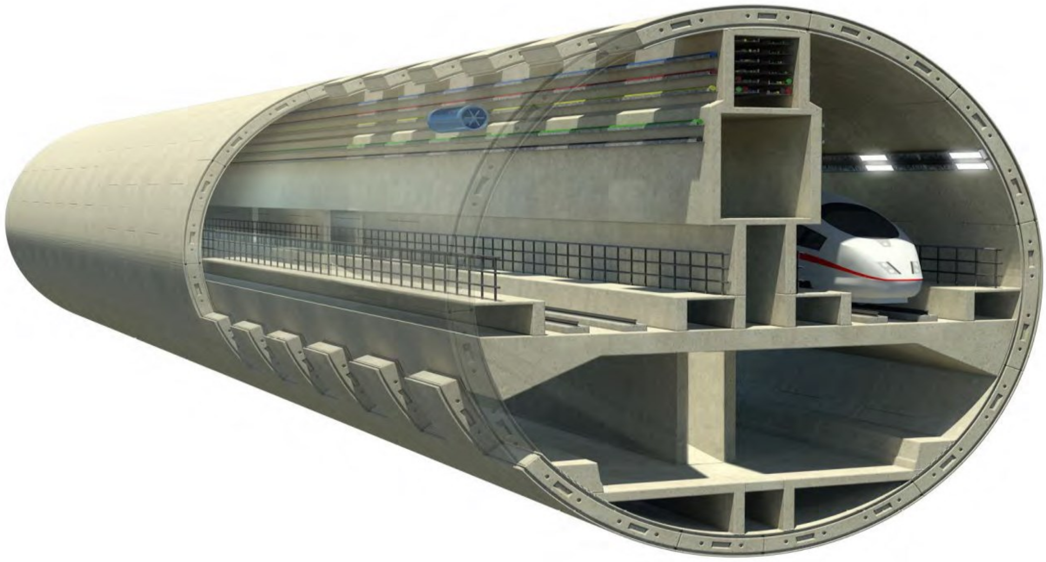
In the conceptual design the road tunnels are placed west of the railway tunnel. The railway tunnel has an internal diameter of 15.2 m while the road tunnels have an internal diameter of 14.2 m.

Each road tube contains two traffic lanes, an emergency lane with edge lines and a step barrier at its walls. At the top of the circular cross-sections, jet fans and signage are installed (Figure 6.22). The road tubes also contain an approx. 2 m wide fireproof side gallery with access from the emergency lane. There will be access via fireproof doors at approx. every 100 m. The gallery also provides access to the levels below the road deck (on the lower floor) via stairs or ramps. The deck below the road contains a cable duct, plant room, rescue and service facilities, and a lane for emergency vehicles.

FIGURE 6.22 Conceptual design of a bored tunnel – Illustration of cross-section of the two motorway tubes

According to the conceptual design the railway tunnel is divided in the middle by a fireproof central gallery and is thus divided into two fire-separated tubes, each with a width of approx. 6 m (Figure 6.23). The rail tracks are installed directly on the concrete deck. Emergency walkways are established on both sides of each track and fans are installed at the top of each tube. The dimensions of the railway tubes allow trains to pass at speeds of up to 200 km/h.

FIGURE 6.23 Conceptual design of a bored tunnel – Illustration of cross-section of the railway with two separate tubes



The conceptual design includes portal buildings for each railway tunnel containing technical equipment used in connection with day-to-day operations. The portal buildings on Lolland are placed on top of the cut-and-cover part of the tunnels, while the portal buildings on Fehmarn are placed underground so that the buildings are not visible in the open landscape.

In the road portals, stairs, and cable shafts can be integrated between the traffic lanes, while the rail portals will contain any shafts and stairs on the outside of the rail profile. The main sumps for drainage water from the tunnels are established below the portal buildings.

To counteract buoyancy and guarantee a stable boring front, the depth of the bored tunnel must be sufficient to leave soil cover over the tunnel that is at least equal to the diameter of the tunnel tube. As a consequence, the tunnel ramps and portals are located relatively deep and they must, therefore, be located further inland than for the immersed tunnel, where these buildings can be constructed within the newly advanced land reclamation areas.

6.5.2 Construction phase of the bored tunnel

Boring method

According to the conceptual design the tunnels are bored and lined with concrete rings by six tunnel boring machines (TBMs), each of which must carry out the almost 10 km of boring from land to the connection point below the Fehmarnbelt. A TBM is a mobile factory designed in such a way as to be capable of handling the various soil conditions below the Fehmarnbelt.

The boring operation takes place under the seabed ahead of the TBM being loosened using a number of cutting discs and teeth fitted in the rotating cutter at the front end of the TBM. The cutter rotates slowly (typically 3 - 5 RPM) while being pressed forward. The bored seabed material is then transported into a collection chamber via holes in the cutter. The cutter is enclosed in a steel shield which protects against the seabed material until the permanent concrete lining (concrete rings) can be installed. The cutter is specially manufactured so that it matches the specific soil conditions and the size and length of the bored tunnel.

According to the conceptual design for the bored tunnel, all six boring machines are expected to be slurry shield TBMs. Such boring machines operate using a special mixture of slurry containing bentonite, which stabilises the boring front (the seabed material) in front of the cutter and is mixed with the bored materials so that they can be pumped through a pipeline to the respective separation plants on land.

A special version of a slurry-shield tunnel boring machine is a mix-shield tunnel boring machine, which is a tunnel boring machine with a double-chamber system that can precisely control the surface pressure by means of a combination of slurry and compressed air. For this type of tunnel boring machine, it is possible to create access to the cutter for maintenance under atmospheric conditions without the risk of the boring machine and its back-up system being flooded in the event of high water pressure on the boring front.

Access to the working chamber can be via air locks in the front bulkhead of the tunnel boring machine. The air locks allow tunnel personnel without specialist training to operate under pressures of up to 3.6 bar. At a surface pressure of over 3.6 bar, specialist divers are required to enter the working chamber. In the conceptual design for a bored tunnel, it is estimated that up to 70 % of the repairs will take place at pressures of over 3.6 bar.

Production of tunnel boring machines

The TBMs are produced outside the production area by a specialist manufacturer. The purchase of TBMs including contract negotiations, design, production, delivery and installation on site is a demanding activity, and the production of the six TBMs is estimated to take approx. 12 months. It is important for the time schedule that the portal buildings are ready when the TBMs are delivered and installed.

Separation plant and storage area for bored materials

The conceptual design for a bored tunnel contains a total volume of bored seabed material of approx. 19.2 million m³ (incl. a bulking factor of 1.3), which is brought ashore and equally distributed between Lolland and Fehmarn. It is difficult to predict in what form and quantity the excavated clay appears at the entrance of the separation plant. In the worst case scenario, a large proportion of the clay will have been dissolved in the slurry, which means that even a large separation plant will have trouble separating the clay from the slurry in order to reuse it for land reclamation.

The potential for reuse of the various quantities of the bored solid material will depend largely on the water content, and the resulting quality of the material. The conceptual design assumes that all material from the separation plants can be used to some extent for land reclamation.

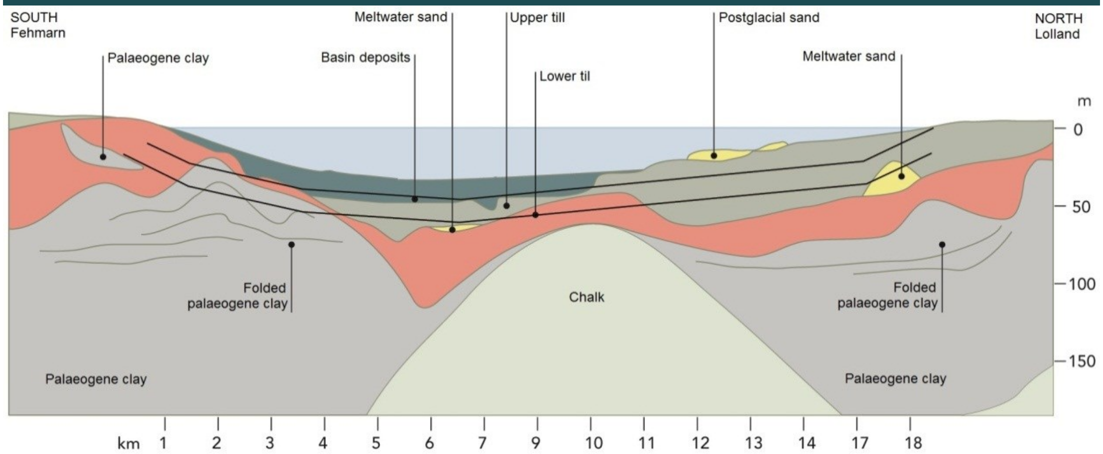
The geological conditions in the Fehmarnbelt

The construction risks associated with a bored tunnel under the Fehmarnbelt are closely linked to the geology. As a consequence of the Ice Age, the soil conditions are non-homogeneous in the area.

Both the German and Danish sides of the Fehmarnbelt have gently sloping near-shore areas. On the Danish side, the gradients are 0.33 % and on the German side they are slightly steeper at 0.66 %. Towards the centre of the Fehmarnbelt, these gradients gradually diminish and end at the deepest level of around 29 m.

The soils to be bored through along the alignment comprise both an Upper and a Lower Quaternary unit consisting of glacial deposits (clay-till and sand-till), followed by a geologically older Palaeogene unit consisting of highly plastic to extremely plastic clay. The German side is dominated by Palaeogene clay and some clay-till, while the centre and the Danish side are dominated by thick deposits of clay-till (Figure 6.24).

FIGURE 6.24 Conceptual design of a bored tunnel – Schematic diagram of the geological longitudinal profile



Temporary production areas on Lolland and Fehmarn

The temporary production areas required for the construction of the tunnels and portal buildings constitute the largest construction areas of the project, in addition to the new land areas, and they are established on both Lolland and Fehmarn. Illustrations of both production areas can be seen below (Figure 6.25 and Figure 6.26).

The production areas on both Lolland and Fehmarn include:

- Factory for pre-cast tunnel segments
- Storage area for pre-cast segments
- Separation plant for handling the bored soil material with associated storage area
- Plant for production of slurry for the individual boring machines
- Office and workshop facilities

FIGURE 6.25 **Conceptual design of bored tunnel – Illustration of the production area on Lolland**

FIGURE 6.26 **Conceptual design of bored tunnel – Illustration of the production area on Fehmarn**

In the conceptual design, a total of 330,000 segments are produced for the concrete lining over a period of approx. 3.5 years, which will require high-capacity concrete casting facilities with appropriate areas for hardening and storage. Elements are also produced for the road and railway decks and partition walls. It is proposed that both the segment and element production sites are located close to the individual tunnel portals. The storage area must have a firm base and it will also be necessary to establish a temporary surface on existing and new roads to allow working vehicles to drive on them.

The total area of each separation plant is estimated at 3.6 ha including space for temporary storage of the filtered materials. An area of approx. 1.5 ha (100 m x 150 m) is planned to be needed for the actual installation of the parts of the separation plant, while the need for extra space for temporary storage depends on the adjoining logistics chain for further transport with lorries, train and/or barges. The storage space should be able to hold excavation materials from approx. 5 days' production, which amounts to approx. 44,000 t or 22,000 m^3.

According to the conceptual design the tunnel portals are built at the same time as the production and delivery of the TBMs. This requirement drives the entire construction programme for both the portal and ramp structures on Lolland and Fehmarn.

Resource and personnel requirements

Construction of a bored tunnel requires large amounts of concrete, reinforcement, and other resources as listed in Table 6.4. Furthermore a large amount of seabed sediment is planned to be dredged from the tunnel trench and work harbours, and there will be a requirement for delivery of freshwater and electricity etc. in the construction phase.

It is estimated that the total man-hours needed for the construction of a bored tunnel under Fehmarnbelt is approx. 30,000,000 hours.

TABEL 6.4 Conceptual design of a bored tunnel – Overview of resource requirements and soil balance

Resource	Quantity
Concrete in tunnel elements	1,842,000 m^3
Reinforcement	448,000 t
Ballast concrete/internal concrete; total	1,280,000 m^3
Structural concrete, portal and ramps & cut-and-cover	274,000 m^3
Freshwater supply	612,000 m^3
Electricity	1,230 GWh
Soil balance	
Total dredged volume – on site (excl. bulking factor)	14,800,000 m^3 *
Total land reclamation area	3,300,000 m^2

Note: * Bored materials and work harbours

Time schedule for construction work

The conceptual design for a bored tunnel contains a time schedule for the completion of the project within approx. 8 years from the signing of the first construction contract. The project's complexity, the long tunnel boring process and the large diameter of the tunnels give the bored tunnel project a special risk profile that may have a serious impact on the time schedule. The critical part of the time schedule is linked in particular to the purchase of the six tunnel boring machines, the start of the boring process and the installation of the permanent equipment.

For more information on bored tunnel as a technical solution please see the background report "Consolidated Technical Report, 2011" (Femern A/S, 2011) which is published at www.femern.com.

6.6 SELECTION OF TUNNEL ALTERNATIVE

The bored tunnel has been compared with the immersed tunnel according to the following factors: 1) environment, 2) navigational safety, 3) safety and emergency response, 4) technical risks, 5) time schedule and 6) finances. On the basis of the comparison of advantages and disadvantages of the two alternatives, the bored tunnel was rejected. The arguments for rejecting the bored tunnel are summed up below.

6.6.1 Environment

An environmental assessment of the conceptual design for a bored tunnel solution has been prepared. The environmental assessment indicates that, in some areas, the bored tunnel is assessed as having larger environmental impact than the immersed tunnel solution, while in other areas it is assessed as having less environmental impact than the immersed tunnel solution.

The bored tunnel is assessed as being an environmentally poorer solution than an immersed tunnel in the following ways:

- Owing to the production period being 18 months longer, the bored tunnel solution will cause more severe temporary adverse environmental impacts than an immersed tunnel solution.
- The bored tunnel solution will require far higher energy consumption than the immersed tunnel solution, and consequently additional greenhouse gas emissions of 0.7 million t CO_2, equivalent to an increase of 39%.
- As a result of the need for significantly larger production facilities on Fehmarn than with an immersed tunnel, the bored tunnel solution will give rise to more severe temporary adverse environmental impacts on Fehmarn than an immersed tunnel solution.

The bored tunnel is assessed as being an environmentally better solution than an immersed tunnel in the following ways:

- Owing to reduced sediment spillage, the bored tunnel solution will have an impact on marine environmental conditions to either the same or a lesser extent than the immersed tunnel solution.
- The bored tunnel solution requires a smaller site for construction activities and production facilities on Lolland than an immersed tunnel solution and consequently its impacts on the area are less severe.
- The bored tunnel does not affect the German Natura 2000 site located in the middle of the Fehmarnbelt (DE 1332-301).

There is some uncertainty associated with the assessment of the bored tunnel. The uncertainty may primarily be attributed to the technical challenges dealing with ensuring that the bored material can be used within a short timeframe. The material is planned to be used for land reclamation on Lolland, where nature with the intended quality will develop as compensation for the affected nature elsewhere in the project area.

It is assessed that the bored tunnel solution will have a slight advantage compared to the immersed tunnel, because it avoids direct impact on the German Natura 2000 area in the middle of the Fehmarnbelt and because it has less sediment spillage, despite a longer construction phase, a higher emission of greenhouse gasses (CO_2) in the construction phase, a larger impact on Fehmarn and an uncertain time horizon for the use of the bores material, with a focus on the marine area.

6.6.2 Navigational safety

During the operation phase neither a bored tunnel solution nor the immersed tunnel will affect the ship traffic in the Fehmarnbelt.

During the construction phase, both tunnel solutions will affect ship traffic in the Fehmarnbelt in connection with the boring and dredging work, during which ship traffic would have to pay attention to the transportation of bored/dredged material. Most of the bored/dredged material is planned to be transported to the Danish coast by barges to be used for land reclamation on Lolland.

In addition to the transportation of dredged material, the immersed tunnel will also affect the ship traffic in connection with the boring and dredging work, the immersion of tunnel elements and the backfilling around the tunnel elements, which will all take place from the surface of the sea. However, measures shall be taken to reduce the impact, such as the establishment of a vessel traffic system (VTS), which will inform ship traffic about the construction activities that are in progress in the Fehmarnbelt.

Overall, a bored tunnel involves fewer marine activities than an immersed tunnel.

6.6.3 Safety and emergency response

The bored tunnel solution has been designed to meet the same safety level as the immersed tunnel. In the bored tunnel solution, escape routes and emergency routes are located under the road and rail deck. This means that car and train passengers shall be able to escape to a safe rescue area under the road and rail deck via stairs or ramps. Similarly, fire and emergency vehicles have access to the accident area via the deck under the road and rail deck and access to the actual scene of an accident via stairs and ramps.

In contrast to the immersed tunnel, the bored tunnel consists of three separate tubes with no cross links and, consequently, there will not be access to/from the scene of an accident from the other tunnel tubes.

6.6.4 Technical risks

Regarding the individual elements, a bored tunnel will be constructed by means of known technologies. On a number of parameters, however, a bored tunnel of the same size (diameter and length), and built in soil conditions corresponding to those of the Fehmarnbelt, does not exist.

The bored tunnel solution will require boring machines with very large diameters, close to the largest diameters ever used for bored tunnels. This size of boring machine has not been tried across distances as large as between Denmark and Germany under the Fehmarnbelt, under high water pressure and in the type of varying soil conditions that exist under the Fehmarnbelt. A fixed link constructed as a bored tunnel under Fehmarnbelt thus seems to exceed the limits of what is considered to be thoroughly tested, state-of-the-art construction technology.

By comparison, the immersed tunnel is planned to be constructed by means of well-known methods and technologies, both in relation to the dredging works and in relation to the production, transportation and immersion of tunnel elements.

Compared to an immersed tunnel, a bored tunnel has therefore been assessed as involving more and higher construction-related risks.

Soil conditions in the Fehmarnbelt

As mentioned, a primary risk factor of a bored tunnel solution is the soil conditions in the project area.

Femern A/S has performed a number of geological/soil analyses which show that the project area consists of complex soil conditions. The upper seabed layers consist of post and late glacial deposits (gyttja, sand, silt and clay), underlying layers consist of glacial deposits (clay-till and melt-water sand) and underneath this are layers of Palaeogene clay consisting of high-plastic clay and chalk. Finally, areas with large boulders were found.

The highly varying soil conditions in the project area represent a significant risk for any boring method due to, among other things, the potential risk of hitting large boulders rooted in an unstable mass, which makes it difficult for the tunnel boring machines to crush the boulders. The highly abrasive effect of the seabed materials will require a high maintenance frequency for the cutter. Moreover, hydraulic instability may cause seabed material to enter the cutter chamber during maintenance. Finally, the handling of the bored masses of high-plastic clay is expected to be complicated. These are all factors which involve a high risk of increased costs and delays for a bored tunnel.

In comparison, seabed material which is not foreseen will only be able to affect the construction of the immersed tunnel during dredging, and as the dredging of the tunnel trench takes place from the surface of the seabed, and the seabed can be studied before the immersion of the tunnel elements, this risk is limited.

The varying soil conditions and the presence of large boulders in the Fehmarnbelt thus represent a significantly higher risk for a bored tunnel solution than for an immersed tunnel with regard to construction time and costs.

Production of tunnel boring machines
A number of technical risks are related to the production of tunnel boring machines as described below:

- For the bored tunnel solution under the Fehmarnbelt, six tunnel boring machines with a diameter of up to approx. 17 metres would have to be designed and produced, each of which must be able to bore approx. 10 km (from the coast to the middle of the Fehmarnbelt) and to resist the high water pressure of up to 6 bar in front of the cutter, as well as handle the non-homogeneous soil conditions and the presence of large boulders.
- Femern A/S does not know of any tunnel projects in which tunnel boring machines had to be able to handle the large diameter, the length and the varying soil conditions at the same time. In addition, once the tunnel boring machines have been manufactured, their flexibility in terms of adapting to unexpected materials will be limited.
- Internationally, there is little experience with design of the tunnel boring machines that are necessary to construct the planned bored tunnel solution. There will therefore be a significant risk associated with the performance of the tunnel boring machines along with time and costs. The performance of the six tunnel boring machines is critical to the construction of the planned bored tunnel solution. If even just one machine fails, this will mean a risk of delays in relation to the overall time schedule for the project and the risk of increased project costs.

In comparison, the projected type of an immersed tunnel solution is widely used in Europe and Asia. An immersed tunnel under the Fehmarnbelt will be the longest immersed tunnel of its kind. However, it will be constructed using known technology for dredging, production of tunnel elements and transportation and immersion of tunnel elements.

For a more detailed comparison of the construction methods for the immersed tunnel and the bored tunnel solution, see “Consolidated Technical Report, 2011” (Femern A/S, 2011) and “Technical description of key issues of tunnel solutions” (Femern A/S, 2012) at www.femern.com.

6.6.5 Time schedule

The construction period for a bored tunnel is estimated at eight years, which is 18 months longer than the construction period for the immersed tunnel. The time schedule includes the production of six tunnel boring machines. In order to keep the construction period at eight years, the tunnel boring machines will have to be produced more or less at the same time. This requires high production capacity, which will contribute to minimising the number of potential manufacturers.

Due to the fact that the construction of a bored tunnel under the Fehmarnbelt seems to exceed the limits for what is considered thoroughly tested, state-of-the-art technology, and due to the limited number of potential manufacturers of the required number of tunnel boring machines, Femern A/S has concluded that the construction phase of a bored tunnel involves a greater risk of delays than the immersed tunnel.

6.6.6 Finances

The estimated construction costs for a bored tunnel solution are approx. EUR 6.8 billion (2008 prices). This is approx. EUR 1 billion higher than the costs of the immersed tunnel, an increase of approx. 25%. The estimated construction costs are calculated on the basis of the conceptual designs prepared for an immersed tunnel and a bored tunnel. The overall construction costs include costs for consultancy and client organisation, reserves, etc.

Furthermore, the expected operating and maintenance costs for a bored tunnel solution are calculated to be approx. 23 % higher than for the immersed tunnel.

Both the construction costs and the operating and maintenance costs are higher for a bored tunnel solution because, with three separate tunnel tubes without cross passages, the bored tunnel solution has a considerably higher volume. The bored tunnel solution is also longer, requires more technical installations and has a longer construction period than the immersed tunnel.

Based on the considerably higher construction costs, Femern A/S estimates that the bored tunnel will involve a significantly higher financial risk than the immersed tunnel.

6.6.7 Summary

The environmental impacts of a bored tunnel solution and an immersed tunnel solution are different. It is assessed that the bored tunnel solution will have a slight advantage compared to the immersed tunnel, because it avoids direct impact on the German Natura 2000 area in the middle of the Fehmarnbelt and because it has less sediment spillage. This advantage is despite a longer construction phase, a higher emission of greenhouse gasses (CO_2) in the construction phase, a larger impact on Fehmarn and an uncertain time horizon for the use of the bored material, with a focus on the marine area.

In the operation phase neither a bored tunnel solution nor an immersed tunnel will affect the vessel traffic in Fehmarnbelt. However, in the construction phase, the bored tunnel solution will involve fewer marine activities than an immersed tunnel.

The planned bored tunnel solution is designed to provide the same safety level as the immersed tunnel. However, in contrast to the immersed tunnel, it consists of three separate tubes with no cross links and, consequently, there will be no access to/from the scene of an accident from the other tunnel tubes.

The planned bored tunnel solution seems to exceed the limits of what is considered to be thoroughly tested, state-of-the-art construction technology, whereas the immersed tunnel is planned to be constructed by means of well-known methods and technologies. The construction of the bored tunnel solution, therefore, involves more and higher construction-related risks than the immersed tunnel.

The construction period for the planned bored tunnel solution is 18 months longer than for the immersed tunnel, and the risk of an even longer construction period is higher for the bored tunnel solution.

Finally, the planned bored tunnel solution involves considerably higher construction costs than the immersed tunnel.

Based on the above comparison of the bored tunnel solution and the immersed tunnel, Femern A/S finds the immersed tunnel to be a better and cheaper technical solution for a tunnel forming a fixed link across the Fehmarnbelt. The immersed tunnel is therefore the preferred tunnel alternative.

6.7 SELECTION OF PREFERRED TECHNICAL SOLUTION

Femern A/S has carried out actual environmental impact assessments of both an immersed tunnel and a cable-stayed bridge based on the new environmental data obtained by Femern A/S in 2008 – 2010. In accordance with Femern A/S's recommendation of November 2010, a cable-stayed bridge has been rejected as a technical solution following a comparison with an immersed tunnel regarding: 1) environment, 2) navigational safety, 3) safety and emergency response, 4) technical risks, 5) time schedule and 6) finances. The reasons for rejecting a cable-stayed bridge are given below.

6.7.1 Environment

The environmental assessments show that both the conceptual design for a cable-stayed bridge and the conceptual design for an immersed tunnel entail impacts on the environment in the Fehmarnbelt and on Lolland and Fehmarn. The environmental impacts of a bridge solution are different from those of the immersed tunnel solution. The expected impacts of the cable-stayed bridge are to a higher degree permanent because of the bridge's impact on the hydrographical conditions of the Baltic Sea and the bird migration in the area. The impacts of the immersed tunnel are primarily related to marine dredging in the construction phase.

- The cable-stayed bridge may affect the hydrographical conditions of the Baltic Sea. Calculations show that a bridge has a demonstrable but limited impact on water exchange in the Fehmarnbelt and may thus have an impact on the hydrographic conditions of the Baltic Sea.
- The studies carried out also show that a bridge may create uncertainty regarding free bird migration in the area which cannot fully be avoided.
- The preliminary Natura 2000 assessment of the cable-stayed bridge shows that significant permanent impacts on five German Natura 2000 sites (DE 1633-491, DE 1530-491, DE 1332-301, DE 1631-392, DE 1532-391), east and west of the alignment cannot be excluded. Furthermore, that significant impacts on the prioritised nature type 1150 Coastal Lagoons in SCI DE 1532-391 "Küstenstreigen West- und Nordfehmarn" cannot be excluded.
- Finally, in a comparison of the immersed tunnel and the cable-stayed bridge it is assessed that the impacts on the surrounding Natura 2000 areas of the immersed tunnel are attached with significant fewer environmental conflicts than the cable-stayed bridge.

For more information on the environmental assessment of a cable-stayed bridge, please see the background reports on the environmental assessment of the coast-to-coast project, which include both the immersed tunnel and the cable-stayed bridge. The background reports are published at www.femern.com.

6.7.2 Navigational safety

The Fehmarnbelt is a densely trafficked stretch of water with 48,000 vessel transits per annum (2006), including many tanker vessels, and it is expected that ship traffic will increase significantly up to 2030 (80,000 - 110,000 vessel passengers).

In the interests of navigational safety, a bridge clearly poses more risks than a tunnel as described in the following:

- The collision risk assessed by Femern A/S' consultant shows that a collision with the bridge structure will occur approx. once every three years. Only in rare cases will the bridge be damaged to an extent that would cause a disruption to traffic or give rise to significant repair costs. The probability of vessel collisions with the bridge leading to long-term (three-month) disruption is low, and is once every 500 years.
- Risk analyses show that navigational safety (i.e. safety seen from the vessels' perspective) will be improved compared to a situation with no bridge and continued ferry crossings, provided that

the bridge is designed with two navigational spans of at least 724 m each and that a Vessel Traffic Service (VTS) system is introduced that covers an area from the south end of the Great Belt to the Cadet Channel.

- A bridge solution will always entail a risk that collisions between vessels and the bridge could cause an environmental accident, for example in the form of an oil spill, chemical spill, etc. The risk of this is, however, assessed as being relatively small and at the same level as the current risk as a consequence of vessel-vessel collisions, running aground, etc.
- The part of the construction phase for the cable-stayed bridge in which marine activities take place extends over a period of around three years. The conceptual design indicates that, throughout this period, there will be activities in progress to construct the three pylons for the main bridge as well as several different activities in relation to the two approach bridges. This means that, throughout the construction period, international ship traffic will have to be routed through the two navigation spans of the main bridge and will thus have the same navigational conditions as in the operational phase. Local traffic will have to be routed past the constructions works near the coasts of Lolland and Fehmarn. In order to maintain navigational safety throughout both the construction and operation phases, it will be possible to introduce a number of risk reduction measures corresponding to the measures planned for implementation during the construction phase for the immersed tunnel.

In connection with the introduction of risk reduction measures, it is Femern A/S's assessment that it would be possible to establish satisfactory navigational conditions and navigational safety for the cable-stayed bridge presented in the conceptual design during both construction and operation.

6.7.3 Safety and emergency response

It is crucial that a future Fehmarnbelt Fixed Link maintains a high safety level and that effective emergency response is in place should an accident happen.

The conceptual designs for both a cable-stayed bridge and the immersed tunnel live up to the requirement for a high safety level as both solutions have a higher safety level (measured by the risk of fatalities) than standard motorway or railway systems.

6.7.4 Technical risks

It is Femern A/S technical assessment that a cable-stayed bridge with two spans of 724 m each would present a greater technical challenge to build than an immersed tunnel. The main reasons are described below:

- The bridge solution would entail the largest spans ever built on a cable-stayed bridge for both road and rail traffic and they would both be more than 200 m longer than the span on the Øresund Bridge. Equally, construction would take place in a channel where the weather conditions are often harsh and where ship traffic intensity is high. Therefore significant risks are estimated for the construction phase, for cost overruns, delays and occupational injuries.
- The risks of the detailed planning are especially focused around the combination of the cantilever method and the long cables, which will require detailed planning and the utmost precision in coordinating the work. The long cables in combination with the free-standing pylons require buffering of vibrations, which must be based on extrapolations based on, for example, experience from the Øresund Bridge. The detailed planning of the cable-stayed bridge is therefore characterised as being development work with related challenges.
- Although the girders of the approach bridges are essentially identical, the substructures differ in shape, size and height due to the curve of the bridge.
- The construction work is also characterised by many heavy and precise lifts and the positioning of bridge elements. The bridge girders weighing up to 8,000 t will have to be raised to a height

of 80 metres for the upper side of the bridge girder and placed with precision within a centimetre. Bridge foundations weighing up to approx. 5,000 t must be placed at a water depth of 30 - 40 m, also with centimetre precision.

- The choice of method, including the sturdiness of the lifting equipment to be used, is a critical factor for timely execution. However, while no such equipment is currently available, new lifting units would be built to handle the project.

An immersed tunnel will also present a significant technical challenge, partly on account of the often harsh weather conditions and the high ship traffic density in the Fehmarnbelt. An immersed tunnel, however, does not involve similar technical activities since it fundamentally concerns executing the same operation as with the construction of the Øresund link's immersed tunnel (the Drogden tunnel), although many more times and in somewhat deeper water (up to 30 - 40 m). Thus, the increased length of the assembled tunnel will not mean an increase of risks to the same degree as is the case with an increase of the span in the navigation spans of the cable-stayed bridge.

6.7.5 Time schedule

On the basis of the conceptual designs for a cable-stayed bridge and an immersed tunnel, it is Femern A/S's assessment that a cable-stayed bridge could be built in approx. six years and an immersed tunnel could be built in approx. 6.5 years.

6.7.6 Finances

In connection with the presentation of Femern A/S' recommendation for the preferred technical solution in November 2010, consolidated construction estimates were prepared for the planned immersed tunnel and the planned cable-stayed bridge. The consolidated construction estimates were prepared before the decision to establish a production site in Denmark. The consolidated construction estimates are available at www.femern.dk.

The consolidated construction estimate for the planned cable-stayed bridge shows that Femern A/S assesses that the planned cable-stayed bridge will cost a total of EUR 5.5 billion (2008 prices) . This is roughly equivalent to the construction estimate for the immersed tunnel.

The operation and maintenance costs for the two projects are calculated on the basis of experience from the Øresund link. The estimates, which are naturally subject to some uncertainty, show that the maintenance costs are somewhat higher for a tunnel than for a bridge.

When the above construction estimates and operation and maintenance costs estimates are taken into account, and on the assumption that the total construction time for the two projects is planned to be 6 years (cable-stayed bridge) and 6.5 years (immersed tunnel), respectively, the repayment time for the two projects is planned to be essentially the same, all told.

This means that, from an overall financial perspective, the projects must be regarded as equivalent.

6.7.7 Summary

The environmental impacts of a bridge solution and an immersed tunnel solution differ. The expected impacts of the cable-stayed bridge are to a higher degree permanent because of the bridge's impact on the hydrographical conditions of the Baltic Sea and the bird migration in the area. In a comparison of the immersed tunnel and the cable-stayed bridge it is assessed that the impacts on the surrounding Natura 2000 areas of the immersed tunnel are attached with significantly fewer environmental conflicts than the cable-stayed bridge.

In the operational phase, a bridge will entail a higher risk to ship traffic than an immersed tunnel, other things being equal. However, Femern A/S assesses that it will be possible, in both the construction and operation phases, for a cable-stayed bridge to establish satisfactory navigational conditions and safety.

The cable-stayed bridge and the immersed tunnel are designed to achieve the same safety level, and both solutions have a higher safety level than standard motorway or railway systems.

It is Femern A/S' assessment that the planned cable-stayed bridge entails more and higher technical risks than the planned immersed tunnel. This is primarily because the cable-stayed bridge is designed with the two largest spans ever built on a cable-stayed bridge for both road and rail traffic and they would both be more than 200 m longer than on the Øresund Bridge.

The construction period for the planned cable-stayed bridge is estimated at six years, which is six months less than for the immersed tunnel. Finally, the construction costs for the planned cable-stayed bridge are on the same level as those for the immersed tunnel.

Based on the above comparison of the cable-stayed bridge and the immersed tunnel, Femern A/S finds the immersed tunnel to be a better technical solution for constructing a fixed link across the Fehmarnbelt. The immersed tunnel is therefore the preferred technical solution.

6.8 THE 0-ALTERNATIVE

The 0-alternative comprises a situation where the Fixed Link across the Fehmarnbelt (coast-to-coast) will not be constructed, the ferry service Rødby-Puttgarden will continue and the land works for the motorway and railway (connecting to the Fixed Link) in Denmark and Germany will not be upgraded.

It is assumed that all freight transported by railway along the Copenhagen-Hamburg corridor will continue to be transported via Great Belt and therefore that the current railway capacity will be able to handle the future passenger traffic. Furthermore, it is assumed that the existing road infrastructure will be able to handle the ordinary traffic growth.

The 0-alternative is applied in the environmental assessment for comparison of the environmental consequences of the project. The 0-alternative that is used in the environmental assessment is defined by road and railway traffic in 2025.

The traffic numbers for road vehicles crossing the Fehmarnbelt via Rødby-Puttgarden are based on the traffic prognosis in the report Fehmarnbelt Forecast 2002 which was made by the Fehmarnbelt Traffic Consortium on behalf of the Danish and German Ministries of Transport. The road traffic numbers are extrapolated from 2001 to 2025.

The number of passenger trains crossing the Fehmarnbelt via Rødby-Puttgarden is estimated on the basis of the passenger railway traffic in 2011.

The traffic numbers for the 0-alternative are set out in Table 6.5.

TABEL 6.5 Extrapolated traffic numbers for the 0-alternative, 2025 (per day)

Number per day	**0-alternative**
Cars	6,700
Lorries	1,550
Coaches	150
Road vehicles in total	**8,400**
Passenger trains	8
Freight trains	-
Number per day	**0-alternative**

The ferry traffic between Rødby and Puttgarden is based on traffic numbers from 2011 with approx. 38,000 crossings annually.

7 TRANSBOUNDARY ENVIRONMENTAL IMPACT ASSESSMENT

7.1 INTRODUCTION

It has been examined whether the construction and operation of an immersed tunnel under the Fehmarnbelt will result in transboundary impacts between Germany and Denmark (countries of origin), and between the countries of origin and third party countries.

This chapter summarises the transboundary impacts of the immersed tunnel during its construction and operation.

The investigations carried out show that the transboundary impacts of the Fehmarnbelt Fixed Link are only temporary, and limited to the construction phase. The types of planned activities with potential impacts on the environment include dredging of the tunnel trench, seabed intervention works, and all construction related vessel movements and anchoring.

Potential impacts from the construction and operation of the tunnel have been identified and assessed. In order to determine the significance of the potential impact on the environment, the impacts have been compared with the present environmental conditions (the baseline conditions) in the Fehmarnbelt area and the conditions at the planned extraction sites at Rønne Banke and Kriegers Flak. Both potential extraction sites are located in the western part of the Baltic Sea.

Numerous environmental and technical investigations have been carried out, allowing optimisation of the tunnel project during the design phase thereby minimising some of the potential impacts caused by the construction and operation of the tunnel. Furthermore, mitigation measures have been proposed as part of the assessment in order to minimise possible impacts, and these can be found under the respective components.

7.2 THE ASSESSMENT METHODOLOGY

To ensure a uniform and transparent basis for the EIA, a general impact assessment methodology for the assessment of predictable impacts of the Fixed Link Project on environmental factors has been prepared. The methodology is defined by the impact forecast methods described in the scoping report (Femern A/S and LBV-SH-Lübeck 2010, Chapter 6.4.2). In order to give more guidance and thereby support comparability, the forecast method has been further specified.

Because the impact assessments cover a wide range of environments (terrestrial and marine) and environmental factors, the general methodology is further specified and in some cases modified for the assessment of the individual environmental factors (e.g. the optimal analyses for migrating birds and relatively stationary marine bottom fauna are not identical).

In this context, concepts from the methodology are primarily visible in the chapters concerning environmental factors such as plankton, benthic flora, benthic fauna, marine mammals, birds, bats and fish ecology. However, the importance is listed for all environmental factors.

7.2.1 Overview of Terminology

An overview of the terminology used is provided in Table 7.2.1. To assist reading the background report as documentation for the German UVS/LPB and the Danish EIA, the Danish and German terms are given in the columns to the right.

TABEL 7.2.1 Overview and explanation of the applied terms

Term	Explanation	Term DK	Term DE
Environmental factors	The environmental factors are defined in the EU EIA Directive (EU 1985) and comprise: Human beings, Fauna and flora, Soil, Water, Air, Climate, Landscape, Material assets and Cultural heritage.	Miljøforhold/-faktor	Schutzgut
Sub-factors	As the Fixed Link Project covers both terrestrial and marine sections, each environmental factor has been divided into three sub-factors: Marine areas, Lolland and Fehmarn (e.g. Marine waters, Water on Lolland, and Water on Fehmarn)	Sub-faktor	Teil-Schutzgut
Components and sub-components	To assess the impacts on the sub-factors, a number of components and sub-components are identified. Examples of components are e.g. Surface waters on Fehmarn, Groundwater on Fehmarn; both belonging to the sub-factor Water on Fehmarn. The sub-components are the specific indicators selected as best suitable for assessing the impacts of the project. They may represent different characteristics of the environmental system; from specific species to biological communities or specific themes (e.g. trawl fishery, marine tourism).	Komponent/ sub-komponent	Komponente
Construction phase	The period when the project is constructed; including permanent and temporary structures. The construction is planned to last for 6½ years.	Anlægsfase	Bauphase
Structures	Constructions that are either a permanent element of the project (e.g. land reclamation at Lolland for tunnel alternative), or temporary structures such as work harbours and the tunnel trench.	Anlæg	Anlage
Operation phase	The period from end of the construction phase until decommissioning.	Driftsfase	Betriebsphase
Permanent	Pressures and impacts lasting for the life time of the project (until decommissioning).	Permanent	Permanent
Temporary	Pressures and impacts predicted to be recovered within the life time of the project. The recovery time is assessed as precise as possible and is in addition related to project phases.	Midlertidig	Temporär
Pressure	A pressure is understood as an influence deriving from the Fixed Link Project; this includes influences deriving from project activities and influences originating from interactions between the environmental factors. The type of the pressure describes its relation to construction, structures or operation.	Belastning	Projekt Wirkung
Magnitude of pressure	The magnitude of pressure is described by the intensity, duration and range of the pressure. Different methods may be used to arrive at the magnitude; dependent on the type of pressure and the environmental factor to be assessed.	Belastnings-størrelse	Wirkintensität

TABEL 7.2.1 Overview and explanation of the applied terms

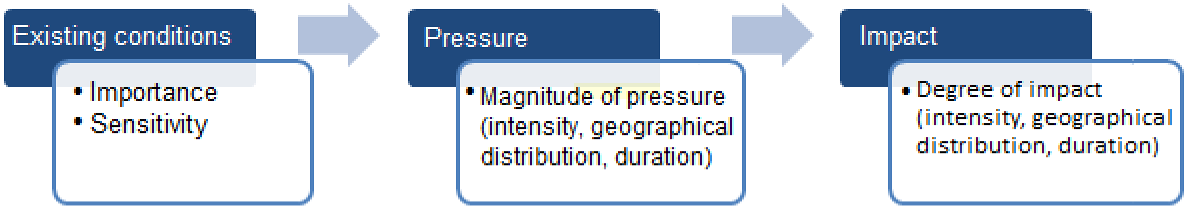
Term	Explanation	Term DK	Term DE
Footprint	The footprint of the project comprises the areas occupied by structures. It comprises two types of footprint; the permanent footprint deriving from permanent confiscation of areas to structures, land reclamation etc., and provisional footprint which are areas recovered after decommissioning of provisional structures. The recovery may be due to natural processes or project-aided re-establishment of the area.	Areal-inddragelse	Flächeninanspruc hnahme
Assessment criteria and Grading	Assessment criteria are applied to grade the components of the assessment schemes. Grading is done according to a four grade scale: very high, high, medium, minor or a two grade scale: special, general. In some cases grading is not achievable. Grading of magnitude of pressure and sensitivity is method dependent. Grading of importance and impairment is, as far as possible, done for all factors.	Vurderings-kriterier og graduering	Bewertungs-kriterien und Einstufung
Importance	The importance is defined as the functional values to the natural environment and the landscape.	Betydning	Bedeutung
Sensitivity	The sensitivity describes the environmental factors' capability to resist a pressure. Dependent on the subject assessed, the description of the sensitivity may involve intolerance, recovery and importance.	Sårbarhed	Empfindlichkeit
Impacts (loss and impairment)	The impacts of the project are the effects on the environment. The impacts are characterised by their intensity, duration, and geographical distribution. Impacts are divided into two types: Loss of habitats as a result of loss of area due to the footprint and Impairment.	Virkninger	Auswirkung
Loss	Loss of environmental factors is caused by permanent and provisional loss of area due to the footprint of the project; meaning that loss may be permanent or provisional. The degree of loss is described by the intensity, the duration and if feasible, the range.	Tab af areal	Flächenverlust
Degree of loss	Degree of loss expresses the consequences of occupation of land (seabed). It is analysed by combining magnitude of the project's footprint with importance of the environmental factor lost due to the footprint.	Omfang af tab	Schwere der Auswirkungen bei Flächenverlust
Impairment	Impairment is a negative change in the function of an environmental factor.	Forringelse	Funktionsbe-einträchtigung

It should be noted that, in the chapters below, only the term 'environmental factor' is used; it covers all levels of the receptors of the pressures of the project (factors, sub-factors, component, sub-components). The relevant level depends on the analysis and will be explained in the following methodology chapters.

7.2.2 The Impact Assessment Scheme

The environmental impact assessment is based on four elements: The importance of the environmental factors, the sensitivity of the environmental factors, the pressures as a consequence of the fixed link, and the impacts of the pressures. Figure 7.2.1 below provides a schematic presentation of the process.

FIGURE 7.2.1 **Schematic presentation of the environmental impact assessment process**



Before the impact assessment process was initiated, the importance and the sensitivity of the environmental factors were determined. This was done in a collaborative effort by the German and Danish authorities.

Subsequently, the magnitude of the pressures was determined. This has been based on the project description and specific (quantitative) information about the project (buildings to be constructed, noise, dredging and digging in land and at sea). As far as possible the pressures have been described quantitatively (amounts, sizes of areas, etc.).

The impact of the pressures on the environmental factors was then assessed. In this analysis, the estimated pressure, the importance and the sensitivity are taken into account. There is a distinction between loss and impairment on the environmental factors, where the loss is due to the footprint, and the impairment is due to other types of pressures. An impairment can be so strong that it results in a loss (if the impact cannot be reversed). As the two types of impacts are of a different nature, they are analysed in different ways. The applied principles are described below.

As much as possible, the pressures and impacts have been quantified. Sufficient knowledge about the relation between pressures and impacts is a prerequisite here, and that there are tools which integrate such relations. Where this is not the case, different kinds of matrix analyses have been applied. Matrix analyses have also been applied for issues where the magnitude or the character of the pressure does not need complex analyses.

7.2.3 The importance of the environmental factors

The importance of the environmental factors has been determined on the basis of expert assessments of their functional values, and/or the protection status of the factors (provided by EU directives, international conventions, environmental protection acts, etc.), or on the basis of population size estimations. The importance is weighted, where possible, using a 4-point scale. The overall principles for the 4-point scale are shown in Table 7.2.2. If it is not possible to use a 4-point scale, in some cases a 2-point scale is used (special and general importance), as defined for the specific case, or the graduation is omitted.

TABEL 7.2.2 **Principles for the 4-point scale for graduation of impordance of an environmantal factor**

Importance	**Criteria**
Very high	Protected by international conventions and/or EU directives and/or especially protected according to the Danish or the German Nature Protection Law and/or of critical importance for overall ecosystem functions, including of international ecological importance
High	In other ways protected by national regulation and/or national red-lists (species or habitats) And/or of importance for overall ecosystem functions
Medium	Of specific value for the Fehmarnbelt area and/or protected by local or regional plans And/or of importance for local ecosystem functions
Minor	Without specific value, or of negative value.

7.2.4 The sensitivity of the environmental factors

The optimal way to describe the sensitivity to a certain pressure varies between the environmental factors. To assess the sensitivity, more issues may be taken into consideration, such as the intolerance to the pressure and the capability to recover after impairment or a provisional loss. When deterministic models are used to assess the impairments, the sensitivity is an integrated functionality of the model. When dynamic models have been used, the deterministic relation is incorporated in the models. For matrix analyses of impairment the sensitivity is graduated by use of a 4-point scale (very high, high, medium, and minor) or a 2-point scale (special, general).

7.2.5 Identifying and Quantifying the Pressures from the Project

The pressures deriving from the project are comprehensively analysed in the scoping report, including determination of the pressures which are important to the individual environmental sub-factors. For the assessments, the magnitude of the pressures is estimated.

The magnitudes of the pressures are characterised by their type, intensity, duration and range. The type distinguishes between pressures induced during construction, pressures from the physical structures (footprints) and pressures during operation. The pressures during construction and from temporary structures have varying duration, while pressures from permanent physical structures and from the operation phase are permanent. Distinctions are also made between direct and indirect pressures, where direct pressures are those imposed directly by the project activities on the environmental factors, while the indirect pressures are the consequences of those impacts on other environmental factors and thus express the interactions between the environmental factors.

The intensity evaluates the force of the pressure and is, as far as possible, estimated quantitatively. The duration determines the time span of the pressure. It is stated as relevant for the given pressure and environmental factor. Some pressures (like footprint) are permanent and do not have a finite duration. Some pressures occur in events of different duration. The range of the pressure defines the spatial extent. Outside of the range, the pressure is regarded as non-existing or negligible.

The magnitude of pressure is described by pressure indicators. The indicators are based on the modes of action on the environmental factor in order to achieve the most optimal descriptions of pressure for the individual factors, such as millimetres of deposited sediment within a certain period. As far as possible, the magnitude is worked out quantitatively. The method of quantification depends on the pressure (spill from dredging, noise, vibration, etc.) and on the environmental factor to be assessed (calling for different aggregations of intensity, duration and range).

For each environmental factor, pressure indicators have been identified which best express the pressure in relation to the environmental factor; e.g. amount, duration, combination of these, etc.

The applied method for quantification of the intensity depends on the pressure and the environmental factor to assess. When the pressure is part of matrix analyses of impairment, the pressure is graduated by use of a 4-point scale (very high, high, medium, or minor) or a 2-point scale (special, general).

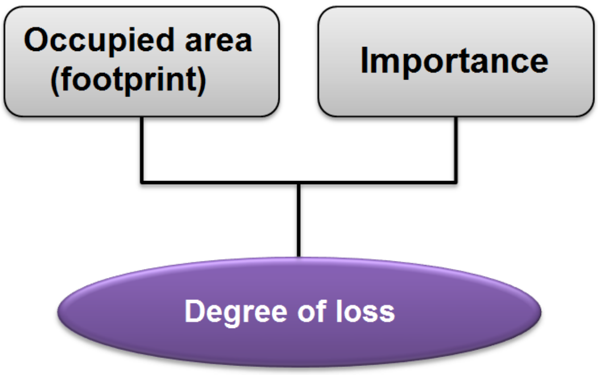
7.2.6 Impacts of pressures

Assessment of loss

Loss is generated as a result of the area occupied by the project (the footprint). All losses are generated in the construction phase. A distinction is made between permanent losses due to permanent structures, and temporary losses like buildings, ports, etc., which are removed once the construction is completed.

The assessment of the degree of loss of environmental factors is based on an estimation of the area occupied, the footprint, and the importance of the area (Figure 7.2.2). Loss of areas is always assessed to be of a very high magnitude of pressure. Graduation of impact of loss is therefore always determined by the graduation of importance.

FIGURE 7.2.2 PRINCIPLE FOR ASSESSMENT OF DEGREE OF LOSS



The geographical distribution of losses can in some instances be shown on maps, and are estimated as areas related to the assessment zones. For the temporary losses, it has been estimated how long time will pass before the natural conditions have been re-established (specified as time and in relation to the project phases).

Assessment of impairment

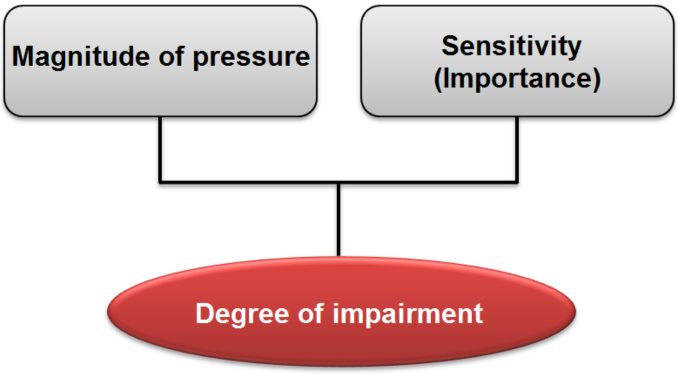
The term "impairment" includes all pressures which are not due to area occupation. Impairment occurs in both the construction and operational phases. Impairment in the construction phase is usually temporary and disappears. How long it takes before it disappears depends on what type of impairment it is and how big it is. An impairment may be so big that it results in a permanent loss of function.

Impairment in the operating phase can start in the construction phase if the pressure causing the impact occurs during this time. Such impairments are in all cases treated as operational phase impairments. Operating phase impairments are inherently permanent when they are due to pressures which continue until the fixed link is dismantled.

The assessments of the degree of impairment are based on the magnitude of the pressure (in terms of intensity, duration and geographical distribution) and the sensitivity of a given environmental factor facing the given pressure. In some cases, where it is irrelevant to consider sensitivity, the pressure is instead related to the importance. If an impairment results in loss of function of the environmental factor, it is treated as a loss.

Impairments are quantified where possible. Quantification is frequently made with various types of computer models. The method used for quantification of an impact depends on the pressure that is involved and which environmental factors are analysed. Where there is sufficient knowledge and/or useful tools, the impacts are assessed using matrix analyses. In addition to analytical results, expert assessments based on data, relevant literature and previous experience are an important part of the basis of the assessment of impairment.

FIGURE 7.2.3 PRINCIPLE FOR ASSESSMENT OF DEGREE OF IMPAIRMENT



The geographical distribution of impairment may be shown on maps (if it is possible) and calculated as areas or numbers of species. Furthermore, the re-establishment of impairments is addressed, normally by indicating the passage of time before the natural conditions have been re-established (time interval).

Assessment criteria

Regardless of the methodology used for the analysis of impairment, the aim is to describe the "degree" of impairment based on predefined assessment criteria. If there are national/international criteria, these have been used. For most assessments, it has been necessary to define the evaluation criteria prior to the assessment of the impacts.

The assessment criteria are defined in order to evaluate the impairment according to a 4-point scale (very high, high, medium, minor). The principles of the 4-point scale are shown in Table 7.2.3. If this is not possible, in some cases a 2-point scale (special and general) is used, as defined for the specific cases, or graduation is omitted.

TABEL 7.2.3 Principles for a 4-point scale for determination of degree of impairment

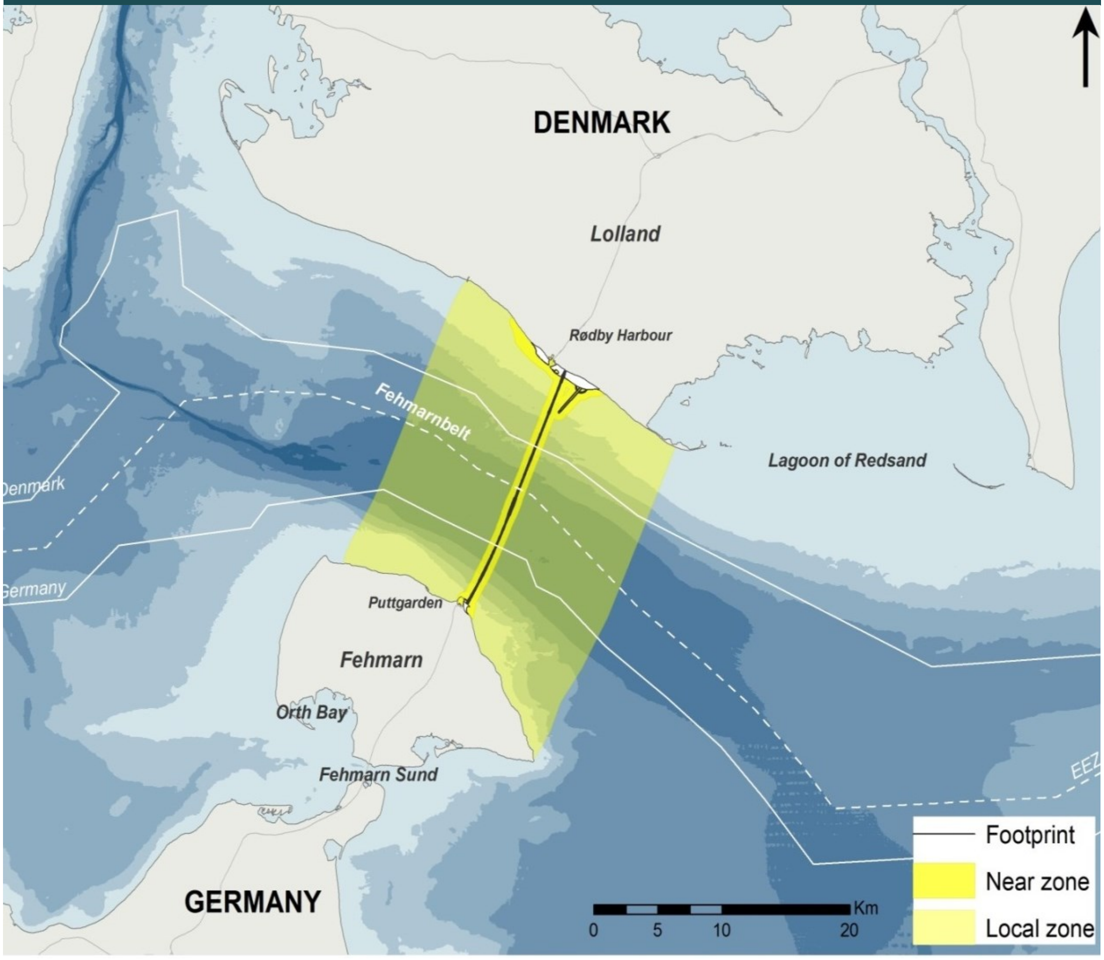
Degree of impairment	Criteria
Very high	There is a very high degree of impact on the environmental factor. Often the impairment is resulting in total loss of the structure and function of the environmental factor.
High	There is a high degree of impact on the environmental factor, which will result in partial loss of the structure and function of the environmental factor.
Medium	There is a medium degree of impact on the environmental factor, meaning that the basic structure and function is intact.
Minor	There is a small degree of impact on the environmental factor, meaning that the impact on the structure and function on the environmental factor is close to the natural variation.

The significance of the impact
The environmental impact assessment is completed by an overall assessment, which determines whether the predicted impacts on the environmental factor and ecosystem are assessed to be significant. This assessment is based on expert judgment of the collected information (including analysis results). The assessment is made for each environmental factor as well as for all environmental factors overall. The assessment includes the degree of the impacts (and the geographical distribution), recovery time and the environmental factor. In the form ending the assessment of each environmental factor, three different grading's are possible: No impact, insignificant impact and significant impact.

7.2.7 Range of impacts

Besides illustrating the impacts on maps, the extent of the marine impacts is assessed by quantifying the areas impacted in predefined zones. The zones are shown in Figure 7.2.4. When relevant, the area of transboundary impacts is also estimated.

FIGURE 7.2.4 The assessment zones applied for description of the spatial distribution of the impacts in the marine area



Note: The Near Zone illustrated corresponds to the alignment of the tunnel alternative. It comprises the footprint and a surrounding 500 m band. The Local Zone is defined by eastern and western borders approximately 10 km from the centre of the alignment

7.2.8 Analyses and analysis tools

The analyses of pressures and impacts have been completed by use of the most optimal analysis tools and methodologies. Furthermore, expert judgements on the basis of data, relevant literature, and earlier experiences form an important part of the assessment of impacts on the environment.

The basic elements of environmental impact assessment are: the importance of the environmental factor, the pressures as a result of the project and the sensitivity of the environmental factor to a given pressure. Knowledge of these elements is combined to assess the impact of the pressure on the environmental factors. If possible, it is done by quantitative analyses. For a number of issues, however, there is insufficient knowledge about the quantitative relationships between stress, importance / sensitivity and impact in order to conduct quantitative analyses with dynamic models and statistical tools. In such cases, the analyses are carried out with a so-called matrix method.

The matrix method
When using a matrix analysis the relevant basic elements are compared in pairs (Tables 7.3.2 and 7.3.3). Thus, for example, to determine the degree of impairment, first determine the

magnitude of the pressure, then determine the degree of sensitivity and finally determine the degree of impairment by looking up the two found degrees in a predefined matrix.

The graduation used in the matrix method follows the same principle as the graduations of relating "impacts" (section 7.2.6). Where possible, the rankings "very high", "high", "medium" and "minor" are used. For "importance" and "sensitivity" the graduation may alternatively be split into two different degrees called "special" and "general". With matrices, it is possible to determine the degree of impact (loss or impairment) any combination will result in; for example, the degree of impairment that a project will result in, if the degree of impact is medium, and the sensitivity of the environmental factor is minor. For impairment, it is assumed in the matrix that this combination - medium level of impairment and little sensitivity – generates a minor degree of impairment (Table 9.5 above).

To investigate the spatial distribution of the various degrees of loss or impairment, a so-called "GIS overlay" analysis has been carried out, where a map of the geographical distribution of a given pressure (with selection of degrees) is overlaid by a map showing the geographical distribution of a given sensitivity (divided into degrees). The resulting map shows the degree of impairment of a given environmental factor.

The assessment of loss has been assessed with a simplified matrix (Table 7.2.4). As described in Chapter 9.2.4 the assessment is based on a combination of the importance of the environmental factor and the pressure, called area occupation (footprint). Area occupation is always assigned the grade "very large", and it is therefore only the importance of the environmental factor that determines how big the impact is. If an area is occupied, where the environmental factor has a high importance, the degree of loss (the impact) in this area is also high.

TABLE 7.2.4 Matrices applied for determination of the degree of loss (4- and 2-point scale). A loss is always assessed as a very high degree of pressure. For that reason the graduation of loss follows the graduation of importance.

Degree of pressure	**Degrees of importance**			
	Very high	High	Medium	Minor
Very high	Very high	High	Medium	Minor

Degree of pressure	**Degrees of importance**	
	Special	General
Very high	Special	General

TABLE 7.2.5 Matrices applied for determination of the degree of impairment (4 grades for pressure and 4 (upper part) and 2 grades for sensitivity).

Degree of pressure	**Degree of sensitivity**			
	Very High	High	Medium	Minor
Very high	**Loss of function**			
High	Very High	High	High	Medium
Medium	High	High	Medium	Minor
Minor	Medium	Medium	Minor	Minor

Degree of pressure	**Degree of sensitivity**	
	Special	General
Very high	**Loss of function**	
High	Very High	High
Medium	High	Medium
Minor	Medium	Minor

Other methodologies

For issues where there is sufficient knowledge to describe the interactions that control the pressures and impacts numerically, static (statistical) or dynamic models are used, if useful tools are available. The advantage of such models is that they can be used to analyse the complex environmental contexts that exist in the project area. A special advantage of the dynamic models is that they take feedback mechanisms into account.

An example of a feedback mechanism is when changes in plankton causes changes in mussels on the seabed, and this change may result in an impact back on plankton. This is taken into account in the dynamic ecological models.

In some cases, a combination of modelling and matrix analysis has been used; for example, if the pressure may be estimated quantitatively with a model, but because of lack of knowledge about the quantitative relationships between the pressure and the sensitivity of the given environmental factor, it is not possible to model the impact of the pressure. Therefore, the matrix analysis is used for this part of the assessment analysis.

Model tools applied by analysis of marine pressures and impacts

Especially for the marine area, a series of complex modelling tools have been applied. The modelling tools used for quantitative analysis of pressures and impacts in the sea are summarised in Figure 7.2.5.

Many of the tools are three-dimensional (3D) dynamic numerical computer models that can simulate what happens in the ecosystems in and around the Fehmarnbelt. By using models, it is therefore possible to take into account the ecosystem's complex relationships when the impacts of the project are analysed. The dynamic computer models contain the areas (ecosystems) that should be modelled, represented by a 3D grid of cells.

The model simulates what happens in each cell, and at short intervals (minutes) takes stock of what has happened in the nearby cells and takes account of it when it simulates the next time step. At the same time, the model takes account of changes in the environment surrounding the model area (the so-called boundary conditions). Meteorological conditions especially play a role in the processes at sea (e.g. air temperature, wind speed and wind direction).

The variations in the boundary conditions are determined in advance and put into the computer model. Since it is impossible to know what the weather will be during the construction phase, data were used from historical periods, mainly the year 2005, when conditions were typical of the Fehmarnbelt area (Western Baltic).

The dynamic models are established with state-of-the-art modelling tools (primarily MIKE and ECO Lab by DHI, but also MOM, GETM and MORPH), which have been used in many contexts internationally to describe existing conditions, particularly impacts and pressures on the environment. In most cases, the point of departure has been existing models (used for previous tasks).

Prior to the analysis of issues related to the fixed link across the Fehmarnbelt, the models have been adapted in terms of geographical coverage, resolution and the specific assessments the models should be used for. The models are tested (calibrated) against data collected in the investigations of existing conditions and in some cases longer time series from HELCOM and other data sources.

In particular, the pressures "construction" and "sediment spill", and the direct and indirect impacts these have on the environmental conditions, are analysed with dynamic models. For example, dynamic models have been applied to calculate how the spill from dredging the tunnel trench (among other things) is spread in the marine environment, and where it ends. The results of this modelling are used as input for simulations of how the scattered sediment changes the light conditions in the water due to suspended sediment, and how this affects macro-algae, eel grass, etc. The same model complex is used to assess the effects of suspended sediment on phytoplankton biomass, and the resulting effects on mussels (less biomass means less food). Subsequently, the possible impacts on Common Eider have been modelled (less mussel biomass means less food for the birds).

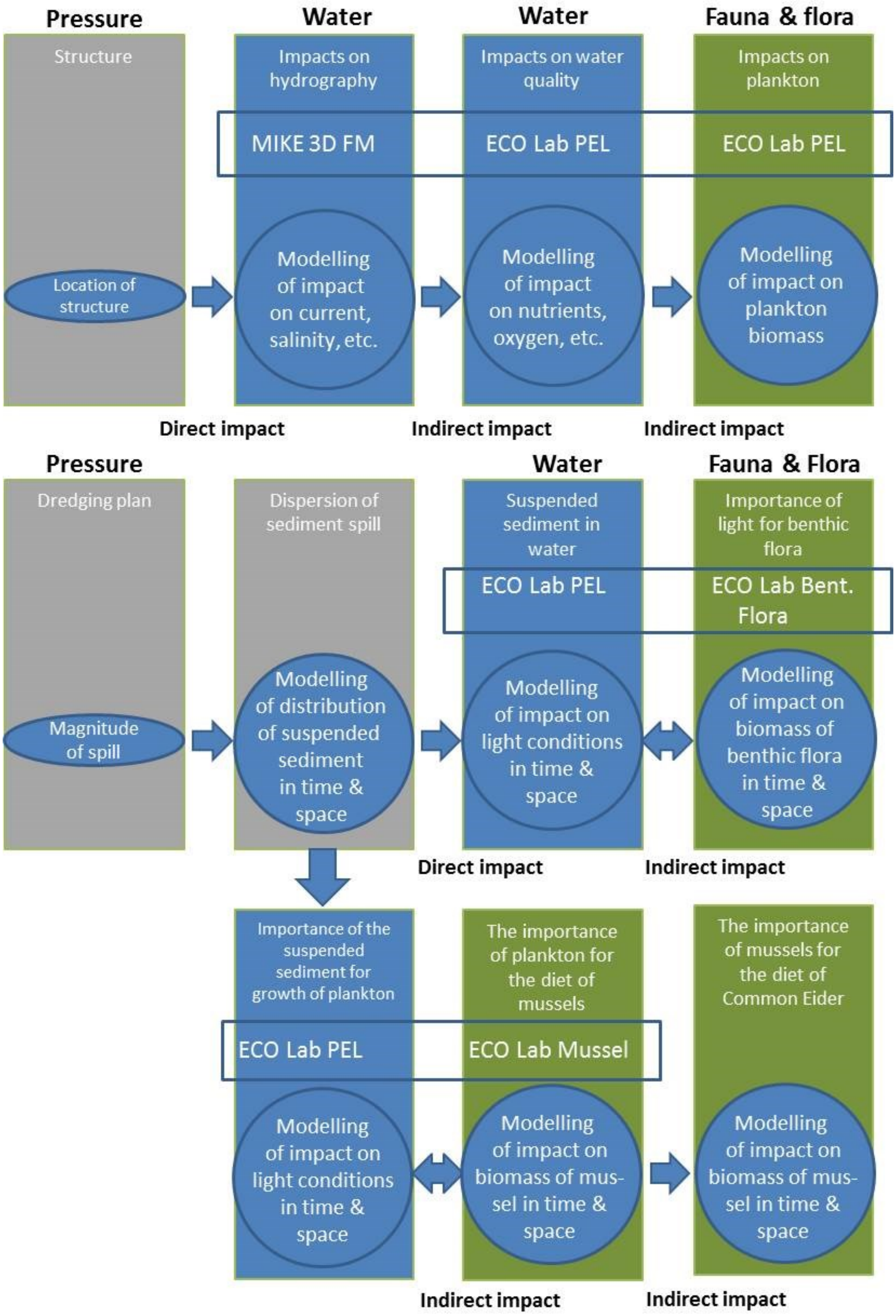
Hydrographical models are used to calculate the extent to which the bridge alternative's piers are affecting water conditions in the Fehmarn Belt and the Baltic Sea. Similarly, the models have elucidated how the coastal construction of the tunnel project will affect the currents. The hydrographical models have, together with wave models, etc., been used to simulate the impact of the tunnel project on seabed morphology and morphology of the coast. Figure 7.2.5 provides examples of the modelling processes and modelling tools which have been part of the analysis of the impacts on marine plants on the aquatic environment and the analysis of the impacts of the suspended sediment from sediment spill on aquatic and benthic plants.

Other models are static or semi-dynamic. This means that they are based on complex mathematical (statistical) formulas, and data on key linkages in the ecosystem calculates the general relationships between pressures and impacts, but without taking account of (all) the dynamics of the ecosystem.

A frequently used model platform is GAM (Generalized Additive Models). GAM is a statistical tool with a "built-in" set of algorithms that make it possible to perform multiple regression emissions based on all the relevant data available. The tool is especially used for habitat mapping and the size and distribution of populations. One example is the mapping of the distribution, population size and density of waterfowl based on data on the ecological and geographical conditions and the preferences of the birds.

An overview of the issues analysed by modelling tools and the model tools used are provided in Table 7.2.6.

FIGURE 7.2.5 Examples of the modelling processes and modelling tools, which are part of the analysis of the impact of the project in the marine environment



Note: The analysis of the impact by the placement on hydrology, water quality and plankton (upper part of figure). The analysis of impacts of the suspended sediment from the sediment spill on the water environment and the benthic plants (central part of figure). The analysis of impacts of suspended sediment on mussels, and Common Eider living off of mussels (lower part of figure). The box around the names of the models indicates that they are integrated, that is, run in one process.

TABLE 7.2.6 Models that have been applied to analyse the marine pressures of the project (direct and indirect) and the impact of the pressures on the environmental factors. For some issues, where the models could have been applied, it has not been done, because the pressures/impacts were too minor. Besides the direct issues, results from the modelling have been used as a basis for other assessments, e.g. expert judgements.

Assessed environmental factors	Modelled issues	Applied models/model platforms
Quantification of pressure **sediment spill**	Distribution and sedimentation of sediment particles lost during the dredging and filling works	MIKE 3 MT (sediment model) MIKE 3 FM HD (hydrography model) and MIKE 21 SW (wave model) Dynamic, 3D (waves 2D)
Hydrography, water quality, plankton Baltic Sea Existing conditions Impact of construction	Existing hydrographical conditions, water quality and plankton conditions in the Baltic Sea Impact of tunnel and bridge construction on the hydrographical conditions in the whole Baltic Sea and the subsequent impact on water quality and plankton	2 regional-models: MIKE 3 FM HD + ECO Lab) and MOM/ERGOM (IOW) Dynamic, 3D Open Foam (3D CFD model for description of environmental conditions close to pier shafts)
Fehmarnbelt Existing conditions Impact of construction	Existing hydrographical conditions, water quality and plankton conditions in Fehmarnbelt and the Belt Sea Impact of the construction of tunnel and bridge on the hydrographical conditions and the subsequent impacts on the water quality and plankton in Fehmarnbelt and the Belt Sea	2 local models: MIKE 3 FM HD + ECO Lab and GETM/ERGOM Dynamic, 3D Open Foam (3D model for description of environmental conditions close to pier shafts)
Water quality, plankton Impact of sediment spill	Impact of suspended sediment from sediment spill on water quality and plankton	MIKE ECO Lab (the water column) MIKE 3 FM HD and MIKE 3 MT Dynamic, 3D
The morphology of the seabed Existing conditions Impact of construction on hydrography, Impact of sediment spill	Existing sediment transport and the dynamics of the seabed forms, and their influence on the water exchange through Fehmarnbelt Impact of changes in the hydrographical conditions (as a result of construction) on seabed forms (e.g. sand waves); only for bridge Impact on sedimentation by sediment spill on seabed forms	MIKE 3 ST MIKE 3 FM HD and MIKE 21 SW Dynamic, 3D (waves 2D) DUNE (2D) or Open Foam (3D) for description of conditions close to the bottom
Coastal morphology Existing conditions Impact by construction	Existing dynamics along the coastlines of Lolland and Fehmarn (erosion; accumulation) Impact of changes in wave environment as a result of construction of tunnel/bridge (changes of hydrography minor)	LITPACK MIKE 3 FM HD and MIKE 21 SW WAMIT
Marine benthic vegetation Existing conditions	Mapping of benthic vegetation in the Fehmarnbelt area	GAM distribution models
Impact of sediment spill	Impact of suspended sediment from sediment spill on the benthic macroalgae and eelgrass	MIKE 3 ECO Lab (water column and benthic vegetation)

TABLE 7.2.6 Models that have been applied to analyse the marine pressures of the project (direct and indirect) and the impact of the pressures on the environmental factors. For some issues, where the models could have been applied, it has not been done, because the pressures/impacts were too minor. Besides the direct issues, results from the modelling have been used as a basis for other assessments, e.g. expert judgements.

Assessed environmental factors	Modelled issues	Applied models/model platforms
		MIKE 3 FM HD MIKE 3 MT Dynamic, 3D
Marine benthic fauna Existing conditions	Mapping of benthic fauna in the Fehmarnbelt area	GAM distribution models
Blue mussels Impact of sediment spill	Impact of suspended sediment from sediment spill on the mussels	MIKE 3 ECO Lab (water column and mussels) MIKE 3 FM HD MIKE 3 MT Dynamic, 3D
Fish Existing conditions	Tracking of place of origin for fish larvae and eggs observed in the Fehmarnbelt area as part of the investigation of the existing conditions	MIKE 3 ECO Lab (IBM version) MIKE 3 FM HD: Dynamic, 3D
	Mapping of the habitat preferences of selected fish species	HSI-models Applied (model)data about hydrography, water quality and benthic habitats Static, 2D
Impact of changing of habitats	Impact on fish as a result of changes in habitats, which are used by the fish (including macroalgae, eelgrass, and mussels)	HSI-models Applied (model)data about hydrography, water quality and benthic habitats Static, 2D
Water birds Existing conditions	Distribution, population size and density of water birds in the Fehmarnbelt area	GAM distribution model Semi-dynamic, 2D (statistical) Applied data from MIKE 3 FM HD and MIKE 3 ECO Lab Mussels
Existing conditions and climate change	Prediction of future distribution and density of water birds in the Baltic Sea, when expected climate changes are taken into account (2 periods modelled: 2005 - 2034 and 2065 - 2095; No fixed link)	Climate Niche Models Static, 2D (statistical)
Common Eider Impact by construction and construction works	Impact of construction and disturbance from construction works on Common Eider in Fehmarnbelt (condition and survival)	IBM Common Eider (with the platform MORPH) Dynamic, 2D
Marine mammals Existing conditions	Calculations of total population and distribution of Harbour Porpoise in the Fehmarnbelt area, based on actual counts	GAM distribution model Static, 2D

Note: HD = Hydrography. CFD = Computational Fluid Dynamics. GAM = Generalized Additive Mode. l HSI = Habitat Suitability Indices. IBM = Individual Based Model

7.2.9 Application of the environmental impact assessment methodology

The general methodology provides a framework for assessing the environmental impacts of the project. The framework is applied to the extent that it is possible to implement this methodological approach, taking appropriate account of the very different issues that arise on land and in a dynamic marine area.

The EIA report presents the results of the assessments. The following allocations of the assessment sections are selected:

- Initially the components to be evaluated are described in each section
- In the description of each component the importance is the point of departure. This summarises the existing condition
- If special circumstances exist in relation to the evaluated component and 0-alternative, this is described
- After this, the evaluation criteria and the sensitivity of the individual sub-component are listed, whereby the basis for further evaluation is determined. The extent of a given impact is described factually (spatial distribution, time frame, etc.).
- Then, the degree of loss and impairment is assessed
- Finally, as a conclusion to the assessment, the significance is described, and the results of the impacts of the individual components are summarised

7.2.10 The Natura 2000 assessment

The impact assessment in Denmark follows the principles of the Statutory Order on Habitats (Order No. 408 of 1 May 2007) on the designation and management of international nature conservation areas and the protection of certain species. In Germany, the German nature protection legislation (BNatSchG § § 34.35) forms the basis for the assessments. Assessments are carried out in Germany by separate guidelines: "Leitfaden zur FFH Verträglichkeitsprüfung im Bundesfernstrassenbau" (Bundesministerium für Verkehr, Bau-und Wohnungswesen, 2004).

It is the Natura 2000 areas conservation objectives of the Natura 2000 areas and criteria for favourable conservation status which forms the basis for an assessment of whether the project affects a Natura 2000 area or not. As the officially used criteria for favourable conservation status are descriptive in character and do not include such exact values that can determine whether there is an impact to a Natura 2000 area or not, the impact assessment is inherently also descriptive.

The background to the descriptive impact assessment is the environmental assessment, which has been conducted throughout the whole influence area of the project, and the specific analyses herein of the impact of the project on the environmental factors. For the purpose of the Natura 2000 assessments, the results regarding the pressures and natural elements (habitats and species) that are relevant to the Natura 2000 impact assessment have been derived from these analyses.

7.3 PEOPLE AND HUMAN HEALTH

The following chapter describes the baseline investigations on humans and health in the Fehmarnbelt area, the possible project pressures induced by an immersed tunnel, and a description of how these can affect humans and health within the Fehmarnbelt area.

7.3.1 Environmental Baseline

Lolland

The investigation area in Denmark is located in Lolland Municipality, which has a population of about 50,000 inhabitants. Approximately 70% of the population lives in urban areas, and approximately 30% lives in rural areas. The municipality is sparsely populated and has in recent years experienced a significant depopulation, of young people in particular. The majority of the population lives in two smaller towns, Rødby and Rødbyhavn of approximately 2,200 and 1,800 inhabitants, respectively. The closest larger town is Maribo, 13 km from Rødby, with approximately 6,000 inhabitants. In addition, there are three summerhouse areas, where the waterpark, Lalandia, is the largest.

Health

Life expectancy is an internationally recognized indicator of public health.

Lolland is among the municipalities in Denmark with the lowest life expectancy (74.8 years against 76.9 years in Eastern Denmark) and is among one of the municipalities in Denmark with the lowest self-assessed health.

The sources of pollution in Lolland consist of air pollution from road traffic, railway and ferry. Air pollution can irritate eyes, the respiratory tract, mucous membranes and skin and lead to serious respiratory and cardiovascular diseases.

The air quality in the investigation area has been analysed for benzene, NO_2, PM_{10}, $PM_{2,5}$ og SO_2. According to the regulation on air quality there are different threshold values for these parameters in relation to human health.

There are no threshold values on air pollution which are violated in the current situation or in the 0-alternative (2025 without a Fehmarnbelt Fixed link).

The railway, ferry and highway are also sources of noise, which potentially may affect the part of the population living close to the railway, the ferry harbour in Rødbyhavn and the highway.

Existing pressures

The existing pressures for the population consist of the following:

- The Highway E47, which today ends just outside Rødby, and which is the direct connection to the ferries between Rødby and Puttgarden
- The railway, which runs parallel to Highway E47, and which ends at the ferry harbour.
- The ferries, which berth at the ferry harbour in Rødby.

Residents near both the highway, railroad and ferry port are today exposed to both noise and air pollution. Especially around the ferry port there is currently a lot of noise and air pollution from both railway traffic to and from the ferries and from the ferries themselves. The effect from these pollutants is included in the assessment of the area's current state.

Fehmarn

Fehmarn Municipality has a total of approximately 13,000 inhabitants. The buildings in the study area consist, like the rest of the island, mainly of small villages which are scattered between rural areas and individual farms. The main town on the Island is Burg, with approximately 4,000 inhabitants. A smaller summerhouse area is located at Marienleuchte.

Northeast and east of Puttgarden, respectively, is a campground and a hotel. The latter is primarily used by ferry passengers for single overnight stays. In several of the houses around the study area, rooms can be rented by tourists.

Health

According to recent statistics for Germany, the current life expectancy is about 78 years for men and 83 years for women.

The sources of pollution in Fehmarn consist of air pollution from road traffic, railway and ferry. Air pollution can irritate eyes, the respiratory tract, mucous membranes and skin and lead to serious respiratory and cardiovascular diseases.

The air quality in the investigation area has been analysed for benzene, NO_2, PM_{10}, $PM_{2,5}$ and SO2. According to the regulation on air quality, there are different limit values for these parameters in relation to human health. This is mostly due to the strong wind conditions, the distance from the work harbour to residential areas, and the relatively low amount of work-related vehicles, which are connected to the construction phase on Fehmarn.

There are also no limits on air pollution which are violated in the current situation or in the 0-alternative (2025 without a Fehmarnbelt Fixed Link).

The railway, ferry and highway are also sources of noise, which potentially may affect the part of the population living close to the railway, the ferry harbour in Puttgarden and the highway.

Existing pressures

The existing pressures for the population in Fehmarn consist of the following:

- The Highway B207, which today ends just outside Puttgarden, and which is the direct connection to the ferries between Puttgarden and Rødby
- The railway, which runs parallel to Highway B207, and which ends at the ferry harbour.
- The ferries, which berth at the ferry harbour in Puttgarden.

Importance

The importance of developed areas and their immediate surroundings (within 500 m) within the investigation area on Lolland have been assessed according to a 4-point scale. Included in the criteria for the assessment of the areas are factors like land use, health functions, and the duration of human occupation of the areas.

The areas with high importance for the population and health on Lolland are the two towns Rødby and Rødbyhavn, and the tropical waterpark, Lalandia. The other summerhouse areas (Bredfjed and Hyldtofte) are assessed to have high importance.

The buffer zones around towns within 500 m and the zones within 50 m around individual residential houses have an importance classified as medium. There are about 330 such houses, primarily scattered close to main roads. All other areas are classified as having minor importance for the population.

The areas on Fehmarn within the investigation area which have been assessed to have high importance for the population are the villages of Puttgarden, Marienleuchte, Bannesdorf, Presen, Hinrichsdorf, Todendorf and Johannisberg, because of their permanent function as residential areas. Facilities with social functions, which are only partly located in Puttgarden, such as schools, kindergartens and health clinics have very high importance because of their essential functions for society.

Camping sites, weekend and holiday homes, by virtue of their temporary accommodation features, have high importance. Green areas closest to residential areas, such as sports facilities, playgrounds, parks, also have high importance to the population because of their proximity to residential areas and their health-promoting function.

The other areas that are located within a buffer zone of 500 meters around the contiguous residential areas, which are not interrupted by roads or other predominant land uses, are assessed to have medium importance. Commercial areas such as industrial areas, commercial areas and supply infrastructure are, in contrast to residential areas, assessed to be of minor importance.

An overview of the importance levels for the different areas on Lolland and Fehmarn can be seen in Table 7.3.1 below.

TABEL 7.3.1 Importance of areas on Lolland and Fehmarn for population and health

Areas on Lolland	Rødby, Rødbyhavn, Lalandia	Bredfjed and Hyldtofte	Buffer zones	All other areas
People and health	Very high	High	Medium	Minor
Areas on Fehmarn	**Puttgarden, Marienleuchte, Bannesdorf, Presen, Hinrichsdorf, Todendorf and Johannisdorf**	**Camping sites, weekend and holiday homes**	**Buffer zones**	**Industrial and commercial areas and supply infrastructure**
People and human health	Very high	High	Medium	Minor

7.3.2 Project pressures

Two pressures have been identified to have a potential impact on human health in Fehmarnbelt and the transboundary region. These are:

- Air pollution from construction machinery on Lolland and Fehmarn and offshore
- Noise pollution from construction machinery on Lolland and Fehmarn and offshore

In the following, the potential impacts of these pressures will be examined.

7.3.3 Transboundary Impacts on Humans and Health

Most of the project pressures for humans and health in relation to an immersed tunnel are local; on neither Lolland nor Fehmarn will there occur violations of these threshold values for the different parameters during construction of an immersed tunnel. However, the air pollution from road traffic, railway, and ship traffic related to construction activities has a potential impact on human health in Germany and Denmark.

The construction of the immersed tunnel will involve a number of construction workers on Lolland and Fehmarn and at sea for marine works. The construction workers at sea for marine works can potentially be affected by air and noise pollution. The construction workers inland in both countries will not be affected by transboundary impacts, because of the distance to the identified noise polluting activities offshore.

Air pollution

The level of air pollution has been modelled on Lolland and Fehmarn concerning the expected emissions from the construction and operation of an immersed tunnel. The air pollution levels of pollutants like NO_x, particulate matter, and SO_x have been assessed and compared to existing limit values for NO_x and particles ($PM_{2,5}$ and PM_{10}).

Emissions of SO_x from shipping due to combustion of marine fuels with high sulphur content contribute to air pollution in the form of sulphur dioxide and particulate matter (including carbon black), harming human health as well as the environment through acidification, particularly around coastal areas and ports. The ships include tugboats, barges, guard ships, etc. The operation of construction machinery inland from conventional diesel engines also emits NO_x and particulate matter.

However, because of the relatively low number of construction ships, the distance to land on both sides, and the generally good air circulation at the German and the Danish sides and at sea, no transboundary impacts from air pollution on human health are expected from the construction and operation of an immersed tunnel.

Noise pollution

The level of noise from the machinery involved in the construction of the immersed tunnel may potentially affect humans and health.

The machinery to be used on Lolland and Fehmarn will not have transboundary impacts because of the distance to the other side. The noise levels from different kinds of construction ships used in the construction phase can only in the middle of Fehmarnbelt be of a transboundary nature. However, because of the distance, the noise levels will not be heard from far away (e.g. on Lolland and Fehmarn), and the only humans close to the middle of Fehmarnbelt will be construction workers. The construction workers working offshore will be wearing hearing protection (among other protective gear) and will not be affected by high noise levels, should they occur. It is therefore concluded that no transboundary impacts from noise pollution on human health are expected from the construction and operation of an immersed tunnel.

7.3.4 Transboundary Impacts on human health between Germany and Denmark

Transboundary impacts between Germany and Denmark at the operational phase of the immersed tunnel will not occur because of the sheer distance, and thus only primary construction-related project pressures are relevant. No impacts are expected in the operation phase.

As can be seen from the previous chapter, the conclusion is that during construction the project pressures on human health on the Danish side will not cause any significant impacts for those on the German side, and vice versa.

7.3.5 Significance of Impact on human health

With no areas of impairment or loss in the Baltic Sea, the assessment shows that in the construction period the immersed tunnel does not have any significance for human health in the Central Baltic Sea or in the Fehmarnbelt in any way.

Therefore, the investigations and assessment shows that an immersed tunnel has no transboundary impacts on human health during construction and operation. In Table 7.3.1 the significance of impact is defined.

TABLE 7.3.2 Significance of transboundary impacts on human health in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on human and health in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Human health	Air pollution	No	No	No	No	No	No	No	No	No	No
	Noise pollution	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant, No = No impact

7.3.6 Mitigation Concerning People and Human Health

An environmental management plan for the project and its activities offshore, on Fehmarn and Lolland, where regulations for emissions, waste, cleaning, covering, watering, noise etc. are described, will be drafted. The plan will take into account the changing weather conditions in the area.

The following mitigation measures are planned to be implemented to prevent and limit the pressures caused by the project:

Fehmarn

- Noise, vibrations, light and air pollution during the construction of an immersed tunnel are planned to be reduced as much as possible

Lolland

- A noise barrier is planned to be built around the tunnel element fabric to prevent the summer cottages and residential areas from noise from the construction site (during construction)

Fehmarn and Lolland

- In order to prevent health problems for residents and visitors caused by noise, vibrations and air pollution during the construction of the immersed tunnel, the production of tunnel elements will take place indoors, and mitigation measures regarding noise, dust and other air pollution will be in place.
- A noise barrier is planned to be constructed around the production facility in the form of an earth embankment. Concerning the outdoor workplaces at Lolland and Fehmarn, noise and dust will be reduced as much as possible.
- Dust emissions from the construction materials themselves will also be reduced as much as possible by watering.

7.4 HYDROGRAPHY

The hydrography of the Fehmarnbelt and adjacent water areas is very important as the water transport, physical property and wave action set the frame for a number of environmental factors.

The Baltic Sea is one of the largest estuaries in the world. It is classified as an “estuary” because its waters are a combination of fresh water runoff from its catchment and saline water from the North Sea.

The outer boundary of the Baltic Sea is the border between the Kattegat and the Skagerrak at the northern tip of Denmark. The saline North Sea water penetrates through the Danish Belt Sea (e.g.

the Fehmarnbelt) into the bottom of the deep basin of the Central Baltic Sea and causes a strong stratification, which is a major factor in determining the hydrography, water quality and biology of the Baltic.

This chapter describes the impact of the Fehmarnbelt Fixed Link structures on the hydrography of the Baltic Sea. Later sections of this chapter address the potential impacts on the Baltic water quality and ecosystem.

7.4.1 Environmental Baseline

The principal baseline factors affecting the hydrography of the Baltic Sea are:

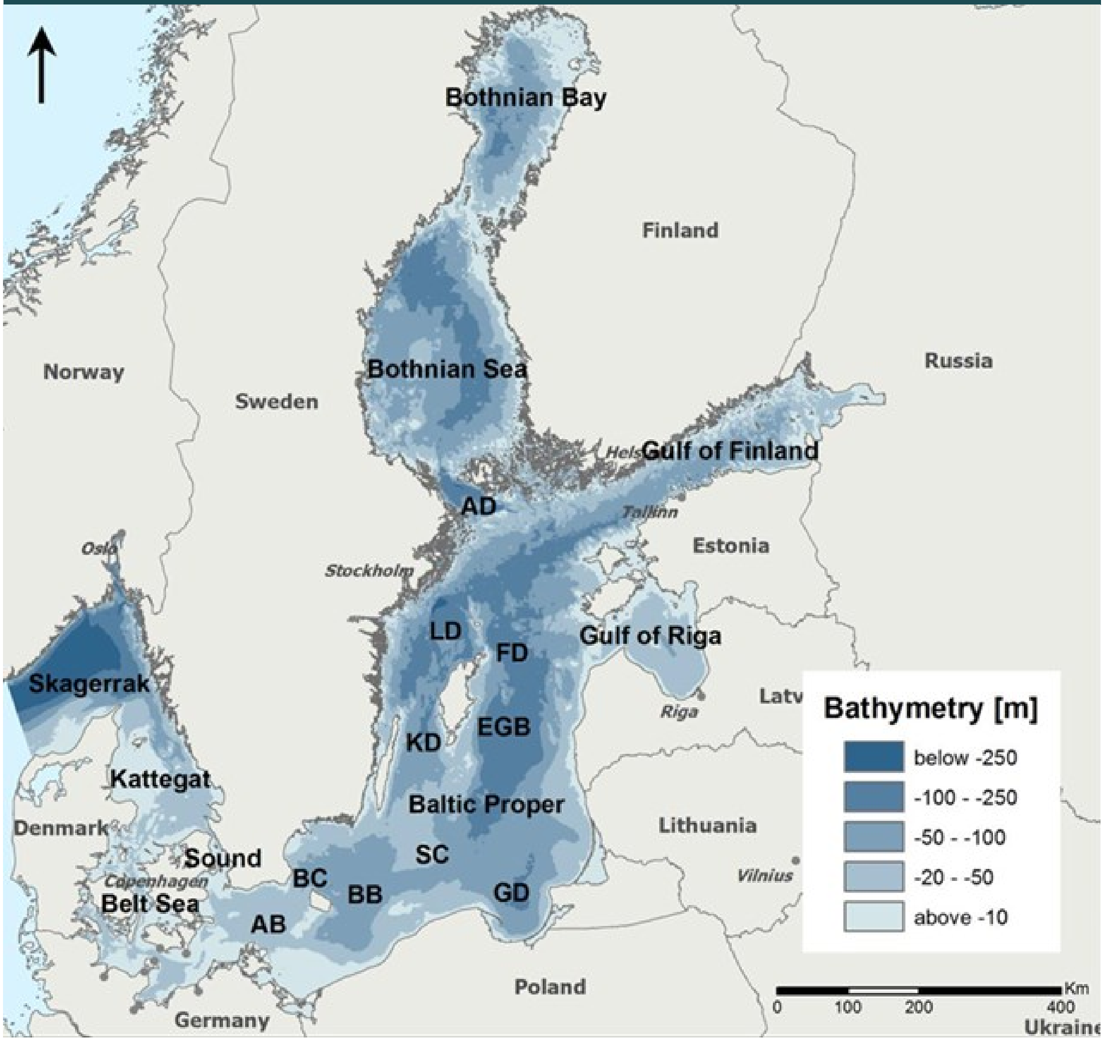
- Bathymetry
- Hydrology of the adjacent watershed (river discharge and low salinity)
- Meteorological conditions (wind, air pressure and heat exchange; precipitation and evaporation at the sea surface)
- Estuarine circulation processes

The description of the hydrographical baseline of the Baltic Sea is derived from literature and scientific reports, and coupled with regional and local investigations of the Fehmarnbelt area.

Bathymetry
The bathymetry of the Baltic Sea is characterised by contractions and sills that influence the currents and mixing between the water masses. The total surface area of the Baltic Sea (including Kattegat and the Belt Sea) is 411,700 km^2 and the volume is 21,100 km^3.

There are three basins in the south-western Central Baltic Sea, namely the Arkona, Bornholm and Gotland Basins (Figure 7.4.1). To the north there are three local deeps: Landsort Deep, Farö Deep and Karlsö Deep. The shallow sill which separates the Central Baltic Sea from the Bothnian Sea contains a local deepening: the Aland Deep. Another sill separates the Bothnian Sea from the Bay of Bothnia. On the other hand, a deep channel connects the northern Central Baltic Sea and the Gulf of Finland.

FIGURE 7.4.1 Bathymetry and geographical structures of the Baltic Sea



Note: Acronyms indicate some basins and connecting channels: Arkona Basin (AB), Bornholm Channel (BC), Bornholm Basin (BB), Stolpe Channel (SC, also called Slupsk Furrow), Gdansk Depression (GD), Eastern Gotland Basin (EGB), Landsort Deep (LD), Fårö Deep (FD), Karlsö Deep (KD) and Aland Deep (AD)

Hydrology

There is a freshwater surplus to the Baltic Sea (i.e. the river runoff plus precipitation exceeds the evaporation).

According to HELCOM (2009) the mean runoff is 14,136 ± 1,545 m^3/s. The difference between direct precipitation and evaporation (P – E) to and from the surface of the Baltic Sea is estimated to range from around 700 m^3/s to 1300 m^3/s, which corresponds to 5%-10% of the river runoff.

The freshwater surplus to the Baltic Sea creates a low salinity water mass close to the sea surface thereby causing the water masses in the Baltic Sea to be stratified. Hence the river inflow is of crucial importance for the conditions in the Baltic Sea.

Meteorological conditions

High and low air pressure fields cross Scandinavia on a weekly time-scale and raise or depress the water levels in the North Sea and Baltic Sea, respectively. The water level differences they cause between the North Sea and the Central Baltic Sea drive an exchange flow between the two seas that either transports low salinity waters from the Central Baltic Sea out to the North Sea or high salinity water masses from the North Sea into the Central Baltic Sea.

The wind-driven exchange in the Danish Straits is an order of magnitude larger than the net outflow generated by the freshwater. Furthermore, the wind shear stress on the sea surface produces wave turbulence that mixes the water masses. The wind also creates a number of phenomena in the Central Baltic Sea and, to a lesser extent, in the transition area:

- Seiching
- Ekman current in the more open sea areas
- Coastal jets closer to the coast line
- Kelvin waves on the sea surface, thermocline or halocline
- Upwelling of water masses below either the thermocline or the halocline.

All these currents have an impact on the redistribution and mixing of the waters and on the biology.

The inflow of North Sea water with high salinity and high oxygen content to the Baltic is a determining factor of the hydrographical, biological and water quality conditions in the Baltic. The inflows are generated by the meteorological conditions over Scandinavia. Low pressure systems over the North Sea raise water levels in the Kattegat and drive water into the Baltic. The regular flow is typically three days outwards and two days inwards, but the durations vary considerably.

The inflowing high salinity water is denser than the Baltic water and therefore follows the seabed all the way through the Central Baltic without intruding into the water column. The largest of the major inflows causes the saline water to penetrate all the way into the Gulfs of Finland and Bothnia.

Estuarine circulation

The estuarine circulation is the exchange flow driven by the density difference between water masses in the North Sea and the Baltic Sea. The estuarine circulation is a relatively slow continuous exchange flow that is retarded by the bathymetry, mainly in the Darss and Drogden Sills, and is enhanced by the wind-driven exchange flow.

When high salinity water originating from the North Sea passes the two sills, it is trapped inside the Central Baltic Sea and propagates further into the Baltic along the seabed. The high salinity water masses can only leave the Baltic again by being entrained upwards into the surface layers which flow out of the Baltic. In the estuarine circulation only two original water masses are involved:

- Water from the rivers, rain and groundwater with a salinity of 0 PSU
- Water from the North Sea with a salinity of 35 PSU

The river water flows in the upper layer at the surface towards the North Sea. Along the way, the higher salinity water in the lower layers is entrained and mixed with the river water, whereby the salinity and volume increase. In the Arkona Basin the salinity has increased to be 8 PSU (23% Atlantic water). Through the transition area the salinity increases further to be about 25 PSU (71% Atlantic water). Finally, it leaves the Kattegat and continues as the Norwegian Coastal Current towards the Atlantic Ocean. In the Fehmarnbelt the salinity has decreased to about 21 PSU.

During the regular and relatively weak inflows, it is only the upper layer of the Baltic transition area that flows over the sills and along the seabed of the Arkona Basin. This water will form an intermediate layer in the Central Baltic Sea.

During the infrequent but very strong inflows, the high salinity lower layer of the Baltic transition area is lifted up and passes over the sills. This water continues to the deepest areas of the Central Baltic Sea.

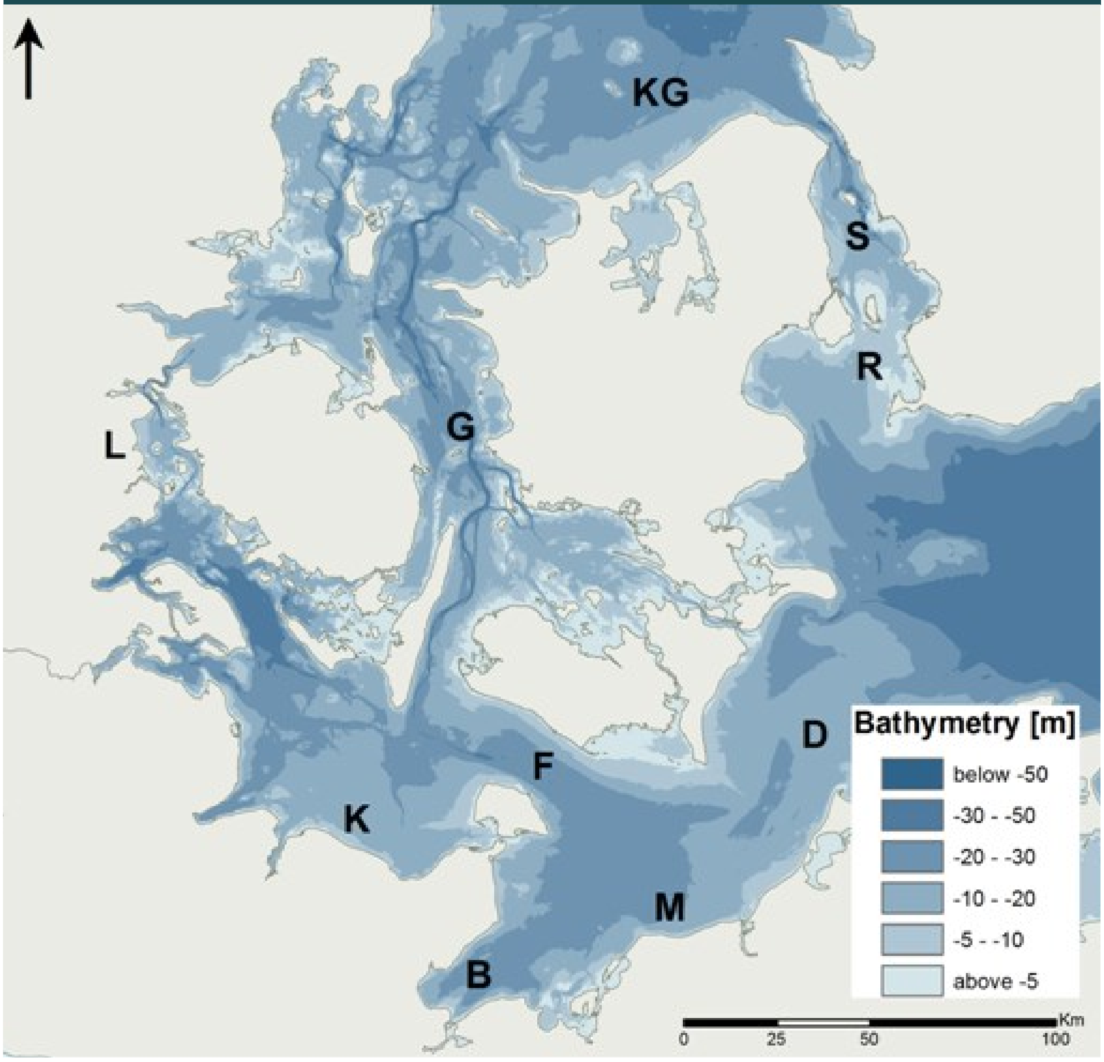
During summer the water masses are heated, and during winter they are cooled by the heat exchange with atmosphere. The heating creates a warm low-density layer at the surface with the thermocline located at 20-30 m depth, both in the North Sea and in the Baltic Sea.

The major inflow causes a sudden rise in salinity followed by a slow reduction due to the mixing between surface and bottom waters.

The assessment of potential impacts to the Central Baltic Sea includes the entire Baltic Sea eastwards from the transition area, i.e. starting at the Drogden Sill in the Sound and the Darss Sill east of the Fehmarnbelt (Figure 7.4.2 and Figure 7.4.3).

FIGURE 7.4.2 Area of investigation for effect to Central Baltic Sea

FIGURE 7.4.3 Bathymetry of the Baltic Sea transition area



Note: Kattegat (KG), Sound (S), Drogden Sill (R), Great Belt (G), Little Belt (L), Kiel Bight (K), Fehmarnbelt (F), Mecklenburg Bight (M), Lübeck Bight (B), Darss Sill (D)

Importance

Part of the basis for assessment of the impact on hydrography in Fehmarnbelt is mapping the importance of the affected components. The importance is either classified as special or general, and the applied criteria for the two steps are provided in table 12.2.

The majority of the Fehmarnbelt is classified as being of special importance, since large parts of the belt have a depth of over 10 m, and the conditions in the deeper parts are crucial for the water exchange between the central part of the Baltic Sea and Kattegat. For the Baltic Sea no proper analysis has been conducted and an importance of ”general” is therefore applied everywhere else in the Baltic Sea.

TABEL 7.4.1 Criteria for determination of importance of the hydrographical conditions in Fehmarnbelt and the western part of the Baltic Sea.

Importance	Criteria
Special	Sea areas of importance for the water exchange and mixing of water layers (water depth of more than 10 m)
	Sea areas around port and harbour entrances (radius 1,500 m, 120˚ angle)
	Sea areas off sandy beaches (out to 3 m water depth)
General	Other parts of the Baltic Sea

7.4.2 Project Pressures

The marine structures of the Fehmarnbelt Project may affect the hydrographical conditions in the Baltic through two mechanisms:

- Project structures potentially cause a blocking of the exchange flow between the North Sea and the Baltic, and thereby may impact the salinity and water quality in the Baltic
- Project structures potentially cause additional mixing between the lower (high salinity) and upper (low salinity) layers of water in Fehmarnbelt, and thereby may have an effect on the salinity and stratification in the Baltic

The impact assessment for the immersed tunnel is based on the following general pressures for the Fehmarnbelt Fixed Link:

- Structures and seabed/coastline changes, such as coastal reclamations, protective reefs or access channels (operation and construction of tunnel)
- Structures in the construction phase, such as work harbours and associated dredging to be removed and seabed to be re-established (construction of tunnel)
- Effluents arising from the project (or changes in existing effluents due to the project), such as dewatering or relocation of existing wastewater discharge at Rødbyhavn (construction and operation of tunnel)
- The potential cessation of ferry service in the future

The pressure elements which could impact the Baltic Sea hydrography include the new reclamation areas at Lolland and Fehmarn, the protection reefs above the tunnel extending from the landfall and about 500 m offshore, and the access channel to the production facility at Rødbyhavn, which is planned to be left open for natural backfilling. This natural backfilling is assessed to take from 1 to 12 years depending on the position. The construction period is planned to last 6.5 years.

7.4.3 Transboundary Impacts for Hydrography

The impact assessment for hydrography in the Central Baltic Sea has been divided into specific assessments for the various sub-components (water level, water exchange at Darss Sill, salinity/temperature, and stratification).

The key tools applied for the assessment are 3D hydrodynamic and water quality models, referred to as regional models for the Baltic Sea and local models for the Fehmarnbelt. To be able to evaluate the uncertainty of the impact estimates, a dual modelling concept was applied where two different regional and local model tools were used. Regional modelling was used and calibrated in relation to the Baltic Sea, whereas the local models were used in the Fehmarnbelt only. The results of the regional model simulations were used in providing the boundary data for the local model simulations.

Regional models:

- MIKE 3, a commercial modelling software package developed by DHI with hydrodynamic, water quality and suspended sediment transport modules
- MOM3/ERGOM, a version of the public domain “Modular Ocean Model” code version 3.1 combined with the ecosystem module ERGOM, both used at IOW

Local models:

- MIKE 3, see above
- GETM/ERGOM, where GETM is developed by Bolding & Burchard (BB) and ERGOM is the water quality module used also for MOM3 by IOW

For the immersed tunnel alternative, regional modelling was not undertaken, as the local modelling showed *negligible* hydrodynamic impacts on the water exchange with the Central Baltic Sea.

The model calibration and validation periods were selected on the basis of the availability of data, the time scales of the processes studied, and the representativeness of key hydrodynamic and water quality characteristics within potential periods.

For the local model, 2005 was selected as the calibration year and 2009 as the validation year.

The year 2005 was a suitable candidate period for the calibration because of the good temporal and spatial coverage of monitoring data for the area of interest. 2009 was used for the validation due to the large amount of data available from the Femern A/S baseline studies on hydrography.

The comparison of the observed and modelled results demonstrates a good representation of key processes, and that differences are small compared to the general range of variability of considered parameters. Hence, the model constitutes a very robust tool for the impact assessment, which measures the relative impact with and without a fixed link.

The potential blocking of salt is critical for the assessment of impacts on the salinity stratification in the Baltic, and with it, the impact on the ecosystem. The local model is used to assess the impact of the project on:

- The blocking of water exchange over Darss Sill
- The blocking of salt exchange over Darss Sill

The underlying detailed modelling and assessment for the immersed tunnel have focused on the comparison of a future situation with the tunnel and continued ferry service (“tunnel+ferry”) with the 0-alternative of continued ferry service (0-alternative equal to reference situation with “ferry”).

However, modelling has also been undertaken to check if the impact would be significantly different for a solely “tunnel” alternative.

The results show that for both comparisons, the effect of the water exchange blocking is very similar (and very small). This is explained by the very limited effect of the ferry service via extra mixing etc. on the hydrography.

The impact of the project on the water and salt exchange across Darss Sill is shown in Table 7.4.2.

TABLE 7.4.2 Impact of the project on water and salt exchange with the Central Baltic Sea for immersed tunnel cases, estimated in local MIKE 3 model using year 2005

Tunnel cases compared to "ferry" case	Net water blocking (Darss Sill)	Net salt flux blocking (Darss Sill)
Tunnel + ferry	-0.01%	0.00%
Tunnel (no ferry)	-0.02%1	NA
Tunnel + ferry in construction period	-0.01%1	NA

Note: 1: Based on a representative shorter design period 9-27 Nov 2005. Therefore no estimation of impacts on salt flux. NA = Not applicable

The blocking of the exchange flow with the Central Baltic Sea in the construction period is -0.01% and similar to the permanent conditions after the construction period. This means that the water exchange in the Fehmarnbelt is slightly increased by the project, and that the impact of the work harbour and production facility on the water exchange is negligible, as it is probably not measureable. This also implies that there is no significant impact on the hydrography of the Central Baltic Sea from the immersed tunnel scenario during the construction period. The small blocking percentage is due to the minimal nature of the restriction on the flow through the Fehmarnbelt by the project structures.

The modelling shows that the project has no impact on the salt flux through the Fehmarnbelt, in either the construction or the operation phase, and therefore no impact on the salinity of the Central Baltic Sea.

The transboundary impacts on hydrography by construction and operation of the immersed tunnel are therefore considered small or non-existent.

7.4.4 Transboundary Impacts for Hydrography between Germany and Denmark

The project features that affect hydrography are the marine structures and works, the land reclamations at the coasts of Lolland and Fehmarn, the access channels to the work harbours and the protection reefs over the immersed tunnel near the coasts. Structures during construction are the breakwaters for the work harbours and the tunnel trench.

Calculations of the wave conditions (wave heights, wave directions and wave periods) are carried out for a time period of 21 years (1989 - 2010) with hourly values. The calculations are performed in a fine grid of calculation points (mesh points).

Detailed modelling studies show that the changes, caused by the structures, to the current speeds are maximum ±0.08 m/s at the surface and extend up to 2 km from the Lolland coast and 0.5 km from the Fehmarn coast. Changes are only seen in the immediate vicinity (100 m) of the reclamations and appear mostly as lee effect on the eastern side of the reclamations. The changes in wave conditions are therefore minor.

According to the model, the changes in other hydrographical parameters such as water levels, salinity, temperature and stratification are negligible. It is therefore concluded that the hydrographical changes in the Danish waters do not cause any subsequent changes in the German waters, and vice versa.

7.4.5 Significance of Impacts for Hydrography

The impact from construction and operation of an immersed tunnel is assessed to have an insignificant impact on the hydrography in the Baltic Sea. It is concluded that the impact of the project on the hydrography of the Baltic Sea and all transboundary territorial waters is insignificant.

TABLE 7.4.3 Significance of transboundary impacts on hydrography in the Baltic Sea, Norway, Germany and Denmark

Factor		**Assessment of impacts on hydrography in the Baltic Sea and Norway**									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Hydrography	Water level	Ins	Ins	Ins	Ins	Ins	Ins	Ins	No	Ins	Ins
	Water exchange at Darss Sill	Ins	Ins	Ins	Ins	Ins	Ins	Ins	No	No	No
	Salinity/ temperature	Ins	Ins	Ins	Ins	Ins	Ins	Ins	No	Ins	Ins
	Stratification	Ins	Ins	Ins	Ins	Ins	Ins	Ins	No	Ins	Ins

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.4.6 Mitigation concerning Hydrography

In relation to the immersed tunnel, mitigation measures concerning hydrography are not relevant, as the impacts of the project on the hydrography are local and insignificant for the general hydrography of the Baltic Sea.

7.5 WATER QUALITY

The water quality in Fehmarnbelt and the Baltic Sea reflects environmental quality in a broad sense and can be seen as the essential condition for the existence of aquatic organisms and for bathing water quality. The water quality is affected by natural conditions, such as hydrography, nutrients introduced from adjacent waters and land, as well as the exchange of substances with the sea bottom and the atmosphere.

A range of sub-components and indicators of water quality are applied in the assessment of the impacts of the Fehmarnbelt Fixed Link. Sub-components concerning water quality are:

- Dissolved oxygen (mean value at surface and bottom and variation over depth)
- Nutrients
- Chemical and hazardous substances
- Suspended matter (transparency)
- Bathing water quality (coliform bacteria)

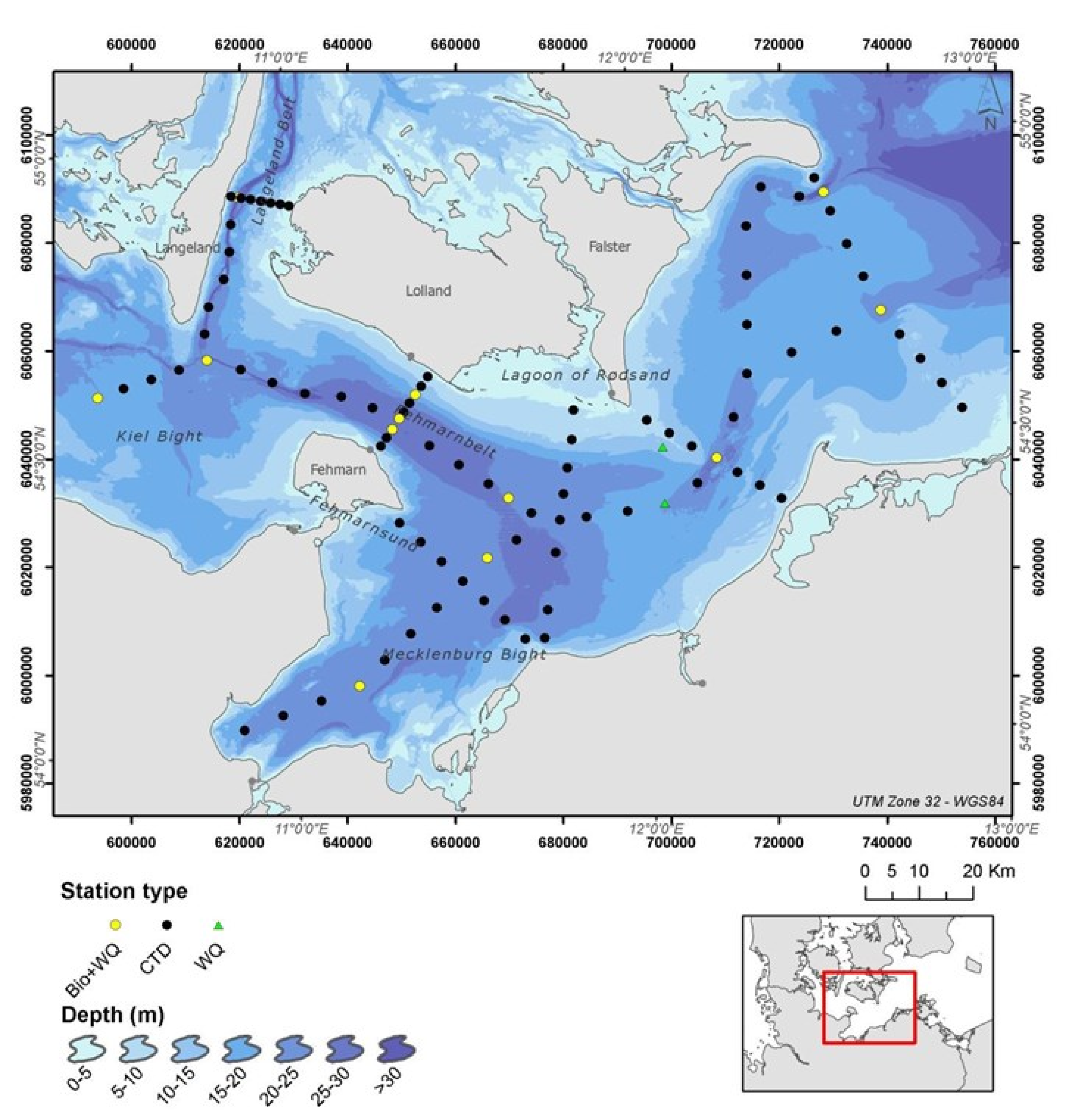
Chapter 7.4 on hydrography handles the sub-components water level, water exchange at Darss Sill, salinity, temperature and stratification; chlorophyll and blue-green algae are handled in Chapter 7.8 on plankton. Direct change in transparency related to sediment spill is described in Chapter 7.6.

This chapter describes the impact of an immersed tunnel on water quality in the transboundary region of the Baltic Sea, and the impact on water quality between Germany and Denmark.

7.5.1 Environmental Baseline

The baseline investigations on water quality were conducted on both a local and regional scale. The local investigation was conducted in 2009 and 2010 in order to collect recent data on the water quality (nutrients, oxygen, water transparency/secchi depth, chlorophyll *a* [chl-a]) in the investigation area (see Figure 7.5.1). Investigations outside the regional Fehmarnbelt area are detailed in Chapter 7.4 on hydrography.

FIGURE 7.5.1 Sample stations for water quality and hydrography in the Fehmarnbelt area



Note: Explanation of sampling station type Bio+WQ: Plankton parameters + water quality; CTD: Conductivity, temperature, depth; WQ: Water quality

The regional investigations were conducted through modelling of the assessment of potential impacts on the Central Baltic Sea including the entire Baltic Sea out to the transition area, defined as starting at the Darss and Drogden Sills.

On a local scale, samples have been collected on monthly cruises covering offshore and near-shore stations (110 and 10 stations, respectively) for the baseline investigations (see Figure 7.5.1).

A comprehensive water quality assessment was conducted at 12 offshore stations and a plankton programme was conducted at 14 offshore stations and at 10 near-shore stations. The offshore stations comprised measurements of nutrients, total chl-a (in vitro analyses), proportion of algal group (based on pigment analyses), species composition, and abundance and biomass of phytoplankton, mesozooplankton and jellyfish.

All sampling (water samples for chl-a, pigments, phytoplankton composition, primary production, and net samples for phytoplankton and zooplankton) was carried out using standardised methods following the HELCOM Combine Manual (HELCOM 2007). A minor deviation from the HELCOM methods was the use of a stronger light source in the incubator for primary production and in-house software to calculate P (production)-E (irradiance) relations and depth integrated primary production.

Chemical contaminants from the dredged sediments

Due to the risk of release of chemical contaminants from the dredged sediments, the chemical properties of the sediment were also studied in detail. The chemical properties of the sediment are reported in the section concerning water quality since chemical contaminants from the dredged sediment are the only environmental parameters likely to impact transboundary waters.

The chemical properties of the seabed sediments are described on the basis of laboratory analyses of samples collected with a gravity core sampler, which can penetrate 3 m into the sediment. The methods used for the laboratory analyses correspond to international standards.

The surface sediments (0 – 30 cm) and the sub-surface sediments (30 – 100 cm) are reported separately in order to show any differences in the pollutant levels due to deposition in the surface sediments during the industrial period of the past 100 years.

Table 7.5.1 lists a selection of sediment quality criteria that is accepted by environmental authorities, and this includes some of the lowest quality criteria (standards) available. The ERL (Effect Range Low) values are based on toxicological data; sediment concentrations below these values are highly unlikely to affect sediment-living organisms. OSPAR (2009) and German standards (Anon 2009) are based on background concentrations and accepted exceedence levels from background concentrations, while the Danish BLST (2008) values are based on both toxicological and background data.

TABLE 7.5.1 Summary of sediment chemical properties compared with Danish, German, ERL and OSPAR standards

Parameter	0 - 30 cm		30 - 100 cm		Danish EPA		German[4]		ERL	OSPAR
	Average	Range	Average	Range	L Ac	H Ac	R1	R2		
Carbon										
Organic C (% dw)	0.65	0.04-1.55	-	-	-	-	-	-	-	-
LOI (% dw)	2.66	0.32-6.92	3.38	0.49-7.89	-	-	-	-	-	-
OD (mg O_2/ml sed 5 hrs)	0.12	0.022-0.301	0.13	0.061-0.217	-	-	-	-	-	-
OD (mg O_2/ml sed 22 hrs)	0.14	0.021-0.31	0.16	0.067-0.35	-	-	-	-	-	-
Nutrients										
Tot-N (mg/kg dw)	572	246-959	715	280-911	n.a.	n.a.	1500	1500	n.a.	n.a.
Tot-P (mg/kg dw)	307	153-540	394	192-584	n.a.	n.a.	500	500	n.a.	n.a.
Released DIN (% of Tot-N)	0.43	0.1-1.1	0.42	0.15-0.95	-	-	-	-	-	0.43
Released PO_4 (% of Tot-P)	0.83	0.4-1.45	1.07	0.35-2.75	-	-	-	-	-	0.83
Heavy metals										
As (mg/kg dw)	<5	<0.5	<5	-	20	60	20	60	8.2	25
Cd (mg/kg dw)	<0.12	<0.05-0.34	<0.18	<0.05-0.16	0.4	2.5	2	6	1.2	0.37
Cr (mg/kg dw)	11.7	1.7-45	20.6	1.7-39	50	270	90	270	81	81
Cu (mg/kg dw)	6.8	0.6-20	10.7	0.6-21	20	90	70	210	34	27
Pb (mg/kg dw)	10.5	2-28	13.7	2-25	40	200	100	300	46.7	38
Hg (mg/kg dw)	<0.01	<0.01-0.03	<0.01	<0.01-0.02	0.25	1	0.4	1.2	0.15	0.07
Ni (mg/kg dw)	8.4	1-31	16.4	<1-28	30	60	70	210	20.9	36
Zn (mg/kg dw)	25.0	4.4-61	30.9	4.5-57	130	500	250	750	150	122
Persistent Organic Pollutants										
PCB (µg/kg dw)	5.8	0.15-74	-	-	20[1)]	200[1)]	40	120	23	1.09
DDT (µg/kg dw)	0.29	0-1.1	-	-	n.a.	n.a.	22	66	1.58	n.a.
HCB (µg/kg dw)	0.05	0.03-0.1	-	-	n.a.	n.a.	2	6	n.a.	n.a.
PAH (mg/kg dw)	0.17[2)]	0.017-0.64[2)]	-	-	3[3)]	30[3)]	3[2)]	9[2)]	4[2)]	0.25
TBT (µg SN/kg dw)	1.0	nd-2.1	-	-	7	200	20	300	n.a.	0
DBT (µg SN/kg dw)	0.6-	<0.4-1.2	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
MBT (µg SN/kg dw)	0.4	nd-<0.6	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Note: n.a. – not available, dw – dry weight 1) – Sum of 7 PCBs 2) – Sum of 16 PAHs 3) – Sum of 9 PAHs
4) – Heavy metals in <20 µm fraction, POPs in < 63 µm fraction, tot-N, tot-P in bulk samples

Danish authorities operate with two sets of quality criteria: Lower Action level (L Ac) and Higher Action level (H Ac), where values below L Ac are considered non-problematic. Standards do not exist for all the parameters. These quality criteria have formed the backbone for the baseline investigations of impacts into the transboundary region.

Importance
The classification of the water quality is based on the functional value of the environmental component and on that basis is divided into two levels. The water quality has been assigned the classification special at low water depths (under 3 m) because, among other things, the quality of bathing water has to be taken into account, including the transparency of the water and the content of coliform bacteria. All other areas are assessed to be of general importance for the water quality.

7.5.2 Project Pressures

The project pressures, which could affect the water quality parameters, and thereby potentially impact the transboundary waters of the Baltic Sea are:

- Discharges of wastewater during construction and operation. This could include reject water from a de-salting facility, if that solution is chosen for water supply for the construction
- Release of organic material, nutrients and contaminants from sediments during dredging activities (construction phase)
- Enhanced vertical mixing of the upper and lower layers of water in the Fehmarnbelt, thereby changing the stratification in the Baltic and redistributing nutrients and dissolved oxygen (construction and operational phase)
- Impacts on the bathing water quality

7.5.3 Transboundary Impacts for Water Quality

The assessment of degree of impairment due to the project pressures is undertaken mainly through detailed numerical modelling. For the hydrodynamic and water quality issues, a dual approach concept is used, with two independent regional model tools: MIKE 3 and MOM (for a more detailed description of these models please, see Chapter 7.4 on hydrography). These regional models cover the entire Baltic Sea area out to the Skagerrak. In addition, a set of local high-resolution models have been applied to the transition area.

The results from the local models are also applied in the Central Baltic Sea impact assessment. Regional modelling has, however, not been undertaken, as the local modelling showed no significant hydrodynamic effects to the water exchange with the Central Baltic Sea.

Discharge of water
Water will be discharged from domestic and industrial activities and from de-watering of areas. Discharges will occur from both the Lolland and Fehmarn construction and operation sites. All domestic and industrial waste water from the project during both construction and operation will be treated, so that effluents from Denmark and Germany comply with the respective standards.

The total discharge will not exceed 1 m^3/s on average and the specific outlets will be placed offshore to ensure sufficient mixing and dilution with the Fehmarnbelt water. The effluents have been assessed to have no effect on the salinity and general hydrography close to the source point, or on larger scales, taking into account the normal variation in salinity in the affected areas (9 – 25 psu) and the efficient flushing. The results indicate that the impacts will be very local and will not spread to the wider Fehmarnbelt area or the transboundary region (for further details see Chapter 7.4).

If a de-salting facility is constructed for the water supply for the production of tunnel elements and operation of the campsite, reject water from the facility will be discharged with waste water and process water from the production. The reject water is very salty, but because the dilution is very large, it would not cause any adverse impacts if discharged to Fehmarnbelt. The reject water would be discharged along with the general waste water and drainage water from the pumping station and would also be diluted in that way before discharge.

The result of the investigation indicates that the impact will be very local and will not be detectably spread to the central part of Fehmarnbelt area or have any detectable transboundary impact outside Danish and German territories (for further details see Chapter 7.4).

Carbon content and oxygen demand

The organic carbon content of the sediments is expressed through the parameters Total Organic Carbon (TOC) and Loss on Ignition (LOI). TOC and LOI values along the alignment of the Fixed Link are typical for the marine environment and vary from low values in clean sand to higher values in the organic sediments in the deeper areas.

Cumulated oxygen demand was determined for 5 hours and 22 hours exposure times. The demand varied between 0.02 and 0.35 mg O_2/ml sediment. The major part of the oxygen uptake was due to oxidation of reduced substances such as sulphides within the sediment.

Analyses showed a good correlation between oxygen demand and organic content, as expected.

An evaluation of the potential impacts of oxygen uptake from suspended sediments under dredging operations is based on a calculated daily oxygen uptake. The expected daily oxygen uptake due to dredging was calculated based on sediment LOI concentration and using the relation between LOI and oxygen demand to calculate the oxygen demand for different sediment types.

Summary data for daily oxygen uptake during dredging at shallow and at deep waters are shown in Table 7.5.2. The average oxygen uptake is estimated to be 93 kg O_2/d and identical for dredging in shallow and deep waters. The lower and higher values (in brackets) give the range in the daily oxygen uptake taking place during the entire dredging operation.

TABEL 7.5.2 Depth integrated oxygen uptake in water column during dredging at shallow waters (<13m depth) and deeper waters (>13m depth). Average oxygen uptake and range of measurements (in parentheses)

Depth	Oxygen uptake (kg O_2/d)
Shallow waters (<13 m)	93 (69-178)
Deep waters (>13 m)	93 (68-181)

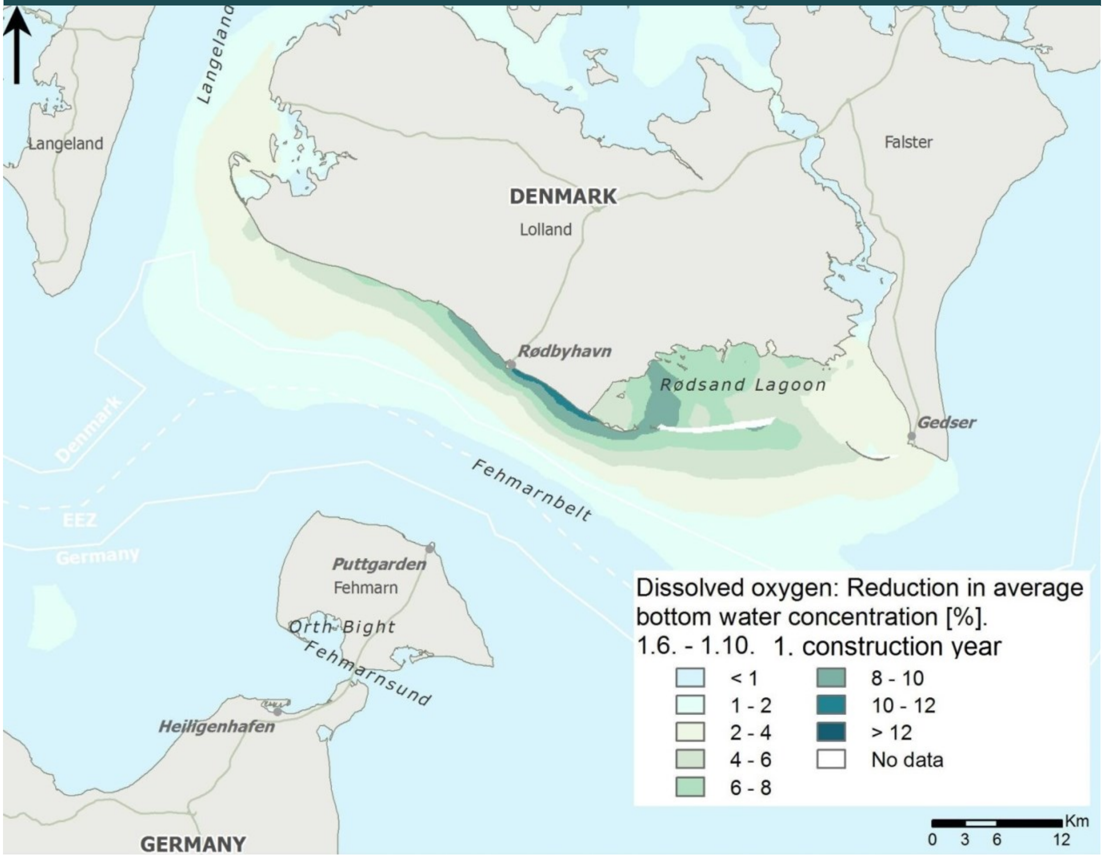
A daily uptake of 68 - 181 kg O_2/d during dredging can theoretically lead to lower concentrations of oxygen in the water column. For reference, the amount of dissolved oxygen within a 100 m wide zone along the entire alignment (18 km) can be estimated at approximately 190 ton O_2 (assuming an average depth of 15 m and a mean oxygen concentration of 7 g O_2/m^3). This means that amount of dissolved oxygen is generally one thousand times greater than the maximum daily oxygen demand due to dredging.

In areas with the largest reduction in oxygen concentration such as in Rødsand Lagoon, the concentration of oxygen does not fall below 6 mg O_2/l. Hence, using a critical level of 4 mg O_2/l, reduction in oxygen levels caused by dredging will not constitute an additional pressure on benthos; therefore, impairment of indirect oxygen reductions is assessed to be minor.

Depressions in oxygen levels may, however, occur during the summer period of the first year of the construction period along Lolland's coast and where the dredging is most intense, but the impact will be very local and will not spread to transboundary areas in the Baltic Sea (see Figure 7.5.2).

The conclusion is that dredging will not impact the oxygen content of any transboundary waters.

FIGURE 7.5.2 Oxygen reduction in the bottom water (%) in relation to an immersed tunnel June - October



Nutrient content and nutrient release

The release of nutrients from disturbed sediments is a key issue to be investigated in projects involving major dredging activities since they may increase the level or risk of eutrophication.

The nutrient content varies between 250 and 960 mg/kg for N (total Nitrogen) and between 150 and 580 mg/kg for P (total Phosphor). There is no significant difference between the surface and sub-surface sediments which reflects the low levels of organic content in sediment in the Fehmarnbelt.

Table 7.5.3 shows a summary of the release of dissolved inorganic nitrogen (DIN) and phosphorus, per dredging day. With a daily dredging intensity of 20,000 m^3, the average release of nitrogen is approximately 500 g DIN/d and the average release of phosphorus is approximately 2,000 g P/d in both cases, irrespective of whether dredging takes place in shallow or in deep waters. The range in daily nutrient release taking place during the entire dredging operation is also shown, and it is similar for both nitrogen and phosphorous at the two water depth intervals.

TABEL 7.5.3 Depth integrated nutrient release during dredging at shallow waters (<13m depth) and deeper waters (>13m depth). Average uptake and range of measurements (in parentheses)

Depth	Nitrogen (DIN) release (g N/d)	Phosphorus release (g P/d)
Shallow waters (<13 m)	496 (296-1455)	2044 (1160-4767)
Deep waters (>13 m)	500 (250-1516)	3008 (1140-4786)

The estimated releases at 0.5 kg nitrogen per day and 2 kg phosphorus per day should be considered as very low, especially considering the horizontal transports through the Fehmarnbelt.

For reference, the daily demand for nutrients by phytoplankton in the Fehmarnbelt within a 100 m wide zone along the entire alignment (18 km) can be estimated from measured primary production (0.65 g C m^{-2} d^{-1}) averaged over the period where phytoplankton is nutrient-limited.

A daily demand for (and assimilation of) nitrogen and phosphorus by phytoplankton within this zone can be calculated at 553 kg N and 35 kg P. For nitrogen, the daily uptake is 3 orders of magnitude higher than the estimated average release, while for phosphorus the demand is about 15 times higher than the average release and 7 times higher than the maximum release. Thus, the release rates are negligible compared to the natural demand, and impacts from nutrient release can be ruled out.

In conclusion, there will be no impacts on transboundary waters from the release of nutrients during dredging operations.

Heavy metals

The concentration of heavy metals in the sediment are low and, with the exception of Cu and Ni, below the lower values of the Danish and German standards. The highest Cu and Ni concentrations are equal to the Danish L Ac, but still far lower than the H Ac. The concentrations in the sediments from 30 - 100 cm are equal to or slightly lower than those in the surface layer 0 - 30 cm.

Regarding release during dredging of sediments, previous studies with sediment from the Fehmarnbelt showed that release of heavy metals from sediments when suspended was low, typically 1% of the sediment concentration. In a comprehensive assessment based on laboratory and field studies of about 100 contaminated sediments from areas across the United States, it was shown that the release of heavy metals was insignificant. The main reason was that during resuspension of sediments (i.e. spill), ferric hydroxide, which is formed in the water column due to oxidation of ferrous iron, acts as a very efficient adsorbent leading to a rapid scavenging of heavy metals in the precipitate. The scavenged metals are then re-deposited in the sediments.

Analyses (the analyses were performed for the metals Cd, Ni and Zn which showed the highest release rates and also for Benz(a)pyrene) showed that the probability of dredging activity in the Fehmarnbelt leading to toxic impacts on the plankton communities is practically non-existent. For the three metals with the highest mobility (Cd, Ni, Zn) median values (50% percentiles) of predicted concentrations were between 20 and 500 times lower than the EU Environmental Quality Standards and between 5 and 50 times below the more restrictive provisional Danish standards.

With a release level of 1% of heavy metals during dredging operations the concentrations are at most expected to be equal to the Danish L Ac level and not to exceed H Ac. With only 1% of the background concentrations of heavy metals released, it is unlikely that there will be any toxic impacts on the biota. It can therefore be concluded that the heavy metals released during dredging in the Fehmarnbelt will not affect benthic or pelagic organisms. Hence, there will be no impact on transboundary waters.

Persistent organic pollutants
Polychlorinated biphenyls (PCBs) were previously used as ingredients in coolants and insulating fluids (transformer oil) and plasticisers in a broad range of industrial products. Apart from one sample, the concentration of PCB in surface sediments was well below the lower values of the Danish and German standards (see Table 7.5.4). Overall, concentration of PCBs is low and confined to the upper 10 - 12 cm. This was determined by the analysis of centimetre slices of surface sediments at two central stations. Since only 1/100 of the sediment column to be dredged contains PCB concentrations above background, (but still below critical values, see Table 7.5.4), there will be no impacts related to the release of PCB during dredging and subsequent settling of PCB on the seabed. Therefore it is concluded that there will be no impacts on transboundary waters.

Concentrations of DDT (dichlor diphenyl trichlorethane – an insecticide) and its degradation products are below the lower values of the Danish and German standards. As with other recently introduced pollutants, DDT is confined to the upper 10 - 15 cm of sediment. It can therefore be concluded that there will be no impacts from DDT spread by dredging.

Concentrations of polycylic aromatic hydrocarbons (PAHs – residuals from combustion of oil products) are also low and far below the lower values of the Danish and German standards (see Table 7.5.4). Below 10 cm depth, PAHs reach background concentrations which are on average 10 times lower than surface concentrations. Therefore there will be no impacts from PAHs due to dredging activities.

Five sediment samples from the central and deep parts of the Fehmarnbelt - where ship traffic is heaviest - were selected for tributyletin (TBT) analysis. TBT is a toxic ingredient in anti-fouling paint for ships. Concentration of TBT and the degradation products was low at all stations and below the lower values of the Danish and German standards (see Table 7.5.4). Being a recently introduced pollutant, TBT reaches zero (background concentration) below 10 cm sediment depth. It is therefore concluded that there will be no impacts of TBT related to spill or disposal of dredged sediment.

For persistent organic pollutants (PAH's, PCB's, DDT, TBT, HCB) and their degradation products, risks for exceeding EQS and water quality criteria are even lower than for heavy metals. In a worst case estimate, concentration of benz(a)pyrene (B(a)P - PAH compound) was estimated at 0.0003 µg/l, which is much lower than the EQS at 0.1 µg/l.

It is therefore concluded that dredging activities will not lead to toxic concentrations of heavy metals or persistent organic pollutants in the Fehmarnbelt area or in any transboundary waters.

Enhanced vertical mixing
Enhanced vertical mixing of the upper and lower layers of water in the Fehmarnbelt can be caused by the marine structures of the Fixed Link project and could thereby change the stratification in the Baltic Sea and redistribute nutrients and dissolved oxygen. Reference is made to the section entitled, Hydrography, for a description of the models which were used to assess the magnitude of the enhanced vertical mixing.

The modelling studies showed that the marine structures of the immersed tunnel will not have any significant impact on the stratification of the waters in the Fehmarnbelt or the Central Baltic Sea.

Therefore it can be concluded that there will be no impact of enhanced vertical mixing in trans-boundary waters.

Water quality at Rønne Banke and Kriegers Flak
The changes in the seabed morphology at Rønne Banke are too limited to cause any changes in the hydrodynamic regime; meaning that there will be no changes in e.g. salinity, temperature, current and mixing. Consequently, no hydrodynamic-based changes in nutrient and oxygen regime and processes will occur.

As the content of organic material in the sediments (LOI) of the investigation area is very low (between 0.08% and 0.73% DW), sand extraction will not give rise to perceptible effects on the concentration of oxygen, nutrients, or chlorophyll *a* concentrations. Therefore there will be no impact on the marine environment due to changes in water quality at Rønne Banke.

The changes in the seabed morphology at Kriegers Flak are also too limited to cause any changes in the hydrodynamic regime, which means that there will be no changes in e.g. salinity, temperature, current and vertical mixing. Consequently, nutrient regime and processes will not be impacted and there will be no transboundary impacts on the marine environment due to changes in water quality.

Impacts on the bathing water quality

Formally, the quality of bathing water is assessed according to the content of faecal coliform bacteria (E. coli, coliform bacteria) and intestinal enterococci (faecal streptococci). The threshold values are set, and the frequency of analysis is done according to the EU bathing water directive from 2006 (2006/7/EC) and a Danish executive order from 2012 (BEK no. 939 of the 18th of September 2012). The quality of bathing water is characterized by four concentration levels of the two types of bacteria (Table 7.5.4). The criteria are valid for four-year periods, and the assessment should be made on the basis of statistical calculations of control measurements distributed over the bathing water seasons.

TABEL 7.5.4 Threshold values for bathing water quality (number per 100 ml) of faecal bacteria for four levels of bathing water quality, as set in the Bathing Water Directive (from BEK nr 939 of 18/9/2012)

Bacteria	Criteria			
	Excellent	Good	Sufficient	Low
E. coli	250*	500*	500**	>500**
Intestinal enterococci	100*	200*	185**	>185**

Note: *)Should be complied with 95 pct. of the time **) Should be complied with 90 pct. of the time

The bathing water quality at the 16 official beaches in Fehmarnbelt is primarily ”excellent” to ”sufficient”, with only one example of being less than ”sufficient” during the four years of measurements (2007 - 2010). This corresponds to an overall compliance with good water quality in approximately 99% of the measurements from the 16 beaches and an ”excellent” grading in 84% of the measurements.

Dredging of sediment, changed discharges and movements of the discharge points may potentially affect the number of faecal bacteria at the different beaches and result in deterioration of the bathing water quality.

In connection with the preparation of the final design of the project and the future discharge of drainage and waste water to Fehmarnbelt, a reassessment of the amounts of waste water and its quality will be made. The discharge will be done in such a manner and at such a distance from the coast that it meets the applicable requirements; and compared with existing conditions, it will only cause insignificant impacts on bathing water quality in the local area.

However, during the construction phase the dredging and land reclamation activities might affect the quality of the transparency of the water along minor parts of the coast, which might affect the use of a few beaches. As the Bathing Water Directive does not specify limits for bathing water transparency, the extent of deterioration is evaluated on the basis of criteria developed in New Zealand. The criteria are based on interviews from when bathers opt beaches with clear water.

The New Zealand criteria show that swimmers' use of beaches can be compared with water turbidity determined by Secchi depth. At Secchi depths lower than 1.5 m, approximately 50% of bathers de-selected the beaches, while they were indifferent if Secchi depth was higher than 2.75 m. In order to take into account that the Danish and German bathers may be more critical, yet another boundary is introduced at 5 m, and at the same time, the duration of degraded conditions is included in the definition of the criteria. The criteria used in the present assessment are shown in Table 7.5.5.

TABEL 7.5.5 Criteria used to assess the impact on bathing water quality as a consequence of water transparency. The duration provides the percentage of the bathing season (June 1st - August 31st)

Duration (pct.)	Secchi depth (m)			
	< 1.5	1.5 – 2,75	2.75 - 5	>5
100	Very high	High	Medium	Negligible
50	High	Medium	Minor	Negligible
25	Medium	Minor	Negligible	Negligible
5	Minor	Negligible	Negligible	Negligible

The aesthetic quality will be affected by the temporary impairment of the visibility of the water as a result of the increased amounts of suspended sediments from the sediment spill, while the hygienic quality may be affected by a temporary increase of bacteria in the water as a result of the waste water discharge, which is increased as a result of the increased population in the project area during the construction phase.

7.5.4 Transboundary Impacts for Water Quality between Germany and Denmark

The project pressures which could affect the water quality parameters, and thereby potentially impact the Danish and German territorial waters, are the same as those listed above.

The general conclusion is that there will be no impacts on the Baltic Sea, but also that in the Fehmarnbelt itself the impacts are insignificant and very local.

All discharges of waste water will comply with regulations and licence conditions, and the direct impacts on water quality will be very local. It is likely that the substances discharged on the Danish side will spread to German waters, and vice versa, due to the highly variable flow patterns in the Fehmarnbelt. The variable flow patterns will cause discharged substances to disperse over large areas over time. However, the quantities of the substances are small and the concentrations so low that there will not be any impacts outside the local areas near the outfalls (see section above).

Similarly, it is concluded that the release of nutrients and contaminants from sediments during dredging will not have any impact on pelagic and benthic organisms due to the very low concentrations in the sediments.

This is because the release of nutrients from dredged and spilled sediments will be very low and will not contribute to eutrophication. Therefore, any changes in nutrient concentrations will be coupled to reduction in primary production and uptake in algae.

For oxygen, it has been found that the organic content of the sediments could cause local depressions of the dissolved oxygen concentrations in the immediate vicinity of a dredger, but that the concentrations would not fall under the critical level of 4 mg/l.

Modelling studies showed that the marine structures of the immersed tunnel will not have any significant impact on the stratification of the waters in the Fehmarnbelt. Therefore it can be concluded that the impact of enhanced vertical mixing is negligible and therefore insignificant and will not impact either Danish or German waters.

Concerning transboundary impacts between Germany and Denmark, the conclusion is that project pressures on water quality on the Danish side will only cause insignificant impacts on water quality on the German side, and vice versa.

7.5.5 Significance of Impact for Water Quality

In the Kattegat and outside the Baltic transition area there are no impacts. An immersed tunnel is therefore deemed to result in no impacts to the Central Baltic Sea both during construction and operation. With no areas of impairment or loss in the Baltic Sea, the assessment shows that during the construction period the immersed tunnel will not have any impact on the water quality in the Central Baltic Sea.

Table 7.5.6 shows the significance of impacts for all sub-components on water quality for all countries around the Baltic, including Germany and Denmark.

TABLE 7.5.6 Significance of transboundary impacts on water quality in the Baltic Sea, Norway, Germany and Denmark

Factor		**Assessment of impacts on water quality in the Baltic Sea and Norway**									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Water quality	Dissolved oxygen	No	No	No	No	No	No	No	No	Ins	Ins
	Transparency	No	No	No	No	No	No	No	No	Ins	Ins
	Contaminants	No	No	No	No	No	No	No	No	No	No
	Nutrients	No	No	No	No	No	No	No	No	No	No
	Coliform bacteria	No	No	No	No	No	No	No	No	Ins	Ins

Note: Sig = Signifikant impact, Ins = Insignificant impact, No = No impact

7.5.6 Mitigations concerning Water Quality

In relation to the immersed tunnel, mitigation measures are not relevant concerning water quality, as there are no impacts on the Central Baltic Sea.

7.6 SEDIMENT AND SEABED FORMS

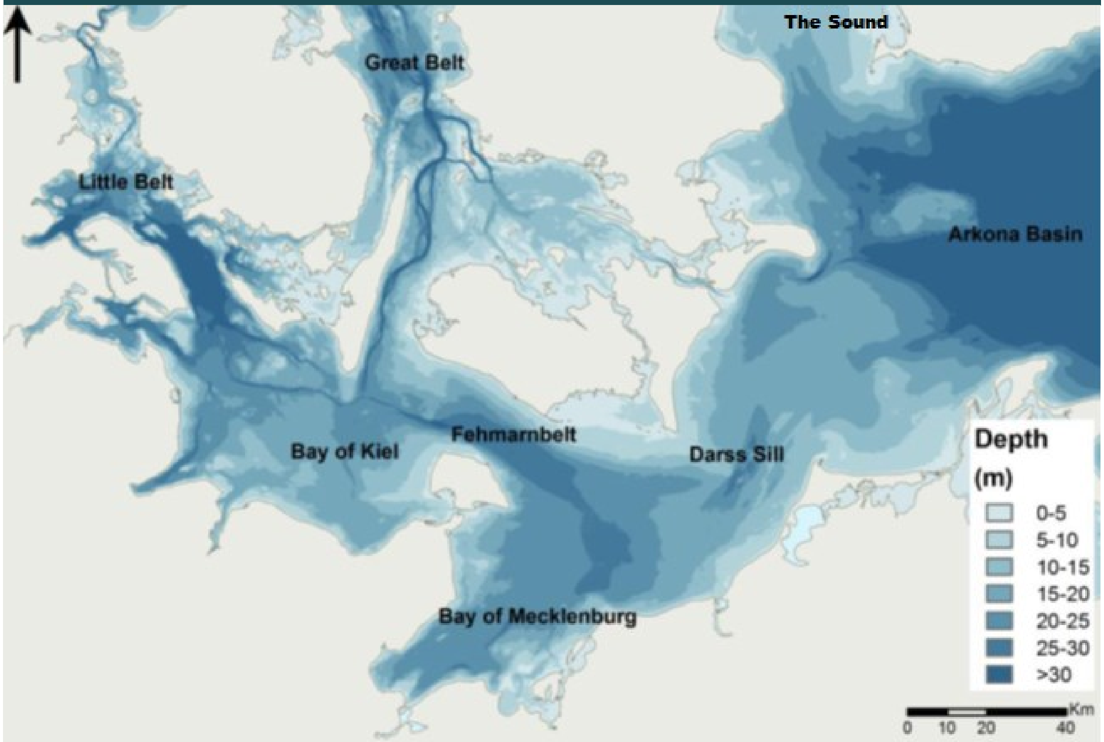
Sediments and morphology of the seabed are issues that concern the state of the seabed, including transport of sediments and the varied seabed forms in Fehmarnbelt. The state of sediments and the seabed are important for both the benthic flora and fauna.

This chapter includes a description of the physical and chemical composition of sea sediments, the sediment spills from the marine works, the migration of non-cohesive sediments (where particles are not sticking to each other along the seabed – sand and coarse sediments), and of the more dynamic seabed forms such as sand waves in the Fehmarnbelt. Fine sediments (silt and clay) in the water phase are mentioned in the chapter concerning water quality (Chapter 7.5).

Seabed morphology in the sea beyond a depth of 6 m is described in this chapter, while the seabed with a depth from 6 m to the coast is described in the chapter regarding coastal morphology (Chapter 7.7). The depth of the Fehmarnbelt and the western Baltic Sea can be seen in Figure 7.6.1, showing the bathymetry of the whole area.

This chapter describes the potential impacts from construction and operation of an immersed tunnel on sediments and seabed forms in the Fehmarnbelt and in the transboundary region.

FIGURE 7.6.1 **The bathymetry map of the Fehmarnbelt region**



7.6.1 Environmental Baseline

The mapping of the existing conditions is based on analyses of results from modelling of current- and wave conditions and of the material migration. The environmental baseline description of the suspended sediment and deposition conditions is based on the same investigation programme which was described for water quality (Chapter 7.5). Further baseline data specific to the Baltic Sea is derived from relevant literature and scientific reports. In particular, data have been obtained from HELCOM and Institut für Ostsee Forschung Warnemünde (IOW).

Apart from the natural processes and the resulting seabed morphology, there are local man-made pressures at the seabed. This is especially relevant for the smaller areas, where permits have been issued for sand extraction or deposition of dredged materials, and for harbour areas and connected smaller areas where dredging is undertaken. Those local pressures in Fehmarnbelt, and the more widely distributed disturbance of the seabed by fishery with trawl and other fishery tools being dragged over the seabed, are assessed to have an overall minor and negligible impact on sediment and seabed forms.

Analyses of current- and wave conditions for calculations of sediment transport on the seabed are based on measurements and model calculations.

Currents
Measurement of flow rates and directions at the two main stations MS01 and MS02 situated in the alignment area in Fehmarnbelt:

- The applied current model has been calibrated towards measured flow rates near the bottom and directions from MS01 and MS02 for the period March 2009 - October 2009
- Modelled current conditions for the year 2005 have been applied for calculating the sediment transport

Waves
Measurement of wave heights, wave periods and wave directions at the two main stations since March 2009:

- Modelled wave conditions in Fehmarnbelt for the year 2005 are applied for calculating the sediment transport

The sediment transport in Fehmarnbelt is going on in periods with relatively high current velocities. The critical current velocity for mobilisation of sediment in Fehmarnbelt is about 0.2 m/s, in 3 m height above the bottom (grain size of 0.1 mm).

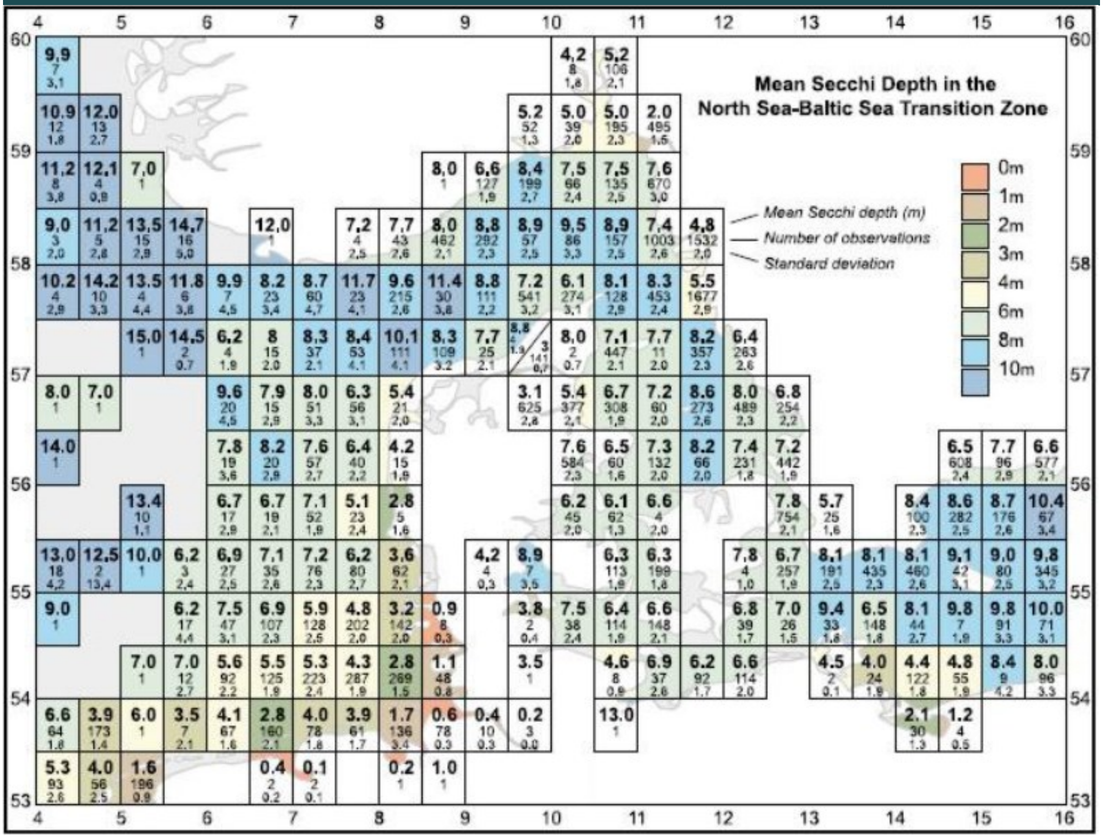
The data most relevant for suspended sediment concentrations is the measurement of water transparency in terms of Secchi depths. Actual measurements of suspended sediment concentrations are not immediately available.

A long time series (> 100 years) of Secchi depths exists from the transitional zone between the North Sea and the Baltic Sea (see Figure 7.6.2), and a few records are available from water samples and in-situ soundings. Most straits in the Belt Sea show a mean Secchi depth of 6 m, which increases to 8 m in the deeper parts of the Kattegat and also in the Arkona and Bornholm Sea. Most optical research has been carried out in the south-western Baltic Sea; more recently, however, a number of programmes have been established in the Gulf of Finland. Depending on time and location, the present level of Secchi depths in the Baltic Sea varies from 5 m to 10 m.

Coastal areas are generally more turbid than open basins, due mainly to re-suspension of fine sediments by wave action.

Mean Secchi depth in the Baltic Sea has significantly decreased during the last 100 years due to anthropogenic influence. A major cause is eutrophication, which has led to an increase in coloured dissolved organic matter and chlorophyll in the Baltic Sea, and in the lakes of its drainage basin.

FIGURE 7.6.2 Mean Secchi depth (top number), number of observations (middle number) and standard deviation (bottom number) for 0.5° x 0.5° squares for the transitional zone of the North Sea and Baltic Sea in the period 1902-1999



Importance

The importance is a measure for the value of the seabed forms as a part of the natural environment and of the functional value of each seabed element.

Coastal elements/sections of the coast are assigned an importance level based on whether they:

- Contain legally protected current conditional seabed forms within Natura2000 sites in Fehmarnbelt
- Have significantly shaped and current conditional seabed forms, which contribute to the diversity of the seabed morphology in Fehmarnbelt
- Have a condition which is far from the natural condition because of pressures from anthropogenic activities

Importance levels for seabed morphology are shown in Table 7.6.1. All areas with active seabed forms have been assigned ”high” or ”very high” importance. The active seabed forms contribute to the diversity of the seabed morphology. The area with sand waves on German territory has been assigned “very high” importance, because the sand waves are part of the conservation objectives for two special protected areas (SPAs), being DE 1332-301 and DE 1631-392.

Exempted from these high importance levels are areas with seabed forms, where licenses have been issued for sand extraction or dredging of sea sediments. Such areas are comparable with dredged areas and harbour areas, which likewise are far from the natural conditions, and are assigned minor importance.

TABEL 7.6.1 Importance levels for seabed morphology

Importance	Criteria
Very high	Legally protected current conditional seabed forms within Natura 2000 areas
High	Areas with significantly shaped and current conditional seabed forms, which are not included in the category “very high”
Medium	All other sea bottom areas, which are not strongly affected by anthropogenic activities
Minor	Sea bottom areas strongly affected by anthropogenic activities

7.6.2 Project pressures

The main pressures on the sediments and the seabed forms are:

- Permanent structures which occupy a part of the seabed, such as land areas and protection layer on top of the tunnel
- Dredging and backfilling of the tunnel trench, which results in removal of seabed forms, resuspension of sediments and sedimentation as a result of spills from the dredging and filling works
- Dredging of fairways for production facilities on Lolland, which results in deepening of the seabed and dredging of natural seabed
- Construction of working harbours at Lolland and Fehmarn, which temporary occupies/changes a part of the seabed
- Dredging for sand at Kriegers Flak for backfilling of the trench
- Dredging for sand on Rønne Banke for the concrete for the tunnel elements

According to the sand extraction plan for the immersed tunnel, 6 mill m^3 of sand for the backfilling of the tunnel trench are expected to be extracted from Kriegers Flak and 1 mill m^3 of sand for the tunnel element production is to be extracted from Rønne Banke. The construction period is estimated to be 6.5 years.

The magnitude of pressures from dredging and land reclamation activities for an immersed tunnel is listed in Table 7.6.2.

TABEL 7.6.2 Estimated sediment spill and volumes of dredging materials of the project

Activity	Volume of dredged materials (million m^3)	Volume of spill (million m^3)
Dredging of the tunnel trench and access channel to the work harbour	15,5	0,540
Containment dikes	1,2	0,007
Dredging of portal and ramps Lolland	0,36	0,002
Dredging of portal and ramps Fehmarn	0,32	0,002
Dredging of work harbour Lolland	2,87	0,020
Dredging of work harbour Fehmarn	0,10	0,001
Incorporation of dredged materials in land reclamation, incl. rehandling	20,80	0,104
Back filling of tunnel trench (DK)	3,40	0,015
Back filling of tunnel trench (DE)	3,00	0,013
Construction of landscape on land reclamation	4,31	0,039
Total	**51,86**	**0,743**

The planned duration of dredging of the tunnel trench, which is used in the assessment, is a period of 18 months. The dredging and earth work activities related to the tunnel trench, work harbours, access channels, portals, ramps and landscaping are described in Chapter 5.

7.6.3 Transboundary Impacts for Sediment and Seabed

The impacts caused by the pressures of the project can basically be divided in two: one type of impacts caused by the footprint and temporary structures with no potential for transboundary impacts, and another type of impacts related to the sediment spill. The impacts are outlined below.

Impacts by the footprint and temporary structures
The assessment of the impacts on the seabed morphology shows that the impacts will affect an area of 1,471 ha within the local zone. The impacts are partly a loss of an area of 356 ha of "other seabed", meaning without special seabed forms, and partly temporary impairments of a total area of 1,115 ha with and without special current dependent seabed forms. The permanent loss of seabed of 356 ha corresponds to 0.9% of the total seabed within the area 10 km from the alignment (near zone + local zone). The seabed within the lost area has no special importance for the seabed morphology in the Fehmarnbelt area, and the loss is assessed as being insignificant.

Likewise, the temporary impacts in the area without special seabed forms are assessed to be insignificant. The area corresponds to approximately 126 ha, which is expected to be naturally re-established within 15 – 20 years after the construction period.

Impacts will occur on 989 ha in total with seabed forms, hereof 984 ha with crescent-shaped seabed forms and 5 ha with sand waves. The impacts on approximately 890 ha are assessed to be of small or medium scale. The affected area corresponds to 6.1% of the existing area of 16,293 ha with special seabed forms (sand waves, lunate-shaped seabed forms and other current related seabed forms) found within 10 km from the alignment. All impacts on the seabed forms are temporary. Most of the changes (90%) are solely related to a temporary change of the size of the seabed forms. In the remaining area (103 ha), corresponding to less than 1% of the area with special seabed forms within 10 km from the alignment, the seabed forms are planned to be temporarily eliminated. In most parts of this area, the seabed forms are, however, expected to be fully re-established within a maximum of 15 - 28 years.

In an area of 5 ha with sand waves, which previously were used for sand extraction, the regeneration of the seabed form takes a longer time, up to approximately 30 - 40 years.

According to applied assessment criteria, temporary changes in the geometry of sea bed forms are assessed to be a small to medium impairment. Based on the relatively limited area of affected seabed forms within the Fehmarnbelt area and the character of the changes, the impacts on the seabed forms from construction and operation of an immersed tunnel are assessed to be insignificant for the seabed morphology.

All impacts are located within the local zone, and therefore, no transboundary or regional impacts are expected.

Impacts related to the sediment spill

The spreading of spilled sediment for the entire dredging operation has been simulated in a set of numerical models developed for the Fehmarnbelt Fixed Link studies. Three different models were used: hydrodynamic models (MIKE FM HD 3D), wave models, and models simulating spreading of spilled sediment (3D model MIKE3 FM Mud Transport, MT).

The hydrographical year 2005 has been used as basis for the simulation of the spreading of the spilled sediment, since the year 2005 was a hydrodynamically representative year based on comparisons of the currents.

Transportation, erosion and deposition of spilled sediment during dredging are determined by the hydrodynamic conditions. In periods with rough weather, large waves and strong currents, the sediment will be kept in suspension and travel with the flow; whereas in periods with calm weather the sediment will settle on the seabed.

The sediment will continue being re-suspended and re-deposited until it reaches a location where the hydrodynamic forces, waves and currents are so weak that the sediment cannot be re-suspended.

The magnitude of impacts from sediment spill is represented by the following three factors:

- Visible sediment plume patterns
- Exceedence of sediment concentration values
- Deposition patterns

The magnitude of impact resulting from the different activities is described below.

Visible sediment plume patterns

The visible plumes (> 2 mg/l) are limited to areas not far from the dredger itself. However, the plumes due to re-suspension of sediments previously deposited in the shallow waters near the coast extend for much greater distances. The plumes from the marine works at the fixed link site are local, and there are no impacts from Denmark and Germany into the transboundary waters.

At Kriegers Flak and Rønne Banke, which are located within Danish territorial waters, the modelling shows that the visible plumes are localised around the dredger and do not extend to the transboundary regions. This is mainly due to the low fine sediment content of the sand deposits in both areas.

Exceedence of sediment concentration values

In the coastal zone, the visibility limit of 2 mg/l is exceeded for up to 100 days a year on the Danish coast, but less than 7.5 days a year on the German coast. Here, the impact on visibility is mainly due to re-suspension. The visible surface plumes will only be seen in Danish and German waters, and at any given time during the construction, the suspended sediment concentration will not exceed the physical threshold value for visibility (2 mg/l) in the transboundary region.

Similar results for Kriegers Flak and Rønne Banke can be found in the summer period, when the currents are lower and the plume does not spread far away from the dredger. Transboundary areas will not be affected by dredging in these areas.

Sediment deposition patterns

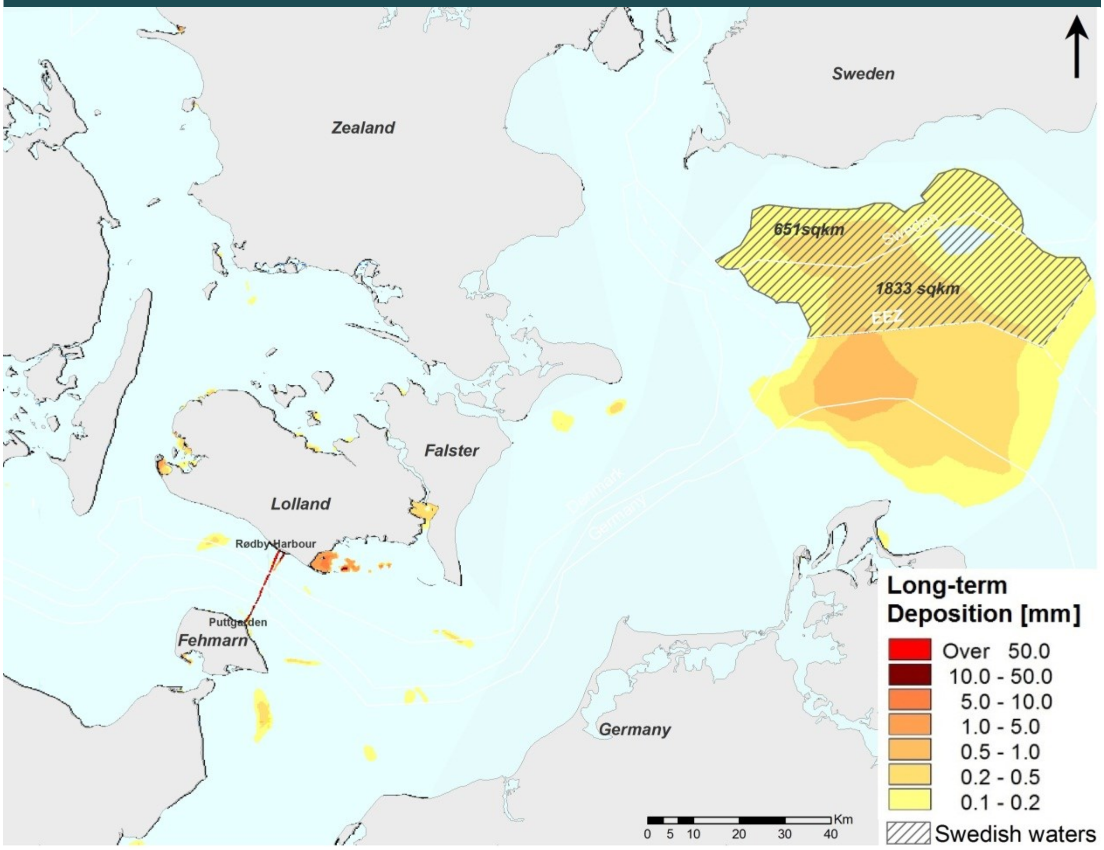
Figure 7.6.3 shows the deposition pattern at the end of the construction period for all operations in Fehmarnbelt itself, i.e. excluding the Kriegers Flak and Rønne Banke dredging. The deposition is shown in mm with the assumption that the sediment deposits at the seabed with a density of 300 kg/m^3, which corresponds to weakly consolidated fine sediments.

The results show little or no sedimentation in the majority of the offshore area in the Fehmarnbelt, away from the alignment. At the alignment, sedimentation is about 5 cm and originates from the coarser part of the spill (the sand fractions) that is less mobile. The spilled sand fractions will deposit within 200 - 600 m from the dredging operation.

The results also show that the final resting places are the Arkona Basin, the edges of the Bay of Mecklenburg and in the deeper waters in the Southern Lillebælt, between Als and Ærø. Therefore, the deposition only occurs in Danish, German and Swedish waters, and not into the rest of the transboundary region.

The deposits in the final resting places originating from the construction activities are very thin: less than 1 mm. In comparison, the natural deposition in the Arkona Basin is approximately 10 mm during the construction period, and thus the effect of the immersed tunnel represents an excess deposition of maximum 10%. The deposition does therefore not influence sand dunes, sediment stability or sediment movement in Fehmarnbelt or the transboundary region.

FIGURE 7.6.3 Deposition pattern for coarse and fine sediment spill from construction activities at the end of the construction period, excluding dredging at Kriegers Flak and Rønne Banke



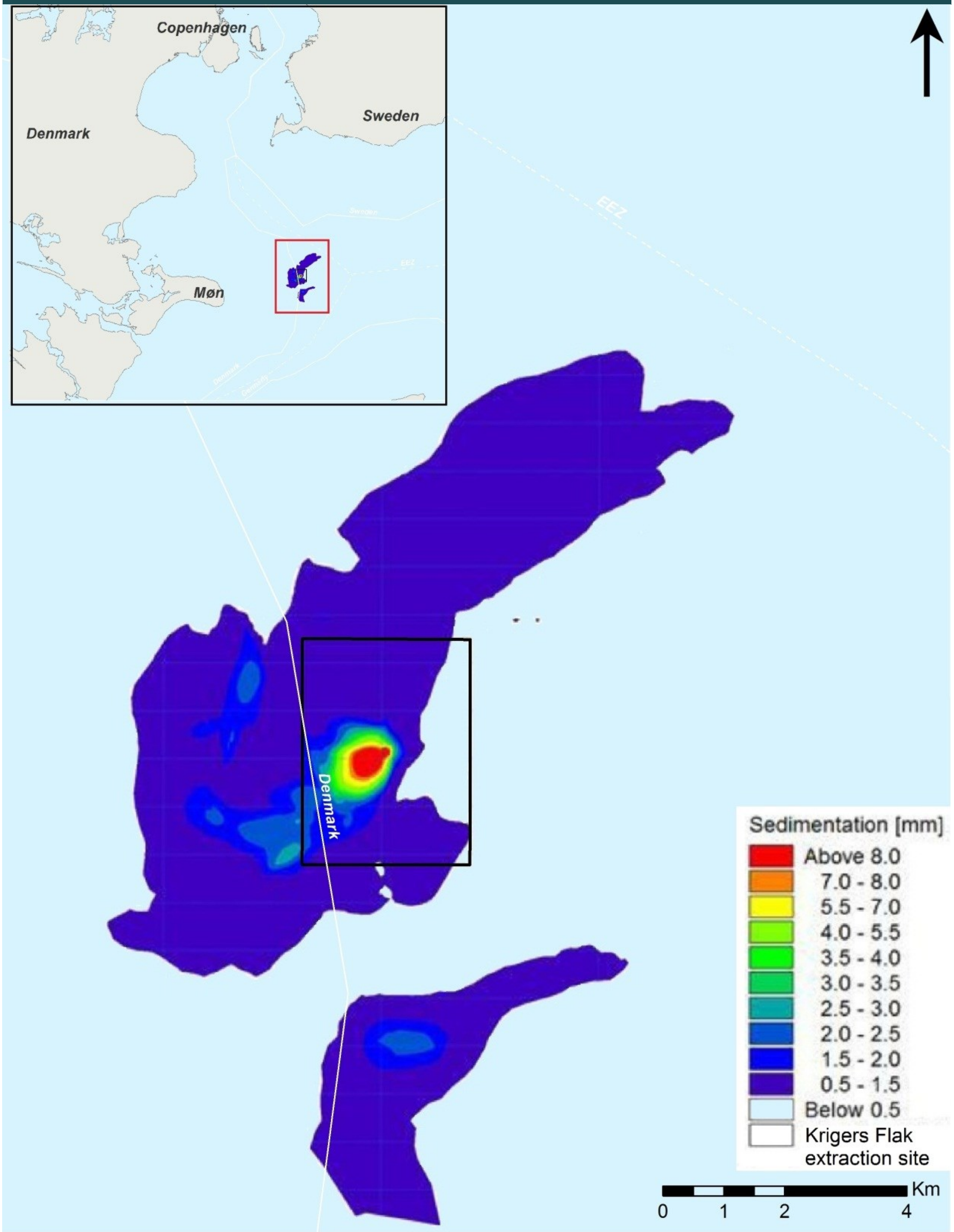
The corresponding results for the dredging operations at Kriegers Flak and Rønne Banke are shown in Figures 7.6.4 and 7.6.5. The Figures show that deposition occurs only within Danish waters and the Danish EEZ.

At Kriegers Flak, the fine sediments are deposited near the dredger during the summer, but the waves during the autumn and winter storms re-suspend nearly all the sediment and move it to deeper areas to the south, where it settles permanently. It is observed that the thickness of the deposition is in the range 0.5 - 2 mm, which equals 5 - 20% of the natural deposition of 10 mm per year. The coarse sediments (> 63 µm) all settle close to the dredger within the extraction area, and all the deposition occurs in the Arkona Basin and within Danish national waters.

There are two scenarios for the extraction period at Kriegers Flak: a full-year and a summer scenario. The maximum deposition of fine sediment has been identified for both a full-year of continuous dredging and for continuous dredging during the summer period. The remaining sediment, above 63 µm, will deposit close to the source at an average thickness of 1.2 cm within 15 - 20 minutes after dredging.

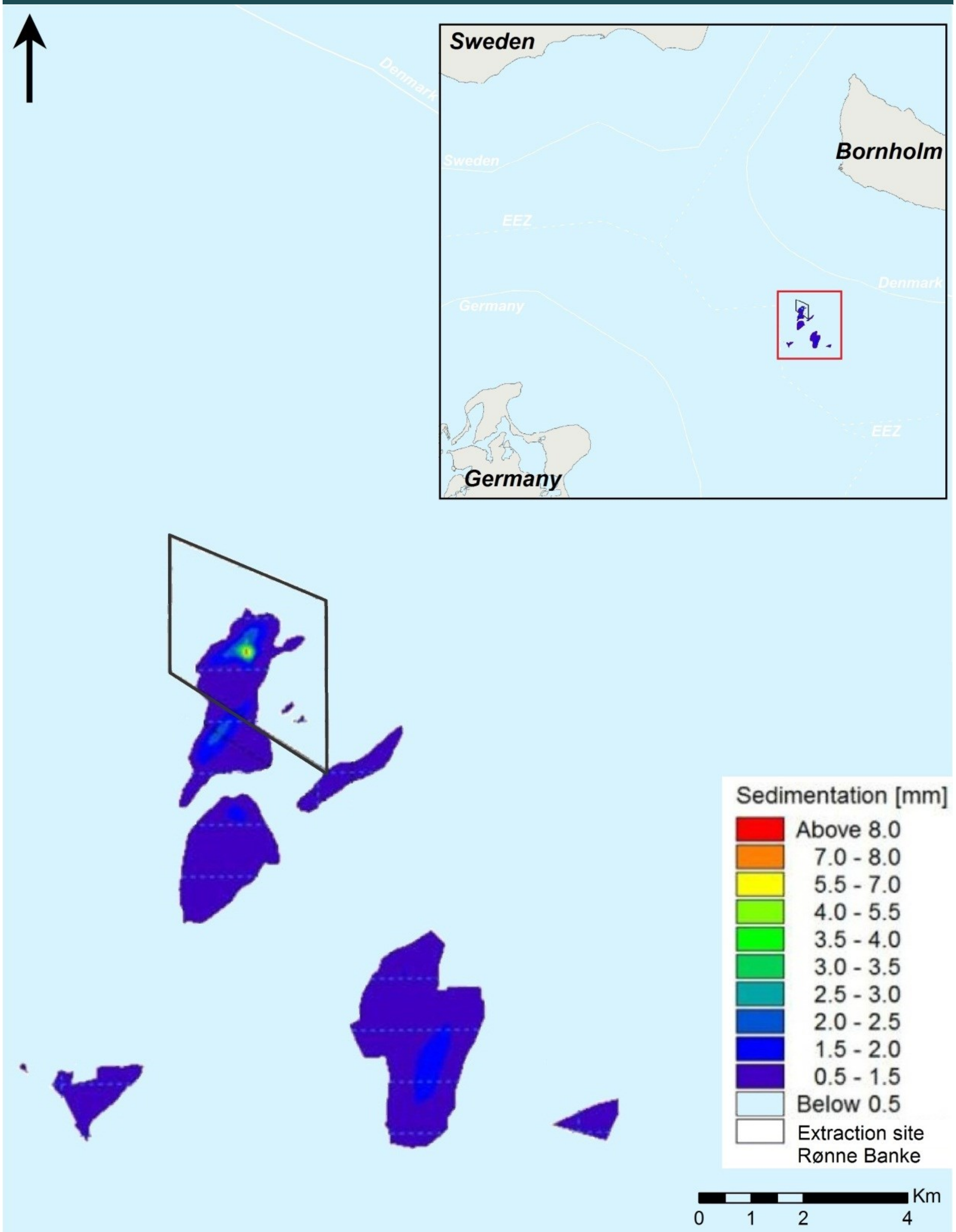
For both the summer and the full-year scenario, the maximum thickness of deposited material will be 8-9 mm occurring only locally within a 1 km distance from the source. At a distance of 1-5 km from the source, the deposition for the one-year scenario is predicted to amount between 1 and 2.5 mm. Deposition from the summer scenario hardly reaches this zone: only in a very small area west of the source, a deposition of 1-2 mm is predicted.

FIGURE 7.6.4 Deposition pattern for fine sediments at Kriegers Flak (The maximum deposition of sediment below 63 µm in mm; extracted from the modelling results considering a full-year scenario of dredging activity)



At Rønne Banke (see Figure 7.6.5), the dredging activity implies small areas with deposition of fine sediments in a thickness between 0.5 and 1.5 mm south-east of the dredging area. The small amount of deposition is due to the small volume of dredging and the clean nature of the sand. As with Kriegers Flak, the coarser sandy sediments all settle close to the dredger within the extraction area.

FIGURE 7.6.5 Deposition pattern for fine sediments at Rønne Banke (The maximum temporary deposition below 63 µm in mm for the full model year (2005)



The maximum deposition of sand (coarser particles) at Rønne Banke is estimated to be up to 10 cm locally within the extracted area just after the trailing suction hopper dredger has passed. Thereafter, the coarse sediment will be spread and incorporated into the local sediment.

The order of magnitude of the temporary maximum thickness of the fine sediment is about 1 mm in a limited number of locations south of the extraction area (see Figure above).

The differences between the extensions of the maximum temporary deposition show the effect of re-suspension due to the waves removing the sediment from the bed. It explains why the deposition patches of the maximum temporary deposition maps are larger, because they only show the maximum deposition at some point in time. The possible sand extraction in the Danish part of Rønne Bank may give rise to a temporary and very small dispersal of spilled sediment into German waters. The effect is temporary and will not lead to significant impacts on the environment.

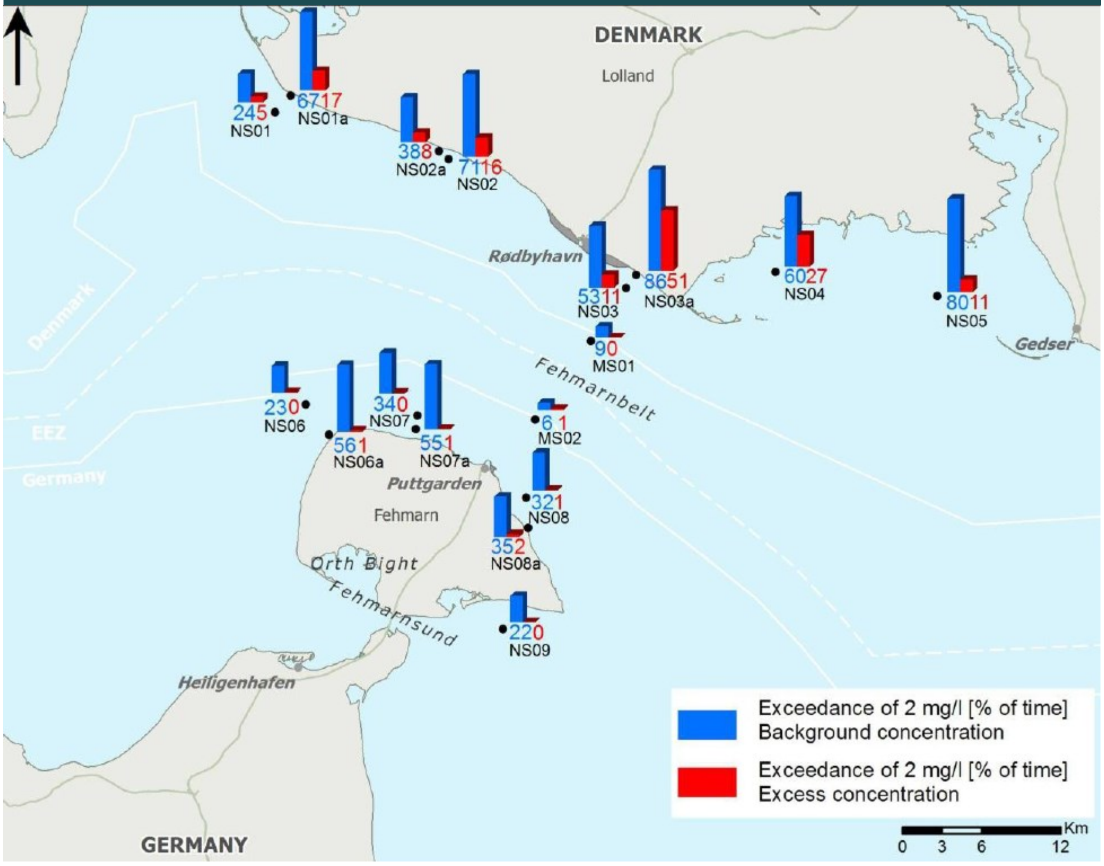
7.6.4 Transboundary Impacts on Sediment and Seabed form between Germany and Denmark

Suspended sediment concentrations and sedimentation in Fehmarnbelt are affected by the sediment spilled during dredging and backfilling of the tunnel trench, dredging of work harbours and access channels and earth works related to portals, ramps and landscaping. The suspended sediments affect water transparency and bathing water quality, while sedimentation can affect the seabed conditions within German and Danish borders. The indirect impacts of sediment spill on benthic flora and fauna, fish, marine mammals and birds are addressed in later sections below.

The sediment is spread by a complex series of events. Sand and coarser fractions settle to the seabed close to the dredger and mostly remain there. The silt fraction spreads in a sediment plume and gradually settles up to 20 km from the dredging site. Waves and currents during storms cause the silt to re-suspend and spread further. The clay fractions remain in suspension for a long time and only settle in areas with quiescent hydrographical conditions such as the Arkona Basin, Mecklenburg Bight and in the deeper waters in the southern Lillebælt within Danish borders.

Figure 7.6.6 shows the time- bound changes of the actual sediment concentrations in a graphical way. The blue columns show the percentage wise exceedences of the background level of 2 mg/l by natural causes. The red columns show the percentage-wise exceedences caused by the anticipated dredging works due to spill in the entire construction phase at all measurement stations. All comparisons are made at the water depth, where the measurements are made.

FIGURE 7.6.6 Comparison between exceedence time of 2 mg/l for the background and the excess concentrations at the measurement stations during the entire tunnel construction period



The comparison shows that the frequency of background concentrations above 2mg/l is always at least 5 times larger than the excess frequency due to dredging when the entire construction period is considered. The excess frequency is largest along the coast of Lolland (measurement station NS01a-03a) and inside the Rødsand Lagoon (measurement station NS04 and NS05). Along the coast of Fehmarn the excess concentration only exceeds 2 mg/l for less than 1% of the time at a few stations.

Except for the period where the dredger is actually dredging in the nearshore zone, the high concentration events will occur when the hydrodynamic conditions are rough. This means that at least part of the time where the visibility limit is exceeded by excess concentration it is simultaneous with natural re-suspension events.

It will therefore be hard to detect a visual difference in the appearance of the water, and thus the effect of dredging is considered insignificant in such cases. In Rødsand there will only seldom be sediment plumes from dredging and thus any concentrations seen here are the result of re-suspension. Since re-suspension of natural material will happen at the same time as re-suspension of the dredged material the frequencies will not change much.

Seen from a “visual appearance” point of view, the natural frequency of sediment events with concentrations above 2 mg/l is so high that a slight increase in frequencies or concentration levels will not be detectable.

It is certain that, due to the highly variable hydrographical conditions in Fehmarnbelt, some of the sediment spilled in Danish waters will spread to German waters, and vice versa. This applies especially to sediments spilled in the central Fehmarnbelt. However, the studies do show that the areas potentially impacted by the suspended sediments are close to the coasts of Lolland and Fehmarn and are caused by the dredging activities near the coasts. Therefore, any impacts on water transparency and bathing water quality on the German side due to sediment spilled on the Danish side are considered minor to negligible, and vice versa.

Sand waves and seabed forms in Fehmarnbelt

Based on the described models of sediment deposition, the immersed tunnel has been assessed to cause impairments on a total of 989 ha of seabed forms within German and Danish territories. All impacts to the different types of seabed in this area are on a temporary time scale (less than the lifetime of the project of 120 years). No permanent loss of seabed forms is predicted. The total area of seabed forms within the local 10 km zone of the alignment is 16,293 ha, and the impacted area of bed forms (989 ha) therefore corresponds to 6.1% of the seabed forms within 10 km from the alignment.

All impacted types of seabed forms are expected to recover. The seabed forms will recover to their baseline conditions where they are dredged away for tunnel trench or will remain in the area with a minor-medium degree of impairment, due to dredging spill, causing a temporary change in their heights and lengths. The longest predicted recovery time is for the sand waves west of the alignment, which are expected to take 30 - 40 years to fully recover to their natural size due to their large size. For other areas of impacted types of seabed forms, the recovery time is shorter.

In the baseline study on seabed morphology made by Femern A/S, the influence of different types of seabed on the flow through the Fehmarnbelt was found to be insignificant. The above-mentioned changes to the seabed do not change this situation, and it is therefore assessed that the impacts on the seabed in the Fehmarnbelt, caused by the immersed tunnel, are insignificant.

The primary contribution to the impacts on the seabed morphology outside of the areas with the prominent bed forms is caused by the loss of seabed in the areas of the coastal reclamations, including the protection reefs. In total, they occupy 356 ha or 0.9% of the total seabed area within 10 km from the alignment. For the seabed morphology, this loss is considered insignificant.

In conclusion, the dredging activity connected to the immersed tunnel and the resulting sediment deposition has insignificant impacts on the seabed morphology in Fehmarnbelt.

The sedimentation of the spilled sediments does therefore not affect the sand waves, sediment stability or sediment movement in Fehmarnbelt.

7.6.5 Significance of Impact for Sediment and Seabed forms

The construction activities in Fehmarnbelt result in the partial destruction of seabed morphology in Fehmarnbelt and the spreading of fine sediments into Swedish waters. The modelling showed a deposition occurring within a total of 1,833 km^2 of the Swedish waters.

The suspended sediments are transported to the Swedish waters at concentrations of less than 2 mg/l at the surface and less than 10 mg/l at the seabed. The total deposition of fine sediments from the construction works in transboundary waters is less than 1 mm, which is less than 10% of the natural annual deposition in the Arkona basin. Therefore, the impact on deposition of sediments is classified as insignificant.

Concerning the impact on sand waves and seabed forms, the dredging activity connected to the immersed tunnel and the resulting sediment deposition has insignificant impacts on the seabed morphology in Fehmarnbelt, and no impacts in the remaining transboundary waters.

The result of the assessment can be seen in Table 7.6.3 below.

TABLE 7.6.3 Significance of transboundary impacts on water quality in the Baltic Sea, Norway, Germany and Denmark

		Impacts on sediment and seabed forms in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Sediment and Seabed forms	Seabed form	No	No	No	No	No	No	No	No	Ins	Ins
	Deposition of sediments	Ins	No	No	No	No	No	No	No	Ins	Ins

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.6.6 Mitigations

The dredging plan has been optimised in order to minimise sediment spill, and because of the insignificant impact of the planned activities, mitigation measures are not relevant. If major changes to the dredging plan occurs, it will be necessary to ascertain that the possible impacts have not changed seriously, primarily regarding the expected impacts in German and Danish waters.

7.7 COASTAL MORPHOLOGY

Coastal morphology concerns changes to a coastline and the adjacent seabed in terms of erosion and accretion. Such developments along a coast are caused primarily by the waves breaking at the coast.

A simplified description of the physical processes involved is that the breaking waves cause intense turbulence and coast parallel currents. The turbulence brings sediments at the seabed into suspension and the currents move the suspended sediments along the coast. If the rate of transport (also called littoral drift) along the coast increases, then erosion along the coastline will occur. Conversely, if the rate of transport decreases then accretion will occur. Thus, if the project causes changes in the wave climate at the adjacent coasts, it is possible that the project will impact the coastal morphology.

The following chapter describes the potential impacts from construction and operation of an immersed tunnel, including sand extraction (the dredging at Kriegers Flak and Rønne Banke), on the coastal morphology in Fehmarnbelt and the transboundary region.

7.7.1 Environmental Baseline

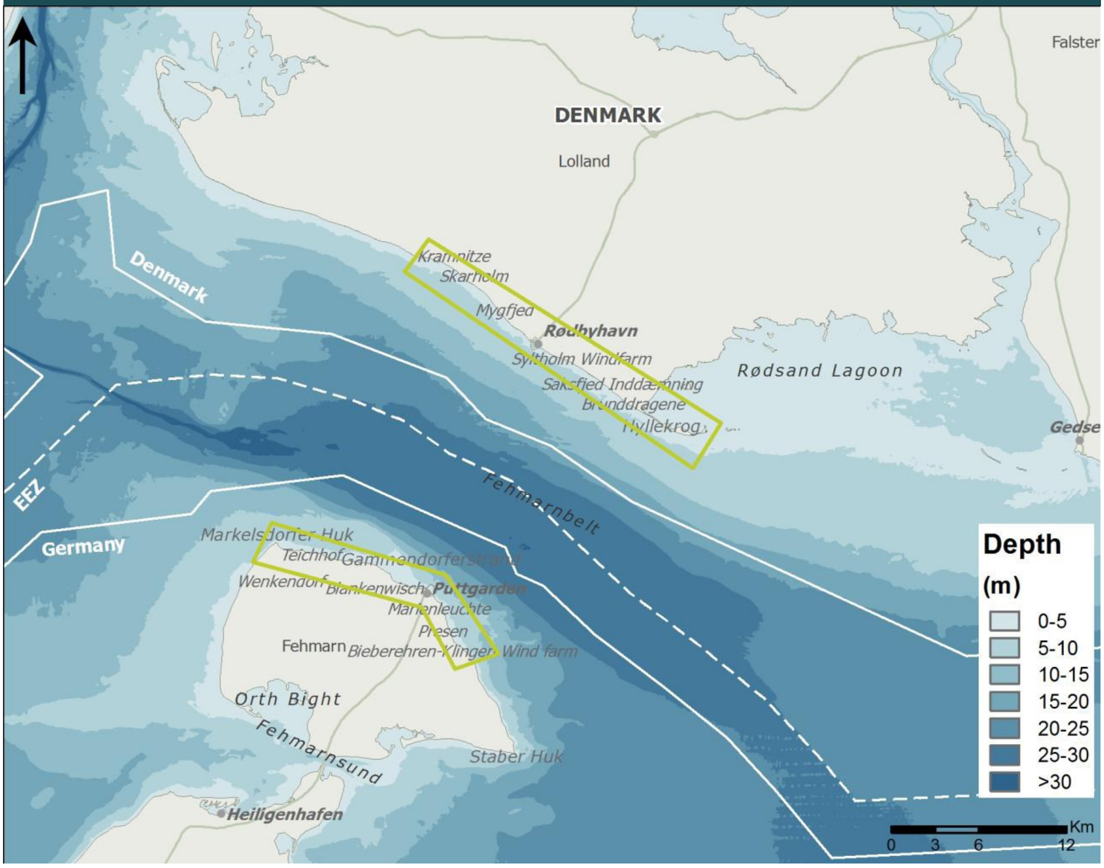
The impacts on the coastlines of Lolland and Fehmarn were assessed by quantifying the impacts by analysis of results from numerical modelling of waves, littoral drift and shoreline evolution. These modelling tools were calibrated and applied in the evaluation of the baseline conditions.

The impacts of the dredging at Kriegers Flak and Rønne Banke, causing sediment spill, were assessed in a desk study of the changes to the wave climate caused by the increased water depths in the dredged area and the extent of the area where the changes would be significant.

A detailed field study of the shorelines of Lolland and Fehmarn, the near coast bathymetry, and the seabed sediment composition has been carried out (Figure 7.7.1).

The baseline descriptions of Rønne Banke and Kriegers Flak are used in the assessment of impacts on coastal morphology in relation to sand extraction for construction and backfill of an immersed tunnel. It is noted that neither Kriegers Flak nor Rønne Banke has any coastline, since they are marine extraction sites.

FIGURE 7.7.1 Investigation areas regarding Coastal Morphology on Fehmarn and Lolland



Kriegers Flak

To characterise and classify the seabed sediment acoustic at Kriegers Flak, data were acquired by use of a side-scan sonar system. By integrating the acoustic data set and the ground truth data, the seabed material can be classified into sediment/substrate types following the classification system introduced by the Danish Nature Agency:

- Type 1: Sand: Areas comprised primarily of sandy substrates with variable amounts of ripples, etc. < 1% gravel and pebbles.
- Type 2: Sand, gravel and pebbles: Areas comprised primarily of sand with variable amounts of gravel and pebbles, and with few scattered stones < 5%.
- Type 3: Sand, gravel, pebbles and scattered stones covering 5 - 25%: Areas comprised of mixed substrates with sand, gravel and pebbles with variable amount of larger stones.
- Type 4: Stones covering approximately more than 25%: Areas dominated by larger stones (stone reefs) with variable amounts of sand, gravel and pebbles.

To confirm the initial classification, ground truthing at selected stations was performed in August 2011 using a Van Veen grab and video inspections. The seabed in the extraction area and the surrounding 500 m impact area is classified as substrate Type 1: medium-grained sand with an average grain size between 0.2 and 0.5 mm with some content of gravel and coarser fractions.

Recent dredging activities have taken place in the north-western part of the extraction and impact area leaving the seabed with scars and spill cones from the sand extraction activities. In these areas, deposits of gravel and cobbles have accumulated in a patchy pattern after the sand fraction of the resource has been extracted. The latter seabed type is in this context considered as an artificial substrate type as a result of human activities.

The sediment transport at Kriegers Flak has been estimated based on data on currents and waves. The current regime at Kriegers Flak is very weak and the current speed is below 0.2 m/s, 99.6% of the time. A current speed of 0.2 m/s is needed to initiate transport of sand at the seabed.

The wave action is also important with regard to sand transport processes. The predominant waves are from W to SW and from easterly directions. The main current direction is towards WSW, which is related to outward flow from the Baltic Sea. The inward flow causes E to SE-ward currents.

Rønne Banke

Previous sediment analyses at Rønne Banke indicate that the seabed sediment within the extraction area consists of well-sorted homogeneous medium sand. The baseline study indicated that the surface sediment is medium- to coarse-grained.

Video inspection of the seabed shows that nearly the entire seabed in the area is covered by sand with no or only very little indication of sand transport and seabed features derived from seabed transport. According to the classification system mentioned under Kriegers Flak, only substrate Type 1 has been recognised in the area. Sand ripples have only been recognised on side-scan data in a limited area to the southwest.

To the north of the area, recent dredging activity has taken place leaving the seabed with scars and spill cones from sand extraction activities. In the north-eastern part of the area, thin medium-grained sand covers the seabed, and late-glacial sediment beneath this thin sand cover can be seen at the seabed. In the southern area, the seabed is covered with medium sand with average grain size around 0.2 mm at deeper water levels.

However, it is evaluated that there are still significant uncertainties due to a lack of information about seabed characteristics. Also, computing transport capacities on the basis of characteristic depths, average seabed sediment characteristics, and characteristic wave and current conditions adds some uncertainty to the baseline description.

Importance

The importance is a measure for the value of the coast as a part of the natural environment and of the functional value of each coastal element.

Coastal elements/sections of the coast are assigned an importance level based on whether they:

- Provide regulatory conservation related to coastal morphology
- Have a recreational value
- Have an existing condition which is far from a natural state because of, for example, maritime structures such as harbours and coastal protection

Ranking the degree of importance to the coast and seabed component coastal morphology is summarised in Table 7.7.1.

TABEL 7.1.1 Importance for coastal morphology

Importance	Criteria
Very high	Coastal sections of Natura 2000 areas, where the coastal morphology is a part of the conservation objective. Coastal sections which are protected according to German legislation as special nature protection areas (Naturschutzgebiete).
High	Coasts with sandy beaches, sandbars, curved spits, barrier islands and coastal lagoons, which are not included under the category "Very high".
Medium	All other coastlines which are not heavily influenced by human activities, as mentioned under the category: "minor".
Minor	Coasts under the strong influence of human activities, such as port areas and stretches with dominant coastal protection without beach.

7.7.2 Project Pressures

The project works and activities which can affect the coastal morphology are the reclamations at the coasts of Lolland and Fehmarn and the sand resource dredging at Kriegers Flak and Rønne Banke. When extracted, sediment is spilled and is subject to transport determined by the hydrodynamic conditions. Fine sediments in the silt-clay fractions have a very low settling velocity and can be carried far away by the ambient currents.

Three pressures can affect the coastal morphology locally:

- Reclamations at the Lolland and Fehmarn coasts
- Protection reefs over the tunnel near the coasts
- The dredged approach channel for the work harbour on Lolland

The impacts on the coasts of Lolland and Fehmarn are caused by the reclamations including new beaches occupying part of the original coastline and blocking the natural transport of sediment along the coast. The effect of these structures is to interrupt the natural transport of sand along the coasts, the so-called littoral drift. If the littoral drift is stopped, then erosion will occur on the down drift side. The littoral drift is predominantly a function of the wave climate, which is a function of the wind conditions. The wind conditions are not affected by the project.

The reclamations and protection reefs, but also the access channel to the production facilities on Lolland, will cause changes to the nearshore wave field and thereby changes to the sediment transport along the coasts of Lolland and Fehmarn. However, no transboundary impacts are expected from this project pressure.

The only project activities which could possibly affect the coasts of other transboundary countries are the dredging at Kriegers Flak and Rønne Banke where sand extraction is planned to take place.

Pressures in relation to sand extraction at Kriegers Flak and Rønne Banke are:

- Dredging of sand from Kriegers Flak for backfilling of the tunnel trench
- Dredging of sand from Rønne Banke for concrete for the tunnel elements
- The changes in water depths at the two sites could change the wave climate, and if the wave changes reach the nearby coasts there could be an impact on the coastal morphology

According to the sand extraction plan for the immersed tunnel, 6 million m^3 of sand for the backfilling of the tunnel trench is planned to be extracted from Kriegers Flak and 1 million m^3 of sand for the tunnel element production is to be extracted from Rønne Banke. The construction period is estimated to be 6.5 years.

Dredging at Rønne Banke is planned to take place from the first year of the construction period until April in the third year of the construction period. Sand extraction at Kriegers Flak is expected to take place from the third year of the construction period and onwards until the period where backfilling is needed (e.g. end of construction period).

7.7.3 Transboundary Impacts for Coastal Morphology

In the following, the magnitude of impact from dredging at Kriegers Flak and Rønne Banke is described:

Kriegers Flak

The coast nearest to the extraction area is the coast of Møn, Denmark, which is located about 23 km towards WSW. The coast of Rügen, Germany, is 43 km towards south and the coast of southern Sweden is 40 km to the north.

Three issues are considered in the assessment of the possible impacts of the sand extraction on the coastal conditions:

- Does the lowering of the seabed impact the wave conditions in the extraction area?
- Will a possible impact on the waves have an impact on the adjacent coasts of Møn, Rügen and southern Sweden?
- Will the sand extraction directly undermine the coastal profile along the east coast of Møn?

The sand extraction will not undermine the coastal profile because of the long distance to the shore and the relatively deep waters (the water depth in the sand extraction area varies between 18 and 21.5 m) in the area between the coast of Møn and the extraction area.

The sand extraction at Kriegers Flak will, on the average, lower the seabed with about 1.0 m; i.e. from a depth of about 20 to 23 m to about 21 to 24 m. This approximately 5% increase in the water depth over the dredging area of 10 km^2 will have an insignificant impact on the wave conditions in the deepened area and absolutely no impact on the wave conditions more than 20 km away from the sand extraction area. This means that because of the distance, there will be no impacts either on the coastlines of Rügen in Germany or on the southern parts of Sweden's coastline.

Only a very small percentage of the waves along the coast of Møn will have passed the dredging area, as only about 4% of the waves come from the direction interval pointing towards the dredging area. It is therefore assessed that the dredging at Kriegers Flak does not change the wave conditions along the coast of Møn.

As a result, the wave conditions are not changed along the coasts of either Møn, Rügen, or southern Sweden and it can thus be concluded that the dredging at Kriegers Flak does not change the coastal morphology along these coasts. Therefore, there will be no transboundary impacts within the project area or in the transboundary region from activities at Kriegers Flak.

Rønne Banke

The closest coast to the extraction area at Rønne Banke is located about 30 km NE on the shore of Bornholm, Denmark. Rügen, (Germany) is 59 km away and the southern coast of Sweden is 67 km away from the extraction area. The assessment of the environmental impact of dredging at Rønne Banke on coastal morphology follows the same considerations as described for Krieger Flak. The impact from dredging at Rønne Banke can be expected to be smaller than from activities at Kriegers Flak because:

- The distance from the extraction site to the coastlines at Germany and Sweden are longer than from Kriegers Flak
- The dredging volume and period is smaller
- The sediment is expected to be very homogenous sand

Only a very small percentage of the waves along the coast of Bornholm will have passed the dredging area, as only a very small percentage (~5%) of the waves comes from the direction interval pointing towards the dredging area. It is therefore assessed that the dredging at Rønne Banke does not change the wave conditions or the coastal morphology along the coast of Bornholm.

The sand extraction at Rønne Banke will, on the average, lower the seabed with maximum 1 m (but will most likely be 0.5 m); i.e. from a depth of about 17 to 21 to about 18 to 22 m. This approximately 5% increase in the water depth over the extraction area of 9 km^2 will have an insignificant impact on the wave conditions in the deepened area and absolutely no impact on the wave conditions at a distance of 30 km away from the sand extraction area. Therefore, there will be no transboundary impacts within the project area or in the transboundary region.

7.7.4 Transboundary Impacts for Coastal Morphology between Germany and Denmark

The project structures and marine works which can affect the coastal morphology in Fehmarnbelt are, as mentioned, the reclamations at the Lolland (Denmark) and Fehmarn (Germany) coasts, protection reefs over the tunnel near the coasts and the dredged access channel for the work harbour on Lolland. The Lolland reclamation has been assessed to cause significant erosion of the coastline to the east of the reclamation and effective mitigation measures in the form of beach nourishment have been included in the project.

The Fehmarn reclamation may give rise to a small potential erosion of the coast, south of Marienleuchte (Germany) and here, too, mitigation measures will be implemented.

Under no circumstances will the reclamations on the Danish side cause changes to the coastal morphology on the German side, and vice versa.

7.7.5 Significance of Impact for Coastal Morphology

It can be concluded that the sand extraction at Kriegers Flak will have no impact on the coastal stability along any transboundary coasts, or at Møn, because of the distance. Similarly, there will be no impact on the coastal stability along the southern coast of Bornholm, at Rügen, or southern Sweden due to the sand extraction at Rønne Banke.

On the basis of the above assessments, it is concluded that construction and operation of an immersed tunnel does not have any transboundary impacts on coastal morphology (see Table 7.7.2).

TABLE 7.7.2 Significance of transboundary impacts on coastal morphology in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on coastal morphology in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Coastal morphology	Beaches/ Unprotected coastline	No	No	No	No	No	No	No	No	No	No
	Coastal protection	No	No	No	No	No	No	No	No	No	No
	Marine structures	No	No	No	No	No	No	No	No	No	No
	Special mor-phological features	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.7.6 Mitigations concerning Coastal Morphology

Mitigation measures reducing impacts on coastal morphology have been included in the assessed design of the immersed tunnel. Additional mitigation and compensation measures have been included in the project, following the impact assessment of coastal morphology. For instance, a new beach section in the land reclamation at Fehmarn has been included in the project as compensation.

Furthermore, planned additional mitigation measures include monitoring and new/improved coastal protection structures, if required, at Ohlenborgs Huk, Germany, to prevent potential erosion along this section of the coast.

7.8 PLANKTON

Plankton populations are generally not considered sensitive to disturbances from construction activities in coastal areas because of their short generation times, fast population changes in relation to environmental changes and the large exchange of water with adjacent areas.

Nevertheless, phytoplankton and zooplankton serve as the base of the food chain, supporting fish, bottom-living animals and other marine organisms. All fish and most invertebrates depend on plankton for food during their larval phases, and some species such as mussels continue to consume plankton their entire lives.

This chapter describes the potential impacts from construction of an immersed tunnel on plankton in the Fehmarnbelt and in the transboundary region. When referring to degree of impairment concerning decrease in Secchi-depth, the following criteria have been used, based on the natural impacts in relation to natural variation:

- Short-term impairment
  - > 50% ~ Very high
  - 30 - 50% ~ High
  - 20 - 30% ~ Medium
  - 10 - 20% Minor

- Permanent impairment
  - > 20% ~ Very high
  - 4 - 20% ~ High
  - 2 - 4% ~ Medium
  - 1 - 2% Minor

A reduction of 10% (half of the “natural” yearly variation) from the average Secchi depth is used in discriminating between negligible and minor impairments.

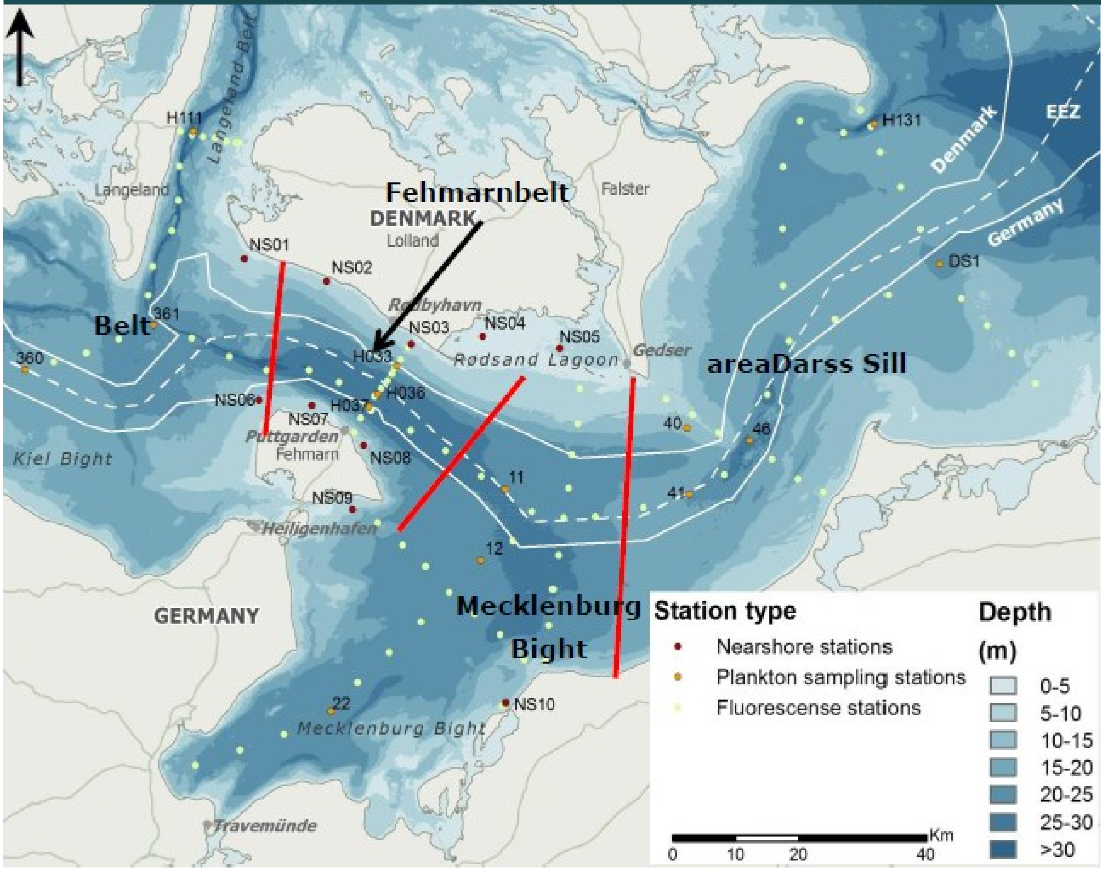
A 5% reduction in phytoplankton biomass has been set as the cut-off value for impairment on phytoplankton biomass, as applied to chlorophyll *a*, according to the methodology used.

7.8.1 Environmental Baseline

The field investigations of plankton encompass the monthly monitoring cruises covering an area from the southern Great Belt in the west, to east of the Darss Sill and also including the Mecklenburg Bight. Within this area, 12 offshore stations (14 for the chlorophyll *a* [chl-a] parameter) and 10 near-shore stations across the investigation area were visited on a monthly basis (see Figure 7.8.1). Data was collected during a two year investigation period from 2009-2010, and relevant historical data was analysed. It incorporated modelling of pelagic biology and supporting information on hydrographical and chemical conditions from modelling and survey cruises from other research results.

The spatial distribution of chl-a, the taxonomical composition and biomass of phytoplankton, meso-zooplankton (0.2 → 2 mm) and macro-zooplankton (jellyfish) communities, as well as the phytoplankton production were some of the biological parameters determined. Feeding rates of jellyfish and the predation impact on meso-zooplankton were investigated in summer 2009 and 2010. Nutrients, oxygen and turbidity were also measured.

FIGURE 7.8.1 Stations sampled in the Fehmarnbelt for water quality, plankton and jellyfish



Note: Stations include 10 near-shore stations (NS01-NS10, dark red), 12 „water quality and plankton" stations (orange dots with associated numbers) and 110 fluorescence and oxygen stations (bright yellow). Red lines separate the investigation area into four subareas: Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill when analysing the data

The methods applied for the sampling of water, filtration, conservation of samples, and analyses of samples and data followed accepted international guidelines – especially the HELCOM Combine Manual (HELCOM 2007), where applicable. The assessment methodology relies extensively on dynamic models, including Hydrodynamic Models, Sediment Model and Water Quality Models.

The release of toxic substances and oxygen demand during dredging are assessed using Monte-Carlo analysis based on distribution functions of dredging spill, of toxic concentration in sediments, of release rates and of current speed (i.e. dilution). Calculated concentrations are compared to EU Environmental Quality Standards (EQS) and Danish Water Quality Criteria (WQC). For oxygen, calculated oxygen demand was subtracted from background concentrations, and the resulting concentration was compared to internationally accepted criteria for minor, high and very high levels of oxygen deficiency (4 mg O_2/l, 2 mg O_2/l, 1 mg O_2/l).

Importance

The importance of the plankton organisms has been defined by the functional value of the environmental components, phytoplankton, meso-zooplankton, and jellyfish in the Fehmarnbelt area. Since these biological components, as well as the environmental component water quality, are not protected by any international legislation or conventions, and none of the plankton species are adopted on any "Red Lists", a two-level scale of importance, special and general, is appropriate for these components.

Areas of special importance have been delineated by a 6 m depth contour. Depth-integrated primary production and plankton biomass increase with water depth. At water depths larger than 6 m the water column production is twice as high as the production at water depths below 6 m. Areas with a depth below 6 m have consequently been assigned as having general importance.

7.8.2 Project Pressures

Four pressures are related to the construction and operation of an immersed tunnel in relation to plankton:

- Suspended sediments (construction)
- Sedimentation (construction)
- Release of toxic substances (construction)
- Land reclamation (construction/operation)

During construction, spill from dredging operations will influence light penetration (measured as Secchi depth) that in turn affects primary production, phytoplankton biomass and composition, and zooplankton production. Furthermore, suspended sediments can bury resting eggs of copepods and potentially affect recruitment of copepods affecting the composition of the zooplankton community.

Other pressures on plankton relates to the release of toxic substances, which can potentially harm plankton organisms, and land reclamation, which leads to loss of pelagic habitats. Land reclamation is, however, only relevant within the project area and not in the transboundary region. Furthermore, land reclamation is the only pressure having permanent impacts, while the others have temporary impacts.

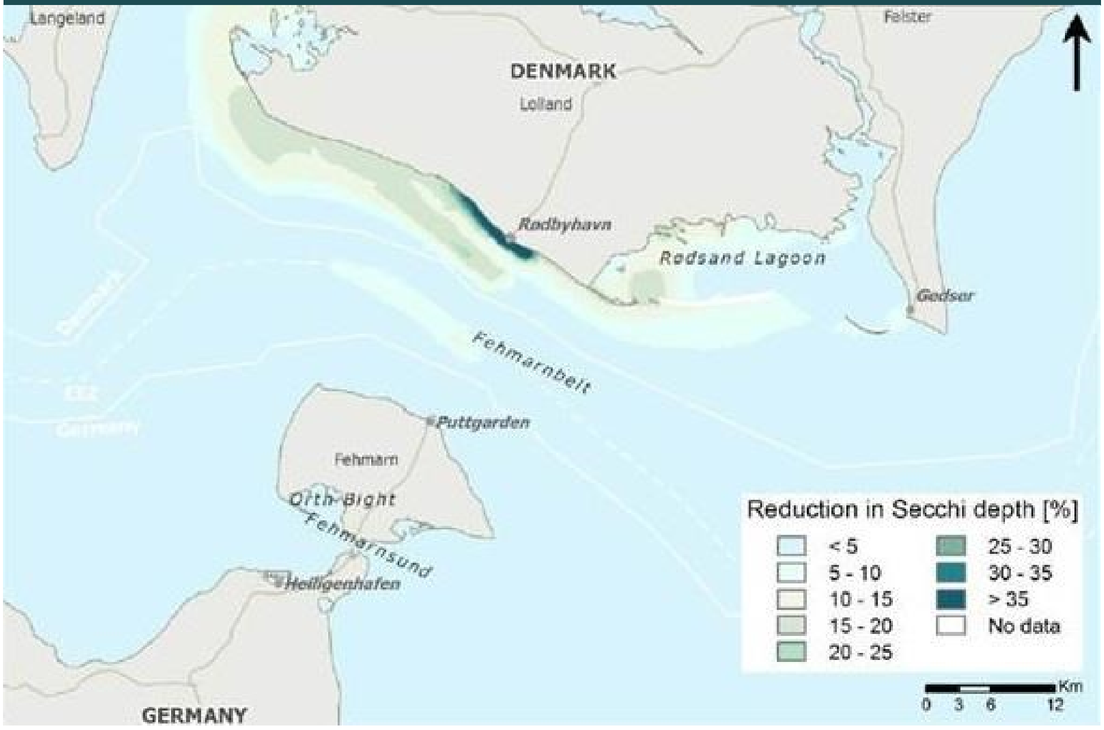
7.8.3 Transboundary Impacts for Plankton

Phytoplankton
By increasing the concentration of suspended matter in the water column above the background level, sediment spill from the Fehmarnbelt dredging can have adverse effects on water quality, plankton populations and productivity. The most important effects of sediment spill derive from reductions in light penetration into the water column, thereby directly affecting transparency of water, i.e. quantified as Secchi depth.

As a result of dredging in the first year, the Secchi depth is planned to be reduced by up to 40% along the Lolland coast and up to 30% in Rødsand Lagoon. In the second year of the construction phase the effect on Secchi depth of sediment spill will decrease with smaller areas affected along Lolland, but with local reductions of up to 40 % in the Rødsand Lagoon. In the third year, only the Rødsand Lagoon is affected; and in the fourth year, baseline conditions of Secchi depths are planned to be fully restored. In German waters, only negligible reductions (< 10%) in Secchi depth are predicted, west of Puttgarden and in Orth Bight in 2016.

The reductions in Secchi depth correspond according to the methodology used, to minor, medium and high degree of impairment in year 0 and 1; minor to medium impairment in year 2; and minor impairment in year 3, depending on the area. In German waters, reductions in the yearly averaged Secchi depths will not exceed 10% at any location, meaning that impacts are assessed as negligible both at local and transboundary levels (Figure 7.8.2).

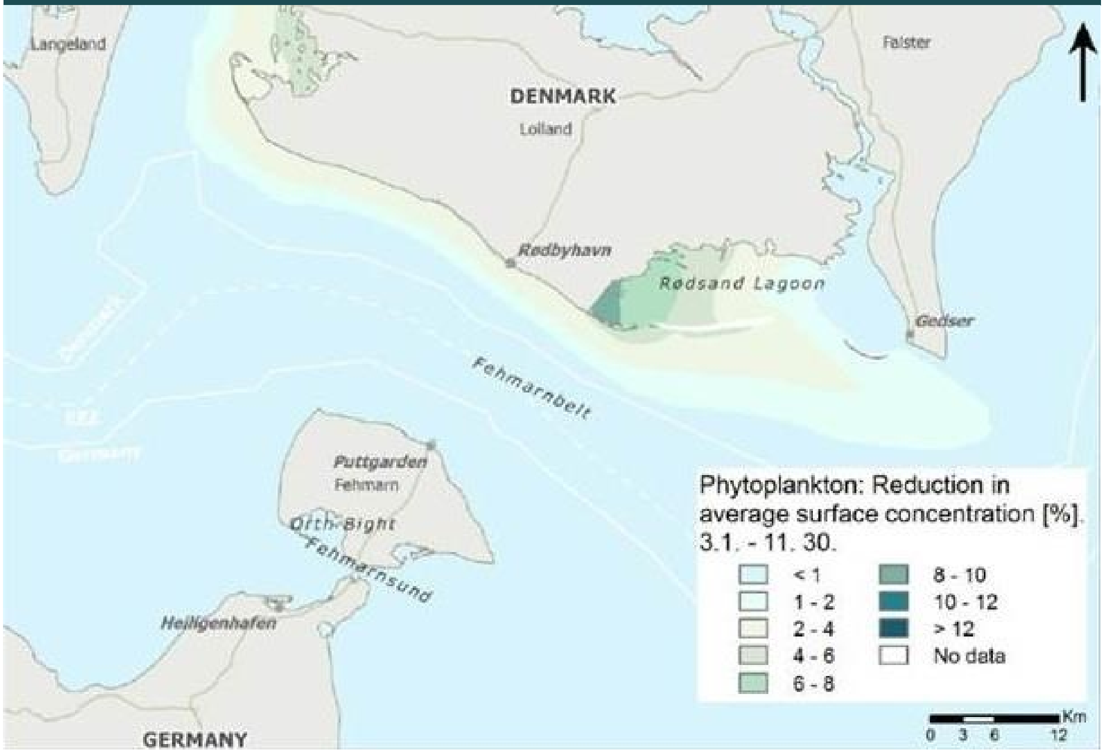
FIGURE 7.8.2 **Modelled reduction in Secchi depth due to dredging within the first two years of construction period**



Chlorophyll *a* is an important light-harvesting pigment that occurs in all algae, and is therefore a much used surrogate measure of plankton algal biomass. Dredging works carried out in the second year of the construction period will lead to reductions in phytoplankton biomass varying between 10% in the western part of Rødsand Lagoon, and 1 - 4% reductions along the Lolland coast. In these areas, concentrations are low even under baseline conditions. Chlorophyll *a* varied spatially under baseline condition, with the lowest concentrations in Rødsand Lagoon and along the Lolland coast, while the highest concentrations were modelled in Mecklenburg Bight and towards Kieler Bight.

The modelled reductions of phytoplankton biomass in areas with water depth > 6m correspond to a minor local degree of impairment, since it is below 5% in every year of the construction phase. Because of the local character of the impact, no transboundary impacts are assessed to occur.

FIGURE 7.8.3 Modelled reduction in biomass of phytoplankton during dredging works for tunnel within the first year of the construction period



Release of nutrients from dredged and spilled sediments will be very low and will not contribute to increased growth of the phytoplankton.

Chlorophyll *a*, phytoplankton biomass and pelagic primary production are, structurally and functionally, tightly linked and therefore the spatial distribution and the relative reduction in concentration and growth rates caused by sediment spill show almost identical patterns for these parameters.

The potential for additional sedimentation of phytoplankton is limited to very small areas and will only occur during spring bloom. Accumulated over a year, the sedimentation may increase locally by up to 1 - 2%, but in the entire assessment area the increase in sedimentation will not exceed 0.01%. Because reduction in primary production is very low (reflecting a very limited reduction in light availability, see Figure 7.8.3), changes in phytoplankton composition are highly unlikely.

Under maximum dredging intensity of one dredger (5000 m^3/d) concentration of persistent organic pollutants (PCB, DDT, PAH, TBT) and heavy metals are not predicted to exceed the environmental quality standards (which have been set to protect the marine environment), not even in the sediment plume near the vessel. More likely, increases in concentrations of toxic substances will be several orders of magnitude below current environmental quality standards. Therefore, the impact on phytoplankton from toxic substances released from the sediments is assessed as insignificant. For more information see section 7.5 on water quality.

The immersed tunnel will lead to a loss of pelagic habitats, due to land reclamation and protection reefs covering 355 ha of seabed in shallow areas. The loss of pelagic volume can be estimated to approximately 9,900,000 m^3. More than 90% of this volume loss is confined to shallow waters of low importance for plankton.

The assessment of changes in the hydrographical regime shows only very small and local effects on current speeds in the vicinity of the reclamation areas (see chapter 7.4). Larger scale effects on water column stratification could not be demonstrated; accordingly, neither water quality nor plankton will be permanently affected by the immersed tunnel.

Overall, permanent impacts of the immersed tunnel will be negligible, local, and insignificant, and it is assessed that no transboundary impacts will occur.

Zooplankton
Under baseline condition the biomass of zooplankton varies 10-fold within the model area - lowest in Rødsand Lagoon and highest west of Fehmarn - depending on the biomass of the phytoplankton. According to the modelled results, the indirect effect of suspended solids on zooplankton will be very low in year one, where sediment spill was highest, not exceeding 1% reduction in average biomass.

Reductions larger than 0.1% were confined to Rødsand Lagoon, along the Lolland coast and Hyllekrog. The impact due to indirect effects on zooplankton of suspended sediments is assessed to be insignificant, because reductions in biomass in all areas are below 1% of the baseline condition, and calculated over the entire model area, reductions are below 0.1%

Change in behaviour, feeding activity and rate of egg production can be affected in some zooplankton species at suspended sediment concentrations above 10 - 20 mg/l, while copepods that dominate the biomass in the Fehmarnbelt are much less sensitive (50 - 100 mg/l). The water column concentration of additional suspended sediments in general is low (< 2 mg/l) in the Fehmarnbelt, except in coastal waters along Lolland, and in Rødsand, where the direct impact of suspended solids on zooplankton is assessed to be very low.

Recruitment of zooplankton (especially copepods) can be impaired if resting eggs in sediments are covered with 20 - 40 mm sediment for extended periods. Resting eggs produced in late autumn that settle in the tunnel trench will probably not hatch because of being buried under several centimetres of fine sand. Likewise, permanent burial of resting eggs will take place in the western part of Rødsand lagoon. The total area affected is 76 ha (Rødsand: 60 ha, tunnel trench: 16 ha). Compared to the total area of assessment (402,282 ha) the affected area is very small (0.02%) and the impact is assessed as insignificant. In addition, when resting eggs are produced in autumn the biomass of zooplankton is very low in Rødsand, indicating a very low production of resting eggs in this area. Also, given the large exchange with the adjacent areas, minor “deficits” in recruitment will be compensated by imports from the Great Belt and the Western Baltic Sea.

In summary, three impacts related to dredging affect zooplankton; direct burial of eggs, and direct and indirect effects of suspended sediment on growth. All impacts are assessed to have a minor degree of impairment, and collectively they are assessed to be insignificant for the zooplankton community. All impacts are restricted to the project area, and no transboundary impacts are expected.

7.8.4 Transboundary Impacts for Plankton between Germany and Denmark

The project pressures which could affect plankton and thereby potentially impact the Danish and German territorial waters are:

- Suspended sediment
- Sedimentation
- Release of toxic substances (construction)
- Land reclamation

Phytoplankton
High concentration of suspended sediments (> 10 g/m^3) can lead to an increased sedimentation of phytoplankton, provided that phytoplankton cells are ”sticky” and that they occur in high concentrations (> 300 mg/m^3). Such situations only occur during the spring bloom in the Fehmarnbelt.

The criteria for aggregation between phytoplankton and sediment spill and subsequent phytoplankton sedimentation are met along Lolland coast for a 6 - 7 day period in late March.

Assuming that all phytoplankton biomass in these areas aggregate with suspended sediments and settle, approximately 14 t organic carbon will be taken out of the water column and added to the seabed.

Under baseline condition where no sediment spill occurs, 8.8 t organic carbon will sediment in "aggregation" areas along the Lolland coast; but measured over an entire year, differences between the baseline situation and the construction of an immersed tunnel in sedimentation are very small. For the entire investigation area the difference in accumulated sedimentation is well below 0.01 %.

Overall, the impact on phytoplankton is considered to be insignificant. Furthermore, it takes place only along the coast of Lolland, and therefore no transboundary impacts will occur on phyto-plankton between Germany and Denmark.

Zooplankton

Production and biomass of zooplankton depend, among other things, on availability of food (primarily phytoplankton). Thus, reduction in food concentration, mediated through shading from suspended sediments, can lead to reduction in growth and biomass of zooplankton (i.e. an indirect effect).

Three impacts related to dredging affect zooplankton; direct burial of eggs, and direct and indirect effects of suspended sediment on growth.

The impact due to indirect effects on zooplankton of suspended sediments is assessed as being insignificant, because reductions in biomass in all areas is below 1% of the baseline condition; and measured over the entire model area, reductions are below 0.1% as described above. The impact is restricted to the local zone, and it is therefore assessed that no transboundary impacts will occur on zooplankton between Germany and Denmark.

7.8.5 Significance of Impact for Plankton

As described above, most of the pressures have an insignificant impact on plankton. According to the methodology used, plankton communities are assessed to be impaired to a minor degree during the first year, which is the year of most intense dredging activity. The assessment showed that the effects will only appear in the Fehmarnbelt region, and therefore only insignificant transboundary impacts are expected to occur between Denmark and Germany, and no trans-boundary impacts on plankton outside the project countries have been identified for an immersed tunnel (Table 7.8.1).

TABLE 7.8.1 Significance of transboundary impacts on plankton in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on plankton in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Plankton	Phyto-plankton	No	No	No	No	No	No	No	No	Ins	Ins
	Zooplankton	No	No	No	No	No	No	No	No	Ins	Ins

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.8.6 Mitigations concerning Plankton

No mitigations have been found relevant to plankton, as the impact from an immersed tunnel is assessed as insignificant.

7.9 BENTHIC FLORA

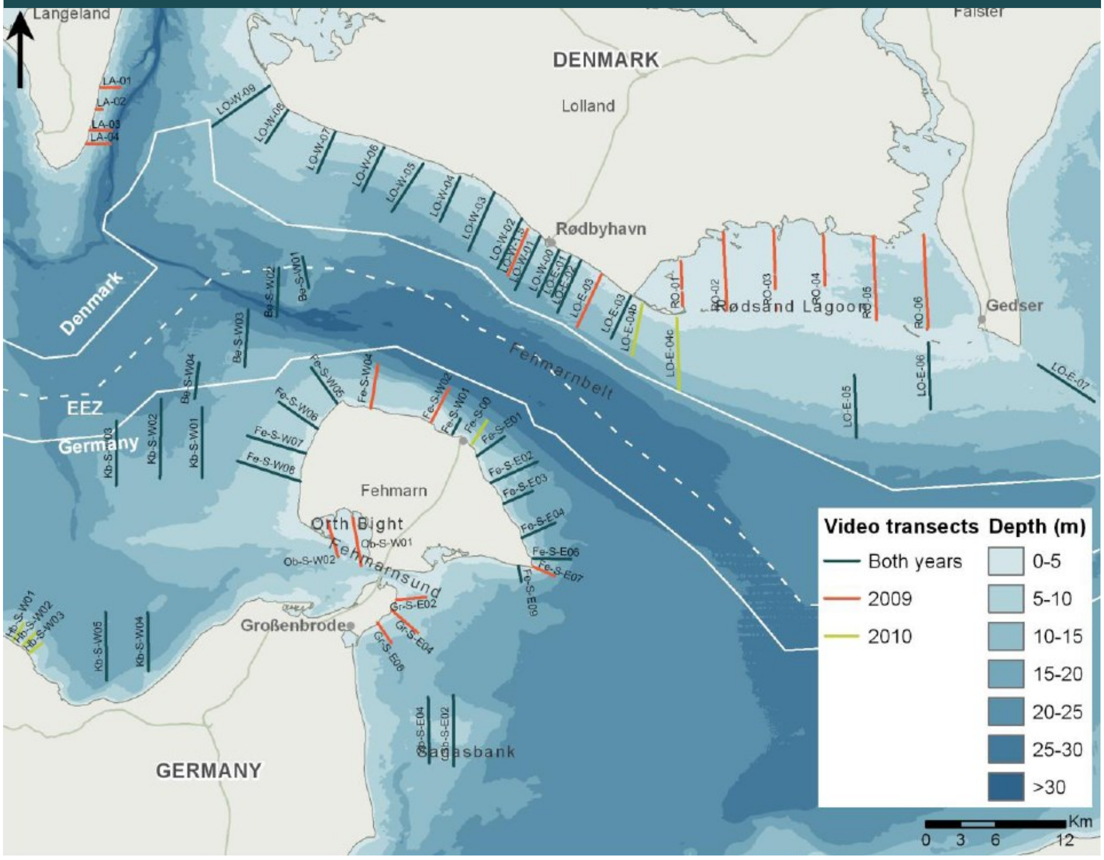
Benthic vegetation is a valuable part of the coastal ecosystem due to its function as a three-dimensional habitat as well as a nursery, breeding or feeding ground for invertebrates and fish (and, to a lesser extent, for birds and marine mammals). The habitat function of vegetation is dependent on the complexity and longevity of their key species as well as the size and coverage of the habitat itself.

The following chapter describes the potential impacts from construction of an immersed tunnel on the benthic flora in the Fehmarnbelt and transboundary region.

7.9.1 Environmental Baseline

The field study covers macro-algal and flowering plant communities. During the two years (2009 - 2010) of baseline investigations a total of eight benthic plant communities were identified. These consisted of five hard-bottom macroalgae communities, two soft-bottom communities with flowering plants and one mixed algae-flowering plant community. The investigation area can be seen in Figure 7.9.1.

FIGURE 7.9.1 Investigation area with position of video transects



Areas covered by the key communities were estimated by combining the map of predicted benthic vegetation distribution (GAM modelling for macroalgae and angiosperms) with the identification of key communities, which were determined at all sampling sites in 2009. Because the 2010 data confirmed the distribution of those communities, the community map was not updated.

In 2009, the programme consisted of the following investigations from mid-June to the end of August:

- cover, biomass and spatial distribution of key macroalgae communities
- cover, biomass, shoot density (only eelgrass, *Zostera marina*), depth limit and spatial distribution of flowering plants (angiosperms)

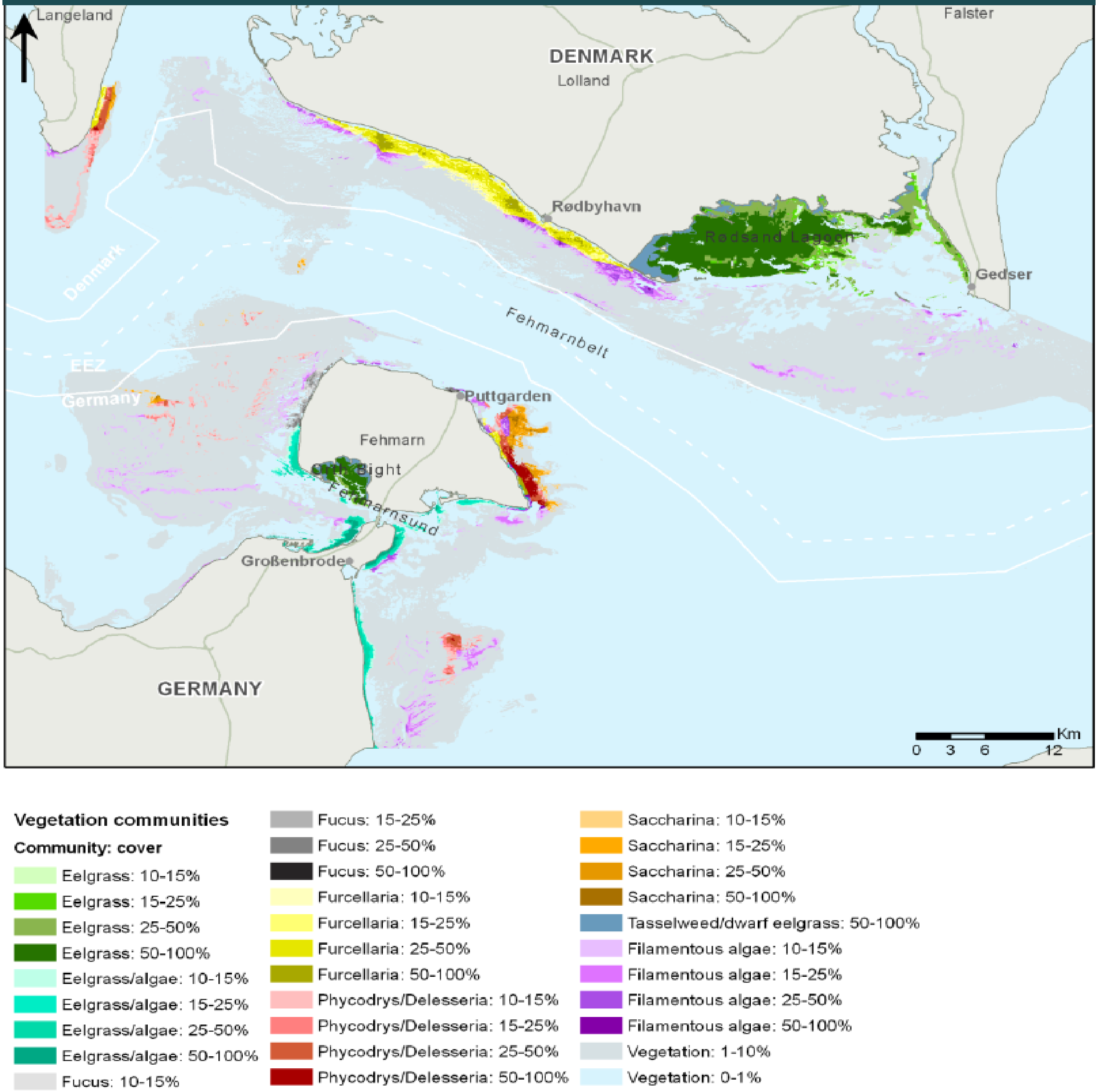
In 2010 the programme was optimised, and the programme then included the following investigations:

- cover, biomass and spatial distribution of key macroalgae communities
- additional biomass sampling of key macroalgae communities and eelgrass communities in winter and spring 2010
- cover and biomass of key macroalgae communities in reference areas

Vegetation cover and depth distribution were assessed by video recording and by in situ observations by divers. Within predefined depth intervals, divers collected samples for species determination, biomass analysis and shoot density (only for eelgrass).

Key communities have only been assigned to areas with benthic vegetation cover > 10%. In some areas macroalgae and angiosperms were predicted in the same area due to occurrence of mixed sediment. In such areas an eelgrass/algae community was assigned. Figure 7.9.2 shows the distribution of the eight key communities in the Fehmarnbelt.

FIGURE 7.9.2 **Distribution of algae and flowering plants in the Fehmarnbelt**



The five hard-bottom (macroalgae) communities were:

- Fucus community (bladder wrack)
- Furcellaria community (red seaweed)
- Phycodrys/Delesseria community (sea oak/sea beech)
- Saccharina community (sea belt)
- Filamentous species community

Many sites within the study area showed a dominance of filamentous, opportunistic algae (the filamentous algae community). The species composition and abundance of this group varies greatly between sites and depths. No single species can be listed as key species.

The two soft-bottom (angiosperm) communities were:

- eelgrass
- tasselweed/dwarf eelgrass community

The two flowering plant communities (eelgrass, tasselweed/dwarf eelgrass) were widely distributed within the soft-bottom dominated areas of western Rødsand Lagoon and Orth Bight. Due to the soft-bottom and sheltered conditions in these areas, both communities occurred with high coverage (> 50%). Both areas are part of different Natura 2000 areas (Rødsand and Eastern Kiel Bight).

The eelgrass community also occurred in very low densities along the western part of the Lolland coastline and in some very small spots along the north coast of Fehmarn. The high exposure and mixed sediment in these areas prevent high coverage for this community type here.

The eelgrass community was also located outside of the sheltered bays along the south and south-west of Fehmarn, east and west of Wagrien and south of Großenbrode with coverage of 25 - 50%. In these areas the eelgrass community was associated with different macroalgae communities, normally filamentous algae, which formed the last of the eight communities, the eelgrass/algae community. The areas for this community are partly included in different Natura 2000-areas.

Along the coast of Lolland, including the vicinity of the proposed alignment area (approx. ± 10 km), the dominating benthic vegetation was the Furcellaria community and the filamentous algae community. Due to limited availability of hard substrate, the total cover of these two communities ranged between 15 - 50%. Only in restricted areas with sufficient hard substrate was the cover > 50%.

Along the east coast of Fehmarn, hard substrate was widely distributed. The amount of hard substrate increased with increasing distance from the proposed alignment. All five macroalgae communities occurred on the hard substrate. In shallow waters, the filamentous algae community was dominant, and the Fucus community occurred in small spots. The Furcellaria community was found at intermediate water depths, while the Phycodrys/Delesseria and the Saccharina community occurred in deeper areas.

Both communities were widely distributed in very high densities, especially at the south-eastern part of the coastline (approx. 4 km away from the alignment) belonging to the Natura 2000 area Staberhuk.

Along the north coast of Fehmarn, west of the proposed alignment (e. g. ± 10 km), the cover of benthic vegetation was low due to lack of hard substrate. Stones are found in a narrow stripe along the whole coastline, although in low density. In some of these stony areas the stones are covered by the Fucus community, particularly in a small area 0.5 km west of Puttgarden harbour and on the west coast of Fehmarn (approx. 10 km west of the proposed alignment area).

In deeper areas, a high dominance of blue mussels occurred and only filamentous algae were located there. Below 8 - 10 m water depth the Phycodrys/Delesseria and the Saccharina community covered the patchy distributed stones. The Fucus community had the highest cover (with 25 - 50% coverage) of all the communities found at the west coast.

Within the deeper part of the Fehmarnbelt most areas are unsuitable for vegetation (sand and silt bottom). It is only within the western part where an area with scattered hard substrates is located. These stones were covered with the Phycodrys/Delesseria and the Saccharina community down to about 20 - 21 m, but total coverage did not exceed 25% due to the scarcity of suitable substrate. The area is part of the Natura 2000 area of the Fehmarnbelt.

Along the coastline of Langeland, the Furcellaria and the Phycodrys/Delesseria community were the dominant vegetation forms. At the lower depth limit the Saccharina community occurred within a small stripe. The algae cover was between 25 and 50%. This area is part of the Natura 2000 area, Langeland.

At Sagasbank (10 km south of Fehmarn) the Phycodrys/Delesseria and the filamentous algae community were distributed with up to 50% coverage in the central part. This area is part of the Natura 2000 area, Sagasbank.

A total of 63 macroalgae taxa were identified; including 15 green algae, 23 brown algae and 27 red algae species. 16 of the species are listed in the German Red List of the Baltic Sea. None of the species are red-listed in Denmark.

Species diversity at sample sites showed a bell-shaped pattern with depth. The lowest diversity was found in the deepest growing Saccharina community. The highest diversity was found in the community occupying the intermediate depths: Phycodrys/Delesseria. The mean species richness was only marginally lower in the Fucus and Furcellaria communities, respectively, which occupy the more shallow depths. Species diversity was also low in the filamentous species community, which is characteristic for the very shallow water.

Importance

The importance of benthic flora has been determined according to a 4-point scale (very high, high, medium, or minor). The classification has been based on the functional value of the benthic vegetation for the ecosystem. Benthic vegetation is a valuable part of the coastal ecosystem due to its function as a nursery, breeding and feeding habitat for many species.

Areas with a coverage of more than 50 pct. of the eelgrass, *Fucus*, tasselweed/eelgrass and eelgrass/algae communities have been classified as having very high importance. Therefore, large parts of the Rødsand Lagoon and Orth Bight have been assessed as having very high importance.

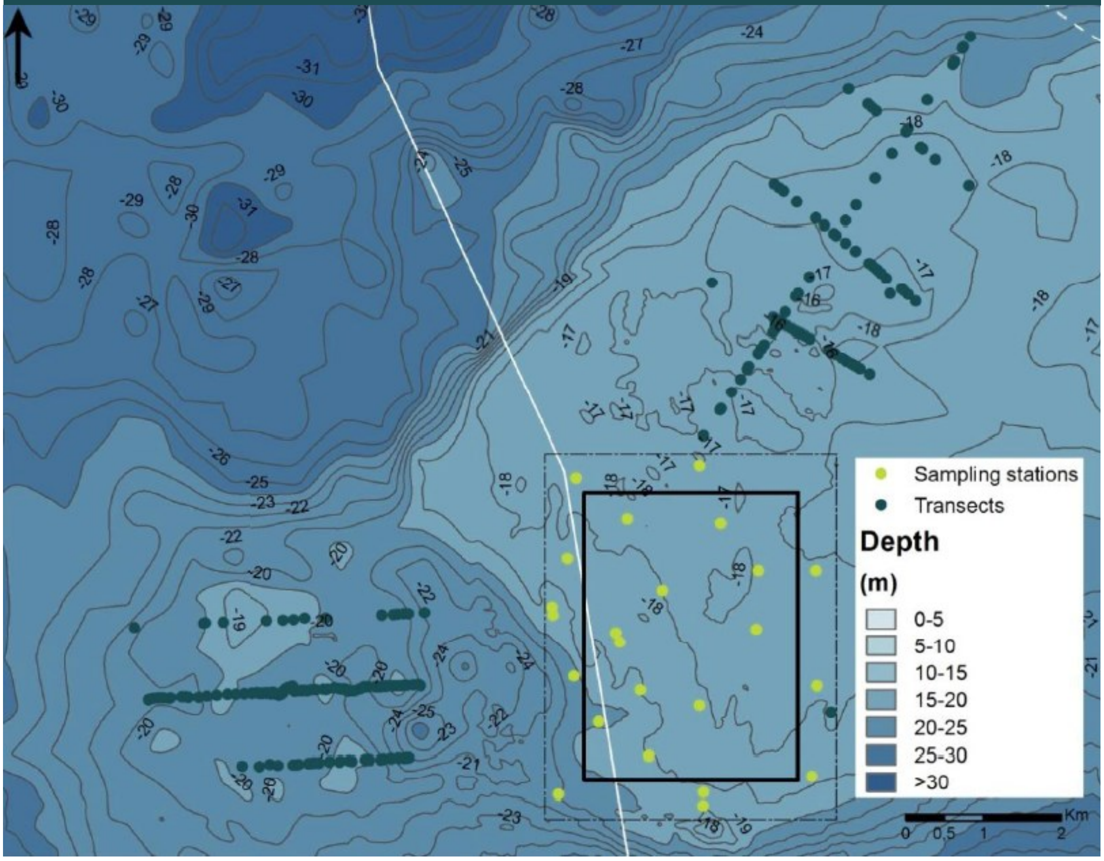
Areas with 25 – 50 pct. coverage of the above mentioned communities, and the *Furcellaria*, *Phycodrys*/*Delesseria* and Saccharina communities, have been classified as having high importance. *Furcellaria* is most aboundant along the Lolland coast and the *Phycodrys*/*Delleseria* and *Saccharina* communities are most abundant along the Fehmarn coast, east of the alignment as seen on figure 7.9.2.

Communities covering more than 10 pct. but not covered by the very high or high criteria's have been assessed as being of medium importance. Areas with a coverage of less than 10 pct. benthic vegetation have been assessed as having minor importance.

Investigations at Rønne Banke and Kriegers Flak

Video observations of flora and seabed structure at Rønne Banke were conducted as part of the sampling of the benthic fauna at the same 20 sampling stations (see chapter 7.10). Each station was recorded for one minute and videos were analysed for the presence of benthic flora. Macroalgae are associated with hard substrate at water depths less than 20 - 25 m (the photic zone). No macro algae, seagrasses or visible concentrations of microalgae (at the seabed surface) were observed in the impact area at the sampling stations. Because the water depths in connecting areas are less than 20 m, investigations of flora outside the impact area have also been carried out. Observations were obtained along transects by video, which was attached to a boat travelling at a speed of 1.5 knots (Figure 7.9.3).

FIGURE 7.9.3 **Transects for flora observations outside the impact area and flora observations within the impact area at Kriegers Flak. White line indicates the Danish border**



7.9.2 Project Pressures

Eight pressures have been determined to have a potential impact on the benthic flora. Five of the pressures related to benthic flora are present in the construction phase and three during the operational phase:

- Suspended sediment (construction)
- Sedimentation (construction)
- Toxic substances (construction)
- Nutrients (construction)
- Construction vessels and imported material (construction)
- Additional solid substrate (operation)
- Land reclamation (operation)
- Drainage (operation)

During construction, an increased concentration of suspended sediment in the water reduces light availability for photosynthesis and growth of benthic flora, while sedimentation leads to physical stress, as sediment reduces the active surface area for photosynthesis and nutrient uptake.

Furthermore, benthic flora can be influenced if dredging activities cause concentrations in the water column to exceed environmental quality standards (EQS) for seawater, or if the nutrient loading is increased. During construction, increased ship traffic and imported material also increase the risk of an introduction of non-indigenous species.

Other relevant pressures during operation of an immersed tunnel include additional solid substrate, which can impact benthic flora communities in three ways: 1) introduction of hard-bottom macroalgae communities to areas previously dominated by soft-bottom communities, 2) increased risk of introducing new species and 3) increase in already existing macroalgae communities.

Moreover, freshwater outlets arising from the accumulation of water from the project structures during operation can result in an increased pressure on benthic flora. Land reclamation can also impact benthic flora directly, but, in the current project, the pressure from land reclamation only results in a local impact.

7.9.3 Transboundary Impacts for Benthic Flora

The magnitude of impact was analysed for the eight relevant pressures. Overall, an immersed tunnel will impact all vegetation communities and single vegetation stands, although most of the pressures will result in minor or no impact on the benthic flora.

The model simulations predict that the response of benthic flora to increased concentrations of suspended sediment is highest during the first two years of the immersed tunnel construction phase. During the succeeding years (two years after the end of construction) the benthic flora recovers to a state close to that of the reference situation with no sediment spill.

Along the tunnel trench, sedimentation is generally seen to be up to 0.5 - 1.5 cm (except for a few small locations with higher values, up to 8 cm) in a band of about 600 m on each side of the alignment centre line. This sedimentation originates from the coarser part of the spill (the sand). Deposition is also seen in the sheltered part of the Rødsand Lagoon with typical values up to 1 cm. Time series analysis for the Rødsand Lagoon showed that the sediments are re-suspended from time to time and therefore the overall thickness of deposited sediments will be reduced with time.

Overall, the immersed tunnel footprint affects 298 ha of benthic flora in an area with high to minor importance. Most of the impact (218 ha) is from permanent loss, due to reclamation areas, and only a smaller part (80 ha) is due to the tunnel trench and other temporary structures. Nearly all of the lost area occurs in Danish waters and EEZ waters (298 ha). In German waters, 0.22 ha are lost; in German EEZ waters, no area with benthic flora is lost. There are no areas lost in the transboundary region.

Impacts from other project pressures are assessed to be small or within natural variation, and benthic flora in the transboundary region will not be impacted during the construction phase or the operational phase.

Benthic flora at Rønne Banke and Kriegers Flak
No macro algae, seagrasses or visible concentrations of microalgae at the seabed surface were observed in the impact area at Rønne Banke. Previous investigations of Rønne Banke sand resources have shown very limited or no hard substrate at the seabed in the areas near the impact area. This was confirmed by the present studies. Hence, there is no expectation of finding benthic vegetation in the investigation area or in nearby areas.

Macroalgae were not observed within the impact area at Kriegers Flak, which consists of the extraction area plus a surrounding 500 m impact zone. Outside the impact area (along transects) only very few small macroalgae of the genus *Laminaria spp.* were observed. The very limited occurrence of macroalgae is most likely due to a lack of solid substrate on which the flora can grow. Other studies on flora at Kriegers Flak have shown that macroalgae are present in areas where there is hard substrate at depths shallower than 25 m. (Sweden offshore Wind AB 2007). At depths greater than 25 m, only very few algae were found. A thin layer of algae was observed on top of the sediment at most sampling stations. The layer probably consisted of a mixture of sedimented algae and benthic microalgae.

Since there are only very limited quantities of macroalgae present in the impact area at Kriegers Flak, or in its vicinity, the impact on the macroalgae from dredging activities will be negligible. The observed green thin layer, which most likely consisted of sedimented algae and benthic microalgae, will be lost when the seabed is extracted. The growth rate of small microalgae is very fast (hours-days) and the algae will consequently re-colonise rapidly after the extraction has ended. The impact on the microalgae is assessed as being negligible.

7.9.4 Transboundary Impacts for Benthic Flora between Germany and Denmark

The response of benthic flora to increased concentrations of suspended sediment is expected to be highest during the first two years of the immersed tunnel construction phase, which is the period when dredging will peak. During the succeeding years, the benthic flora is expected to recover to a state close to the reference situation with no sediment spill. The impacts on benthic flora biomass from suspended sediment are therefore temporary, and in combination with a relatively fast recovery (2 years after end of construction), impacts will not have significant long-term effects on the function of the local or regional ecosystem.

Sedimentation will affect 764 ha of benthic flora communities. Of this area, 65% is affected to a minor degree of impairment in Danish (284 ha) and German national waters (217 ha), while 32% is affected to a medium degree of impairment, and almost exclusively in Danish waters (244 ha). A high degree of impact appears exclusively in a very small area (10 ha) along the Lolland coast.

The impacts from sedimentation are distributed among most communities, but the *Furcellaria* and eelgrass communities are affected the most. The impacts on these communities are largely minor or medium. This level of impairment for macroalgae corresponds to sediment thickness between 0.2 – 1 cm. Such sedimentation thickness will not cause increased mortality and only a slight reduction in growth/biomass. Only the recruitment success will be reduced since hard substrates will be covered, thus reducing the possible settlement area for propagules. It is therefore assessed that the viability of the communities is not impaired. All macroalgae can balance the temporary failure of recruitment success within the subsequent reproduction periods, and the duration of the impact is limited to the construction phase.

Since the impact on benthic flora from sedimentation is temporary, it will not have significant effects on the function of the local or regional ecosystem.

As mentioned above, a total area of 298 ha of seabed with benthic flora is lost because of the construction- and structure-related footprint of the immersed tunnel. The degree of loss is assessed as minor for 90 ha, as medium (Furcellaria cover 10 - 50%) for 190 ha, and as high (Furcellaria cover > 50%) for 18 ha of seabed. Nearly all of the lost area occurs along the coast of Lolland. The loss of seabed covered by benthic flora along the Fehmarn coast is estimated to be 0.22 ha.

The total footprint of the immersed tunnel causes loss of the *Furcellaria* and the filamentous species communities. Most of the impacted area (208 ha) is dominated by the *Furcellaria* community.

The loss is mainly caused by structure-related permanent footprints (188 ha), and therefore not reversible. The 188 ha of lost *Furcellaria* community corresponds to 8% of the community in the Fehmarnbelt and to 5% of the occurrence in the assessment area. The area's loss will not threaten the existence of the community in the Fehmarnbelt, but is assessed to be significant for the functioning of the local ecosystem. This is because perennial macrophytes are important as habitat-structuring elements, contributing to the coastal primary production, O_2 production and creating habitats for associated flora and fauna.

With regard to solid substrate, 80 ha is added in the depth interval 0-20 m due to the structures of the immersed tunnel in the Fehmarnbelt. If all new solid substrate is colonised by macroalgae, with the same biomasses as found on natural rocks in the baseline study, the new area corresponds to 10% of the area and 7% of the biomass of the existing communities in the near zone (i.e. within 100 m of the alignment).This is a positive impact and, assuming that the same communities will be established on the new substrate, this will counterbalance the loss from the immersed tunnel footprint to some degree.

On the larger scale (e.g. over the entire Fehmarnbelt), the potential new communities will, however, not significantly change the functioning of the ecosystem as they only make up 1.5% or less of the existing area and biomass of benthic flora.

The impact due to changes in coastal morphology covers a total area of 8 ha. The main impact is on the *Furcellaria* community (6 ha) corresponding to < 1% of the *Furcellaria* community in the Fehmarnbelt. The impact due to changes in coastal morphology is therefore insignificant for the benthic flora communities.

7.9.5 Significance of Impact for Benthic Flora

Of the eight macro-algae communities identified, only one has been assessed to be impacted significantly as a result of loss of habitat caused by the footprint of the immersed tunnel. The impact on benthic flora from construction and operation of an immersed tunnel is only assessed to have a significant impact on the hard-bottom macro-algae *Furcellaria* community on a *local* scale (i.e. along Lolland's coastline). The area loss will not threaten the existence of the community in the Fehmarnbelt, but is assessed to be significant for the functioning of the local ecosystem of the Fehmarnbelt. This is because perennial coastal macrophytes are important as habitat-structuring elements, contributing to the coastal primary production, O_2 production and creating habitats for associated flora and fauna.

The *Furcellaria* community is common in the whole Baltic Sea area and is dominant or occurring frequently from Skagerrak to the Bothnian Sea. Therefore, the loss will not threaten the existence or function of the community in the Baltic Sea and no transboundary impacts will occur. In all other communities, the assessment is that there will be no impact from the immersed tunnel.

The construction and operation of an immersed tunnel is therefore considered to have no impact on benthic flora in the transboundary region (Table 7.9.1).

TABLE 7.9.1 Significance of transboundary impacts on benthic flora in the Baltic Sea, Norway, Germany and Denmark

Factor		Significance of impacts on benthic flora in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Benthic Flora	Hard bottom macro-algae communities	No	No	No	No	No	No	No	No	Ins	Ins
	Furcellaria community	No	No	No	No	No	No	No	No	Ins	Sig
	Soft bottom communities	No	No	No	No	No	No	No	No	Ins	Ins
	Mixed algae-flowering community	No	No	No	No	No	No	No	No	Ins	Ins

Note: Sig = Significant impact, Ins = Insignificant impact, No = No significant impact

7.9.6 Mitigations concerning Benthic Flora

The land reclamation area along the Lolland coastline causes a significant loss of the *Furcellaria* community (18 ha along the coastline of Lolland). The project has already sought to minimise the impact of the footprint through the comparison of alignments. Also, along the Fehmarn coastline, the chosen shape and area of footprint preclude the loss of vegetation nearly completely. The present footprint fulfils technical requirements of the project and further mitigation is therefore not possible.

7.10 BENTHIC FAUNA

The benthic fauna communities in The Fehmarnbelt are important components of the marine ecosystem, since benthic fauna functions as a key link between primary producers and the higher trophic levels, and many benthic fauna communities also contribute to the creation of the substrate that actively shapes their surroundings.

Benthic fauna are all invertebrate animals larger than 1 mm and can be divided into two groups:

- The infauna that lives in the sediments, and
- Epifauna that lives on top of the sediment and solid substrates, e.g. on the seabed, on stones, on vegetation, on mussels etc.

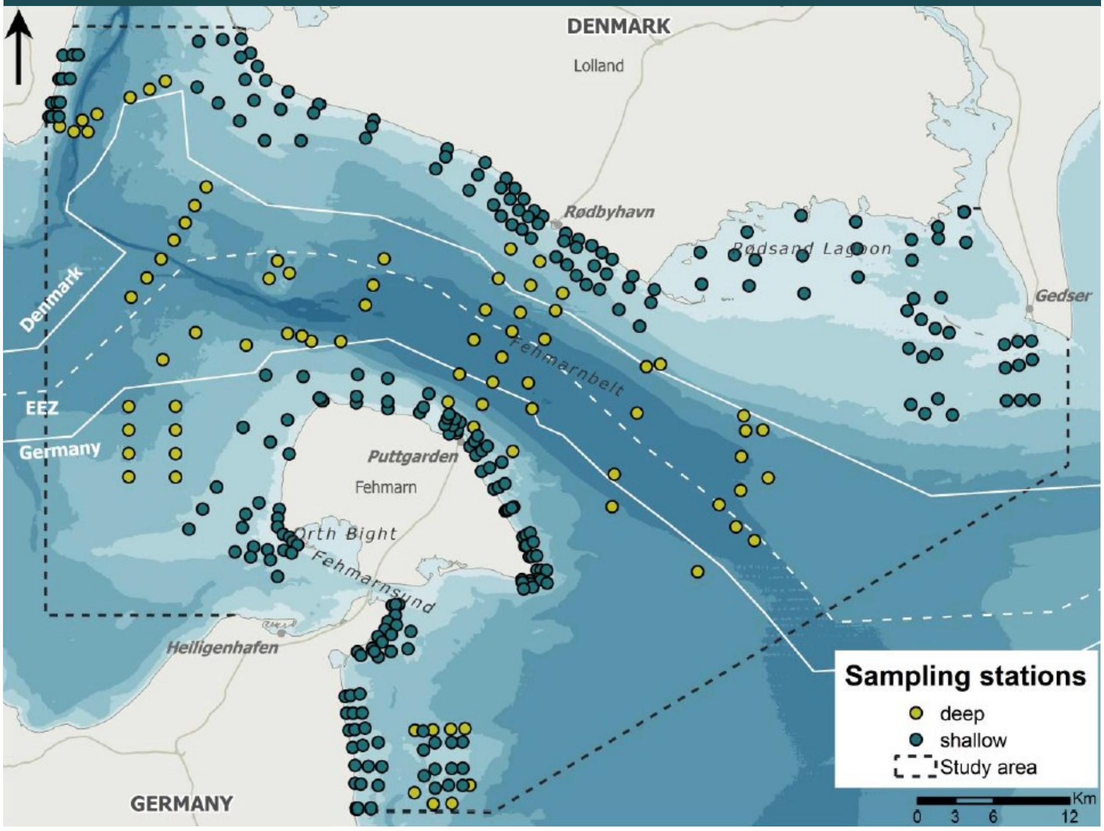
Within each group, the species can be divided into different feeding strategies (e.g. filter feeders, deposit feeders, suspension feeders, and predators).

The following chapter describes the potential impacts from construction of an immersed tunnel on the benthic fauna in the Fehmarn and transboundary region.

7.10.1 Environmental Baseline

Femern A/S has conducted extensive monitoring and mapping of the benthic fauna within the years of 2009 - 2010. Benthic epi- and infauna were sampled at 348 stations using standardised methods (van Veen grabs operated from a ship at deep stations and frame samples operated by divers at shallower waters). The area covered the greater Fehmarnbelt, including shallow and deep waters, and seven Natura 2000 areas. The investigation area can be seen in Figure 7.10.1.

FIGURE 7.10.1 Geographical positions of the sampling stations for the benthic fauna baseline sampling campaign. The dark-coloured symbols denote shallow stations, whereas the light-coloured symbols denote deep stations



The fauna was characterised by species distribution of abundance and biomass in terms of ash free dry weight (AFDW). For mussels that play an important role as food for winter-resting eider ducks, length distribution was also quantified.

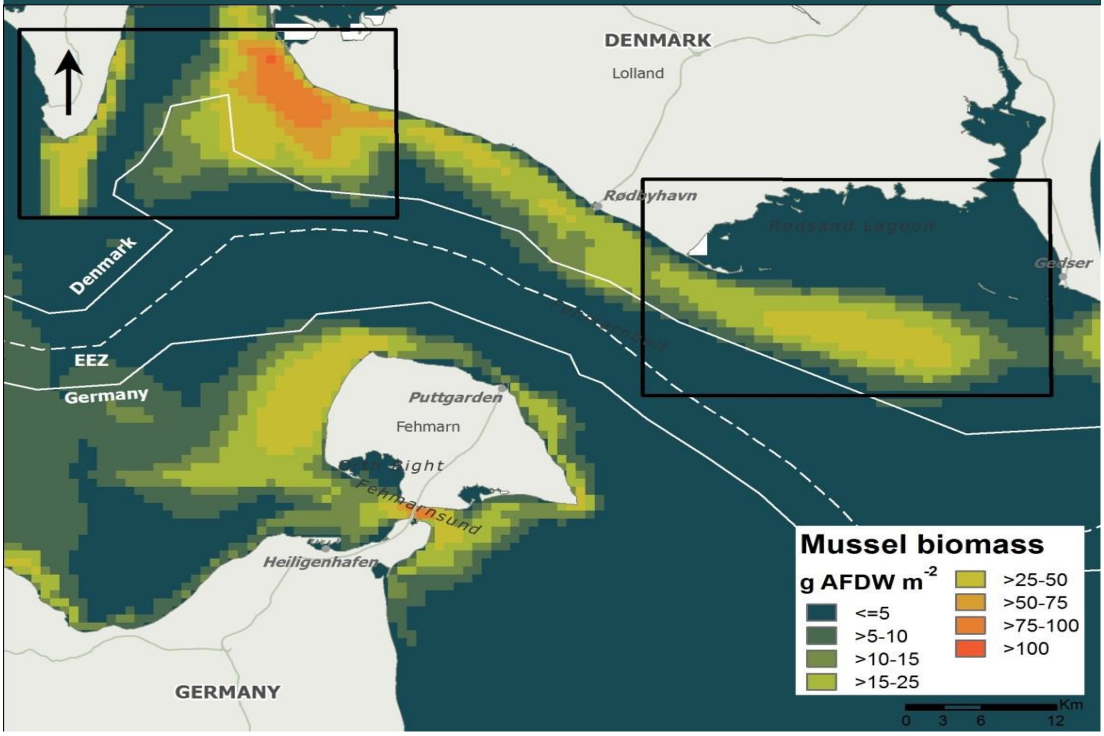
Blue mussels were sampled according to a specific sampling programme because of the uneven distribution. The programme encompassed video- or diver-observations of mussel cover (> 5000 observations), as well as frame sampling carried out by divers and supplemented by quantitative dredge sampling.

There are two main spatial gradients in species richness in the Fehmarnbelt, both of which are linked to salinity. The most obvious gradient runs from shallow waters to the deeper parts. The other gradient in species number runs from west to east. The areas with the highest species richness are notably the south-east reef offshore the Danish island of Langeland (Langeland Rev) and areas north-west of Fehmarn (125 - 162 and 75 - 162 species, respectively).

Areas with the lowest species richness in the study area can be found especially on the south-west coast of Lolland (Albuen Bank), in the Lagoon of Rødsand and just south of the Lagoon of Rødsand (7 - 24, 7 - 49 and 7 - 49 species, respectively).

Blue mussel (*Mytilus edulis*) by far dominates the biomass in the shallow waters of the Fehmarnbelt. Mussel biomass (see Figure 7.10.2) varied between 0 at deep waters below the pycnocline and a maximum of 120 g AFDW per m^2 on the south-west coast of Lolland (Albuen Banke) at 8 – 12 m depth (averaged over areas of 750 x 750 m).

FIGURE 7.10.2 Map of mussel biomass (g AFDW m-2) in the Fehmarnbelt region

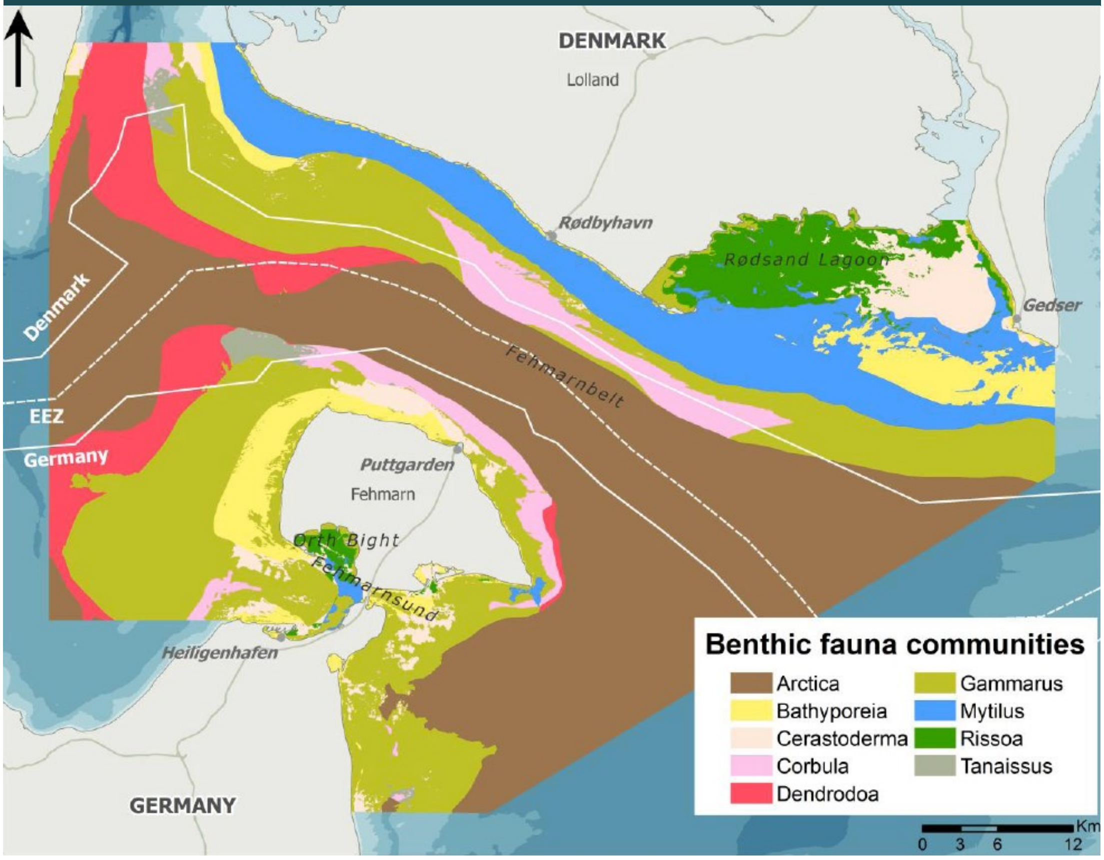


Note: Rectangles inserted de-lineate areas where biomass was corrected for mussel condition. The biomass values refer to averages over 750 x 750 m grid cells

Within the Fehmarnbelt area, the total mussel biomass was estimated to 27,000 t AFDW, which is equivalent to 480,000 t wet weight. When blue mussels were excluded, the highest biomass was found in the deeper waters of the central Fehmarnbelt between the sub tidal slopes of the Fehmarn and Lolland coasts, primarily due to presence of the large, long-living bivalve *Arctica islandica* (ocean quahog).

Overall, nine in- and epifauna communities were identified. Two of them were found in both deep and shallow waters. Four communities were unique to deep waters and three communities were only found in shallow waters. The extent of the different communities in the Fehmarnbelt was modelled using the sampling data, and the results are shown in Figure 7.10.3. Each particular benthic fauna community has been named according to a prominent indicator species of that community.

FIGURE 7.10.3 **The extent of communities in the Fehmarnbelt modelled using the sampling data**



Importance

The importance for benthic fauna has been determined according to a 4-point scale (very high, high, medium, or minor) based upon legislative, scientific and conservation arguments. The importance criteria and classification of the nine fauna communities is described in Table 7.10.1.

TABEL 7.10.1 **Importance of the different benthic fauna communities found in Fehmarnbelt**

Importance level	Description
Very high	Benthic fauna communities that are determined by indicative or discriminate species, which are protected under international conventions, like the FFH-guideline and/or HELCOM guidelines. The communities act on a between-regional scale with regard to ecosystem functioning. Community: Rissoa, Arctica
High	Benthic fauna communities that are determined by indicative or discriminate species, which are protected under national legislation (BNatSchG and LNatSchG in Germany) and/or which appear on Red Lists. The communities act on a regional scale with regard to ecosystem functioning. Community: Mytilus, Dendrodoa, Tanaissus
Medium	Benthic fauna communities that are characteristic for the greater Fehmarnbelt area, and of importance for local ecosystem functioning. Community: Gammarus, Cerastoderma
Minor	Benthic fauna communities with a temporary character, e.g. subject to high environmental disturbance on short time-scales. Community: Corbula, Bathyporeia

The zones with benthic fauna communities which are classified particularly as of “Very high” Importance include the deepest central part of Fehmarnbelt, the western part of the Lagoon of Rødsand, as well as an area in the Orth Bight. These areas are dominated by either *Arctica* or *Rissoa* communities.

The areas classified as of “High” importance include the coastal zones of Lolland, the slopes and the deeper parts in the Langeland Belt, and a region in the eastern part of the Kiel Bight, as well as outer boundaries of the Lagoon of Rødsand and Albue Bank SW offshore Lolland, which are dominated by *Mytilus*, *Dendrodoa,* or *Tanaissus* communities.

Areas where the *Gammarus* or *Cerastoderma* communities dominate are classified as ”Medium” importance and are found in shallow waters around Fehmarn island, in Sagas Bank southeast of Fehmarn, in and around the Fehmarn Sound, in the near-shore parts of Orth Bight, Großenbrode, and the Eastern part within the Lagoon of Rødsand, as well as in the region southeast offshore Gedser.

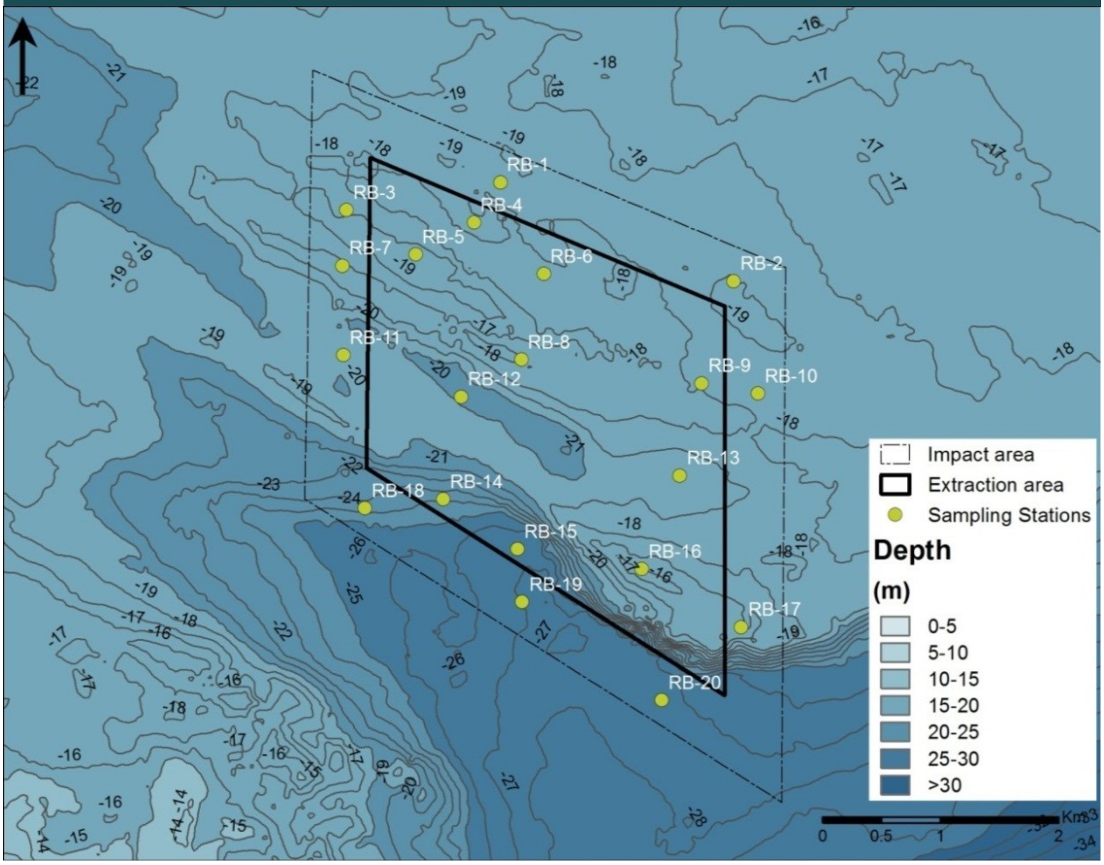
The coastal zones west of the island of Fehmarn, as well as highly dynamic areas southeast offshore Gedser, are the regions for the dynamic Bathyporeia and Corbula communities and classified as of “Minor” importance.

Baseline investigations of the benthic fauna at Rønne Banke

The baseline description for benthic fauna is based on a field survey conducted at Rønne Banke in August 2011. The results are compared to earlier investigations.

Quantitative samples of the benthic fauna and subsamples of surface sediment were collected at 20 stations at Rønne Banke in August 2011 (Figure 7.10.4).

FIGURE 7.10.4 Map of fauna stations at Rønne Banke sampled in August 2011



Number of species, abundance and biomass

Number of species

A total of 14 species and one higher taxon (Oligochaeta) were recorded at Rønne Banke. The number of species depends on the number of samples (area of the seabed) collected. The average number of species was 7 per 0.1 m^{-2} and ranged between 2 and 12 per 0.1 m^2 at the stations.

Abundance

The average abundance of the benthic fauna was 755 individuals per m^2 and ranged between 30 and 2,860 individuals per m^2. However, the abundance was extremely low at station RB-7. The abundance was above 1,000 individuals per m^2 at five stations in the southern and deeper part of the area.

Biomass

The average benthic biomass was 1.443 g AFDW (Ash Free Dry Weight) per m^2 and ranged between 0.082 and 9.74 g AFDW per m^2. The biomass was lowest at station RB-7. The biomass was highest and above 1 g AFDW m^{-2} at five stations in the deeper south-western part of the area.

Common and dominant species

Polychaetes and oligochaetes

The polychaetes accounted for 69%% of the total benthic abundance and 20% of the total biomass. Details about the species can be found in the background report.

Bivalves

The four species recorded accounted in average for 16% of the benthic abundance and 78% of the biomass. Details about the species can be found in the background report.

Gastropoda

The mud snail *Hydrobia ulvae* was extremely scarce and the abundance very low.

Crustaceans

Crustaceans were the most diverse taxonomic group. However, the five species found were all scarce and only accounted for 5% of the average benthic abundance and 1.4% of the biomass. Details about the species can be found in the background report.

Summary

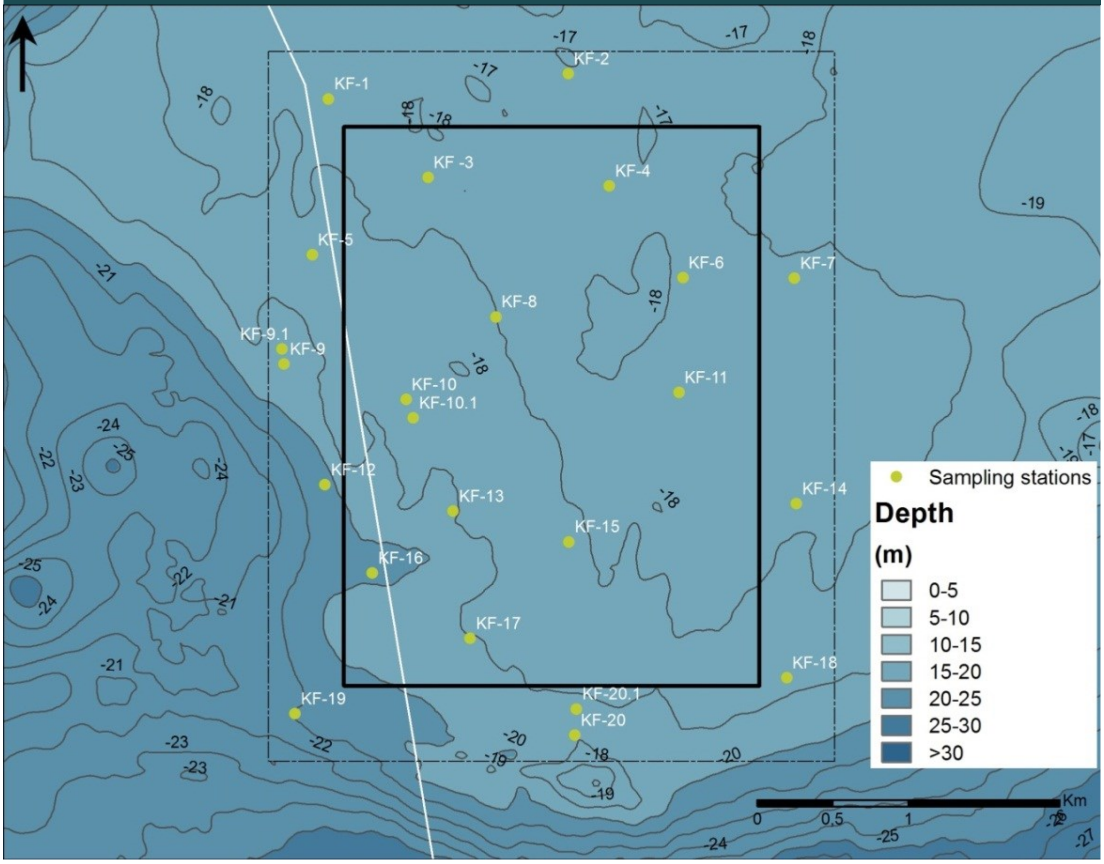
The surface sediment consisted mainly of medium and coarse sand in shallow water. The sediment becomes finer and the content of silt/clay and organic matter increases in deeper water in the southern part of the area. The species richness was low and characteristic for shallow, low saline areas in the Baltic Sea. The abundance and biomass of benthic fauna were low and dominated by a few species of polychaetes (*Pygospio elegans* and *Marenzelleria viridis*) and bivalves (*Mytilus edulis, Mya arenaria* and *Macoma balthica*).

The similarity of the benthic fauna between sampling stations was high, and the spatial difference in the structure of the benthic community was associated with differences in water depth and associated changes in the structure of the sediment such as the content of organic matter and higher salinity in deeper water. The benthic fauna community at all stations resembles a shallow-water community, which predominantly is found above a seasonal halocline, and which is associated with soft-bottom that is muddy to sandy. The community is named the Cerastoderma community.

Baseline Investigations of the benthic fauna at Kriegers Flak
The baseline description for benthic fauna is based on a field survey conducted at Kriegers Flak in August 2011. The results are compared with earlier investigations.

Quantitative samples of the benthic fauna and subsamples of the surface sediment were collected at 20 stations at Kriegers Flak in August 2011 (Figure 7.10.5).

FIGURE 7.10.5 **Detailed map of the location of the benthic fauna stations at Kriegers Flak visited in August 2011. White line indicates the Danish border. Solid black square indicates extraction area and dashed line indicates impact area**



Number of species, abundance and biomass

Number of species
A total of 20 species and one higher taxon (Oligochaeta) were recorded at Kriegers Flak. The number of species depends on the number of samples (area of the seabed) collected. The number of species was between 4 and 12 per 0.1 m^2 at the stations. Details about the species can be found in the background report.

Abundance
The abundance of the benthic fauna was between 210 and 2020 individuals per m^2. Abundance above 1,000 individuals per m^2 only occurred at a number of stations located in the western part of the survey area.

Biomass
The benthic biomass was between 0.190 and 13.26 g AFDW per m^2. The biomass was highest at stations K-12 and K-13 located in the south-western part of the survey area.

Common and dominant species

Polychaetes and oligochaetes
Polychaetes and oligochaetes were the most diverse taxonomic groups and eight species were recorded. The polychaetes accounted for 73% of the benthic abundance and 9.2% of the biomass. Details about the species can be found in the background report.

Bivalves
The five species of bivalves recorded accounted for 23% of the benthic abundance and 90% of the biomass. Details about the species can be found in the background report.

Gastropoda
The mud snail (*Hydrobia ulvae*) was scarce and the abundance very low.

Crustaceans
Crustaceans were the second most diverse taxonomic group. However, the six species found were scarce and only accounted for 1% of the average benthic abundance and less than 0.5% of the biomass. Details about the species can be found in the background report.

Summary
The impact area at Kriegers Flak is characterised by a limited range of water depth and uniform sediment with a low content of organic matter. The species richness is characteristic for shallow, low saline areas of the Baltic Sea. The community of the area resembles the Cerastoderma community. The abundance and biomass of the benthic fauna were low and dominated by a few species of polychaetes (*Pygospio elegans* and *Marenzelleria viridis*) and bivalves (*Mytilus edulis, Mya arenaria* and *Macoma balthica*). The similarity of the benthic fauna between sampling stations was high and only slightly different at a few stations due to a high abundance and biomass of *Mytilus edulis*. The Macoma (Cerastoderma) community is typically found at all depths in the Baltic Sea and is widely distributed in the surrounding areas (Øresundskonsortiet 1995). The community has a recovery time of 2 - 5 years if destroyed.

Other studies of benthic fauna at Kriegers Flak have shown higher species diversity than observed in the present investigation. In the EIA for a wind farm at Kriegers Flak on the Swedish part, 90 species have been described (Sweden offshore Wind AB 2007) and in the EIA for a wind park in the German part of Kriegers Flak, 83 species were described (IFAÖ 2003). The large difference in species number is due to sampling depths and the consequently higher salinity occurring in deeper waters of the Arkona Basin.

At the shallow sampling stations in the Swedish part of Kriegers Flak, the same species were dominant as observed in the present investigation (Sweden offshore Wind AB 2007). Furthermore, the species number was comparably low at the shallow sampling stations. The studies indicate that the benthic fauna community Cerastoderma is present throughout the shallow parts of Kriegers Flak.

7.10.2 Project Pressures

Eight pressures have been determined to have a potential impact on the benthic fauna in Fehmarnbelt, four of which are active in the construction phase, while four pressures are due to the project structures during the operation phase:

- Suspended sediments
  All kinds of solid particulate sediments (solids) suspended in water during construction work and extraction of raw materials, including other possible suspended particles contained in the sediment (construction)

- Sedimentation
  All kinds of material spilled and deposited on the seabed during construction works (construction and extraction of raw materials)
- Toxic substances
  All substances harmful to living organisms, either by killing (poisoning) or damaging them, and which are released from the sediment during construction work (construction)
- Construction vessels and imported material
  All kinds of material with an origin outside the assessment area. This is e.g. sand from sand extraction sites or stones from land or marine areas (construction)
- Footprint and other types of loss of habitat
  Areas planned to be lost temporarily or permanently due to constructions like reclamation areas, ramps, and activities related to extraction of raw materials, or the tunnel trench (operation)
- Solid substrate
  All structure-related solid structures located under-water and available as potential settling ground for marine organisms (operation)
- Hydrographical regime and water quality
  Changes in current speed, salinity and temperature of the bottom waters (operation)

Drainage
Freshwater outlets coming from the accumulation of water from the project structures during operation (operation) Transboundary Impacts on the Benthic Fauna

The magnitude of impact is analysed for each of the eight pressures related to the construction and operation of an immersed tunnel. The pressures, which have a magnitude ranging within the natural variability or below a legal threshold value, are rendered negligible, and thus not considered further, since they do not exhibit any threat to the benthic fauna in the transboundary region.

The following three pressures have magnitudes of pressure that may exceed natural levels:

- Suspended sediments
- Sedimentation
- Footprint (local pressure – Denmark and Germany)

The magnitude of impact on the benthic fauna is considered as follows:

Increased suspended sediments
Several groups of benthic invertebrates can be affected by high suspended sediment concentration (SSC). Suspension feeders such as mussels, clams and other bivalves, barnacles, or tunicates are most sensitive to high concentrations of SS because the solids can dilute their primary food (i.e. phytoplankton) and overload the filter-feeding apparatus.

In general, other feeding groups are less sensitive as long as other water quality issues such as dissolved oxygen and toxic substances are not affected negatively along with high SSC. High SSC can lead to reduced growth and, in extreme cases, also to negative growth. Depending on concentration, the consequences can be fatal if the duration is long, compared to the typical turnover of body mass for a specific species and individual.

Approximately 60,000 ha of benthic fauna communities are affected by suspended sediment from the construction phase. 99% of the area shows a minor degree of impairment, while 1% is impaired to a medium degree, mostly in the Dendrodoa community. None of the impacts affect mortality, only viability (e.g. lower growth rates or a decrease in biomass). Most of the impact is observed in the shallow waters along the coast of Lolland; a smaller area is observed along the northern and eastern coast of Fehmarn. The maximum decrease in mussel biomass is estimated to be 10% within small local areas. However, the growth of blue mussel is fast, and it is assessed that the biomass will be re-established within a couple of months after the pressure has ceased. The impact is local and is not going beyond the local zone (Figure 7.2.4) of the project.

Sedimentation

Generally, the macrofauna can cope with the deposition levels occurring in their natural environment and will remain unaffected, due to its burrowing/escaping ability. The sensitivity to deposition does however vary with species, dependent on whether they are sessile or mobile, on the type of deposition (instant or gradually deposition) and type of deposited material (clay, sand etc.).

According to earlier scientific investigations, deposition below 3 mm, regardless of the duration of the deposition, the rate of deposition and the fauna community, will have no impact on the benthic fauna.

1,871 ha of benthic fauna communities are affected by increased sedimentation from the project. 85% of this area is affected with a minor or medium degree of impairment and are of minor importance. Nearly 15% of this area is affected with a medium or high degree of impairment and have a high importance, and 16 ha with very high or high importance are affected with a high degree of impairment. The impact is distributed across all fauna communities, and the Arctica community is affected most in terms of area. Along the tunnel trench, sedimentation is generally seen to be up to 0.5 - 1.5 cm (except for a few small locations with higher values, up 8 cm) in a band of about 600 m on each side of the alignment centre line. This sedimentation originates from the coarser part of the spill (the sand). Deposition is also seen in the sheltered part of the Rødsand Lagoon with typical values up to 1 cm.

The areas with medium impairment caused by SSC, which are also impaired with a medium or high extent of sedimentation, comprise less than 0.1% of the total area of the benthic fauna, and therefore no significant impacts from the aggregated impact of these two pressures are expected.

The results from the sediment spill scenario show that there are also final sedimentation places in the Arkona Basin in Swedish waters. However, the deposits are very thin: less than 1 mm in total. In comparison, the natural deposition in the Arkona basin is approximately 10 mm during the construction period, and thus the impact of the immersed tunnel represents an excess deposition of 10%. The final deposition therefore does not influence benthic fauna in Fehmarnbelt or the transboundary region, as the sedimentation is considered insignificant.

Footprint and other types of loss of habitat

584 ha of benthic fauna communities are affected by the footprint of the project. Most of the impact is from permanent loss due to reclamation areas at Lolland and Fehmarn and from temporary loss due to the tunnel trench. 204 ha of solid substrate are added due to the structures of the immersed tunnel; the main part (85%) is the stone protection layer on top of the tunnel elements. Most solid substrate is introduced into the soft-bottom Corbula and Arctica communities. The impact is temporary in the tunnel trench, since the stone protection layer in time will be covered by sediment, due to natural sediment transport along the seabed. All temporary impacts of the 229 ha are recovered within 5 - 22 years, depending on the location and the affected community.

Benthic Fauna at Rønne Banke and Kriegers Flak

The impacts from suspended sediment and sedimentation from dredging at Kriegers Flak and Rønne Banke are not considered to have an impact on the adjacent areas, since the deposits are very thin: less than 1 mm. In comparison, the natural deposition in the Arkona basin is approximately 10 mm during the construction period, and thus the effect of the immersed tunnel represents an excess deposition of 10% compared to natural deposition. Therefore, the deposition in these areas does not influence benthic fauna in the transboundary region (see below). The areas with excess sedimentation from the immersed tunnel do not overlap with the sedimentation area from the sand-extraction, and therefore no cumulative impact is expected.

Loss of benthic fauna habitat at Rønne Banke
The loss of benthic fauna habitat will correspond to the area exploited for sand extraction; i.e. the maximal extracted area is 9 km^2. The loss of fauna in this area will be total, as the upper approximately 0.5 m of sediment will be removed. It must also be stated that the plan is not to dredge the entire area; hence the impact will be much smaller (max. 2 km^2).

Re-colonisation of the seabed after completion of the dredging activities will take place by migration of adult species and settling of larvae from nearby unaffected areas. The nature of the area that the benthic animals are re-colonising will be similar to pre-project conditions. Most of the species which are abundant at Rønne Banke, especially polychaetes and oligochaetes (which account for 79% of the abundance and 21% of the biomass), have a relatively short life cycle and will most likely re-establish after one or two growth seasons.

Mussels (which account for 16% of the abundance and 78% of the biomass) have a longer life cycle and reestablishment will take longer. *Macoma balthica* and *Mytilus edulis* have a generation time of approximately 2 - 4 years, while *Mya arenaria* have a generation time of 2 - 5 years.

The re-colonisation could be hampered by the seabed recovery processes. However, this is very rapid for the shallower parts of the area. Reestablishment of the biodiversity and biomass of the benthic fauna community in the impacted area will therefore most likely take place within 5 years after dredging has stopped.

The reestablishment of the seabed will not hamper the re-colonisation process, as the sand processes in the extraction area will resemble the existing seabed processes, which the benthic fauna is already adapted to.

Suspended sediment concentration at Rønne Banke
Several groups of benthic invertebrates can be affected by high suspended sediment concentration. Suspension feeders, such as mussels, clams and other bivalves, barnacles, or tunicates, are most sensitive to high concentrations of SSC because the solids can dilute their primary food (i.e. phytoplankton) and overload the filter-feeding apparatus.

In general, other feeding groups are less sensitive as long as other water quality issues, such as dissolved oxygen and toxic substances, are not affected negatively along with high SSC.

The threshold for no impact is defined as 25 mg/l, meaning that the benthic fauna can cope with an increase in SSC below this limit. Only within 3 km from the dredging site do the sediment concentrations exceed 15 mg/l, and this will happen less than 1 - 3% of the time. Hence, the SSC will rarely exceed 25 mg/l, and only very close to the dredger and for very short time. Consequently, it can be concluded that the benthic fauna at Rønne banke will not be impacted as a result of the increased SSC.

Deposition at Rønne Banke
The maximum deposition within less than 500 m from the dredger is less than 3 mm at any point in time. Consequently, there will be no impact on the benthic fauna due to deposition of the sand fraction less than 63 µm. Deposition of sand and the fine sand/silt fraction (>63 µm particles) within the extraction area will mostly occur in areas where the benthic fauna has been directly affected by removal of the sediment and habitat loss. The deposition within the extraction area will therefore not add significantly to the impact on the benthic fauna.

The only severe pressure on the benthic fauna is the destruction of the seabed in the dredged areas. The area lost is estimated to be maximum 9 km^2 (though the actual area is planned to be smaller). The impact is reversible, and the fauna community will recover within 5 years. The Cerastoderma community is widely distributed in the Baltic Sea, and the temporary impact in the extracted area will not be significant to the overall biomasses and abundances of benthic fauna in the area; thus, the function of the ecosystem in the area will still be intact.

Considering the prevalently south-southeast spreading of the plumes, which only exceeds 15 mg/l at 1 - 3% of the time, and the thickness of deposition outside the dredged area is less than 1.5

mm, it can be concluded that there will be no impact on the benthic fauna outside the extracted areas at Rønne Banke.

Loss of benthic fauna habitat at Kriegers Flak

The loss of benthic fauna habitat will correspond to the area exploited for sand extraction; i.e. the maximal extracted area is 10 km^2. The loss of fauna in this area will be total, as the upper approximately 1 m of sediment will be removed. Re-colonisation of the seabed, after completion of the dredging activities, will take place by migration of adult species and settling of larvae from nearby unaffected areas.

The nature of the area that the fauna is re-colonising will be similar to pre-project conditions. Most of the species which are abundant at Kriegers Flak, especially polychaetes and oligochaetes (which account for 73% of the abundance and 9.2% of the biomass), have a relatively short life cycle and will most likely re-establish after one or two growth seasons.

Mussels (which account for 23% of the abundance and 90% of the biomass) have a longer life cycle and reestablishment will take longer. *Macoma balthica* and *Mytilus edulis* have a generation time of approximately 2 - 4 years, while *Mya arenaria* have a generation time of 2 - 5 years.

The re-colonisation could be hampered by the seabed recovery process. However, this is assessed to be so slow that it cannot be expected to influence the faunal re-colonisation. Re-establishment of the biodiversity and biomass of the benthic fauna community in the impacted area will therefore most likely take place within 5 years after dredging has stopped.

Suspended sediment concentration at Kriegers Flak

The threshold for no impact is defined as 25 mg/l, meaning that the benthic fauna can cope with an increase in SSC (exceedence) below this limit. It appears that the sediment plumes at the bottom are always localised within 1 km from the extraction source, and the SCC values never exceed 15 mg/l. Hence, there is no impact on the benthic fauna as a result of the increased SSC.

Deposition at Kriegers Flak

As mentioned, a deposition below 3 mm, regardless of the duration of the deposition, the rate of deposition and the fauna community, will have no impact on the benthic fauna. As the maximum deposition 1.5 – 2 km away from the extraction source at Kriegers Flak is less than 3 mm at any point in time, it is therefore concluded that deposition will not impact the fauna outside the extraction area significantly.

Deposition of sand and the fine sand/silt fraction within the extraction area will mostly occur in areas where the benthic fauna has been directly affected by removal of the sediment and habitat loss. The deposition within the extraction area will therefore not add significantly to the impact on benthic fauna.

The only significant pressure on the benthic fauna is the destruction of the seabed in the dredged areas. The area lost is estimated to be 10 km^2 (though mitigation measures can lead to a smaller area). The impact is reversible and the fauna community will recover within 5 years. There will be no impact on the benthic fauna outside the extracted areas at Kriegers Flak.

7.10.3 Transboundary Impacts for Benthic Fauna between Germany and Denmark

The overall conclusion is that there are no transboundary impacts on benthic fauna in the Baltic Sea area. Furthermore, in Fehmarnbelt itself the impacts are very local, and none of them are significant beyond Danish or German territories.

Regarding suspended sediment, approximately 60,000 ha of benthic fauna communities are affected from the construction phase. 99% of this area is affected with a minor degree of impairment, while 1% is affected to a medium degree, and mostly in the Mytilus community. None of the impacts affect mortality, but only viability of species.

Most of the impacts are observed in the shallow waters along the Lolland coast (Danish territory), and a smaller area is observed along the northern and eastern coast of Fehmarn (German territory). The maximum decrease in mussel biomass is estimated to be 10%, with local reductions of 5 – 6 g/m^2. In most of the impacted area, the reductions are estimated to be lower than 2.5 g /m^2. Thus, the impact is assessed as being insignificant.

Concerning sedimentation, 11,871 ha of benthic fauna communities are affected by sedimentation. 85% of this area is affected with a minor or medium degree of impairment and are of minor importance. Nearly 15% are affected with a medium or high degree of impairment and have a high importance, and 16 ha with very high or high importance are affected with a high degree of impairment. The impact is distributed across all fauna communities, and the Arctica community is affected most in terms of area.

The impact is located largely around the tunnel trench (in the near zone) and in the Rødsand Lagoon. The maximum accumulation of sediment is modelled to 7 cm near the tunnel trench. In the remaining part of the impacted areas, sedimentation rates are typically below 1 mm/d. The overall impact is therefore small, and assessed as insignificant.

584 ha of benthic fauna communities are affected by the footprint of the project. Most of the impacts are from permanent loss, due to reclamation areas at Lolland and Fehmarn, and from temporary loss due to the tunnel trench; 41% of the impacted area has a high degree of loss due to the important Mytilus community at Lolland; 28% of the impacted area has a minor degree of loss and is located in the Bathyporeia and Corbula community.

17% of the affected area of benthic fauna has a very high degree of loss, and is located in the Arctica community; 14% of the area has a medium degree of loss and is located in the Gammarus and Cerastoderma community. All temporary impacts are recovered within 5 – 22 years, depending on the location and the affected community. The impact is assessed to be insignificant.

Concerning additional solid substrate, 204 ha of solid substrate are added due to the structures of the immersed tunnel, mainly (85%) due to the stone protection layer on top of the tunnel elements. Most solid substrate is introduced into the soft-bottom Corbula and Arctica communities. This impact is considered temporary, since the stones in the tunnel trench will be covered by sediment with time. Solid substrate will be added to a maximum of 0.6% of the community area in relation to the comparison zone. The transboundary impact is assessed as insignificant.

7.10.4 Significance of Impact for Benthic Fauna

The impacts identified in Chapter 7.10.3 and 7.10.4 are all temporary. The impact from construction and operation of an immersed tunnel is assessed to have insignificant impact on benthic fauna in the transboundary region, since the final deposition of sediment in Swedish waters is less than 1 mm in total thickness and considered insignificant. All resulting impacts from construction and operation of an immersed tunnel on the benthic fauna are local and in the Fehmarnbelt area (Table 7.10.2).

TABLE 7.10.2 Significance of transboundary impacts on benthic fauna in the Baltic Sea, Norway, Germany and Denmark

Factor		Significance of impacts on benthic fauna in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Benthic Fauna	Benthic epifauna	No	No	No	No	No	No	No	No	Ins	Ins
	Benthic infauna	Ins	No	No	No	No	No	No	No	Ins	Ins

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.10.5 Mitigations concerning Benthic Fauna

Compensation is a legal requirement if protected habitats/species are lost or impaired significantly. As none of the pressures will affect benthic fauna by significant loss or impairment, compensation of benthic fauna is not necessary for an immersed tunnel.

7.11 FISH ECOLOGY

The Fehmarnbelt plays a key role in the water exchange system of the Baltic Sea and is an important passage for migrating cod, herring and silver eel, as well as a spawning area for a number of fish species, including cod and flatfish. The project may affect fish communities at different levels of significance, caused by specific activities during construction and operation.

Several fish species and fish communities in the Fehmarnbelt area are of ecological importance. Furthermore, several fish species are of economic importance both locally and regionally. The ecosystem in the Baltic is, however, highly dynamic and has undergone large changes in fish communities during the last two decades. Cod, herring and sprat are exploited heavily by commercial fishing, which, among other things, is expressed by a dramatic decrease in cod and herring stocks. Parallel to this development, a large increase in the sprat stock and the landings of sprat have been registered.

The following chapter describes the potential impacts from construction of an immersed tunnel on fish ecology in the Fehmarnbelt and the transboundary region including Norway.

7.11.1 Environmental Baseline

The baseline investigations took place from 2008 to 2010 and included the following:

- A programme designed to catch fish eggs and larvae. This was performed with a bongo-net along a 20 km coastline of Lolland, including Rødsand, and along the northern and eastern coastline of Fehmarn as far south as Mecklenburger Bight. The sampling was performed as 12 discrete campaigns in spring, summer, autumn, and late winter 2008 - 2010 in order to cover the spawning season of almost all fish species in the area. Gonad maturity of the commercially important species cod, herring, sprat and flatfish in the Fehmarnbelt was estimated in order to identify seasonal spawning patterns.
- Herring gill net surveys and video screenings of the sea bottom for herring eggs along the German and Danish coast in autumn and spring. The gill net surveys included registrations of herring gonad development, herring worm infection and genetic analysis.
- Investigations of fish communities in specific habitats, based on monthly sampling with multi-mesh gill nets in Danish and German coastal waters and trawl surveys in the deeper parts of

the Fehmarnbelt. The investigations of nursery grounds in specific habitats were based on sampling by fyke nets and beach seine-nets in the coastal waters of Fehmarn and Lolland. Furthermore, a YOY-trawl was used in the shallow sandy areas in Rødsand and west of Rødbyhavn.

- Hydro-acoustic surveys, which included monthly surveys along the planned alignment and three large scale surveys performed in spring, autumn, and winter. The equipment consisted of a split beam echo sounder (120 kHz) and a single beam dual frequency transducer (38/200 kHz).
- Tagging experiments on migrating silver eel (European eel, *Anguilla anguilla)* performed with both intelligent tags (DST) (logging depth, temperature and time) and T-bar tags. The surveys included tagging and release of eel captured in pound nets from the coastal areas of Lolland and Fehmarn in late autumn, and release of eel in the Arkona Basin.
- A small scale tagging experiment on spawning cod caught by local fishermen on the spawning grounds in the western part of the Fehmarnbelt during spring 2010. The cod was tagged with T-bars or DSTs.

Rødsand Lagoon was assessed with respect to impacts from sediment spill, since excess concentrations of suspended sediment in the lagoon from the construction of the tunnel is modelled to be the highest expected in the Fehmarnbelt area.

Furthermore, impacts from modelled changes in the hydrographical regime on the reproduction volume of cod in the Arkona Basin have also been included in the assessment.

In general, the selected investigation areas limited the assessment to direct, on-site impact results alone. However, the classification of the severity of impairment also included rating the importance of the specific components (e.g. species) according to their regional and trans-boundary significance. This means that implicit, regional and transboundary impacts were assessed although not quantified.

In particular, long distance migration patterns among fish might cause transboundary impacts, but also spawning grounds of regional importance with drift of egg and larvae over great distances may affect the recruitment of fish stocks across national waters.

Many fish species use the Fehmarnbelt area as a transit area. Cod, for example, are known to migrate long distances between spawning and feeding areas. Also the spring- and autumn-spawning herring use the Fehmarnbelt as a transit area for migrating to and from their main spawning grounds around the island Rügen. For the European eel, the Danish sounds and belts are vital for the migration between the Baltic Sea and the North Sea. Although the Sound seems to be the most important migration route, the tagging studies during the baseline investigation indicated that up to 30 % of the silver eel migrates through the Fehmarnbelt.

In total, 57 different fish species were registered during the mapping of fish communities in the area. The coast along Fehmarn had 43 species and was the most species-diverse area, compared to 37 species registered along the coast of Lolland. The lowest number of species was found in the deeper areas of Fehmarnbelt, where 35 species were registered. Ten of these species were only registered in the deeper parts of the Fehmarnbelt.

The shallow water fish community (<2 m) was generally dominated by small fish such as sticklebacks, gobies and sand eel, but larval and juvenile stages of pelagic fish such as herring and sprat were also frequently registered. The fish community reflected a typical community of the Belt Sea, and subareas along the coasts of both Fehmarn and Lolland were shown to function as nursery grounds for several fish species.

The western and north-western sandy habitats of the coast of Fehmarn were dominated by flatfish species such as dab (*Limanda limanda*) and flounder (*Platichthys flesus*). In addition, the highest abundance of hooknose (*Agonus cataphractus*) and whiting (*Merlangius merlangus*) were also found in these habitats.

The highly structured habitats with vegetation, stones and boulders along the eastern and south-eastern coast of Fehmarn were dominated by cod, whereas almost no flatfish species, except flounder, were caught within these habitat types. Besides cod, species like sea stickleback

(*Spinachia spinachia*), wrasse (mainly goldsinny wrasse (*Ctenolabrus rupestris*)) and gobies were characteristic for these habitats.

Cod was the dominant species along the coast of Lolland in habitats with vegetation, stones and mussels, while dab and whiting were most numerous in sandy habitats. In the lagoon of Rødsand, the extensive eelgrass habitat was dominated by small fish species like three-spined (*Gasterosteus aculeatus*) and nine-spined (*Pungitius pungitius*) stickleback, eelpout (*Zoarces viviparus*) and several species of gobies. The most dominating benthic species in the deeper areas of the Fehmarnbelt was dab; but whiting, cod and plaice (*Pleuronectes platessa*) were also numerous.

The pelagic fish community of the Fehmarnbelt includes at least 10 species with sprat, herring, whiting and cod as the most numerous. Considerable seasonal variability was observed (abundance and species composition) and occasionally pelagic species like garfish (*Belone belone*) and Atlantic horse mackerel (*Trachurus trachurus*) were highly abundant. The density of pelagic fish in the Fehmarnbelt was low compared to observations made in other areas, including the Sound.

In total, nine red listed species (according to the German and Danish Red lists) were recorded during the investigations. These were:

- Snake blenny (*Lumpenus lampre-taeformis*)
- Sea stickleback
- Corkwing wrasse
- Ballan wrasse (*Labrus bergylta*)
- Sea trout (*Salmo trutta*)
- Atlantic salmon (*Salmo salar*)
- Greater weever (*Trachinus draco*)
- European eel
- Painted goby (*Pomatoschistus pictus*)

In addition, autumn-spawning herring is also listed as critically endangered on the German red list. The majority of the red-listed species occurred at very low numbers.

However, the sea stickleback in particular was frequently abundant in the autumn. Other species, like corkwing wrasse, ballan wrasse and greater weever, showed a significant seasonal distribution. The river lamprey (*Lampetra fluviatilis*) is listed in the EU habitats directive Annex II and a small number of this species was caught in the Fehmarnbelt by local fishermen during the baseline study period.

Importance

The assessed fish species are either included because of their ecological importance or because of their protection level. The degree of importance has been determined according to a 4-step scale (very high, high, medium, or minor). The classification has been based on the environmental screening, where also the different subareas in Fehmarnbelt have been assigned an importance for each component (Figure 7.11.1).

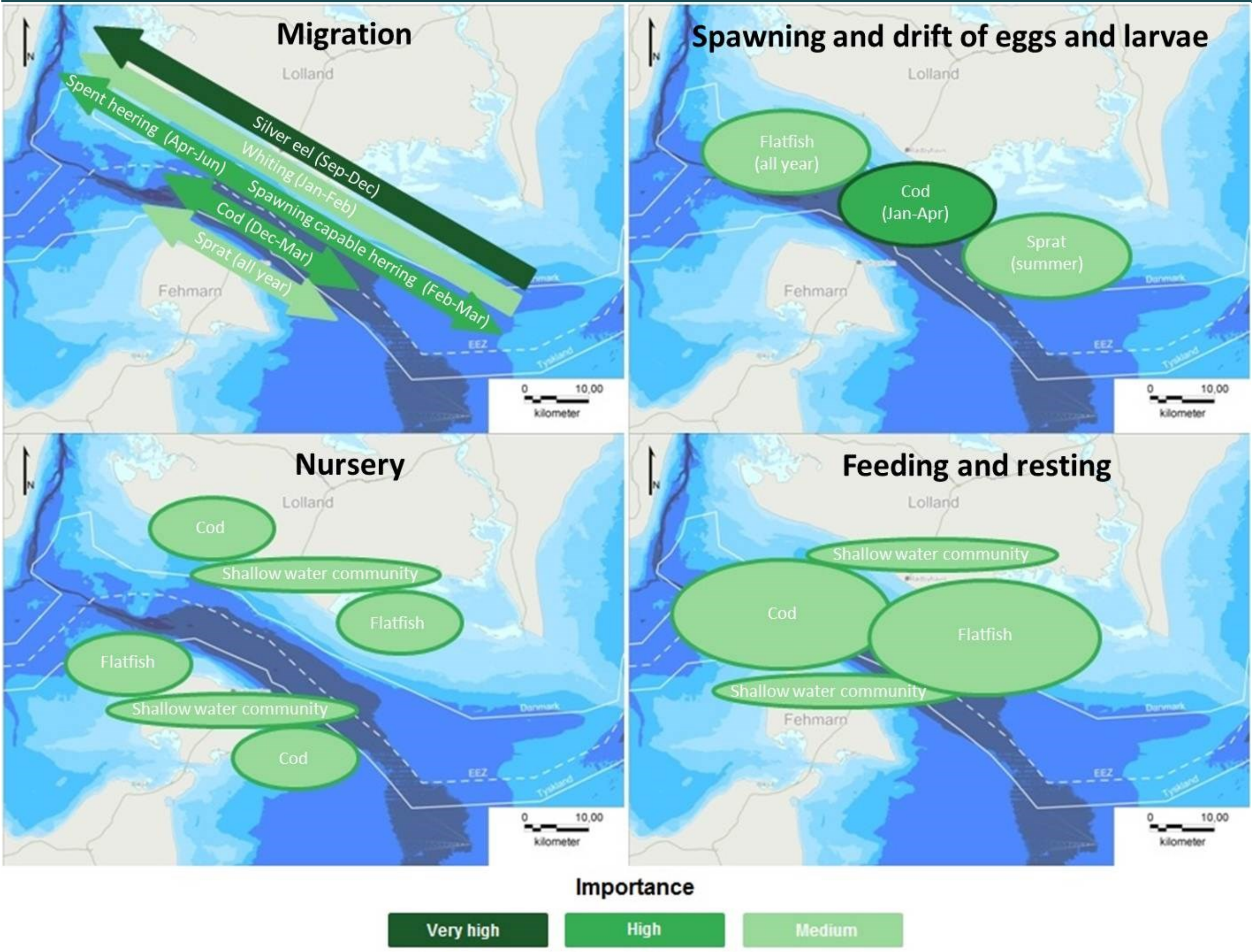
In Table 7.11.1 below, the importance for the individual fish species/components are presented. For the ecologically important species, crucial phases of the life cycle such as spawning, egg- and larvae drift, nursery, feeding, migration have equally been assigned an importance. Apart from eel, sea stickleback and snake blenny this has not been possible for the internationally protected or nationally red-listed species, as they only appeared in moderate numbers during the environmental investigations.

TABLE 7.11.1 Importance of the individual fish species/components in Fehmarnbelt

Component	Spawning	Drift of egg and larvae	Nursery areas	Feeding areas	Migration	Overall import-ance
Cod	high	high	medium	medium	high	high
Whiting	-	-	minor	-	medium	medium
Herring	minor	minor	minor	minor	high	high
Sprat	medium	medium	minor	minor	medium	medium
Flatfish	medium	medium	medium	medium	minor	medium
Fish fauna in shallow water	medium	minor	medium	medium	-	medium
International-ly protected species						
Eel	-	-	minor	minor	very high	very high
Red-listed species						
Sea stickleback	high	high	high	high	-	high
Snake blenny	high	high	high	high	-	high

Note: [Remove this line if you don't want any note]

FIGURE 7.11.1 Geographical and timely importance of Fehmarnbelt for key species split up for important life phases



7.11.2 Project Pressures

Five pressures were identified relevant to fish ecology in relation to construction and operation of an immersed tunnel in the Fehmarnbelt:

- Land reclamations (permanent or temporary loss of habitats)
- Changes in the hydrographical regime
- Sediment spill
- Noise and vibrations
- Changes/impairments of fish habitats (indirect pressures)

The impacts on fish ecology due to the different pressures from the dredging activities are noise, increased suspended sediment concentration, deposition, removal of sediments and temporary loss of seabed in the tunnel trench. The pressures are characterized by type, intensity, geographical distribution, and duration. The project pressures derive both from the construction phase, the operation phase, and from permanent structures.

7.11.3 Transboundary Impacts for Fish Ecology

Land reclamations

The permanent land reclamation will affect the shallow part of the near zone, and the extent of loss for the shallow water fish community, including the red-listed sea stickleback, ranges from medium to high in German and Danish waters. The temporary seabed reclamation will, in addition, affect benthic species at greater depths, including the red-listed snake blenny, along the tunnel trench. However, the impact from footprints and temporary land reclamation is local and does not extend into transboundary areas.

Changes in the hydrographical regime

No transboundary impacts are expected on fish as a result of changes in the hydrographical regime, which result from the construction and operation of an immersed tunnel.

Sediment spill

The possible direct transboundary effects are mainly caused by sediment plumes and re-suspension of material. Apart from the Fehmarnbelt, the central areas of the Mecklenburg and Arkona Bights will be affected by sediment spill. A medium level of sedimentation is expected in these bights (maximum size of sediment deposition is 0.5 mm for the first three years of the construction period). The Mecklenburg and Arkona Bights are important spawning areas for flatfish and particularly for cod. A temporary impairment of eggs and larvae of these species cannot be excluded, although the natural background level of suspended sediment is considered a much more severe pressure. For the same reason, it is unlikely that the sediment spill will have major importance for transboundary populations.

Changes/impairments of fish habitats and noise/vibration

During the construction phase, a barrier effect caused by dredging of the tunnel trench and immersing the tunnel elements is expected for anadromous fish species and fish species with long term migrations (cod, whiting, herring and sprat). These species avoid areas with a high intensity of sediment plumes and noise/vibration. Thus, the migratory fish species might not reach areas of importance (spawning and feeding areas) in adjacent waters.

Sediment spill and noise can cause a temporary local impact on the migration of the Rügen herring from the spawning grounds at Rügen to the feeding areas in Skagerrak, meaning a minor degree of impairment with high importance. This can potentially have an impact on the Rügen herring stock in Norwegian and Polish waters. The construction of the immersed tunnel may also affect the spawning migration of cod and the survival of eggs and larvae locally, which might theoretically affect the cod recruitment in Swedish and Polish waters. Impacts on the migration of whiting from nursery areas in the Baltic, back to the North Sea, might affect the whiting stock outside the project area, while impacts on sprat migration are only local. These impacts are all temporary, the pressure is of very low intensity, and therefore only insignificant transboundary indirect impacts are expected outside the German and Danish areas. There are no impacts on fish ecology in the operation of the immersed tunnel.

7.11.4 Fish Ecology near Rønne Banke and Kriegers Flak

Increases in suspended sediment and noise in periods of intense dredging activity and heavy ship traffic may affect fish in the extraction area and lead to periodic decreases in the local abundance of fish in the area. The impact will most likely cause a displacement of fish in the extraction area; however, there is a high probability that fish will return to the area and an impact on the local fish populations over a longer period is highly unlikely. The overall conclusion is that there will be only insignificant impacts on fish within the extraction areas due to extraction of sand.

Due to the low level of direct impacts by sedimentation at Rønne Banke and Kriegers Flak, the potential transboundary impacts for these areas are assessed to be insignificant. Furthermore, the impacts in the extraction area are temporary and have only minor and insignificant impacts on any components of the ecosystem (including fish) in this part of the Baltic Sea. Transboundary Impacts for Fish Ecology between Germany and Denmark

Overall only insignificant impacts are expected outside the near zone (i.e. more than 500 m from the alignment). In the near zone most impacts are expected to be due to footprints, where land reclamation in both German and Danish shallow waters reduces nursery areas/grounds for cod and flatfish as well as habitats of shallow water species, including the protected sea stickleback.

Transboundary impacts between Germany and Denmark in the operational phase of the immersed tunnel are minor (noise emission, sediment spill and barrier effect are insignificant), and therefore only construction-related impacts are relevant.

The overall conclusion is that project pressures on fish ecology on the Danish side will not cause any impacts on fish ecology on the German side, and vice versa.

The following lists the investigated species and how they are affected by the project pressures within the near zone.

Cod
Temporary land reclamation will lead to a medium impairment of spawning, egg-larvae drift and feeding for cod in the near zone. During operation, the physical structures in the Danish near zone are expected to cause a medium impairment of cod feeding; and due to land reclamation there is a small, but less severe loss of cod nursery in both the German near zone and the Danish near zone.

Whiting
All impacts from the construction phase of the immersed tunnel on whiting are considered as minor impairments, except for a medium impairment on nursery areas. A high impairment on whiting nursery areas, due to land reclamation, is assessed as being only of minor importance due to the relatively small size of the area; and the project impacts during the operation phase are insignificant.

Herring
During construction, sediment spill causes a medium impairment of the herring egg- and larvae survival. However, since the Fehmanbelt area is not an important herring-spawning site, the extent of this impairment is low. During operation, no impacts on herring are expected.

Sprat
The impairment of the construction phase on sprat is minor. During operation, only minor impacts are expected. There are no aggregating impacts causing changes in the project impairment, and the impact is assessed as not significant during both construction and operation.

Flatfish
The impact of the construction phase on flatfish is limited to the temporary land reclamation in the near zone, where spawning, eggs, and larvae are affected to a medium degree in both Danish and German waters. In the German near zone, a medium impact on feeding areas is expected as well. No impairment on flatfish exceeds a minor rating during the operation. Due to permanent land reclamation there is a small, but medium extent of loss on flatfish nursery and feeding grounds in both the German and the Danish near zone, where there is an additional small, but medium extent of loss on flatfish spawning sites.

Shallow water species
There are only minor impairments on shallow water species during the construction and operation of the immersed tunnel. Due to land reclamation there is a loss of habitats in the German near zone and in the Danish near zone. The loss of habitat is small compared to the total availability of shallow water habitats in the Fehmarnbelt and is not considered significant.

European eel

There are only minor impacts on European eel during the construction and operation of the tunnel. Even though there are potential impacts from barriers in the Fehmarnbelt during the construction phase, the pressures are of low intensity and extension, and only minor transboundary impacts are expected.

Sea stickleback

There are only minor impairments on sea stickleback during the construction and operation of the immersed tunnel. However, due to land reclamation there is a loss of habitats in the Danish near zone. The loss of habitat is small compared to the total availability of shallow water habitats in the Fehmarnbelt and is not considered significant.

Snake blenny

Temporary land reclamation will lead to medium impairment of spawning, egg-larvae drift, nursery, and feeding for snake blenny. For all other pressures, no or minor impairment is expected, and the overall project impact for snake blenny during the construction phase is assessed as medium in the near zone of the immersed tunnel. During operation no impacts are expected.

Legally protected species

Apart from stickleback and snake blenny there are only minor impacts on legally protected species during the construction and operation of the immersed tunnel.

7.11.5 Significance of Transboundary Impacts for Fish Ecology

The marine environment within the coastal areas of Lolland and Fehmarn, and dredging areas at Kriegers Flak and Rønne Banke will be affected by construction and operation of an immersed tunnel. However, the impacts on fish ecology are mainly temporary and do not reach beyond the German-Danish areas.

Only minor impairments of fish ecology are expected outside the near zone of the project. Since the near zone is small compared to the total area of the Fehmarnbelt, the overall significance of impacts for all fish species in both Germany and Denmark is considered minor.

Since a minor theoretical impairment of the migration of herring, cod and whiting might also affect the stocks in Norway, Sweden and Poland in particular, the significance of impacts has been rated insignificant for these species in these countries as well. However, the impact is temporary and most probably very small.

In conclusion, impacts from the construction and operation of the immersed tunnel only have insignificant transboundary impacts on fish ecology in the Baltic Sea or adjacent marine areas. Table 7.11.2 summarises the assessed impacts from the project.

TABLE 7.11.2 **Significance of transboundary impacts on fish ecology in the Baltic Sea, Norway, Germany and Denmark**

Factor		Significance of impacts on fish ecology in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Fish Ecology	Herring	Ins	No	No	No	No	No	Ins	Ins	Ins	Ins
	Cod	Ins	No	No	No	No	No	Ins	Ins	Ins	Ins
	European Eel	No	No	No	No	No	No	No	No	Ins	Ins
	Whiting	Ins	No	No	No	No	No	Ins	Ins	Ins	Ins
	Sprat	No	No	No	No	No	No	No	No	No	No
	Flatfish	No	No	No	No	No	No	No	No	No	No
	Shallow water species	No	No	No	No	No	No	No	No	No	No
	Sea stickleback	No	No	No	No	No	No	No	No	No	No
	Snake blenny	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.11.6 Mitigations concerning Fish Ecology

Impacts from project pressures such as hydrographical changes and contaminants are considered very low or non-existent and therefore not relevant in relation to mitigation measures. This also applies to indirect impacts caused by impairments of suitable habitats and food resources of fish. Hence, no mitigations are considered necessary for the immersed tunnel project regarding fish.

7.12 COMMERCIAL FISHERY

The Baltic Sea is one of the world's largest brackish water areas, and several marine fish species have adapted to the low salinity and are an important resource for the commercial fisheries in the western Baltic and Fehmarnbelt region.

A number of the commercial fish species present in Fehmarnbelt migrate over large distances between spawning grounds, nursery areas and feeding grounds. During these migrations and residency periods, these commercial species will come to pass through or reside in national waters of other countries or in international waters and will be available to the respective fisheries of other countries.

Denmark and Germany are the only two countries that have commercial fisheries in Fehmarnbelt and its region in the Western Baltic. The establishment of a fixed link across Fehmarnbelt can potentially negatively affect the transboundary fisheries by creating disturbances or restrictions that make it difficult or impossible to perform fishing with different gear, and by affecting the abundance, distribution and migration of commercial fish species and their stocks, and hence the resource yield in the region.

This chapter describes the impact from an immersed tunnel on transboundary commercial fishery.

7.12.1 Environmental Baseline

The German and Danish commercial fisheries and fleet statistics for the ICES rectangles (38G0, 37G0, 38G1, 37G1, 38G2 and 37G2) and the harbours in the near field and regional area of

Fehmarnbelt and the Western Baltic were obtained from the Danish Directorate for Fisheries (FD) in Denmark, and from the Bundesanstalt für Landwirtschaft und Ernährung (BLE) in Germany.

Additional fleet statistic information on vessel lengths, gear use, home-based harbours and for the number of small vessels (<8 m) in the Western Baltic was obtained from the Fisheries EU registry. German and Danish vessel monitoring system (VMS) data was also obtained from the Danish Directorate of Fisheries and the Bundesanstalt für Landwirtschaft und Ernährung (BLE), respectively.

To supplement official fishery statistics, which are bound by the spatial resolution of the ICES rectangles (30x30 nautical miles) and which do not give a thorough description of the distribution of the fisheries (and to gather more specific income data), group and individual consultation meetings and surveys were held with both German and Danish vessel owners, fishermen and their representatives around Fehmarnbelt.

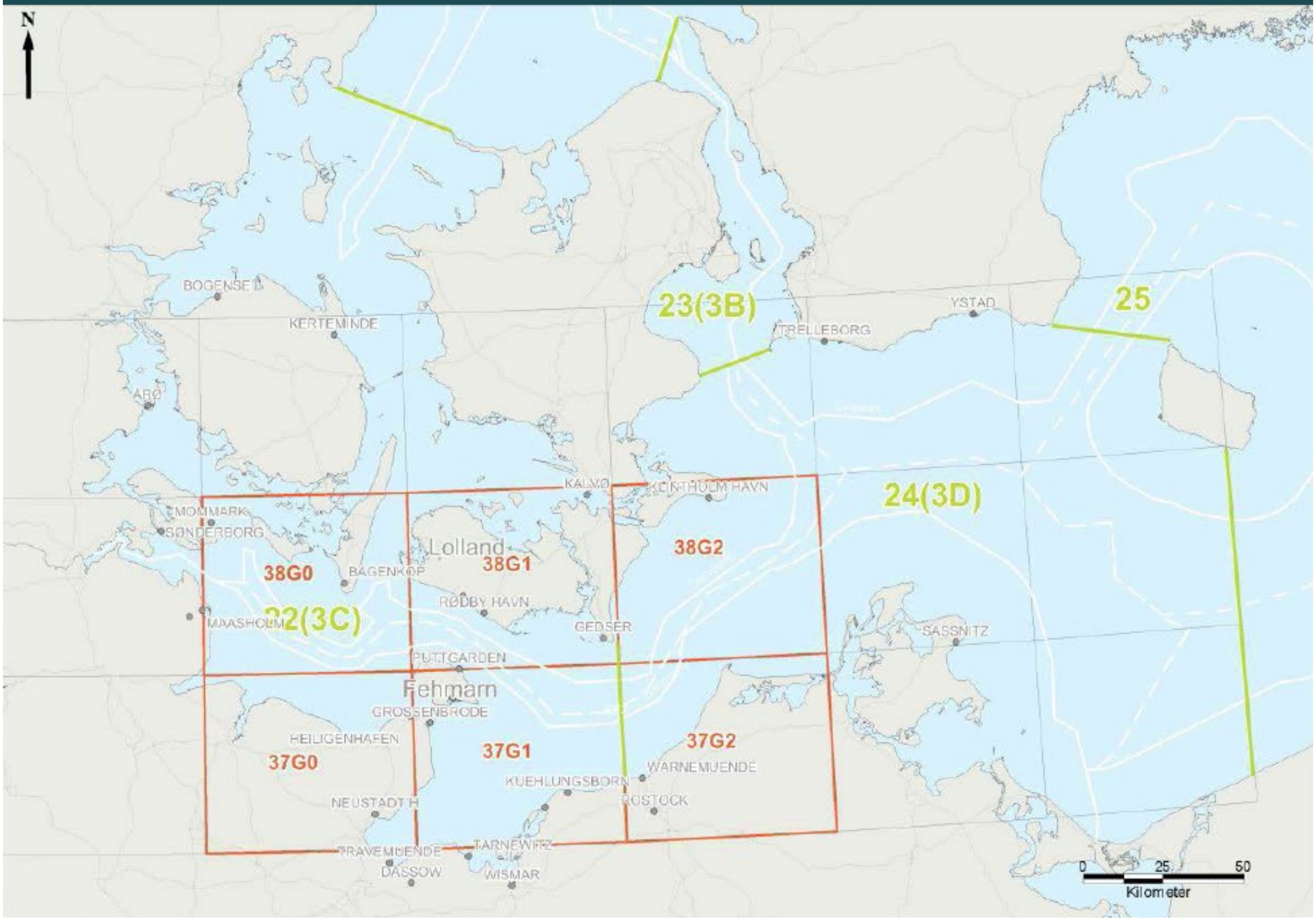
The baseline investigations showed that Denmark and Germany are, in reality, the only two countries that undertake commercial fishing in Fehmarnbelt and its regional area. The primary components to these fisheries are the different gear, the trawls used in deeper waters (>10 m) with soft bottoms, gill nets used in all types of seabed habitats, pound nets placed near the coastline and Danish seine nets typically used in deeper open waters. The following table shows the primary areas of commercial fishing in relation to main countries carrying out fishing on commercial fish stocks. See Table 7.12.1.

TABLE 7.12.1 Primary areas of commercial fisheries in relation to main countries carrying out fishing on commercial fish stocks

Commercial fish stocks	Primary areas of commercial fisheries	Main countries that undertake fisheries on these stocks
Cod (Gadus morhua)	Western Baltic	Denmark, Germany, Sweden, Poland, Estonia, Latvia, Finland and Lithuania
Herring (Clupea harengus)	Western Baltic, Kattegat, Skagerrak and North Sea	Denmark, Sweden, Germany, Norway, Faroe Islands and Lithuania
Sprat (Clupea sprattus)	Western Baltic	Denmark, Germany, Sweden, Poland and Finland
European eel (Anguilla anguilla)	Baltic Sea and Kattegat	Denmark, Sweden, Poland, Lithuania, Estonia, Latvia, Germany and Finland
Whiting (Merlangius merlangus)	Western Baltic	Denmark, Sweden and Norway

As mentioned, Denmark and Germany are the only countries that carry out fishing in the Fehmarnbelt and are by far the dominant countries that fish commercially in the regional area (represented by ICES statistical rectangles ICES 37G0, 38G0, 37G2 and 38G2, see Figure 7.12.1 below).

FIGURE 7.12.1 **ICES rectangles in the Fehmarnbelt area**



Note: Green colour indicates ICES sub-divisions, red colour indicates ICES rectangles. Map of the Western Baltic Sea including the outlines of ICES subdivisions (SD) 22, 23 and 24 and the statistical ICES rectangles including Fehmarnbelt (38G1) and the regional area (ICES 37G1, 37G0, 38G0, 37G2 and 38G2) of the Fehmarnbelt

Importance

The selection of the forms of fishery such as trawls, nets, pound nets and seine fishing is carried out based on their importance and value to the overall fishery in local and regional areas in and around the Fehmarnbelt. The criteria for the assessment of importance of each form of fishery consist of the size and value of the catches, and partly in the possibilities of using alternative fishing grounds.

The degree of importance of the Fehmarnbelt for the various forms of fishery is determined by a 4-point scale. This assessment is presented in Table 7.12.2 below.

TABLE 7.12.2 Criteria and importance of Fehmarnbelt for the different forms of fishery

Subcomponents (forms of fishery)	Criteria	Importance
Trawl fishery	Fehmarnbelt is an area which is of a certain local and regional importance and value for trawl fishery.	Medium
Gill/trammel nets	Fehmarnbelt is an area which is used for fishery with gill/trammel nets and is of certain local and regional importance and value for this subcomponent.	Medium
Seine nets	Fehmarnbelt is specifically used for fishery with seine nets and is of high importance and value for this subcomponent.	Very high
Pound nets	Fehmarnbelt is an area which is only rarely, or not at all, used for fishery with pound nets, and therefore is only of minor local or regional importance and value for this subcomponent.	Minor

Note: The criteria for the assessment of the importance of the different forms of fishery consist partly of an assessment of the size and value of the catches in Fehmarnbelt and the region, and partly of the possibilities of applying alternative fishing grounds.

7.12.2 Project Pressures

The establishment of the Fehmarnbelt Fixed Link may cause a number of temporary and permanent impacts to transboundary fisheries. Pressures caused by the fixed link can directly affect transboundary fishing and indirectly affect the presence of the commercial species (fisheries resource).

The project pressures relevant to the commercial fisheries and their resources (commercial fish) are as follows:

- Land reclamation (construction and operation)
- Sediment spill (construction)
- Noise and vibration (construction)
- Hydrological regimes (construction and operation)
- Other pressures potentially causing avoidance responses and loss of fish habitats (construction and operation)

The magnitude of pressures resulting from light, electro-magnetic fields and contaminants has been assessed to be insignificant.

Suspended material in the water phase, as well as sedimentation, is a natural part of the environment in which fish live. However, excess amounts can cause an avoidance response which affects the distribution of the different species, depending on the species' specific tolerance.

The construction of an immersed tunnel will involve a number of offshore works on areas that were previously used for commercial fisheries. Areas lost to footprints may also previously have contained specific environmental characteristics or habitats allowing the undertaking of different fisheries, such as soft bottoms for trawls after different important commercial fish species, and hard or stony bottoms for the valuable flatfish species turbot.

Loud noise and vibrations during the construction phase can cause an avoidance response which affects the distribution of the different species depending on the species' specific tolerance, and thus this response has the potential to affect the fisheries indirectly.

Hydrographical changes may affect the fisheries indirectly by potentially influencing the migration and distribution of the commercial species (resource to the fisheries). Added structures and changes in the topographical characteristics and morphology of the seabed and coastline areas due to dredging, ramps and landfills, can result in changes in current strength and directions, as well as backwater build-up behind obstructions.

Indirect consequences may include changes in the flushing and water exchange rates from the inner Baltic as well as changes in under-water currents that are important for regulating salinity concentrations, water temperature and oxygen distribution.

The impacts on the fisheries at Rønne Banke and Kriegers Flak due to the extraction operations at the sites are a combination of the impacts on the fishery resource (fish and shellfish) and on the fishermen's possibility to undertake their fishing.

7.12.3 Transboundary Impacts for Commercial Fishery

The methodology used in determining the impairment of different pressures (footprints, increases in suspended sediment, noise etc.) to the commercial fisheries has been based on a step-wise process including elements such as identifying the environmental factors (component and subcomponents), and defining sensitivity and threshold values of the environmental indicators to pressures.

Furthermore, the magnitude of pressures was often quantified on lost or impaired fishing areas based on exceeding threshold values and modelled scenarios of specific pressures (suspended sediment, etc.) overlapping fishery areas.

All components and subcomponents have been assessed for the identified pressures in the areas of investigation. The smallest spatial unit for which comprehensive commercial fisheries data from the Fehmarnbelt was available was an ICES rectangle (30 x 30 nautical miles) (see Figure 7.12.1 above). Therefore, this was the primary unit of measurement used in the baseline report and was also the unit of measurement used in the assessment.

The importance of the components representing the different fisheries in the Fehmarnbelt according to gear types is determined by their importance and value to the fisheries in the local and regional areas of the Fehmarnbelt.

There are no significant impacts on trawl fishery, gill net fishery or seine net fishery in the Fehmarnbelt region during construction activities, operation or due to reclamation of areas/footprints. As the migration behaviour of fish (e.g. herring, cod and eel) is not affected, no impacts on distant subpopulations or on distant fishing of these species, which also occur in the Fehmarnbelt, will be impacted. Thus, in the case of commercial fisheries with trawl, gill net or seine net, no transboundary impacts will occur.

The loss of pound net fishing areas, due to the 7.2 km long permanent reclamation area along the Lolland coastline, results in a medium impact in the Danish pound net fisheries on a local scale, as the impact is permanent on Danish territory. There are no impacts on the pound nets fishery in the Fehmarnbelt region during construction or operation activities, although sediment plumes will be greatest along the coastal areas of Lolland and may have an impact for short-term intervals. The impact on pound net fishing is, however, only relevant on a local scale and there will be no restrictions on the fishing activities in the transboundary region.

In general, the impacts from the immersed tunnel pressures such as land reclamations, noise and vibrations, and hydrographical changes that cause commercial fish species to flee from or avoid an area used by the fisheries in the Fehmarnbelt are only minor or insignificant in all cases on a local scale (see Chapter 7.11 Fish Ecology).

Of the pressures affecting the commercial fish species, it is anticipated that sediment spill is the pressure which will have the most impact. During immersed tunnel construction, excess suspended sediment during the first two years will at times be considerable in small, local areas. This will primarily impact the fisheries by causing the most sensitive fish species (cod, herring, sprat, whiting, horse mackerel, salmon, sea trout and garfish) to either flee from or avoid impacted areas that overlap with the different fisheries.

A number of the commercial fish species present in the Fehmarnbelt also migrate over large distances between spawning grounds, nursery areas and feeding grounds.

During these migrations and residency periods, these commercial species will come to pass through or reside in national waters of other countries or in international waters and will be available to the respective fisheries of other countries. Thus, it is recognised that the commercial fisheries in other countries could be indirectly affected if shared commercial fish stocks are substantially affected by the establishment of the Fehmarnbelt Fixed Link immersed tunnel.

Assessments in relation to potential transboundary impacts to the commercial fisheries of other countries were carried out on the migratory fish stocks in the Fehmarnbelt (mentioned in Table 7.12.1). They are listed together with the main countries that include these stocks in their commercial fisheries.

Impacts from the construction, operation and structures of the immersed tunnel were assessed to be low on all commercial fish stocks that have extended geographical distributions. Impacts greater than "low or insignificant" were only registered in the near vicinity of the fixed link and can be considered insignificant in relation to potentially impacting any of the fish stocks migrating to international waters or national waters of other countries.

Fishery at Rønne Banke

The impacts on the fishery at Rønne Banke are restricted to loss of fish within the extracted area, because of loss of food source for the fish. This impact is only expected to occur within a five year period, whereafter a re-colonisation of the benthic infauna and epifauna is expected (see Chapter 7.11 Fish Ecology). Furthermore, fishery can be affected due to fishing restrictions during dredging activities. The impact is low (only lasts for a couple of days) and is temporary within dredging periods.

Only trawler fishing is undertaken in the extraction area on Rønne Banke. Both trawl fishing and gill net fishing are undertaken with large gill net vessels in an area to the southeast. There is no seine net fishery in or near the extraction area and thus assessment of potential impacts to this type of fishing is not relevant.

During the dredging phase, there will be an impact on the fish resource due to dredging activities. The impact will primarily be on trawl fishing, since the impact on the fish is within the extraction site. The impact will only be short-term (days). Fish stocks can be re-distributed to other areas due to increased sediment deposition, and this may cause a low impact on trawl fishing in the surrounding area. This is only temporary and will be negligible after a few months.

The impact on net-fishing is negligible since the impact from dredging activities primarily occurs within the extraction area, where net fishing does not take place.

Because of the risk of collision, there will be zones around the extraction activities where fishing is not possible. Regardless of the extent, this impact is only expected over a short time period (hours). An impact on the fishery is only short-term (days during the extraction period) and in a small area (< 9 km^2). There are no restrictions on the net fishing activities.

Fishery at Kriegers Flak

The impact on trawl and net fishing at Kriegers Flak within the extraction period (days) is only minor because fish move to other areas, away from where they can be caught. An impact on fishing is only short-term (during the extraction period). Regardless of the extent, the extraction is only expected to take place over a short period (days).

Only trawl fishing is undertaken in the extraction area at Kriegers Flak. Gill net fishing is undertaken in an area close to the extraction area to the West. The impact on trawl and net fishing within the extraction period (days) is low because fish move to other areas, away from where they can be caught.

When the extraction period has ended, the loss of benthic habitat and loss of food for the fish within the extraction area can lead to changes in fish distribution. The duration of this impact is assessed to be a maximum of five years, whereafter the food source is expected to have recovered (see Chapter 7.11 Fish Ecology). There will be an impact on trawl fishing due to this substrate removal.

The impact is reversible (five years) and it is expected that fish stocks in the area will be re-established. The impact on net-fishing is non-existent because the impact is limited to the extraction area, where net-fishing does not take place.

The impact on trawl and net-fishery due to suspended sediment and noise is very low because the impact on the fish stocks from these pressures is very small (see Chapter 7.11).

In connection with sand extraction, fishing will be impacted during the sand extraction periods. Because of the risk of collision there will be zones around the extraction activities where fishing is not possible. Regardless of the extent, the impact is only expected over a short time period (hours).

All extracted material is planned to be retained in the dredge hopper, and large boulders and stones will not be left on the seabed. Thus, bottom trawls are not expected to be obstructed by stones and boulders during this extraction activity.

7.12.4 Transboundary Impacts for Commercial Fishery between Germany and Denmark

Below, the impacts on German and Danish fisheries are assessed for all fishery components.

Trawl
Impacts due to construction activities, operation of the immersed tunnel and reclamation of areas/footprint on German and Danish trawl fishing in the Fehmarnbelt and its region are expected to be local, and therefore non-existent, as a transboundary impact between Denmark and Germany.

Gill nets
Results of the assessment indicated that there will be an impact to Danish gill net fishing by having a potential impairment of 57 ha of their fishing grounds from the dredging of the tunnel trench. Furthermore, in the construction area 22 ha will be lost permanently and 5 ha lost short-term, which could potentially cause a significant impact. However, the areas lost are generally not used as Danish gill net areas, so the impacts are considered local and not significant as transboundary impacts between Denmark and Germany.

Furthermore, the potential mobility of such a fishery to other nearby gill net fishing areas, and the very small total loss of gill net fishing area (0.12% of the gill net fishing area in the Fehmarnbelt), confirms an insignificant local impact to gill net fishing.

Pound nets
The impacts of the reclamation areas and footprints from the immersed tunnel on the Danish pound net fishing are significant on a local scale. This impact is primarily in the area of the land reclamation along the southern coastline of Lolland, where more than 331 ha of pound net fishing areas will be lost. This will have some consequences for 6 pound net fishermen, who have their fishing areas in and adjacent to the area of the land reclamation.

The other impacts (increased suspended sediment, sedimentation, noise and changes in hydrographical characteristics) on pound net fishing in the Fehmarnbelt and its region are only considered locally insignificant during construction and operational activities, and there will be no transboundary impacts on pound net fishing between Denmark and Germany.

However, the sediment plumes with the highest suspended sediment concentrations were greatest along the coastal areas of Lolland (see Chapter 7.6), and when sediment plumes are most intense, these conditions could create an avoidance response by some important commercial species in a few local areas.

Danish seine nets

Impacts from the immersed tunnel on Danish seine net fishing in the Fehmarnbelt and its region are insignificant and only local during the construction activities, the operation of the immersed tunnel or due to reclamation of areas/footprints.

Seine net fishing is undertaken in the deeper central parts of the Fehmarnbelt, where impacts from sediment plumes, noise and hydrographical changes have least effect.

Commercial species

In general, the impacts from the tunnel pressures such as sediment spills, noise and vibrations, and hydrographical changes that cause commercial fish species to flee from or avoid an area used by the fisheries in the Fehmarnbelt were only locally insignificant in all cases.

Of the pressures affecting the commercial species, it is anticipated that sediment spills are probably the pressure that has the most impact. During immersed tunnel construction, excess suspended sediment during the first two years will at times be considerable in small, local areas.

This will primarily impact the fisheries by causing the most sensitive fish species (cod, herring, sprat, whiting, horse mackerel, salmon, sea trout and garfish) to either flee from or avoid affected areas that overlap with different fisheries.

The overall conclusion is that project pressures on commercial fishing on the Danish side will not cause any impacts on commercial fishing on the German side, and vice versa.

7.12.5 Significance of Impacts for Commercial Fishery

Impacts from the construction, operation and structures of the immersed tunnel were insignificant on all commercial fish stocks that have extended geographical distributions (see Chapter 7.11 Fish Ecology). However, there are no transboundary impacts for commercial fishery due to an immersed tunnel.

The impacts from construction and operation of an immersed tunnel lead mainly to temporary impacts, which do not reach beyond the German-Danish territories.

However, in spite of the fact that the impact caused by the land reclamation on the Lolland coastline is considered insignificant in all cases, on a local scale, this pressure has a considerable impact on Danish local pound net fishery, which is along the shore where suspended sediment plumes will be greatest, and because such fishery is stationary and cannot move to alternative areas.

At Rønne Banke and Kriegers Flak the impact on net fishery is non-existent, since impact primarily occurs within the extraction area, where net fishery does not take place. Therefore, no transboundary impacts are expected within the Fehmarnbelt and the transboundary region.

TABLE 7.12.3 Significance of transboundary impacts on commercial fishery in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on commercial fishery in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Commercial Fishery	Trawl	No	No	No	No	No	No	No	No	No	No
	Gill nets	No	No	No	No	No	No	No	No	No	No
	Pound nets	No	No	No	No	No	No	No	No	No	No
	Danish seine nets	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.12.6 Mitigation concerning Commercial Fishery

Femern A/S will, if necessary, compensate for negative economic impacts concerning commercial fishery in accordance with Danish legislation.

7.13 MARINE MAMMALS

In the Fehmarnbelt and in the Baltic Sea three species of marine mammals occur regularly: the harbour porpoise, (*Phocoena phocoena)*, the harbour seal, (*Phoca vitulina),* and the grey seal, (*Halichoerus grypus)*.

The harbour porpoise is a small cetacean, which, in Denmark, is widely distributed in the western Baltic Sea and the North Sea. The harbour seal occurs in both the North Sea and Baltic Sea and has haul-out sites in the Rødsand lagoon where a substantial proportion of the small sub-population in the western Baltic Sea resides. The grey seal occurs in low, but growing numbers in Rødsand lagoon where it also has its only and southernmost breeding grounds in Denmark.

The marine mammals are protected under various conventions and legislation. The harbour porpoise is listed in Annex 4 of the Habitat Directive and is thus subject to an assessment of strictly protected species in relation to Article 12 of the directive. Both seal species are listed in Annex 2 of the Habitat Directive and it is prohibited to hunt seals in Denmark, since they are covered by a national nature protection act. Hunting of seals is also banned by other countries around the Baltic, but in Norway harp seal (*Pagophilus groenlandicus*) and hooded seal (*Cystophora cristata*) hunting is allowed. Russia also has hunting seasons for seals, but not in the Baltic.

This chapter of the report describes the impact on marine mammals in Fehmarnbelt and the adjacent transboundary region.

7.13.1 Environmental Baseline

The baseline investigations provide information on the spatial and temporary use of Fehmarnbelt and adjacent transboundary waters by marine mammal species. The area of investigation stretches from a line between Kiel and Langeland in the west, to a line between Gedser and Dahmeshöved in the east. Therefore, the baseline investigations are within a restricted area and do not expand throughout the entire Baltic Sea except for the telemetry study, which covers both the North Sea and the Baltic Sea, since the animals are tracked throughout their individual home ranges.

The principles of Ecological Quality Objective (EcoQO defined by OSPAR, 2007) have been applied in determining the significance of the effects of the fixed link on harbour porpoise, harbour seal and grey seal. Whilst the EcoQO only specifically names grey seals, it has been concluded that this criterion is equally applicable for the harbour seal. EcoQOs express the desired qualities of a component of the ecosystem. OSPAR has been developing the EcoQO system for the North Sea, in collaboration with the International Council for the Exploration of the Sea (ICES), since 1992 (OSPAR, 2010, 2009 and 2007).

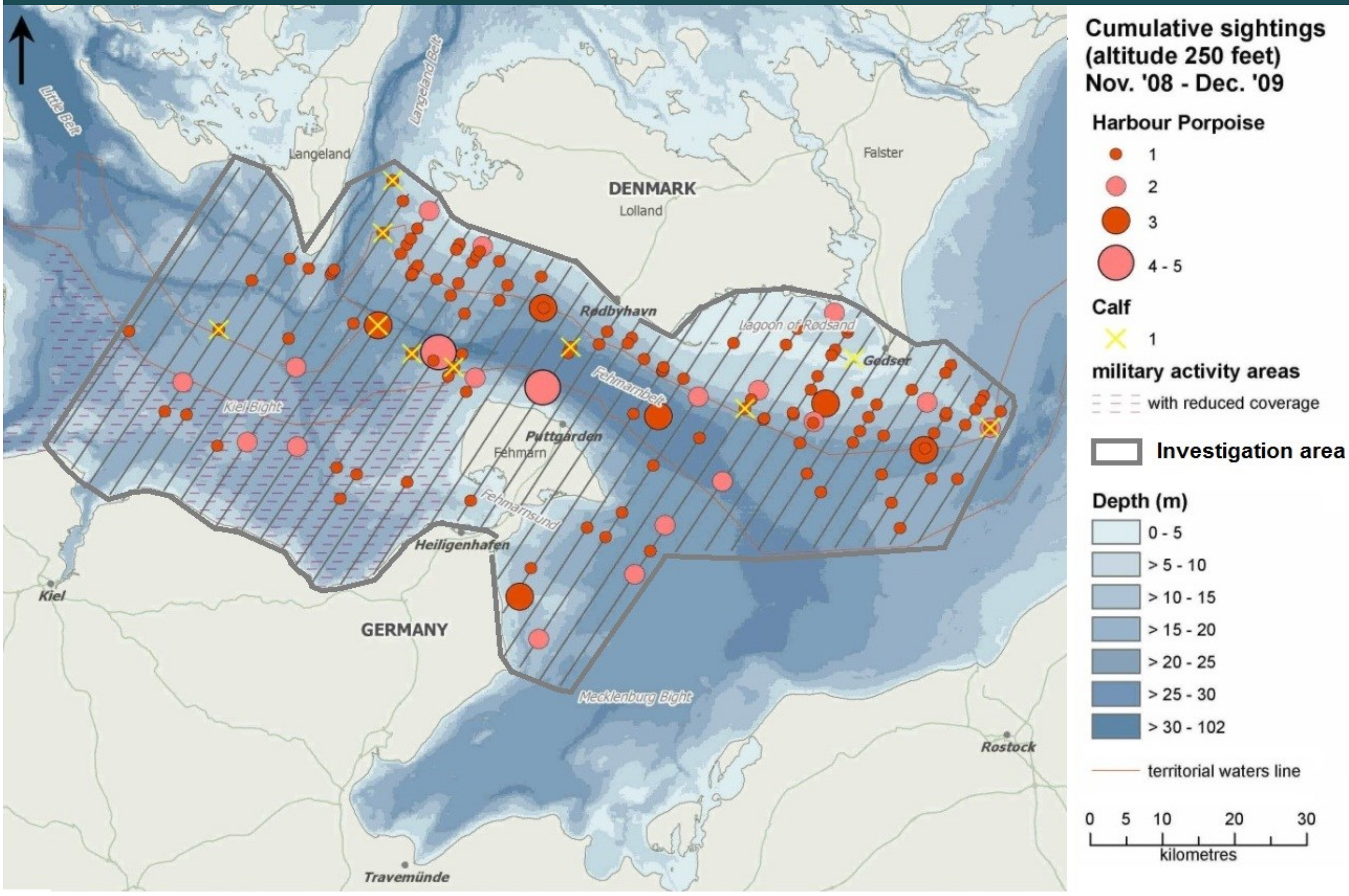
The investigations included visual and acoustic surveys for mapping distribution and estimating abundance. Further studies on movements and behaviour were conducted using telemetry techniques. In the following paragraphs, the environmental baseline investigations on the three species are described.

Harbour porpoise

For the baseline study, harbour porpoises were counted at monthly intervals by aerial transect surveys between November 2008 and November 2010 in a 4,800 km^2 study area. Surveys were conducted from a 600 feet altitude for mammals only, and from a 250 feet altitude for combined mammal and bird surveys. Densities were calculated by applying the Distance-Sampling methodology (Buckland et al., 2001). The results show a marked seasonal pattern with lowest numbers during the winter months and higher numbers from spring to autumn. The highest densities in 2009 were recorded in April with 0.59 porpoises/km^2. In 2010, the highest densities reached 0.94 porpoises/km^2 in May with densities in summer 2010 generally higher than in summer 2009.

Calf sightings made up 13.04 % of all observed individuals (18 calves from 122 individuals) in 2009 but only 5.5 % in 2010.

FIGURE 7.13.1 Harbour porpoise observations in the investigation area from aerial transect surveys (November 2008 – December 2009)



Porpoise activity was monitored using passive acoustic monitoring with autonomous porpoise click detectors (C-PODs). C-PODs were deployed at 27 locations in the wider Fehmarnbelt area in order to obtain maximum spatial resolution along with the very high temporal quality of the acoustic monitoring. C-POD data was used to model distribution of harbour porpoise in relation to fine-scale hydrodynamic variables. There was an almost constant presence of harbour porpoises in the Fehmarnbelt area over the whole study period (January 2009 - January 2011). A general west-east gradient, with more recordings in the northwest and fewest recordings in the southeast, is in line with earlier studies on the distribution of harbour porpoises in the western Baltic Sea.

Movements of harbour porpoises in the study area were investigated in the Baltic Sea by means of satellite telemetry. As part of the Fehmarnbelt Marine Mammal studies, available data from on-going studies by the National Environmental Research Institute (NERI) were analysed, with additional porpoises being equipped with transmitters as part of the FEMM baseline study. In total, data from 82 animals, tagged between 1997 and 2010, could be analysed. The aim of the analysis was to describe the function of the Fehmarnbelt area and habitat choice in the annual cycle of harbour porpoises, especially in relation to large-scale movements of the animals, which can only be detected by telemetry. In addition, possible responses of porpoises to existing bridges in the western Baltic Sea were investigated. The analysis provides evidence that the harbour porpoises of the Fehmarnbelt area are part of the subpopulation of the Belt Sea, which separates them from the more northern Skagerrak subpopulation. A substantial number of the animals tagged in the Belt Sea, however, migrated to the Skagerrak in the winter months. Seasonal movements, as indicated by data from animals tagged for a longer period of at least three seasons, were very pronounced and indicated that a substantial part of the population seasonally migrates between the Skagerrak and the Belt Sea, including the Fehmarnbelt and the areas to the east of Fehmarn. Based on the analysis of tracks and the studies undertaken by others, it was concluded that although porpoises tend to cross areas with bridges less often than areas without bridges, no apparent avoidance behaviour was observed.

Importance

The degree of importance has been determined according to a 4-point scale (very high, high, medium, or minor). The classification has been based on the environmental screening, also where the different subareas in Fehmarnbelt have been assigned an importance for each component. For harbour porpoise, the importance of Fehmarn Belt as a staging area, nursing area and as a migration corridor has been assessed. It has only been possible to make a spatial distribution of the importance as a staging area in Fehmarn Belt, since no special nursery areas or specific migration routes through the belt could be identified. Overall, Fehmarn Belt has been assessed as being medium important as a nursery area and as migration corridor. As a staging area, data from the aerial surveys show that the harbour porpoise is most abundant in the summer period. The areas west of the alignment, along the Lolland coast and covering parts of the central belt area, have been assessed as having very high importance as a staging area. Areas in the central Fehmarn Belt, west of the alignment and east of Gedser Reef, have been assessed as having high importance as a staging area.

Seals

Sandbanks and rocks in the Rødsand Lagoon provide haul-out sites for both seal species which occur in high numbers in this area. Close to 200 harbour seals and a small but increasing number of grey seals are regularly observed in the lagoon. The Fehmarnbelt area forms the southernmost haul-out site for harbour seals in the Baltic Sea. Rødsand Lagoon is home to about one third of the small sub-population of harbour seals in the Baltic Sea.

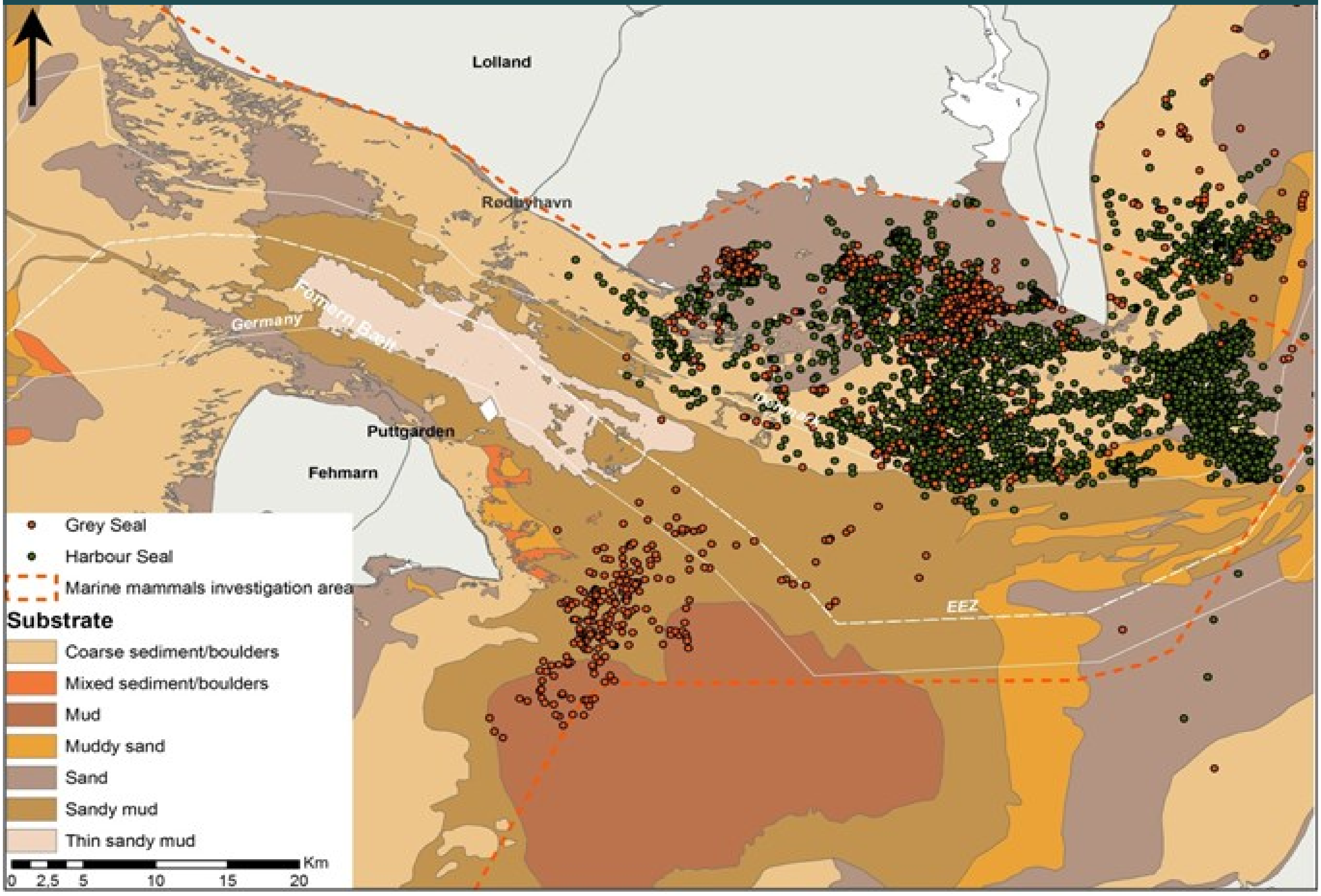
Seals were counted between January 2009 and September 2010 at the haul-out sites in Rødsand Lagoon by aerial monthly surveys. Numbers obtained during the surveys were lower for harbour seals than those obtained during national surveys, but provided new maximum numbers for grey seals. Surveys indicate a seasonal pattern with highest numbers of seals hauled-out in summer and lower counts in spring and autumn. There was very limited survey coverage during the winter months. Grey seal counts reached a maximum of 57 animals in June 2010. The seasonal increase in seal numbers at haul-outs during summer coincides with pupping and moulting activity.

Telemetry studies show that the seals very seldom cross the project area.

Importance

It has not been possible to do a spatial assessment of the importance of the whole Fehmarn Belt for the seals, since the seals have only been counted at their haul-out sites in Rødsand Lagoon. Rødsand Lagoon is an important breeding area for seals, and several haul-out sites were identified during the baseline studies. The nearest haul-out site is situated 8,5 km from the alignment. Rødsand Lagoon has been assessed as having very high importance for harbour seal and high importance for grey seal.

FIGURE 7.13.2 **Areas with foraging harbour seals and grey seals in and around the investigation area (January 2009 - September 2010)**



7.13.2 Project Pressures

The following pressure descriptions and the associated descriptions of marine mammal sensitivity provide the foundation for this impact assessment.

Five main pressures have been identified from the construction and operation of an immersed tunnel:

- Noise (from dredging and backfilling, drilling and piling operations, and construction and operational traffic)
- Habitat loss (from dredging and backfilling, placement of tunnel sections, the temporary harbour, and reclamation works)
- Habitat change (from dredging and backfilling, the temporary harbour, reclamation works, and tunnel in situ) including habitat structure change, siltation rate, hydrography, and turbidity changes
- Toxic chemicals (from the dredging and backfilling works)
- Barrier effects (from construction vessels and construction works)

The sensitivity of marine mammals to man-made noise is not easy to predict, as it depends on a number of inter-related internal and external factors. The sensitivity of marine mammals has been based on available knowledge from the literature and, accordingly, the defined assessment criteria refer to types of response at different noise levels.

It is assumed, unless evidence is provided for certain species, that animal populations are likely to be limited by availability of suitable habitats, so that any loss of habitat or reduction in habitat quality will lead to an equivalent reduction in the number of animals living in this habitat.

The sensitivity of marine mammals towards habitat loss or change is determined by a change in environmental key drivers which govern - directly or indirectly - the presence of these animals in a specific area; the latter is primarily driven through changes in prey availability and distribution. Any change in important key drivers may lead to a negative impact on marine mammals.

A contaminant can be a biological, chemical, physical or radioactive substance, which, in sufficient quantities, can have an adverse effect on living organisms through their environment and/or food. Contamination of marine mammals may be direct or through the process of bio magnification up the food chain. Given that marine mammals are top level predators, they accumulate the highest levels of biomagnifying contaminants.

Barrier effects arise when physical structures or perceived ‘barriers’ alter the behaviour of animals in their vicinity and may also prohibit movements across the barrier. Perceived barriers might include construction noise (e.g. extended dredging activity across a strait) or operational noise (e.g. traffic crossing a bridge).

Physical structures would include the artificial structures in the water column. Barrier effects would be of particular concern in constrained areas, which are utilised by migrating and foraging animals.

7.13.3 Transboundary Impacts for Marine Mammals

The investigations of the five different pressures identified from the construction and operation of an immersed tunnel show that there will be no transboundary impacts for any of the marine mammals that are present in the Fehmarnbelt. The reasoning for impacts on marine mammals, with focus on harbour porpoises, is set out below. No impacts on seals are expected, since the nearest haul-out site is 8.5 km from the alignment, and because the seals very seldom cross the alignment area. As a result, they are only mentioned when it has been deemed relevant.

Noise

The number of harbour porpoises affected by noise during construction is estimated by comparing the worst case scenario for the noise pattern during construction with the highest counted presence of harbour porpoises. The assessment of the number of affected animals is based on the flight survey data, since this is the only method that gives quantitative data on densities.

The noise from the dredging operations is expected to affect an area of approximately 5.2 km^2 with a minor to medium degree of impairment in the winter period, and around 4.2 km^2 in the summer period with a minor to high degree of impairment. Pile driving has an impact on approximately 5 km^2 (as a consequence of noise), but with a slightly higher noise level (the impairment ranging from minor to high). A high degree of impairment is only expected in a small area near the pile driver, in an area of around 0.34 h.

The worst case scenario for the noise during construction is when pilling and dredging occurs at the same time. Only a few individual porpoises (3 - 7) will be affected at a time by noise in winter and summer, which disturbs a maximum of 0.45% of the local Fehmarnbelt study area population and less than 0.1% of the estimated population in the Kattegat, the Belt Sea and the Western Baltic. This will cause a displacement effect, and harbour porpoises are expected to leave the area with elevated noise levels. The area disturbed by noise above the threshold, where minor behavioural changes are expected, constitutes approximately 13 km^2, which is less than 0.3% of their habitat in the survey area. Therefore, the impact is insignificant at the population level for the occurrence (staging) and nursery areas (because <1% of both the Fehmarnbelt study area population and the population in the Kattegat, the Belt Sea and the Western Baltic is affected).

Habitat loss
In relation to habitat loss, very few porpoises (1 - 2) will be affected by construction, using the most conservative scenario calculated from the harbour porpoise densities in summer time, which are higher than in winter. The habitat loss constitutes a temporary very high magnitude of impact in an area that is of high importance only in the summer. A maximum disturbance of 0.1% of the local Fehmarnbelt study area population and less than 0.1% of the population in the Kattegat, the Belt Sea and the Western Baltic is expected.

Moreover, a total of less than one porpoise is expected to be affected by habitat loss during the operational stage, using the most precautionary scenario of summer densities, with a maximum disturbance of less than 0.1% of the local Fehmarnbelt study area population. The impact is therefore insignificant at the population level (<1% of both the Fehmarnbelt study area population and the population in the Kattegat, the Belt Sea and the Western Baltic).

Habitat change
The modelling demonstrates that elevated levels of suspended sediment only occur for a short period and mostly along the Lolland coast and in Rødsand Lagoon.

Harbour porpoise hearing and echo-location are adapted for navigation and foraging in conditions where vision is limited or absent. Seals successfully live and forage in turbid environments with vibrissae (whiskers) playing an important role when faced with reduced visibility. Therefore, no impacts on harbour porpoise, harbour seal or grey seal are expected from an increase in turbidity due to sediment spill.

Toxic chemicals
In the Fehmarnbelt seabed chemistry study, the results of the chemical analyses were compared with the background levels for the area. These include the German and Danish national and OSPAR Action Levels for a range of toxic chemicals, such as key components from the OSPAR & HELCOM primary and secondary lists. It was concluded, that the levels of toxic chemicals in the Fehmarnbelt study area were at or below the lowest sediment quality guideline (Action Level), at which the level of the chemical is virtually certain to have no adverse effects. Therefore, no impacts from toxic chemicals are predicted on marine mammals.

Barriers
While multiple vessels may be dredging at the same time, the dredging work will be undertaken in sections. The worst barrier case for dredging on a spatial scale is about 5.3 km, which corresponds to ~30% of the line between Puttgarden and Rødby; however, this worst case will only take place for a maximum of 10 weeks.

Since the harbour porpoise is highly mobile, and the existing pressures from ship traffic and the ferries is displaced in both time and space, it has been concluded that there will be no impact on migration due to barrier effects during construction, because animals will be able to easily bypass each dredging section. The additional number of construction vessels is negligible compared to the number of ships sailing through the Fehmarnbelt under baseline circumstances.

There will be no impact from the immersed tunnel during operation, as the animals will be able to pass over the immersed tunnel once it is constructed. Furthermore, the removal of the ferry service across the channel will reduce the number of vessels in the region.

Extraction activities at Rønne Banke and Kriegers Flak
The planned sand extraction activities on Kriegers Flak and Rønne Banke will have little impact on harbour porpoises and seals in the area. There are few animals in these areas, and the sound levels are not assumed to affect the animals except at very close range. The noise is expected to cause a displacement effect and therefore not harm the animals. The impact on the marine mammals is so low that the impact is not significant.

The extraction activities will inevitably cause sediment dispersal affecting the turbidity of the water in the local areas. The extension/propagation of the plumes is strongly dependent on the local current conditions at the time of construction. However, considering the results of the sediment spill modelling, sediment plumes are not expected to have any direct impact on seals and porpoises.

Sediment spill during the dredging activities may impact the availability of prey, especially juvenile fish, which could indirectly have an impact on seals and porpoises. However, since the affected areas are expected to be very small compared to the total area available to the animals on Kriegers Flak and Rønne Banke, and since the duration of the impact is short, no significant negative impacts due to sediment dispersal are expected.

7.13.4 Transboundary Impacts for Marine Mammals between Germany and Denmark

Of the three species of marine mammals occurring in the Fehmarnbelt, only the harbour porpoise may be affected by the project. The seals seldom forage in the near-zone of the planned alignment, they seldom cross the alignment, and their haul-out places are located at least 8.5 km from the alignment and therefore cannot be affected.

Although there are no significant impacts on harbour porpoises, there will be a small area with noise levels from the construction work that might cause avoidance behaviour, with a high to minor degree of impairment. The highest noise level is caused by pile driving in the construction harbour. Pile driving is expected to cause elevated noise levels above the 144 dB re 1μPa^{2}s in distances up to 1.9 km, which is the sound exposure level at which exceedence is expected to cause minor behavioural reactions (minor degree of impairment).

Noise from dredging will cause elevated noise levels above the 144 dB re 1μPa^{2}s at a distance of up to 870 m. Estimates, which are based on the density of the animals at a given time within a certain area, have the expectation that the noise from dredging and pile driving will cause displacement of less than 7 harbour porpoises in the area, which corresponds to less than 1% of the local population in the Fehmarnbelt. This is assessed by comparing sound emissions with the density of the animals within a given area. The displaced area corresponds to less than 0.2% of harbour porpoise habitat in Fehmarnbelt.

In a worst case scenario, the dredging is expected to cause a continuous noise barrier above 144 dB re 1μPa^{2}s over a distance of approximately 5.3 km, which corresponds to less than 30% of the total length of the alignment. The worst case scenario will last less than 10 weeks, and due to this short period, no impact on migration of harbour porpoises or seals from construction noise is expected.

As described for the transboundary impacts, the severity of impairment from the sediment spill, footprint, change of habitat, and reduction in food availability is also assessed as being insignificant for the transboundary impacts between Denmark and Germany.

7.13.5 Significance of Impacts for Marine Mammals

The construction and operation of an immersed tunnel is assessed to have no significant impact on marine mammals in the Fehmarnbelt and transboundary region.

The assessment shows that there are no impacts in the transboundary waters that are important habitats for the marine mammal species.

None of the impacts between Denmark and Germany, which are all of a local character, are in themselves significant, and overall the project is assessed to have an insignificant impact on seals and porpoises. It can therefore be concluded that there will be no transboundary impacts on marine mammals as a result of the construction and operation of an immersed tunnel in the Fehmarnbelt.

TABLE 7.13.1 Significance of transboundary impacts on marine mammals in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on marine mammals in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Marine Mammals	Harbour Porpoise	No	No	No	No	No	No	No	No	Ins	Ins
	Harbour Seal	No	No	No	No	No	No	No	No	Ins	Ins
	Grey Seal	No	No	No	No	No	No	No	No	Ins	Ins

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.14 BIRDS

In the Fehmarnbelt, the bird community is dominated by non-breeding water birds, which use the area for moulting, staging or wintering. In addition, a variety of bird species pass through the area during migration. Although a high number of migratory birds do not touch ground in the Fehmarnbelt area, it serves as a special function for a number of species which concentrate in this area outside the breeding season. The coastal areas also offer suitable habitats for breeding water birds.

Birds registered in the Fehmarnbelt are mainly recruited from the area of Fennoscandia and western Russia. Any significant impact on these bird populations derived from construction or operation of an immersed tunnel will therefore be regarded as transboundary effects.

More than 200 bird species have been observed during the baseline investigations in the Fehmarnbelt. However, this chapter focuses on species where a local impact has been identified and hence a possible transboundary impact may occur. These are:

- Common Eider (*Somateria mollissima*)
- Red-breasted Merganser (*Mergus serrator*)
- Eurasian Wigeon (*Anas penelope*)
- Common Pochard (*Aythya ferina*)
- Tufted Duck (*Aythya fuligula*)

The potential main impact on birds derived from the construction works is associated with change of habitat as a result of sediment spill from dredging. In addition, during construction work, construction vessels operating in the Fehmarnbelt may lead to a barrier effect for migrating birds. As a result, wintering or staging water birds may be displaced and redistributed in the Fehmarnbelt. Migrating birds may face an increased risk of collision or will be forced to deviate from their migration route.

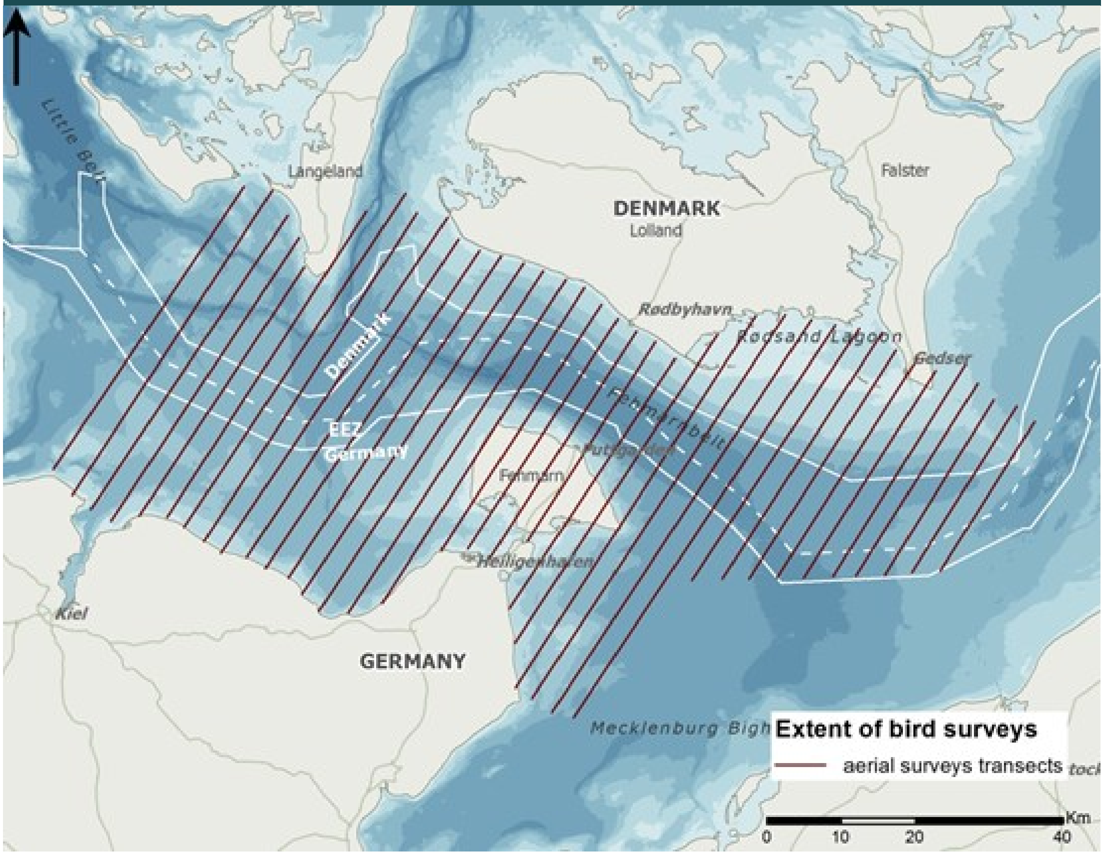
The following sections describe the baseline investigations on birds in the Fehmarnbelt, then possible pressures induced by an immersed tunnel are listed, followed by a description of how these affect birds *within* the Fehmarnbelt area. Finally, potential transboundary implications for the affected bird populations are assessed.

7.14.1 Environmental Baseline

The area of investigation for the bird studies stretches from a line between Kiel and Langeland in the west to a line between Gedser and Dahmeshöved in the east (see Figure 7.14.1). The demarcation of the area of investigation ensures that all Natura 2000 sites are covered, namely the Special Protection Areas (SPAs) designated for the protection of birds in the Fehmarnbelt and adjacent areas.

The relatively wide extent to the east and west allows for the registration of possible distribution gradients and focal points of the different bird species. In addition, the area of investigation covers the maximum area potentially influenced by suspended sediments as identified in earlier investigations.

FIGURE 7.14.1 Demarcation of the project-specific area of bird investigations in the Fehmarnbelt



Migrating behaviour

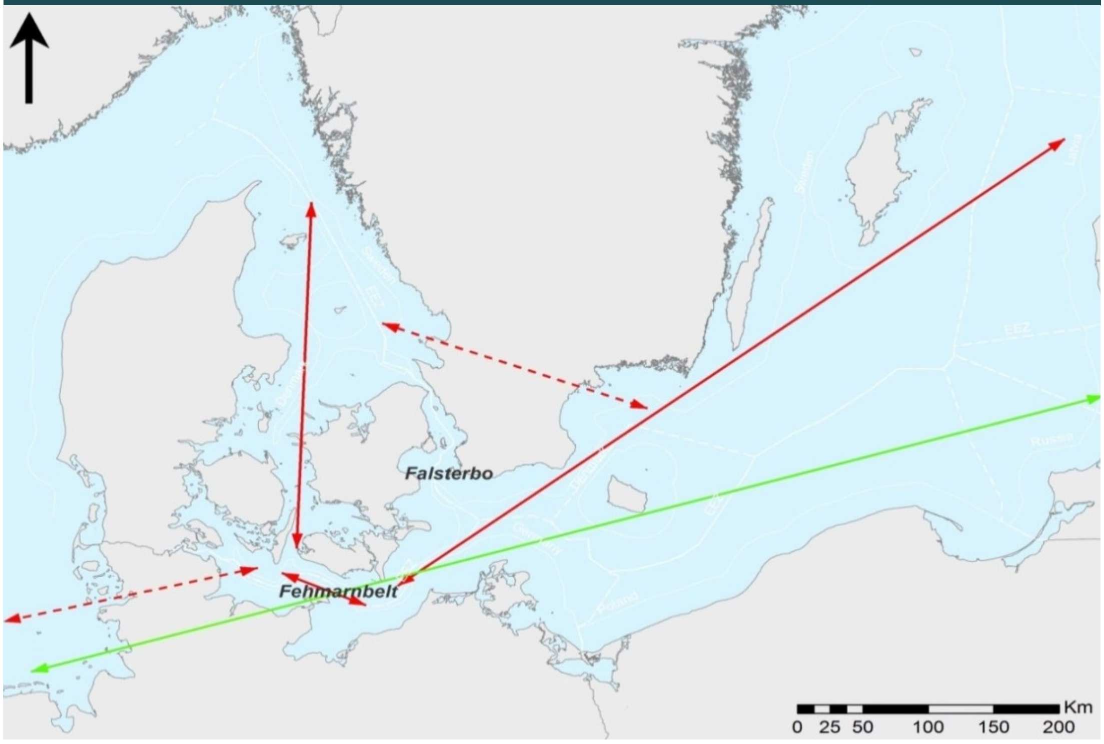
During the baseline study of bird migration, data on 230 bird species migrating through the Fehmarnbelt have been collected. The investigated species were grouped into four main types of migration behaviour:

- Water birds like sea ducks which preferentially migrate over water (type 1 species)
- Water bird species like waders which are less dependent on migrating over water (type 2 species)
- Land birds migrating during daytime (type 3 species)
- Land birds migrating broad-front during night time (type 4 species)

Characteristics of bird migration, such as phenology, distribution, direction, altitude, and weather dependence, have been described for each of the migration behaviour types.

In Fehmarnbelt, two principle major migration routes cross each other. The first is concerned with migrating land birds with an overall north/south direction (mainly type 3 and 4 species). The second migration route has an overall east/west direction, representing the major flyway of water birds (mainly type 1 and 2 species, see figure 7.14.2).

FIGURE 7.14.2 Principle illustration of migration routes for water birds



Note: Schematic migration routes of water birds across the Fehmarnbelt Region. Red solid lines: water bird species preferring to fly over water; dashed red lines: water birds preferring to fly over water, but crossing land in order to avoid large detours; green solid line: geese, ducks, waders with less pronounced preferences to fly over water

Foraging behaviour

In general, lower proportions of fish-eating seabirds use the Fehmarnbelt as compared to benthic-feeding water birds. Despite this, the numbers of Red-necked Grebe and Little Gull (fish-eating seabird) exceed 1% of the biogeographic population and are thus of international importance.

The baseline investigations show that:

- Molluscs dominated the diet of Common Eiders during both study seasons. Blue Mussel (*Mytilus edulis*) being the most common prey, amounting to at least 80% of the diet composition of dissected birds and was per wet weight and energy value among the most important prey type, together with crabs and gastropods
- Common Scoters almost exclusively fed on bivalves, mostly small clams (particularly *Cerastoderma* and *Astarte*) and Blue Mussels
- Diet composition of Long-tailed Ducks was highly variable, but Blue Mussels were numerically the most common prey species, with fish being the second most important prey type

The results for these three most abundant seaduck species wintering in the Fehmarnbelt indicated that each species has plasticity to adapt to changing foraging conditions and shift to alternative prey if needed.

Foraging behaviour studies show that:

- Common Eiders and Long-tailed Ducks were almost exclusively diurnal foragers
- Tufted Ducks foraged either exclusively at night, when birds were resting during daytime on freshwater ponds during mild winter periods, or during both day and night when staying in marine waters all the time during cold winter periods

Foraging intensity also differed between species:

- Common Eiders spent up to 60 % of daylight hours diving
- Long-tailed Ducks were engaged with foraging activities for up to 90 % of daylight hours during winter months

Energy budgets based on recorded Common Eiders foraging intensity, diet composition and literature data were balanced and indicated that the Fehmarnbelt area is a favourable wintering area for Common Eiders and Long-tailed Ducks.

The movements of Common Eiders were investigated and indicated that the birds are relatively sedentary during their winter staging period. Distances between Common Eiders weekly location recordings were rather small, and each bird used only one or two discrete wintering sites.

About half of the tracked individuals stayed at the same wintering site through the entire winter. Tracking of 13 Common Eiders tagged with satellite transmitters extended over the two winters, and all these birds returned to the greater Fehmarnbelt area the following winter.

Birds at Kriegers Flak

The available historic and recent data on the occurrence of water birds at Kriegers Flak unambiguously document that no species occur regularly in the area in concentrations of international importance. The most important occurrence of water birds is the concentration of Long-tailed Duck, which regularly exceeds 10,000 birds in winter and spring (see Figure 7.14.3). Other sea ducks seem to use the area irregularly, while pelagic species like auks and gulls use the area more regularly. Aggregations of large gulls are typically associated with intensive fishing activities.

Baseline investigations undertaken in relation to the planned wind farms on the Swedish and German parts of Kriegers Flak and Adler Ground (Arkona Becken Südost, Ventotec Ost 2) have provided the main sources of recent information on the timing and intensity of bird migration through the Arkona Basin. The migration of water birds through the Arkona Basin seems mainly to take place over a relatively broad front, and is dominated by Common Eider, Barnacle Goose (*Branta leucopsis)* and Common Scoter. A radar study from the Swedish south coast indicated that 30% of the water birds were moving within a distance of 10 km from the coast, while the remaining 70% were dispersed over a wide front without any obvious use of specific corridors.

The migration of land birds through the region is markedly different during day and night, both with respect to dominating species and migration altitude. Recorded flight intensities during the night indicate that the flux of birds peaks on very few nights. During spring, nocturnal migration was most intense 5 - 6 hours after sunset; and during autumn, 3 - 4 hours after sunset, indicating recruitment areas in Mecklenburg and southern Sweden, respectively. Diurnal migration was less intense, and showed no obvious peaks.

The diversity of bird migration can be quite high, as shown by counts of visual migration at Kriegers Flak (surveyed for 65 days in the German part) in which 116 species were observed. The vertical distribution of migrating birds showed the same general trends documented by other studies that birds tend to fly at lower altitudes during head winds and at lower altitudes during the day as compared to during the night. Overall most bird echoes during the night were recorded in the lower 200 m.

FIGURE 7.14.3 Distribution of four selected species of water birds during winter in relation to the location of the sand extraction site at Kriegers Flak and Rønne Banke. The map shows mean modelled densities (birds per km^2) between 2007 - 2009. The Kriegers Flak extraction area is located at the arrow and Rønne Banke extraction area is the black polygon further to the east

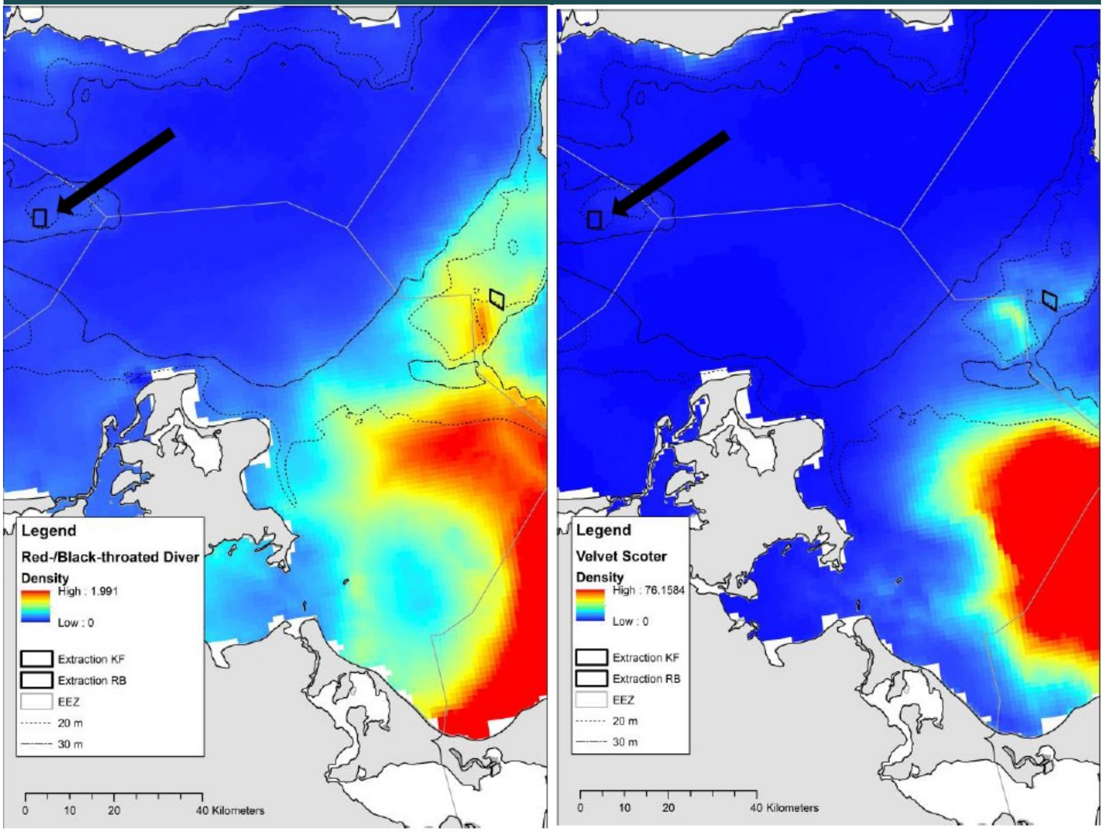
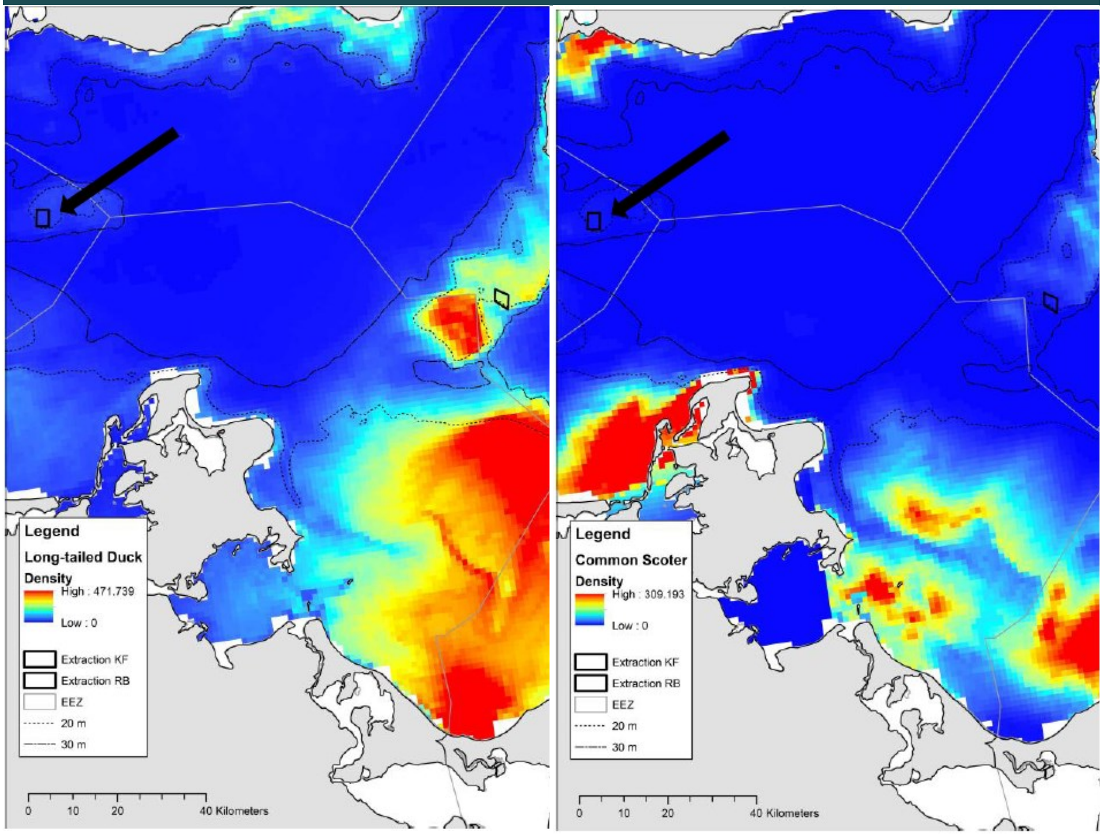


FIGURE 7.14.3 Distribution of four selected species of water birds during winter in relation to the location of the sand extraction site at Kriegers Flak and Rønne Banke. The map shows mean modelled densities (birds per km^2) between 2007 - 2009. The Kriegers Flak extraction area is located at the arrow and Rønne Banke extraction area is the black polygon further to the east



Birds at Rønne Banke

The extraction site on Rønne Banke does not house any local breeding water birds. Accordingly, the baseline description is focused on the occurrence of non-breeding water birds which stage and feed locally, and the regional characteristics of bird migration.

Historic and recent data on the occurrence of water birds at the extraction site on Rønne Banke document that no species presently occur at the site in concentrations of international importance. The most important occurrence of water birds is the concentration of Long-tailed Duck, which regularly exceeds 10,000 birds over the southern part of Rønne Banke and Adler Grund in winter and spring.

Within a distance of less than 5 km (to the southeast), concentrations of wintering water birds of high international importance are found in the Pomeranian Bay (Figure 7.14.3). Other seaducks, divers and Red-necked Grebes seem to use the area regularly, albeit in low densities. More pelagic species, like auks and gulls, also use the area; aggregations of large gulls are typically associated with intensive fishing activities

The baseline investigations undertaken in relation to the planned wind farms on the Swedish and German parts of Kriegers Flak, which is also situated in the Arkona Basin and Adlergrund (Arkona Becken Südost, Ventotec Ost 2) have also provided the main sources of recent information on the timing and intensity of bird migration through the Arkona Basin and at Rønne Banke. The investigations made, therefore, correspond with the section above on migrating birds at Kriegers Flak and conclude that migration of water birds through the Arkona Basin seems mainly to take place over a relatively broad front and is dominated by Common Eider, Barnacle Goose *Branta leucopsis* and Common Scoter.

Also, the vertical distribution of migrating birds showed the same general trends as described for Kriegers Flak and documented by other studies. Birds tend to fly at lower altitudes during head winds and at lower altitudes during the day as compared to during the night. Overall, most bird echoes during night were recorded in the lower 200 m.

Importance

The importance of Fehmarnbelt has been assessed for breeding, non-breeding and migratory birds. The degree of importance has been determined according to a 4-point scale. The importance criteria are based on the number of birds in Fehmarn Belt in relation to their biogeographical population, originating from the Ramsar convention and their conservation status. Fehmarnbelt has been classified as of very high importance if more than 1% of the biogeographical population use the area. Since more than 200 species have been assessed, this report will describe subareas of special importance for water birds in general and focus on the five species where a local impact has been identified and hence a possible transboundary impact may occur.

The baseline investigations of water birds have underlined the importance of particular sites in the Fehmarnbelt to staging water birds during the winter months. Four sites are of high international importance:

- The shallow offshore areas east and west of Fehmarn. The shallow areas around Fehmarn are used by a wide range of water birds, but the proportion of sea duck populations using these sites is particularly high
- The Albue Bank southwest of Lolland, used by large numbers of non-breeding Common Eiders
- The Rødsand Lagoon is of high international importance to Mute Swans during their moulting period
- The eastern part of Kiel Bight (and the Rødsand-Hyllekrog area) support further important concentrations of Greater Scaup, Tufted Duck, Greylag Goose and other species feeding in inshore and inland habitats

Common Eider

The concentration of Common Eider in the Fehmarnbelt area is presently the largest within its wintering range in the Baltic Sea and the Wadden Sea. The concentration in the Fehmarnbelt area is highest at Flüggesand, Sagas Bank, Stoller Grund, Albuen Bank, Hyllekrog and Gedser Rev, as well as Orth Bight and Kiel Bight. All these subareas have been classified as of very high importance.

Red-breasted Merganser

The baseline investigations show that the species is not evenly distributed in the investigation area, but mainly concentrated in sheltered areas like Rødsand Lagoon and being mostly confined to the inshore zone. Consequently, all coastal areas between Lolland and Fehmarn and the alignment area of a fixed link were assessed to have very high importance for red-breasted merganser, but the larger part of the deep water alignment area was assessed to be of minor importance.

Eurasian Wigeon

The entire study area is of very high importance to Eurasian Wigeon. During the baseline investigations, the species was observed being confined to shallow coastal areas and sheltered bays and lagoons.

Common Pochard

The entire study area (including inland areas of the SPAs) was assessed to be of very high importance to Common Pochard. The baseline investigations indicate that the species occurs in higher densities in sheltered areas and also uses the immediate areas around the ferry harbours in high numbers for resting. Main resting areas are located along the mainland German coast and south of the island of Fehmarn. The species is nocturnal (night-time active), thus the nocturnal distribution may differ from the distribution during the daytime. However, it is expected that the alignment area is also of high importance for nocturnal foraging of the species.

Tufted Duck

The entire study area (including inland areas of the SPAs) was assessed to be of very high importance to Tufted Duck. The baseline investigations indicate that the species occurs in higher densities in sheltered areas, such as Fehmarnsund, than in the immediate alignment area; but the areas around the ferry harbours also hold numbers of resting Tufted Ducks of high importance. The species is nocturnal, thus nocturnal distribution may differ. However, it is expected that the alignment area is also of high importance for nocturnal foraging of the species.

7.14.2 Project Pressures

Six main pressures with respect to birds have been identified from the construction and operation of an immersed tunnel:

- Habitat loss from tunnel footprint (construction and operation)
- Habitat change from sediment spill (construction)
- Barrier from construction vessels (construction)
- Reduced light conditions from sediment spill (construction)
- Disturbance from construction vessels (construction)
- Collision risk with construction vessels (construction)

During the 6.5 year construction period of the immersed tunnel, regular sediment spills will lead to increased concentration of suspended material in the water column as well as depositions on the seabed. The major part of dredging, and hence the major part of sediment spills, will occur during the first two years of the construction period (as described in Chapter 7.6).

An increased concentration of suspended matter from the construction of an immersed tunnel in the Fehmarnbelt is identified as the pressure which is predicted to have the highest impact and also the largest spatial extent on benthic vegetation (see Chapter 7.6 on sediment and seabed forms and 7.9 on benthic flora). The indirect effect of sediment spill is therefore also among the highest pressures on birds. The highest levels of degree of impairment are predicted to occur along the Lolland coast and within Rødsand Lagoon, which are both within Danish territory.

The construction of an immersed tunnel will require various ship traffic activities in the offshore part of the alignment area and between the construction sites and working harbours and reclamation sites at Lolland and Fehmarn. The ship traffic and other construction activities will cause disturbance as well as barrier effects to - and collisions with - a number of species of water birds described as being sensitive to these activities. The pressure consists of the physical presence including noise and light emissions of these ships involved in the construction activities.

A conservative impact assessment is described in the following, based on the sensitivity of the relevant water bird species and an assumed complete displacement of birds from the impairment zone, which measures 3 km around the alignment of the immersed tunnel during the construction phase.

As mentioned in the introduction, any significant impact on bird populations from the immersed tunnel is regarded as transboundary, because most of the bird species present in the Fehmarnbelt use the whole area of Fennoscandia and western Russia during their life-cycle.

7.14.3 Transboundary Impacts for Birds

Three different methods were used to quantify the degree of habitat changes and displacements of birds. For an estimation of the consequences of habitat impacts on Common Eider, an individual-based model (IBM) has been developed. For an estimation of the consequences for other species of water birds, GIS-analyses have been undertaken between the distribution models and the affected relevant components. Finally, impacts for species for which limited data were available were assessed qualitatively.

For those species where suitable habitats exist in the impairment zone or in adjacent areas, but the species are not expected to occur there due to already existing pressures (such as ferry traffic and human activities near shore and on the water), or due to reasons of their bio-geographical distribution, there will be no assessment. The same applies to species where no negative impacts are expected.

The significance of the transboundary impacts on birds has been assessed using the 1% criteria, i.e. an impact is significant if it affects more than 1% of the bio-geographical population of a given bird species and thereby a number of birds of international relevance.

The impacts of construction and operation of the immersed tunnel on migrating water birds, or breeding water birds and migrating birds, are small or non-existing. Therefore, no impacts are expected for these species. This is basically due to the low sensitivity of those species concerning the listed pressures.

Breeding water birds (habitat loss)

The overall assessment of the severity of habitat loss from the footprint of an immersed tunnel across the Fehmarnbelt has been assessed to be minor for all breeding waterbird species.

As such, the impact of the habitat loss by the tunnel footprint has been assessed to be only relevant for birds breeding in the northern part of Fehmarn, in the south of Lolland and partly for birds breeding in the western part of Rødsand Lagoon which might commute between the impact zone and the breeding area. Cormorants breeding in the western part of Fehmarn and birds of other breeding colonies within the German Special Protection Areas (SPAs) are mostly expected to use marine areas close to their colonies and not regularly visit the affected project area.

Since the impact from habitat loss has been assessed to be insignificant for all breeding water birds on a local scale, there will be no transboundary impact for those living outside German and Danish territories.

Red-necked Grebes

Red-necked Grebes *(Podiceps grisegena)* breeding at Grüner Brink (30 pairs) or further west on Fehmarn are unlikely to cross the alignment area and the ferry harbour in Puttgarden, and are thus not expected to be affected by the footprint area located east of the harbour. Therefore the severity of loss from the tunnel footprint is assessed to be minor for Red-necked Grebes breeding in SPAs.

Red-breasted Merganser

The breeding birds of Rødsand Lagoon are expected to rear their offspring within the lagoon, and therefore would not be affected by the habitat loss west of Hyllekrog. Red-breasted Mergansers breeding at Grüner Brink or further west on Fehmarn most likely do not cross the highly disturbed ferry harbour in Puttgarden and therefore are not expected to be affected by the footprint area located east of the harbour. There are no records of breeding Red-breasted Mergansers close to the footprint area on Lolland. Therefore the severity of loss from the tunnel footprint is assessed to be minor for Red-breasted Merganser.

White-tailed Eagle

White-tailed Eagles (*Haliaeetus albicilla*) forage on a variety of prey including carrion, birds and fish, and the species use different inland and coastal habitats for feeding. The coastal areas which are predicted to be lost to land reclamation represent potential foraging habitats of White-tailed Eagle, but are assessed to be of minor importance to the species, since these areas are already highly disturbed by the existing ferry traffic and tourist activities. Therefore, the severity of loss from the tunnel footprint is assessed to be minor for White-tailed Eagles breeding in the area.

Gulls

The different gull species breeding in the vicinity of the impact area are assessed as not being sensitive to habitat change due to their opportunistic foraging strategy, which allows them to feed on a variety of prey and use various habitats. Therefore, the alignment area is assessed to be of minor importance to gulls breeding in the area and therefore the severity of loss is assessed to be minor as well.

Terns

Terns catch their prey by plunge-diving mostly in shallow waters, where small fish are abundant. The total loss of such shallow water habitats on the German side would be rather small (approximately 22 ha) and therefore the severity of loss from the tunnel footprint for the Common Tern and Little Tern colonies at Grüner Brink and further west is expected to be minor.

The breeding pairs of Arctic Tern and Little Tern in the SPA Hyllekrog-Rødsand could possibly use shallow water areas close to Rødbyhavn which are predicted to be affected by the land reclamation. However, it is more likely that birds use the shallow waters of Rødsand Lagoon for fishing, since it is closer to their breeding colonies and provides a suitable habitat. Therefore the severity of habitat loss from the footprint to terns breeding in the SPA Hyllekrog-Rødsand has been assessed to be minor. There were no other tern colonies identified on Lolland that would be located close to the alignment.

Other species

For other breeding waterbird species, the impact area of the tunnel footprint is assessed to be of minor importance, and the severity of loss from the tunnel footprint has therefore been assessed to be minor for these species.

Since the impact from habitat loss has been assessed to be negligible for breeding water birds, there will be no impact for those living in the transboundary region.

Non-breeding water birds

Sediment spill

Based on model calculations it is estimated that there will be impacts on 8,300-8,800 Common Eider and 950 - 990 Red-breasted Merganser for the first two winters of the construction period, within the investigation area, due to sediment spill, which leads to reduced light in the water column. This impact is expected to cause a displacement of foraging areas. The food availability is not affected significantly.

In total, the resulting impact of the sediment spill is expected to be a reduction in number of diving water birds in the affected areas within German and Danish territories. The impact is estimated to be temporary and confined to the first two years of the construction phase.

An increase in density of the Common Eider means a doubling of the mortality rate to 1,200 individuals. This extra mortality of 600 individuals corresponds to less than 0.1% of the bio-geographic population and is far below the natural variation in mortality (which is 17,500 p.a., equal to 7% of the total bio-geographical population). Even though the number of displaced birds is higher than the 1% criterion, the transboundary impact has been assessed as insignificant, since the increase of the mortality from the project is low compared to the natural variation in mortality in the Eastern Baltic.

Re-distribution of 950 - 990 Red-breasted Merganser the first two winters of the construction period, which is approximately 0.6% of the bio-geographical population, is below the international criteria of 1%. The impact is therefore assessed as insignificant for the transboundary region and as local.

Disturbances and barrier effects from vessel traffic
It is estimated that 1,500 Eurasian Widgeon, 700 Pochard and 7,000 Tufted Duck will be displaced due to disturbances from service vessels and marine works during construction. In addition, calculations show that 4,100 Common Eiders will be displaced due to these pressures. This is less than 1% of the bio-geographical population of all four species, and there are thus no transboundary impacts outside German and Danish territories on these species. The impact is furthermore temporary for those species, since it will be confined to parts of the construction phase.

The impact on the mentioned bird species consists of a local displacement of sensitive water birds on the Danish and German territories, mostly on stretches along the Lolland coast which means that the impacts are local. A consequent redistribution of water birds within the Fehmarnbelt area leads to minor statistical increased mortality. No transboundary impacts outside German and Danish territories are expected for non-breeding water birds due to disturbances and barrier effects from vessel traffic.

Common Eider
The displacement due to sediment spill of Common Eider will lead the species to spread to less affected areas in the Fehmarnbelt. The density and competition for food will therefore increase in these areas. The results from the individually based models show that the supply of food in the Fehmarnbelt area is large enough to allow significantly greater winter populations of Common Eider than the actual one of approximately 250,000. However, an increase in number or density of Common Eider will induce a statistical increase in winter mortality.

Under existing conditions, the mortality is calculated to about 600 individuals each winter. An increase in density of birds in other areas means a rise in the mortality rate to 1,200. This extra mortality of 600 individuals corresponds to less than 0.1% of the total bio-geographic population and is far below the natural variation in mortality (which has a maximum of 17,500 p.a., equalling up to 7% of the total bio-geographic population) and will not be measurable in the Common Eider breeding area in the Eastern Baltic.

These considerations also apply to the 4,100 Common Eider that are temporarily displaced by service vessels and construction activity.

The overall conclusion is that the transboundary impact outside of Denmark and Germany on the Common Eider caused by sediment spill or disturbances from service vessels and marine construction works is of minor severity and insignificant.

Red-breasted Merganser
The modelling of impacts from sediment spill shows that for the Red-breasted Merganser about 866 - 892 individuals or approximately 0.5% of the bio-geographical population will be excluded from the project area due to increased water turbidity. This is below the international criteria of 1% and the impact is therefore assessed as being an impairment of minor severity.

It is expected, as with the Common Eider, that approximately 1,000 individuals will be redistributed to less affected areas because of sediment spill. This will lead to a minor increase in mortality, which will have a negligible impact on the bio-geographical population. Equally, it is therefore assessed that the immersed tunnel will have no significant transboundary impacts on the Red-breasted Merganser outside of Denmark and Germany.

Eurasian Wigeon, Common Pochard and Tufted Duck
Sediment spill has not been assessed to cause an impact on Eurasian Wigeon, Pochard, or Tufted Duck. Disturbances from service vessels and construction works will cause a temporary dislocation to 1,500 Eurasian Wigeon, 710 Pochard and 7,100 Tufted Duck accordingly. This is less than 1% of the bio-geographical population for all three species.

The expected relocation of the birds to less affected areas will lead to a non-measurable increase in winter mortality. Since the natural mortality varies for the three species respectively, the temporary increase in mortality is assessed as being of minor severity. It is therefore concluded that the sediment spill or disturbances from service vessels and marine construction works caused by the immersed tunnel constitute insignificant transboundary impacts on Eurasian Wigeon, Pochard, and Tufted Duck outside of Denmark and Germany.

Impacts on birds at Rønne Banke

The impacts (due to sediment spill and vessel traffic/light) from the extraction at Rønne Banke on non-breeding water birds and migrating birds are assessed as being locally insignificant and negligible, respectively. There are no breeding birds at Rønne Banke or Kriegers Flak.

The planned dredging site at Rønne Banke is located within 5 km from the SPA Pomeranian Bay, which holds the largest concentration of water birds in the German EEZ of the Baltic Sea. The habitat displacement impacts and habitat change impacts on water birds at the extraction sites will be very small (less than 200 Long-tailed Ducks (*Clangula hyemalis*) and single individuals of divers and Black Guillemots (*Cepphus grille*)). The impacts will mainly take place during winter and spring (November-April).

Sediment dispersal affecting available food supplies for fish and foraging conditions for diving water birds is estimated to be small-scale (see Chapter 7.6 on sediment and seabed forms). Simulations of the dispersal of suspended matter showed that the generated plume due to extraction operations is quickly dispersed, and the plume was mainly located within the limits of the extraction area and only visible for a few days in total. The plume was detected further away at low concentrations (2-10 mg/l), around two or three km from the dredging area and only for about 1 - 2% of the dredging period. The impact is therefore assessed as being negligible.

Given the broad front migration of water birds at the site, collision risks of migrating water birds with the dredging vessel can be expected to be at a low level with no impact on the populations passing the sites.

Impacts on birds at Kriegers Flak

Since the numbers of water birds using the area show strong seasonal variability, the potential habitat displacement of divers, Long-tailed Duck and Black Guillemot will depend on the timing of extraction activities with the largest impacts conceived during winter and spring (November-April). Given the impacted area (10 km^2) and densities of the sensitive species, the number of birds, which the dredger will potentially disturb, will be in the range of less than 100 Long-tailed Ducks and single individuals of divers and Black Guillemots.

Accordingly, the habitat displacement impacts on water birds in the extraction site will be very small.

The key food resources for water birds are mussels and fish. At the site, the benthic fauna is dominated by mussels, which comprise approximately 90 % of the total benthic biomass. During the extraction period, no reduction is expected in the biomass of mussels outside the extraction area due to increased concentrations of suspended sediments. Disturbance effects on potential benthic prey organisms living in the extraction site are therefore assessed as being limited.

Since the loss of removed seabed is maximum 10 km^2 then the maximum number of impacted Long-tailed Ducks can be estimated at less than 100 individuals, while a small area of mussels living on the seabed could be disturbed. Because the recovery time of the mussels is expected to be five years, the removal of seabed will have no long-term impacts on water birds.

Sediment dispersal affecting available food supplies of fish and foraging conditions for diving water birds is estimated to be small-scale. The simulations of the dispersal of suspended matter showed that the generated plume due to extraction operations is quickly dispersed, and the plume was mainly located within the limits of the extraction area and only visible a few days in total. The plume is only detected further away at low concentrations (2 - 10 mg/l), around two or three km from the dredging area and only about 1 - 2% of the dredging period. The impact of sediment dispersal is therefore assessed as being negligible.

Given the broad front migration of water birds at the site, collision risks of migrating water birds with the dredging vessel can be expected to be at a low level with no impact on the populations passing the sites.

7.14.4 Transboundary Impacts for Birds between Germany and Denmark

The pressures with respect to birds within the German and Danish project area from the construction and operation of an immersed tunnel have been identified as the same as those listed above.

As mentioned, the significance of the transboundary impacts on birds has been assessed using the 1% criteria, i.e. an impact is significant if it affects more than 1% of the bio-geographical population of a given bird species and thereby a number of birds of international relevance.

The indirect effect of sediment spill is among the highest pressures on birds within the German and Danish project area. The highest levels of degree of impairment are predicted to occur along the Lolland coast and within Rødsand Lagoon which are both within Danish territory.

Increased concentrations of suspended matter originate directly from the dredging as sediment plumes, but a large part of the impact is also caused by re-suspension of sediment. The orientation of the sediment plume and results of re-suspension are dependent on the present weather regime and current patterns. Therefore, sediment spilled in German territorial waters and consequently in Danish territorial waters could end up crossing the border.

The bird-related impact from sediment spill is, however, related to shallow waters (i.e. near coastal water). The general trend is that sediment spilled near the coast will have the highest impact on the near coastal waters within the same country as where the sediment is spilled (i.e. Germany and Denmark).

The indirect impacts from sediment spill will cause displacement of birds, which is significant to only Eider Ducks. For the first two winters of the construction phase, when the most intensive dredging works take place, it is estimated that on both sides of the German and Danish project area the reduction in the population of Eider Ducks will be in the scope of 8,300-8,800 birds (corresponding to approximately 1.09 - 1.16% of the bio-geographic population). Since Eider Ducks are mobile, they can be displaced from across the Fehmarnbelt, meaning that an impact in Rødsand Lagoon can result in displacement of birds into German shallow waters.

The displacement of non-breeding birds (Tufted Duck and Pochard) caused by the construction vessel traffic offshore has been assessed as not having a significant impact because only 0.59% and 0.20% of the total bio-geographic population is affected, respectively. The assessment of Common Eider and Wigeon in relation to this pressure presents the same conclusion because only 0.1% and 0.64% of the total bio-geographic population of these species is affected.

A reduction in the light conditions in the water column due to sediment spill, which causes indirect impacts on water birds resulting from changes in affected benthic flora and fauna and fish communities, has been assessed to have an insignificant impact on Common Eider and an insignificant impact on Merganser. The displacement due to this indirect impact from the sediment spill is 1.2% of the bio-geographic population of Common Eider during the construction period and 0.6% of the bio-geographic population of Merganser.

Individual-based modelling on the Eider Ducks shows that the impact from reduced light conditions in the water column *does not* reduce the food resources significantly. Therefore, the mortality rate caused by the displacement is not expected to be significantly higher than under reference conditions; hence the impact from the sediment spill is assessed as insignificant for Eider Ducks.

The final conclusion from the impacts on birds within the German and Danish project area is therefore assessed as insignificant for Common Eider and Tufted Duck, Merganser, Pochard and Wigeon.

7.14.5 Significance of Impact for Birds

The assessment shows that there will be an insignificant transboundary impact on water birds on the Danish and German area as described in the above sections. This impact will be transboundary between Denmark and Germany, but will be insignificant for Common Eider and other non-breeding water birds. For any of the other sub-components analysed, there will be no transboundary impacts (see Table 7.14.1).

TABLE 7.14.1 Significance of transboundary impacts on birds in the Baltic Sea, Norway, Germany and Denmark

Factor		**Assessment of impacts on birds in the Baltic Sea, Norway, Germany and Denmark**									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Birds	Common Eider	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins
	Breeding water birds	No	No	No	No	No	No	No	No	No	No
	Other non-breeding water birds	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins
	Migrating birds	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.14.6 Mitigation Concerning Birds

Mitigation is defined as actions taken to minimise or eliminate impacts on protected species during design, construction and/or operation of the Fixed Link.

In addition to the mitigation measures already included in the planning and design of the project, it is recommended to reduce and control light emissions during construction activities as long as this is not in conflict with safety requirements. Light emissions may attract birds during bad weather conditions and consequently enhance collision risk, or act as a barrier during other situations when birds would avoid intensively lit areas. In relation to the planning of the construction works, the expected impacts within Denmark and Germany optimise the methods used during the dredging period in order to minimise the sediment spills.

7.15 MIGRATING BATS

As part of the transition area between Scandinavia and the middle European mainland, the Fehmarnbelt (and the Belt Sea) is traversed by migratory bats. A wide range of shallow water- and water influenced habitats gives rise to rich food supplies for the insectivorous bats. Bat activity is clustered within areas of vertical structures like hedgerows and wood patches.

In the Fehmarnbelt, bat species migrate through the region during spring and autumn, with species such as Soprano Pipistrelle (*Pipistrellus pygmaeus*), Nathusius´ Pipistrelle (*Pipistrellus nathusii*) and Noctule (*Nyctalus noctula*). These species were regularly detected during the offshore surveys.

The following chapter describes the potential impacts from construction of an immersed tunnel on the migrating bats in the Fehmarnbelt and transboundary region. Impacts on local bat populations on Lolland and Fehmarn are not described in this report, since they per definition are not trans-boundary.

7.15.1 Environmental Baseline

Some European bat populations are known to migrate between their summer and winter residence. However, knowledge about their migration routes, flight altitudes and distances is limited.

In order to obtain specific data on bat migration intensity, species composition and patterns across the Fehmarnbelt, various investigation methods were developed and tested during the autumn migration period in 2009 (13 August - 19 October 2009). The methods were applied during a survey carried out between 1 April and 1 November 2010, which focussed on the presumed migration periods during spring and autumn.

The presence of bats was investigated by recording bat calls using two different ultrasound detector types: the Pettersson 240x ultrasound detector and the AnaBat SD1 system.

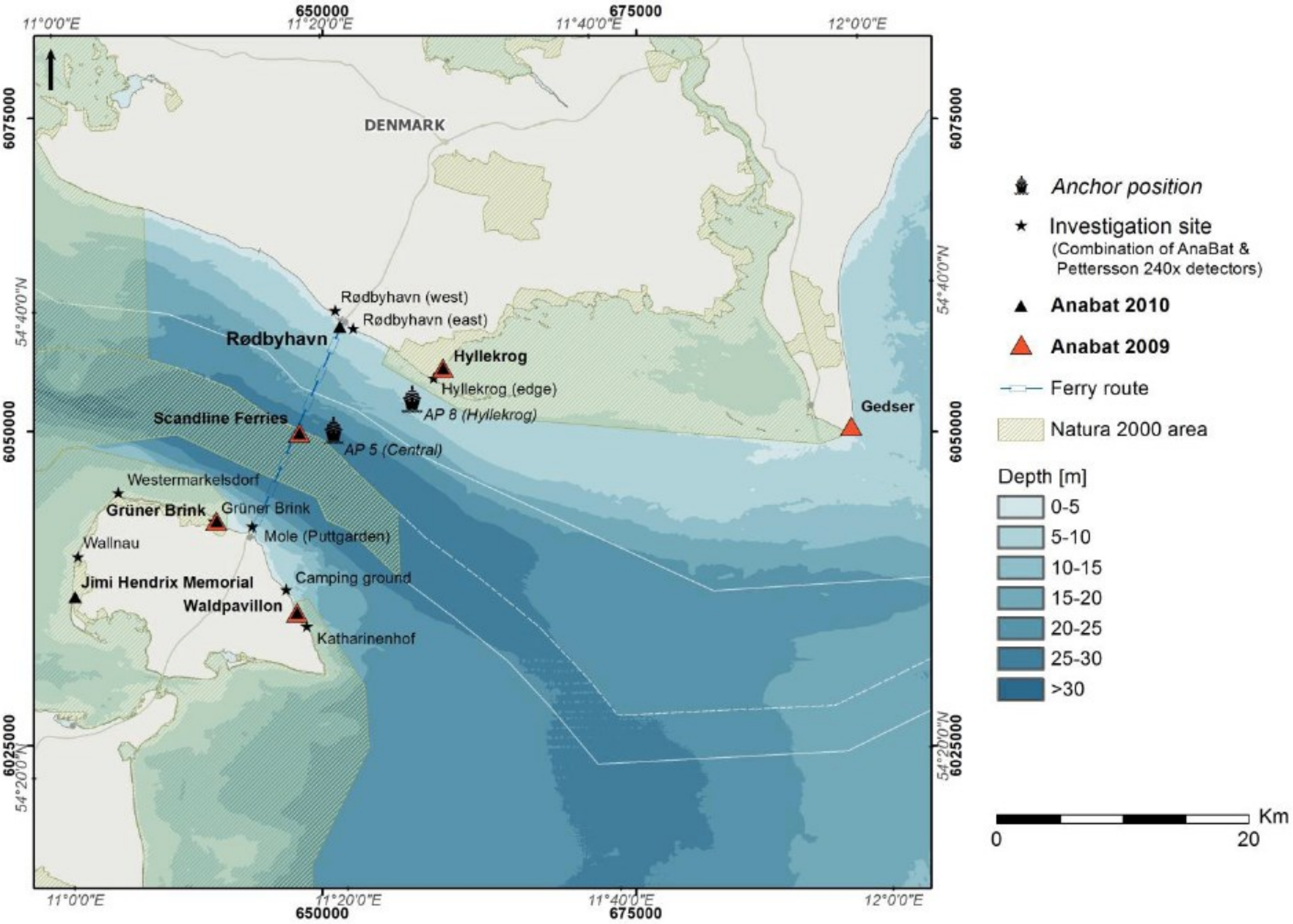
Bat migration was studied on board the vessel Arne Tiselius Ⅱ. In autumn 2009, the vessel was moored at two different anchor positions in the Fehmarnbelt: one in the central Fehmarnbelt (47 survey nights) and one near Hyllekrog (15 survey nights). In spring 2010, the anchor position at Hyllekrog was abandoned. An anchor position was therefore added in the middle of Øresund in order to study the bat migration near a large bridge and across open sea. A total of 10 night surveys were carried out here.

Recordings were also carried out from two Scandlines ferries in the Fehmarnbelt, and the Pettersson D 240x ultrasound detector was used during personal surveys at nine different locations on the coast of Lolland and Fehmarn. This is a method where someone walks with the detector to track sounds from bats. A total of 12 night surveys were carried out in 2009 and 16 night surveys in 2010.

Finally, investigation of whether bats use altitudes higher than 60 m above sea level for migration were performed by attaching a kite to the radar vessel, which lifted an AnaBat SD1 up in the air. The investigation was conducted for four nights in the Fehmarnbelt.

On the Danish and German mainland, five AnaBat SD1 detectors were installed at selected sites to identify a possible change in species composition during the migration period. In addition, personal observations took place at Fehmarn, Lolland and Gedser coastal sites (see figure below).

FIGURE 7.15.1 The area of investigation for the bat studies covers the coastal areas of Fehmarn and Lolland and the Fehmarnbelt. The demarcation of the area of investigation ensures that all relevant Natura 2000 sites and adjacent areas are covered



In 2009, 15 bat boxes, where the bats can rest, were installed in a coastal wood patch near Katharinenhof and the AnaBat study site “Waldpavillon”. The intention was to detect whether or not the boxes were used. The bat boxes were checked during the supposed migration periods.

The coastal and sea-based baseline bat studies verified a total of 10 species, of which three have been shown to migrate across the Fehmarnbelt and will be considered in the following (namely Soprano Pipistrelle (*Pipistrellus pygmaeus*), Nathusius’ Pipistrelle (*Pipistrellus nathusii*), and Noctule (*Nyctalus noctula*)).

The ship-based investigations provided 237 bat registrations. The most frequently recorded bat species was the Nathusius‘ Pipistrelle, which is known from bat ringing studies to be a long-distance migrant.

At sea, the Noctule, which is another bat known to be a long-distance migrant, was also detected regularly. The Soprano Pipistrelle was identified in relatively high numbers, implying that this bat species also migrates across the Fehmarnbelt. The following species were rarely recorded during the offshore surveys: Serotine, Pond Bat and the Common Pipistrelle.

Bat flight altitudes were regularly registered by visual observation. The Pipistrellus species were observed flying at altitudes usually between 2 - 5 m. Species of the genera *Nyctalus* and *Eptesicus* were usually registered at altitudes between 15 - 25 m or even higher.

During the offshore survey near the Øresund Bridge the following bat species were registered: Leisler‘s Bat, Noctule, Particoloured bat, Nathusius‘ Pipistrelle and Soprano Pipistrelle. In total, 23 calls were recorded near the Øresund Bridge. Whether the bats prefer to cross the Øresund across the open sea or in the vicinity of the bridge could not be studied because no data concerning bat activity could be collected for the structure of the bridge itself. However, the survey does show that bats are crossing Øresund.

The shore-based and offshore-based surveys have provided insight for the first time into bat behaviour during migration periods in the Fehmarnbelt area. Species which are known to be long-distance migrants (Noctule, Leisler’s Bat, Particoloured Bat and Nathusius’ Pipistrelle) and those which are not supposed to be migratory (Barbastelle, Serotine, Common Pipistrelle and Soprano Pipistrelle) could be regularly observed leaving the shore – presumably to cross the Fehmarnbelt.

The baseline investigations show that bats do occur regularly in the Fehmarnbelt coastal area and some species are proved to migrate across the Fehmarnbelt. During the autumn in particular, bats were observed crossing the Fehmarnbelt.

The baseline investigations showed no indications that bats were using specific migration corridors. Based upon this, it is assumed that bats are crossing the Fehmarnbelt on a broad front and that the alignment area of a planned fixed link does not play a special role in bat migration to or from adjacent areas in the transboundary region.

Importance

Lack of current knowledge about bat migration biology only makes it possible to classify importance on a two grade scale (special and general importance). Fehmarnbelt has been regarded as being of general importance for all three regarded species, as the baseline study indicates some migration, but no special migration corridor in the area.

7.15.2 Project Pressure

Several pressures have been assessed for potential effects on migratory bats from a fixed link during construction and operation. The main pressures during construction (temporary) and the potential effects identified are:

- Working areas, equipment, facilities and physical structures of the fixed link structures, including land approaches and sea areas
- Collision risk with construction vessels
- Barrier effects from construction vessels
- Habitat change at tunnel entrances/land approaches

Potential effects induced by the presence of the (permanent) physical structures and associated facilities of the fixed link, or related to the operation of the fixed link:

- Habitat loss and/or change
- Traffic-related collision risks for bats
- Habitat change at tunnel entrances/land approaches

Noise has been excluded as a pressure because no passive listening species of bats were detected during surveys.

Only the pressure ‘Traffic-related collision risk’ was assessed to be relevant for bats. This pressure was assessed in detail with regard to both the degree of impairment and the severity of impairment.

7.15.3 Transboundary Impacts for Migrating Bats

The impact of an immersed tunnel plays a subordinated role in concern for migratory bats because the main part of the construction is situated away from the sphere of bat activity. Most of the bat registrations near the coast were recorded at Hyllekrog several kilometres from the alignment. Bat migration is assumed to occur on a broad front, which implies that only a small proportion of the bats migrating across the Fehmarnbelt and the adjacent areas could be affected by construction of an immersed tunnel. This is unlike some migratory birds, which can be disturbed by structures or construction activities in their direct migration path or from activities in staging areas.

Earlier investigations in the areas of Kriegers Flak and Rønne Banke have indicated that bats do not pass these locations on a regular basis. Therefore, further baseline investigations for the two sites concerning migrating bats have not been found relevant in relation to the immersed tunnel. Because the construction work in the Fehmarnbelt region and dredging at Kriegers Flak/Rønne Banke is temporary and very local, it has been assessed that there will be no impact on the migrating bats near the sites or in the transboundary region.

Due to flight behaviour of bat species of concern and the fact that bat migration in the Fehmarnbelt area occurs on a broad front, and because no important migration routes were identified during the baseline investigations, the overall collision risk was assessed to be no higher during the construction phase for bats.

Traffic collisions and the tunnel entrances have been assessed as the only relevant pressure. The estimated traffic volume with regard to operation of a fixed link was estimated to be between 8,000 and 9,450 vehicles on an average day. The collision risk for migrating bats near the tunnel entrances at Rødbyhavn and Puttgarden is assessed to be medium for Soprano Pipistrelle and Nathusius' Pipistrelle and low for Noctule. All three species might be attracted to light at the tunnel entrance, or otherwise cross the highway at the tunnel entrance. The Noctule flies and hunts above traffic, while the Soprano Pipistrelle and Nathusius' Pipistrelle fly and hunt nearer to the ground, and therefore are more prone to be hit by traffic.

Consequently, the degree of impairment regarding traffic-related collision risk is assessed to be minor for Noctule and medium for Nathusius' Pipistrelle and Soprano Pipistrelle in the area of the tunnel entrances.

Accordingly, the overall magnitude of impact on bat migration is insignificant in the Fehmarnbelt and no impacts are expected in the transboundary region.

7.15.4 Transboundary Impacts for Migrating Bats between Germany and Denmark

Only three migrating bat species (Soprano Pipistrelle, Nathusius' Pipistrelle, and Noctule) are assessed to be relevant for the EIA of the fixed link, since the remainder of the 10 species were only found very rarely at sea (less than five registrations during all offshore surveys). All but one of the potential pressures are assessed to cause no impacts on the relevant bat species during their migration phase.

Only traffic-related collision risk is assessed to be relevant for the EIA, and the other pressures mentioned earlier are not assessed further. Traffic-related collision risk is assessed as a medium impairment to migratory *Pipistrelle* species in the area of the tunnel entrances. However, the impact is insignificant. Therefore, any impacts on migrating bats on the German or on the Danish side are considered to be insignificant, and vice versa.

Significance of Impact for Migrating Bats

Because the investigations indicate bat migration is assumed to occur in a broad front, only a small proportion of the bats migrating across the Fehmarnbelt and the adjacent areas might be affected by the construction and operation of the immersed tunnel. None of the pressures in the construction phase were assessed as having an impact. As the construction work in the Fehmarnbelt region and dredging at Kriegers Flak/Rønne Banke is temporary and very local it is likely that there will not be an impact on migrating bats in the transboundary region.

Most of the potential pressures in the operational phase were assessed to cause no impacts on the relevant bat species during their migration phase. Only the pressure 'Traffic-related collision risk' was assessed to have an impact on migrating bats.

The degree of impairment regarding traffic-related collision risk is assessed to be minor for Noctule and medium for Nathusius' Pipistrelle and Soprano Pipistrelle in the area of the tunnel entrances.

The impact assessment therefore concludes that any predicted impacts are insignificant at local (the Fehmarnbelt) and population level. Furthermore, the investigation on bat migration predicts that only a few bats on a local scale will be impacted. Therefore, no transboundary impacts are expected.

TABLE 7.15.1 Significance of transboundary impacts on migrating bats in the Baltic Sea, Norway, Germany and Denmark

Factor		**Assessment of impacts on migrating bats in the Baltic Sea, Norway, Germany and Denmark**									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Migrating Bats	Soprano Pipistrelle	No	No	No	No	No	No	No	No	Ins	Ins
	Nathusius Pipistrelle	No	No	No	No	No	No	No	No	Ins	Ins
	Noctule	No	No	No	No	No	No	No	No	Ins	Ins
	Other Species	No	No	No	No	No	No	No	No	Ins	Ins

Note: Sig = Significant impact, Ins = Insignificant impacts, No = No impact

7.15.5 Mitigations concerning Migrating Bats

In relation to the immersed tunnel, mitigation measures are not assessed to be relevant with regard to migrating bats, as there are no significant impacts for these in the transboundary region.

7.16 STRICTLY PROTECTED SPECIES

The construction and operation of the immersed tunnel will potentially impact strictly protected species (as defined by the Habitats Directive) on land and in the marine area. The strictly protected species which could potentially be impacted are: amphibians (on Lolland and Fehmarn), birds, bats, fish and marine mammals.

Pressures from construction and operation of an immersed tunnel on the different strictly protected species are assessed in the sections with the relevant environmental component and include the following:

- Area occupation by footprint and loss of habitat
- Barrier effects
- Kills by traffic

Other pressures such as e.g. lighting, noise, vibrations, ground water lowering's, nitrogen de-position and pressures as a result of release of pollutants are included in the assessment, where relevant.

In order to give an overview, a short summary of the findings with respect to protected species and transboundary impacts are presented in this section.

On Lolland and Fehmarn several strictly protected species of amphibians and bats occur. Impacts on species on Lolland and Fehmarn are linked to the footprint of the project, and by nature confined to Denmark and Germany. With the implementation of planned mitigation and compensation measures it is assessed that no significant impact will occur on either of these species groups and no transboundary impact are expected.

Assessment of impacts on relevant birds listed in Appendix 1 of the Bird Directive is addressed in Chapter 7.14. Furthermore, Chapter 7.14 contains the assessment of impacts on birds listed in the Natura 2000 areas as conservation objectives.

This assessment showed that an impact could occur on Common Eider in the transboundary waters between Denmark and Germany due to displacement from construction vessels and sediment spill, but this impact was insignificant in both Danish and German waters and in other transboundary waters. No transboundary impacts were expected on the other protected bird species from the immersed tunnel.

During the baseline investigations, none of the strictly protected species of fish were observed inside the survey area. The project is therefore assessed as having only an insignificant impact.

The assessment of strictly protected species of marine mammals is presented in Chapter 7.13 regarding marine mammals and Chapter 7.17 concerning the Natura 2000 areas. Only insignificant impacts are expected in Danish, German or transboundary waters.

7.17 NATURA 2000

The following chapter serves two main objectives. Firstly, it has to be documented if and in what way significant impacts on Natura 2000 sites can be expected from the construction of the Fehmarnbelt Fixed Link within the territory of the possibly affected parties, Secondly, since the Natura 2000 network is a common European concern, potentially affected parties are provided with summarised information on impacts on the Natura 2000 sites within the territory of the Parties of Origin.

Pursuant to European law implemented in Denmark and Germany, Femern A/S has assessed the project in relation to possible environmental impacts on Natura 2000 sites. Natura 2000 is an EU-wide network of protected natural areas comprising Sites of Community Importance (SCI, habitat area) designated under the Habitats Directive and Special Protection Areas (SPA, bird protection area) designated under the Birds Directive. The assessment in relation to designated sites is conducted in two phases. The first phase concerns a screening of the potential impact on each designated site, to assess whether a “significant impact” on the conservation status of habitat and/or species that are part of the conservation objectives of the site can be excluded. If such an impact cannot be excluded, an appropriate Natura 2000 assessment of that site needs to be carried out during a second phase.

7.17.1 Project Pressures

Based on the specific project and the overall conservation objectives, it is deemed important to include the following types of pressures in the assessment of the impact on the Natura 2000 site designation of species and habitats:

Construction phase:

- Loss of habitats due to area occupation (”construction footprint”)
- Changes of the conditions for flora and fauna as a result of dredging, (increased suspended sediment in the water column and deposition of sediment

- Increased turbidity and impairment of foraging possibilities for birds as a result of decreased visibility in the water
- Disturbances from construction vessels and activities (including vibrations, noise, dust and light)
- Barrier effect from construction vessels
- Collision risk from construction vessels
- Waterborne pollution
- Ground water lowering's
- Increased N-deposition

Operation Phase:

- Permanent loss and/or changes of habitats as a result of area occupation ("footprint")
- Development of artificial reefs on structure (local)
- Increased Nitrogen deposition
- Hydrographical changes (currents, water levels, salinity, temperature, stratification and waves)
- Changes in coastal morphology and their importance for terrestrial habitats and associated species

Considering the nature of the above-mentioned pressures, only sediment spill and deposition have the potential of affecting remote areas situated hundreds of kilometres away from the construction site, depending upon hydrographical conditions. The other impacts are short range and therefore confined to the Fehmarnbelt Region itself.

With regards to sediment spill, the results of hydrodynamic models describing both distribution of sediment plumes and amount of deposition in different areas have been presented earlier in this report in Chapter 7.6. It is revealed that besides the two countries of origin, only Swedish marine waters may possibly be affected by sediment plumes and subsequent sediment deposition (see also Figure 7.17.1). Of the Swedish marine Natura 2000 sites, the closest sites to the deposition area are Falsterbo-Foteviken (SE0430002) and Falsterbo-halvön (SE0430095), which can be considered as potentially affected sites.

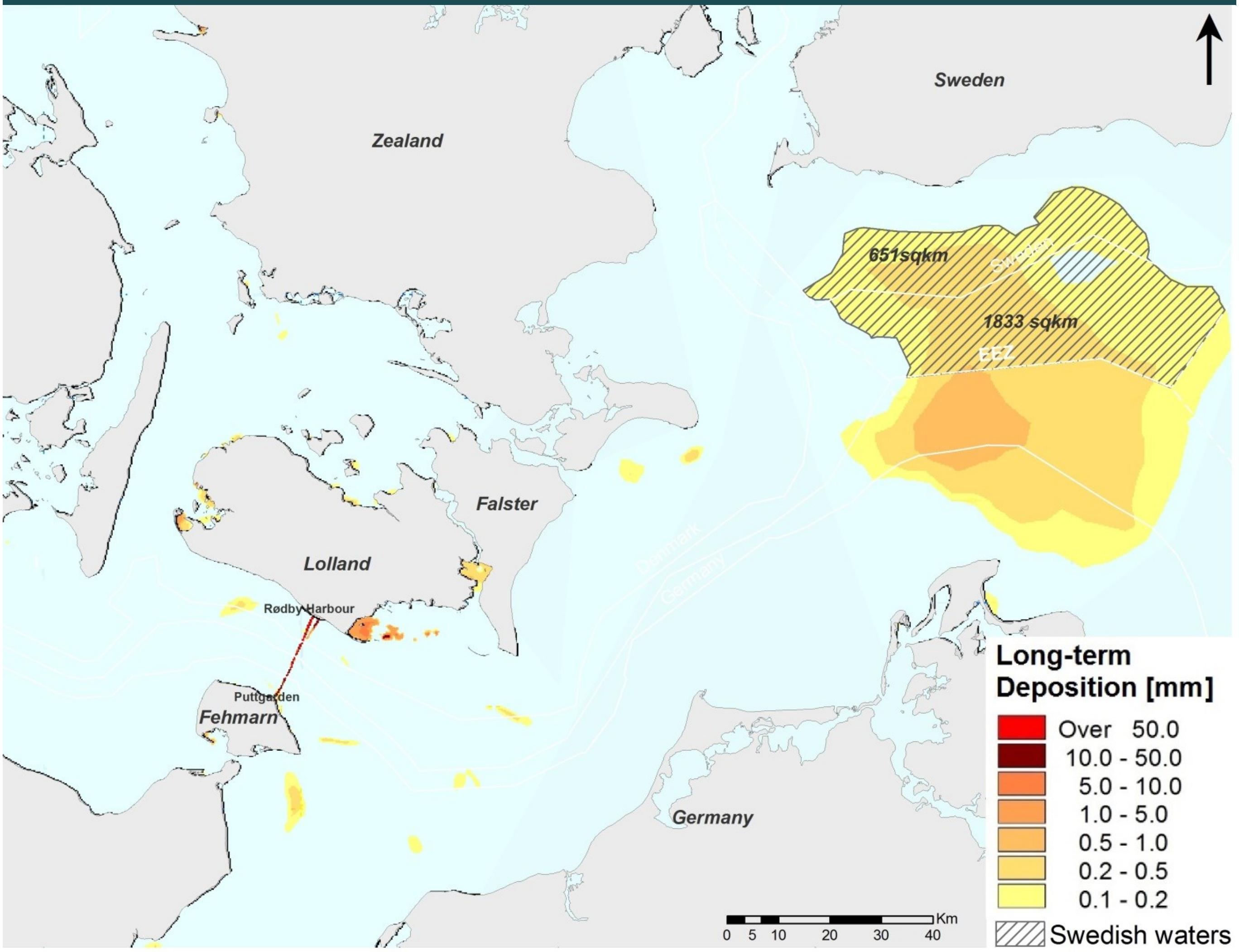
However, both areas lie outside the deposition area (closest distance is 6.6 km) and neither direct, nor indirect impacts are expected at these sites. As stated in Chapter 7.6, excess sediment concentrations in the water column as well as the expected amount of deposited sediment in Swedish waters are low compared to the natural background in the Arkona Basin, and therefore the impact is considered insignificant also outside of the Natura 2000 sites.

All other countries further east, i.e. Finland, Poland, Estonia, Latvia, Lithuania and Russia as well as Norway, and other sites in Sweden and Finland, will only receive non-measurable sediment plumes and deposition. Therefore their Natura 2000 sites are excluded from the screening.

Also under consideration, as part of the construction phase, is the extraction of sand at Krieger's Flak and Rønne Banke in the western part of the Baltic Sea in order to obtain sand for concrete production and backfilling of the tunnel trench, respectively. The possible sand extraction activities on Krieger's Flak and Rønne Banke may, by their sediment spill, noise and other disturbances during the extraction and transportation, potentially affect appointed habitat types and species, which must be conserved as a part of the objective of the Natura 2000 sites located in the influence area of the sand extraction sites.

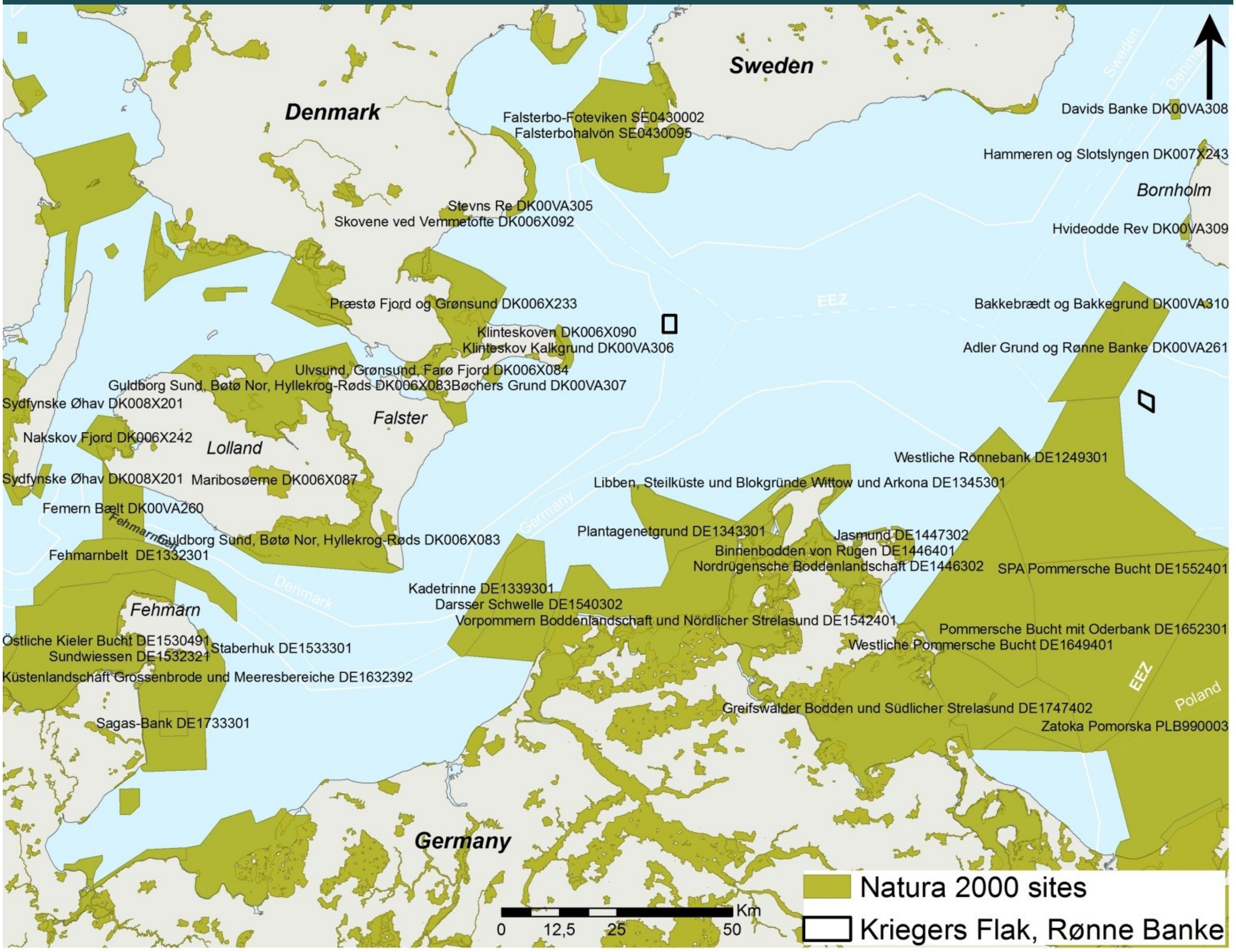
With regards to hydrographical changes, the entire Central Baltic Sea can potentially be affected and with that all marine Natura 2000 sites. However, as stated in Chapter 7.4., hydrographical changes will be negligible since alterations of the seabed profile are small and confined to the nearshore areas of Lolland and Fehmarn. Thus, significant impacts on Natura 2000 sites in countries other than the parties of origin, due to hydrographical changes caused by the project, can be excluded.

FIGURE 7.17.1 Sediment deposition pattern at the end of the construction period in relation to Natura 2000 sites



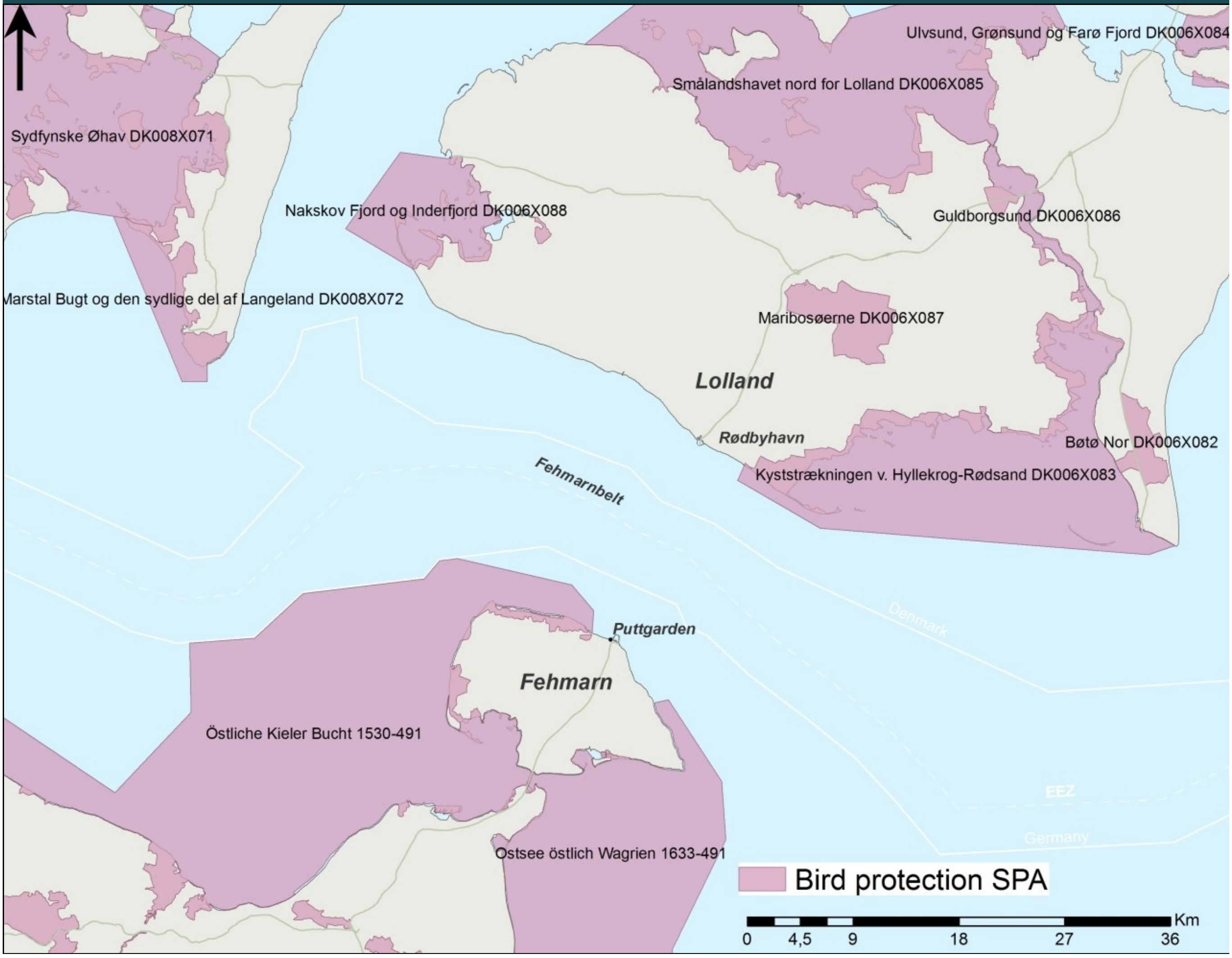
The analysis of the impact zones resulting from the different pressures shows that only Natura 2000 sites of the countries of origin are relevant for the Natura 2000 screening.

FIGURE 7.17.2 German and Danish Sites of Community Importance (SCI) in the region around the planned Fehmarnbelt Fixed Link



In Figure 7.17.2 and 7.17.3 the location of Sites of Community Importance (SCI) and Special Protection Areas (SPA) within the Fehmarnbelt Region is shown. The final selection of sites to be considered in the screening phase of the Natura 2000 assessment is listed in Table 7.17.1 and 7.17.2.

FIGURE 7.17.3 German and Danish Special Protection Areas SPA in the region around the planned Fehmarnbelt Fixed Link



Generally, the main pressures from the Fehmarnbelt Fixed Link are linked to the marine environment and leads to the selection of marine Natura 2000 sites to be included in the screening phase. As the only exception, the inland SCI/SPA “Maribo Lakes” have been included since this site hosts species of ducks on the conservation objective, which rest on the site during daytime hours and commute to marine areas such as Fehmarnbelt during the night. Thus, effects on this site cannot be excluded in advance.

In addition, the western border of the SCI “Smålandsfarvandet North of Lolland, Guldborg Sund, Bøtø Nord and Hyllekrog-Rødsand” is located in the vicinity of the area claimed for the production facilities for the immersed tunnel. Disturbance from construction activities (light, noise, dust, traffic) and other types of pressures can therefore potentially affect the site.

7.17.2 Methodology – Screening

The key issue in relation to the methodological approach is to describe favourable conservation status for each habitat and species and assess whether an impact from the project could be considered significant. The approach has been to evaluate the potential impact on each single habitat and species in relation to the legal obligations defined by the habitats and birds directives.

For habitats, area, range, structure and function, conservation status for characteristic species, and future prospects have been addressed. For species, focus has been on population size, range, habitat, and future prospects.

The assessment of the impact on habitats and species in this screening is divided into (in compliance with the habitats directive):

- Insignificant, implying that a significant impact can be excluded.
- Significant impact cannot be excluded; there is a need for an appropriate assessment for the site in question.
- Not relevant. A significant impact on conservation status of specific habitats and species can be excluded.

Generally, in relation to the assessment, a conservative approach has been used in the screening, following the precautionary principle. This means that any uncertainty about the significance of impact has led to the interpretation that a potentially significant impact cannot be excluded. However, on the level of the appropriate assessment, this uncertainty has been analysed in detail and the final conclusion revised accordingly.

These criteria have been applied for hydrography, seabed, marine biology, relevant fish species (five species from Annex II of the Habitats Directive, which are included in the conservation objective for the Natura 2000 sites, which is covered by the screening), mammals, and especially birds.

7.17.3 Methodology – Appropriate Assessment

The appropriate assessment (phase 2) is built upon the results of the screening, which means that all potential impacts are included while there will be a strong focus on those issues, where a significant impact could not be excluded in the screening.

To attain a transparent evaluation of the likely impacts from the Fehmarnbelt Fixed Link on the marine and terrestrial environs, a general methodology has been developed by the project.

In the context of Natura 2000 appropriate assessment, however, it is the site's conservation objectives and the criteria for favourable conservation status which is guiding the decision of whether a project leads to negative impacts or not. Since the officially applied criteria for favourable conservation status in Denmark and Germany are more descriptive and in many cases do not define exact thresholds (e.g. Søgaard et al. [2003] and Dahl et al. [2005]), the appropriate assessment is accordingly descriptive in character.

With regards to marine habitat types, the assessment focuses on the integrity of benthic flora and fauna communities that constitute the habitats, e.g. for the habitat.

7.17.4 Screening of Natura 2000 sites in Denmark

Since none of the Danish Natura 2000 sites are located within the construction area, a significant impact on habitats and species that are listed as conservation objectives of the sites can be ruled out for most of the mentioned pressures beforehand because of the distance alone. Thus, for six out of the eight Danish habitat and a bird protection areas, the conclusion from the screening phase is that an appropriate Natura 2000 assessment should not be conducted (Table 7.17.1).

For the remaining two areas, "SCI 006X238 Hyllekrog-Rødsand" (Smålandsfarvandet North of Lolland, Guldborg Sund, Bøtø Nord and Hyllekrog-Rødsand) and "SPA DK 006X083 Coastal Zone Hyllekrog-Rødsand", the conclusion is, however, different, as the screening indicates that an appropriate Natura 2000 assessment should be conducted for the immersed tunnel. The rationale behind this evaluation is that it cannot be excluded that the expected amounts of spilled sediment during the construction phase within the Rødsand Lagoon will affect benthic communities of habitat type 1160 (shallow bays and inlets), and 1170 (reefs) through light attenuation and sediment deposition (Table 7.17.1).

Sediment spill may also affect food resources and feeding possibilities of breeding and staging birds. None of the other pressures mentioned have been assessed to lead to significant impacts on the conservation objectives.

The SPA DK 006X083 forms part of the SCI 006X238, hence the two sites are dealt with together in the appropriate assessment.

TABEL 7.17.1 Potential impacts on Danish Natura 2000 sites during the construction phase of the immersed tunnel

Natura 2000 site Species & Habitats	Hyllekrog – Rødsand (SCI+SPA)	Stone Reef southeast of Langeland (SCI)	Fehmarn-belt (SCI)	Maribo Lakes (SCI + SPA)	Nakskov Fjord (SCI+ SPA)
1110 Sandbanks covered by seawater: Marine biology Fish	N-S N-S	N-R N-R	N-S N-S	N-R N-R	N-S N-S
1140 Mudflats and sand flats not covered at low tides: Marine biology Fish	N-S N-S	N-R N-R	N-R N-R	N-R N-R	N-S N-S
1150* Coastal lagoons: Marine biology	N-R	N-R	N-R	N-R	N-S
1160: Shallow bays and inlets: Marine biology Fish	S N-S	N-R N-R	N-R N-R	N-R N-R	N-S N-S
1170: Reefs: Marine biology Fish	S N-S	N-S N-S	N-S N-S	N-R N-R	N-S N-S
Mammals: Grey Seal	N-S	N-R	N-R	N-R	N-R
Mammals: Harbour Seal	N-S	N-R	N-R	N-R	N-R
Mammals: Harbour Porpoise	N-S	N-S	N-S	N-R	N-S
Birds	S	N-R	N-R	N-S	N-S
Fish	N-S	N-S	N-R	N-S	N-A

Note: This table is restricted to the screening of conservation objectives from the marine environment. In the original Natura 2000 reports the terrestrial components are formally included. Given the nature of the project the dominating pressures are linked to the marine environment.
Abbreviations: N-S: Not significant, S: Significant impact cannot be excluded and appropriate assessment required, N-R: Not relevant or impact can be excluded, N-A: Not assessed in the screening)

7.17.5 Screening of Natura 2000 sites in Germany

Only one of the German Natura 2000 sites coincides with the alignment of the Fehmarnbelt Fixed Link. For all other Natura 2000 sites the distance is at least 5 km away (mostly much more). Due to the sheer distance, a significant impact on habitats and species that are reason for the designation of the sites can be ruled out beforehand for most pressures. Thus, for five out of the eight habitat and bird protection areas included in the screening, the conclusion is that an appropriate Natura 2000 assessment should not be conducted (Table 7.17.2).

For the remaining three areas, SCI DE-1332-301 “Fehmarnbelt”, SPA DE 1631-392 “Meeres-gebiet der östlichen Kieler Bucht”, and SPA DE 1633-491 “Ostsee östlich von Wagrien” the screening indicates that a significant impact on the conservation objectives cannot be excluded.

An appropriate Natura 2000 assessment is therefore required for these sites. All potential impacts are related to the construction phase. Relevant pressures to be considered are related to construction of harbours and sediment spill with subsequent spreading of sediment over a large area. In Table 7.17.2 the results of the total screening are summarised.

TABEL 7.17.2 Potential impacts on German Natura 2000 sites during the construction phase of the immersed tunnel

Natura 2000 site / Species & Habitats	Fehmarnbelt (SCI)	Küsten-streifen West- und Nordfehmarn (SCI)	Staberhuk (SCI)	Meeresgebiet der östlichen Kieler Bucht (SCI +SPA)	Küsten-landschaft vor Großen-brode (SCI)	Sagas-Bank (SCI)
1110 Sandbanks covered by seawater: Marine biology Fish	 N-R N-R	 N-R N-R	 N-R N-R	 N-S N-S	 N-R N-R	 N-S N-S
1140 Mudflats and sand flats not covered at low tides: Marine biology Fish	 N-R N-R	 N-S N-S	 N-R N-R	 N-S N-S	 N-R N-R	 N-R N-R
1150* Coastal lagoons: Marine biology	 N-R	 N-R	 N-R	 N-R	 N-S	 N-R
1160: Shallow bays and inlets: Marine biology Fish	 N-R N-S	 N-R N-R	 N-R N-R	 N-S N-S	 N-S N-S	 N-R N-R
1170: Reefs: Marine biology Fish	 N-S N-S	 N-R N-R	 N-R N-R	 N-S N-S	 N-S N-S	 N-S N-S
Mammals: Grey Seal	N-R	N-R	N-R	N-R	N-R	N-R
Mammals: Harbour Seal	N-S	N-R	N-R	N-R	N-R	N-R
Mammals: Harbour Porpoise	S	N-R	N-S	N-S	N-S	N-S
Birds	N-R	N-R	N-R	S	N-R	N-R
Fish	N-R	N-R	N-R	N-R	N-R	N-R

Note: This table is restricted to the screening of conservation objectives from the marine environment. In the original Natura 2000 reports the terrestrial components are formally included. The nature of the project means that the dominating pressures are linked to the marine environment.
Abbreviations: N-S: Not significant, S: Significant impact cannot be excluded and appropriate assessment required, N-R: Not relevant or impact can be excluded

7.17.6 Appropriate Assessment of Danish Natura 2000 sites

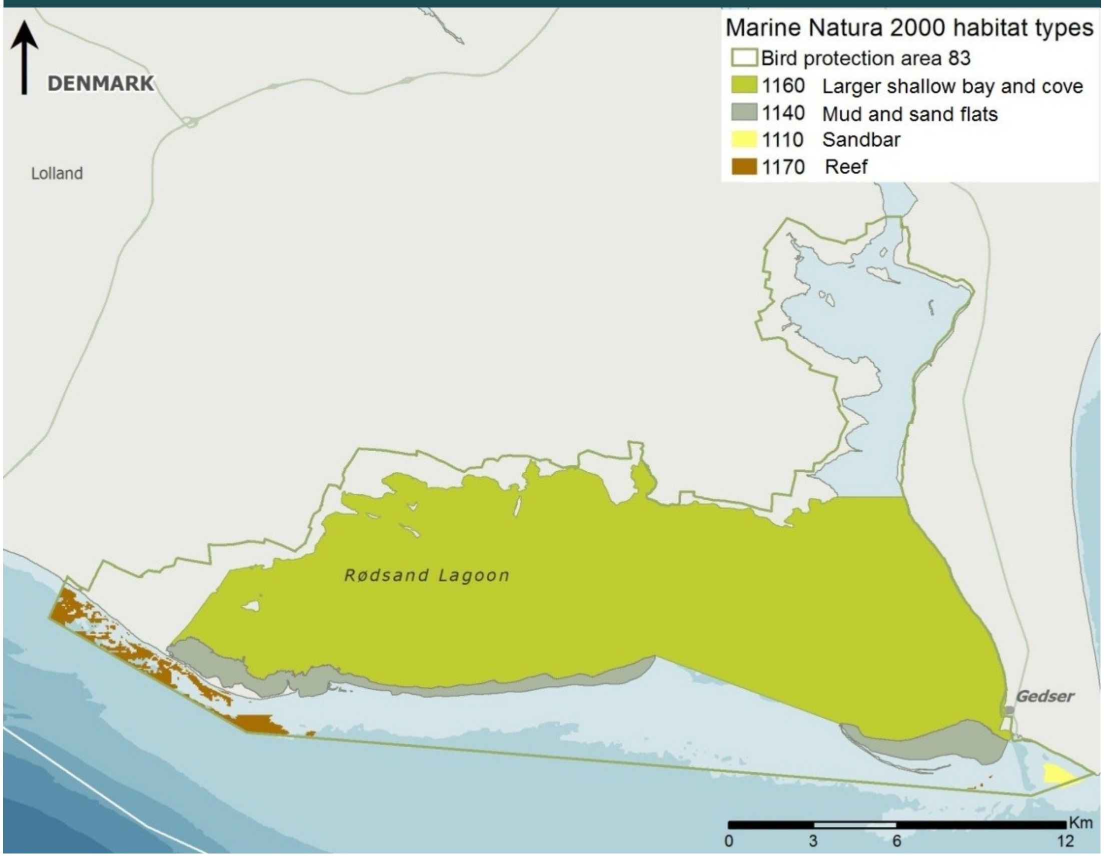
According to the results of the screening, an appropriate assessment has to be conducted for Natura 2000 site no. 173 "Smålandsfarvandet nord for Lolland, Guldborgsund, Bøtø Nor og Hyllekrog-Rødsand" comprising "SCI 006X238 Hyllekrog-Rødsand" (Smålandsfarvandet North of Lolland, Guldborg Sund, Bøtø Nord and Hyllekrog-Rødsand) and "SPA DK 006X083 Coastal Zone Hyllekrog-Rødsand" (Figure 7.17.2 and 7.17.3).

The marine assessment focuses on the southern part of SCI 006X238 that geographically overlaps with SPA DK 006X083. This area comprises the large shallow-water complex and shoreline north of the Rødsand and Hyllekrog sandbanks embraced by Lolland in the north and west and Falster in the east, generally called "Rødsand Lagoon".

The southern part of Guldborgsund as well as the terrestrial part of Saksfjed Inddæmning, are also parts of this area. Within the focal area, 5 marine habitat types, 12 terrestrial habitat types, and 6 animal species are part of the SCI's conservation objectives. However, there will be no impacts in Gulborgsund.

During a revision of the conservation objective of Rødsand Lagoon, an animal species (Crested newt), a bird species (Spotted crake) and a habitat type (1230 Vegetated sea cliffs of the Atlantic and Baltic coasts) have been included on the list of species and habitats to be protected at the site, while habitat type 7220 "Springs with calcareous (hard) water" was removed from the conservation objective. Most of Rødsand Lagoon is comprised of habitat 1160 "Large shallow inlets and Bays" as can be seen from Figure 7.17.4.

FIGURE 7.17.4 Marine habitats in the Rødsand Lagoon, Danish Natura 2000 area Hyllekrog-Rødsand



For the SPA DK 006X083 "Coastal Zone Hyllekrog-Rødsand", 9 breeding bird species and 8 resting bird species are registered as conservation objectives. Besides that, the area hosts a number of species which are part of Annex IV of the habitats directive, whereof Harbour Porpoise is the only species bound to the marine environment.

Below, a summarised description of the results of the assessment is given. Since sediment spill is the major issue to be considered, this will be the focus. Other issues will only be briefly mentioned.

Terrestrial habitats

Terrestrial habitats may be affected by additional nitrogen deposition during construction phase and through hydrographical changes along the coastline. It has been estimated that the additional deposition of nitrogen during the construction phase will amount to 0 - 0.3 kg N/ha/y. None of the nitrogen-sensitive habitats will, through the additional deposition, reach the threshold value (if not already exceeded by current background values, which are above 10 kg N/ha/y).

The excess nitrogen deposition is confined to the construction phase. A permanent impact on protected terrestrial habitats can therefore be excluded.

The hydrographical changes along the coastline of Lolland and Fehmarn have been studied in detail. It is concluded that the establishment of the Femarnbelt Fixed Link will lead to a minor local modification of coastal sediment transport east of the alignment up to Hyldtofte Østersøbad, where the protected area begins. No changes are expected further east along the Hyllekrog headland and within Rødsand Lagoon. Accordingly, habitats and species associated with these areas will not experience any change of conditions. The minor reduction of sediment near Hyldtofte Østersøbad will be compensated for by beach nourishing.

Marine habitats

The starting point of the assessment has been the definition of sensitivity of the flora and fauna communities, which are comprised in the different habitat types, in relation to the main pressures of increased sediment concentration and deposition.

It is revealed that the excess sediment concentration will lead to light attenuation within the Rødsand Lagoon's shallow waters during the first three years of the construction phase, with the strongest effect in the first year and declining intensity the following two years.

Reduction of light at the bottom, within the Rødsand Lagoon, will in the first year of the construction phase reach up to 18 – 20% in the growing season. In the second and third year, light reduction will be much less and return back to normal in the fourth year of the construction phase.

With regards to sediment deposition, an excess layer of up to 10 mm is expected in smaller parts of the western Rødsand Lagoon, while up to 1 mm will be deposited within the first two years of construction in the majority of the shallow water areas. The impact of excess sediment concentration and deposition on benthic communities has been estimated by conducting ecological modelling. In the model, the sensitivity of the communities is confronted with the strength of the pressure, i.e. a time series of concentrations and deposition rates over the entire impact area and over the entire construction period. The model calculates the percentage of loss of biomass for the different communities, which then have been classified using a four-step scale from very high to minor degree of impairment.

The ecological model used is considered to be conservative concerning the used light reduction coefficients and due to the fact that the on-going removal of suspended sediment caused by filtering mussels and consolidation caused by the on-going reworking of soils and sediments by animals or plants (bioturbation) have not been taken into account. As a result, the model is likely to represent a worst-case scenario compared to the actual impact under natural conditions.

Impact on marine habitats from increased suspended sediments

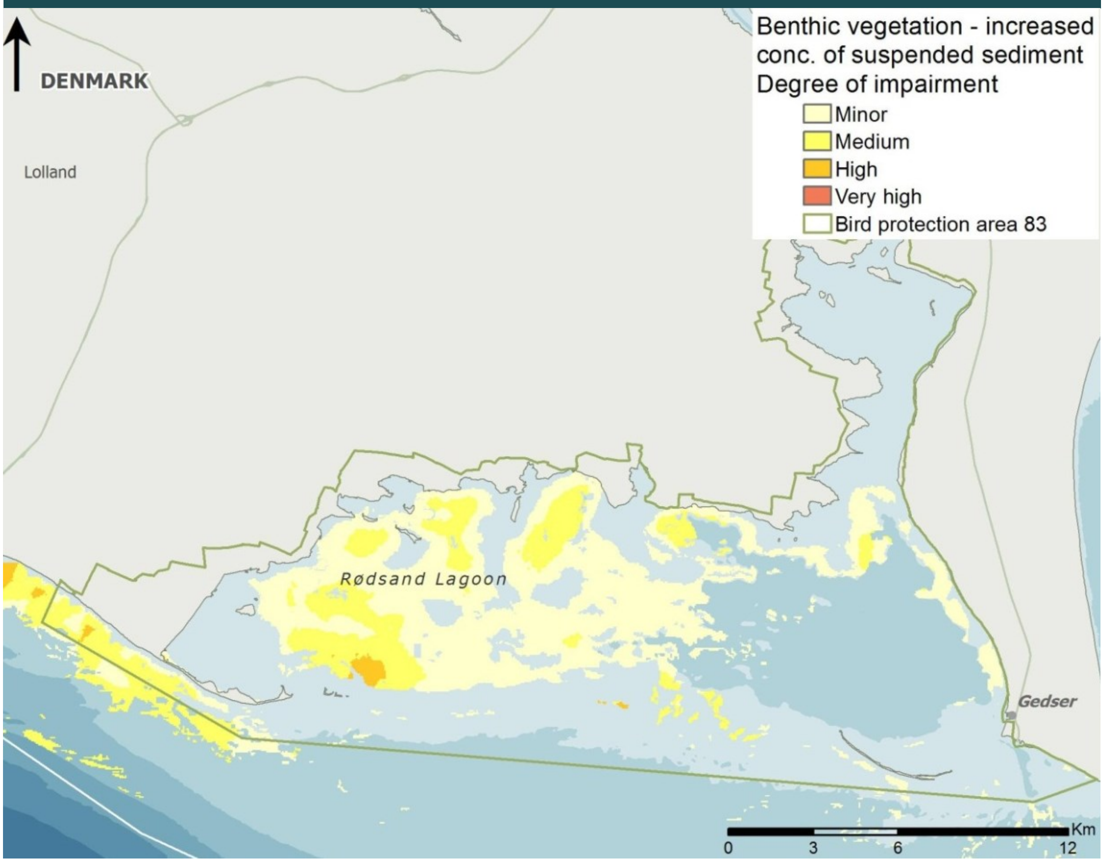
Figure 7.17.5 shows the result of the model for the first year of construction for benthic vegetation in the focal area. Around ¾ of the combined impact on vegetation is predicted to experience a minor degree of impairment (6,455 ha), corresponding to a reduction of 10 - 25% in biomass, which lies within natural year to year variability. A medium degree of impairment with 25 - 50% reduction of biomass is predicted for 2,344 ha of vegetation, and a high degree of impairment with 50 - 75% reduction applies to 112 ha, corresponding to 0,6% of the area covered by benthic vegetation (11,900 ha).

The impact will be most profound in the first year of construction, and vegetation will gradually reach initial status during the subsequent 3 years. The vast majority of the impacted area is comprised of eelgrass communities. Eelgrass in Rødsand Lagoon is naturally exposed to large variations in light intensity.

Strong winds frequently stir up sediments leading to concentrations which are higher than those predicted to come from the construction works (>200 mg/l). Eelgrass is equipped with carbohydrate stores, which render the plant able to continue growing in periods with limited light. Accordingly, it is not expected that the project will have an influence on the depth limit of eelgrass in the Rødsand Lagoon.

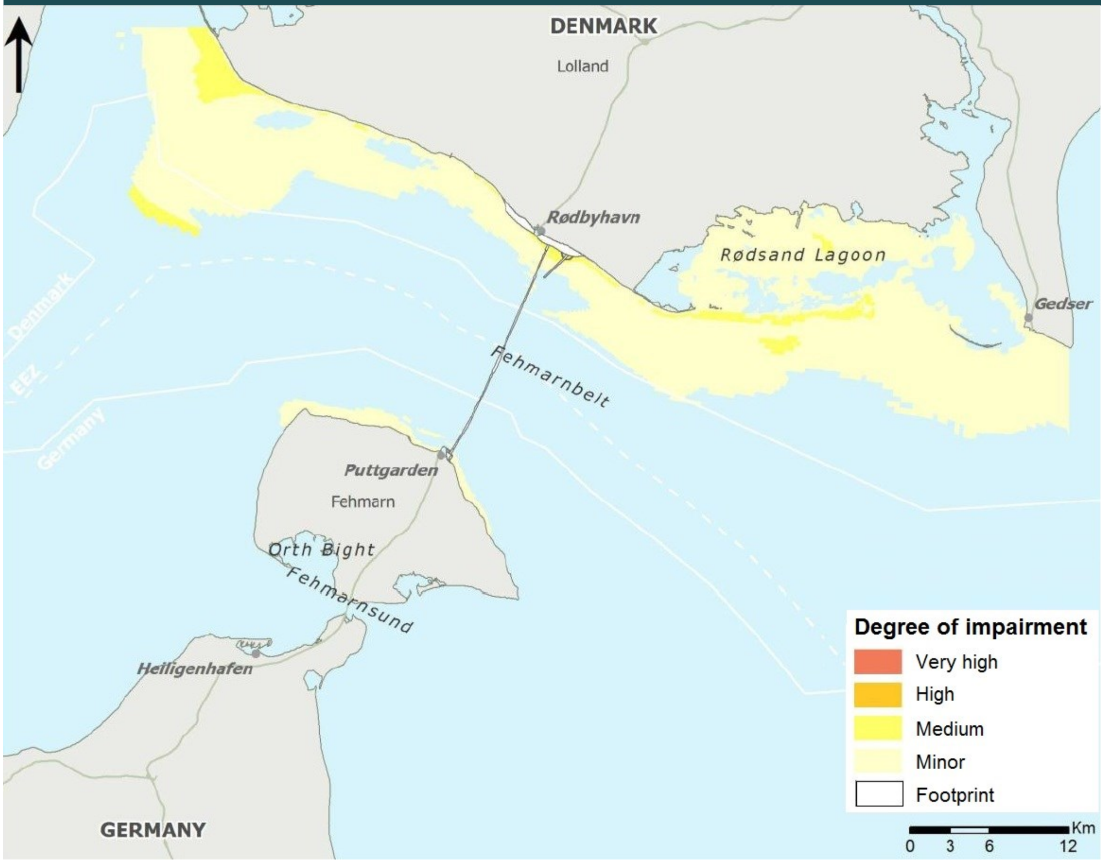
Based on results of modelling, it is estimated that benthic fauna only will be affected by excess suspended sediment within the first year of construction. Already during the second year, and thereafter, the degree of impairment will not exceed natural fluctuations. For the first year of construction the models predict that an area of 17,858 ha of benthic fauna communities will be affected with a minor degree of impairment, which according to the applied classification, corresponds to small changes of living conditions, such as availability of food. Changes in mortality caused by suspended sediments are assessed to be insignificant.

FIGURE 7.17.5 Degree of impairment expressed through reduction of biomass for benthic flora communities at the end of vegetation period in the first year of construction



Minor: 10 - 25 %, Medium: 25 - 50%, High: 50 - 75 %; Very high 75 - 100 %

FIGURE 7.17.6 Degree of impairment expressed through reduction of biomass for benthic fauna communities after the first year of construction



Minor: 10 - 25 %, Medium: 25 - 50 %, High: 50 - 75 %; Very high 75 - 100 %

Impact on marine habitats from excess sediment deposition

The impact from excess sediment deposition on vegetation is expected to be small. Since no applicable quantitative dose response correlation on the effect of sediment on growth, reproduction and mortality of eelgrass community is available from the literature, the assessment is done by expert judgment.

Based on this judgment, a medium degree of impairment is expected for 239 ha of vegetation and a minor degree of impairment is expected for 5 ha. No increase in mortality is expected for eelgrass, but growth rate may be reduced temporarily during the first two construction years.

The reaction upon sediment deposition from benthic fauna will be somewhat higher compared to excess suspended sediment (2,826 ha minor degree of impairment, 382 ha medium, 6 ha high). Around 6 ha of the Rissoa community will be affected with high degree of impairment, which results in a significant change of living conditions and an excess mortality of up to 50%. Since this impact is temporary, the eelgrass habitat can recover, and because it amounts to only 0.06% of the total Rissoa community in the focal area, only insignificant consequences for the integrity of the ecosystem's functions are expected.

Medium and minor degree of impairment is classified as being small and temporary changes of living conditions on blue mussels, without significant increase in mortality. Calculations predict that the total reduction of biomass of blue mussels caused by the project (total Fehmarnbelt Region) is 0.87%, and that local reductions of 10% are possible. The majority of this reduction, though, will happen outside of the focal area along the southern coast of Lolland.

Conclusion on marine habitats
The major part of the predicted impact on benthic flora and fauna will be within year to year variability. Smaller areas will, however, be affected with a medium, and for some exceptions, high degree of impairment, which means a degradation of living conditions with subsequent reduction of biomass and in some cases increased mortality.

All impacts are temporary and confined to the first 3 years of construction, and full recovery is anticipated for all components. Furthermore, it has been concluded that there are no impacts on marine habitats in Natura 2000 areas that lie outside Danish or German borders. It is thus concluded that the prescribed impacts will neither change integrity nor the conservation status of the habitats, which constitute the conservation objectives of the SCI.

Impact on species
Conservation objectives of the SCI includes 6 animal species (Narrow-mouthed Whorl Snail, Hermit Beetle, Barbastelle Bat, Pond Bat, Grey Seal and Harbour Seal).

Of these, a negative impact on Hermit Beetle and Narrow-mouthed Whorl Snail can be excluded beforehand, since none of the project-related activities contain elements that could affect these animals or their habitats.

With regards to the two bat species, construction activities around Rødbyhavn (outside of the SCI) may potentially affect feeding grounds of species from the SCI. It is concluded, however, that the actual significance of this impact is small and insignificant for the status of the bats in the SCI.

With regards to the grey seal and harbour seal, impacts caused by increased sediment concentration have already been ruled out in the screening.

Construction activities around Rødbyhavn, especially sheet piling for the construction harbour, can potentially cause a 4 - 6 week disturbance of seals within a radius of about 10 km. In light of the distance to the most important haul-outs for grey seal and harbour seal (>25 km and 15 – 25 km, respectively), an impact on the two species can be excluded.

It is concluded that the Fehmarnbelt Fixed Link will neither in construction nor in operation phase affect the favourable conservation status of species that constitute the conservation objectives of the SCI.

Impact on bird species of SPA DK 006X083 "Coastal Zone Hyllekrog-Rødsand"
A total of 9 breeding and 8 resting bird species are listed among the conservation objectives of the SPA (see Table 7.17.3).

TABEL 7.17.3 Listed bird species for SPA "Hyllekrog-Rødsand"

SPA DK 006X083 Coastal Zone Hyllekrog-Rødsand	
Breeding birds	Eurasian Bittern
	White-tailed Eagle
	Marsh Harrier
	Avocet
	Sandwich Tern
	Common Tern
	Arctic Tern
	Little Tern
	Short-eared Owl
Resting birds	Great Cormorant
	Mute Swan
	Whooper Swan
	Bean Goose
	Dark-bellied Brentgoose
	Common Goldeneye
	Smew
	Common Coot

For five of them, a negative impact caused by the Fehmarnbelt Fixed Link could be excluded in the light of their minor affiliation to the marine environment. This concerns European Bittern, White-tailed Eagle, Marsh Harrier, Avocet and Short-eared Owl. The remaining includes 4 species of breeding terns and 8 species of resting water birds.

Sediment spill from construction of the immersed tunnel can affect birds of the SPA in two ways. Firstly, foraging conditions can be impaired by the increased amount of suspended sediment; secondly, food resources can be reduced.

The following will focus on the major project pressures, which are linked to the sediment spill during the construction phase. For the other pressures mentioned in Chapter 7.17.1, significant impacts have already been ruled out in the screening.

Sandwich Tern, Common Tern, Arctic Tern and Little Tern

In general, terns are adapted to feeding in waters with high turbidity and they are reported to be able to forage even with 0.5 m visibility. In the Rødsand Lagoon, high turbidity is a common phenomenon. It is therefore concluded that the expected increase of suspended sediment will not have a significant negative effect on foraging conditions for terns.

Terns prey almost exclusively on small fish species, such as sand eels and young sprat or herring. Common Tern preys also on larger water insects. It is assessed that the expected slight effect on fish stocks in the Rødsand Lagoon in the first year of the construction phase will not affect the amount of available food for terns feeding in the SPA.

Great Cormorant

Generally, cormorants are adapted to waters with high turbidity and are reported to be able to forage even with very low visibility (1 m or less). It is therefore concluded that the project-induced increase of suspended sediment will not have a significant effect on foraging conditions for cormorants. Due to the expected small effects on fish stocks from the project during the first year of construction only, no effects on feeding conditions or food availability for the Great Cormorant is expected.

Mute Swan

Calculations show that the construction of the immersed tunnel will cause a reduction of standing biomass of eelgrass of 10 and 7%, respectively, in the first two years of construction. Thereafter, the reduction of biomass will be less and make up 1%, compared to baseline conditions, already after the third year of construction.

It is calculated that Mute Swan's consumption need of biomass will account for 13.4% of the standing biomass and yearly biomass production in the first year of construction, around 13% in the second year, and 12.4% in the third year, which is close to baseline conditions.

The estimation shows that the percentage of available biomass consumed by Mute Swans will rise about 1% during the first years of construction, and thus a shortage of food resources will not occur. The increase is considered insignificant for the conservation status of the Mute Swan.

Whooper Swan

In the Rødsand Lagoon, Whooper Swan utilises the same food resources as the Mute Swan. In addition, Whooper Swans spend a considerable amount of time on land, where they feed on crop residues, e. g. potato fields, beets, winter seed, and meadows. They are therefore less dependent upon benthic vegetation compared to the Mute Swan.

Analogous to the considerations made for the Mute Swan, it is concluded that the food resources will be sufficient during winter time also for the Whooper Swan, with a 10% reduction of standing biomass in the first years of construction. The project-induced impact will not render the favourable conservation for the Whooper Swan in the SPA. In addition, the Whooper Swan is not considered sensitive towards increased turbidity.

Bean Goose

It is not expected that project-induced changes of standing biomass of eelgrass and tassel-weed/dwarf eelgrass will significantly impair the species' foraging possibilities in the SPA. The project will therefore not have an influence on the conservation status of Bean Goose.

Dark-bellied Brent Goose

The species forage either on land, preferably on grazed salt meadows with short vegetation or alternatively on benthic vegetation (eelgrass and macroalgae) in low areas. Since the predicted reduction of biomass in the Rødsand Lagoon will mostly concern the deeper areas of the Rødsand Lagoon (according to the models), a significant impairment is not expected for this species that mainly feeds in shallow areas. The project will therefore not have an influence on the conservation status of Dark-bellied Brent Goose in the SPA.

Common Goldeneye

A superposition of the map with the modelled impairment of benthic fauna with the distribution of Common Goldeneye revealed that the birds mostly occur outside the impairment zone or in the area with a minor degree of impairment. It is therefore concluded that Common Goldeneye will not be affected significantly and the conservation status of the species will not be influenced.

Smew

Since the effect on fish stocks from the project is expected to be very limited and restricted to the first year of the construction phase only, it is concluded that the food resources and feeding conditions of the Smew will not be reduced significantly and its conservation status remains unchanged in the SPA.

Coot

The Coot's diet consists of a variety of plants and animals, among these are various kinds of green algae, characean algae, pondweed, eelgrass and other roothold plants.

The vegetarian diet is supplied with small mussels, snails, worms, and insects, whereof mussels play an important role during winter. With the Coot's varied choice of food and preference for shallow waters, it is expected that construction-induced changes will only cause a minimal impairment of the Coots. The favourable conservation status of the species in the SPA will therefore not be influenced.

The assessment's results for the SPA DK 006X083 "Coastal Zone Hyllekrog-Rødsand and the southern part of SCI 006X238 "Hyllekrog-Rødsand" indicate that all potential impacts are related with the construction phase of the Fehmarnbelt Fixed Link. Overall, it is concluded that for none of the protected species or habitats will a degree of change occur that will alter their conservation status, deteriorate the areas' integrity or impair the conservation objectives of the areas.

7.17.7 Appropriate Assessment of German Natura 2000 sites

According to the results of the screening, an appropriate assessment has to be conducted for the three German Natura 2000 sites; SCI DE-1332-301 "Fehmarnbelt", SPA DE 1631-392 "Meeresgebiet der östlichen Kieler Bucht"" and SPA DE 1633-491 "Ostsee östlich von Wagrien".

Appropriate Assessment of SCI DE-1332-301 "Fehmarnbelt"

The alignment of the immersed tunnel intersects with SCI DE-1332-301 "Fehmarnbelt", which is located within the EEZ of the German Baltic Sea. The site is purely marine and designated for the conservation of marine habitats and marine mammals.

Below, a summarized description of the results of the assessment for this site is given.

Marine Habitats

There are two protected habitat types, sandbanks (1110) and reefs (1170), located in the vicinity of the alignment (closest distance 12 and 14 km respectively). Because of the distance, the only relevant potential project pressure identified is sediment spill, i.e. increased concentration of suspended solids and increased sediment deposition. The distribution of the protected habitats is shown in Figure 7.17.7.

A special feature of the Natura 2000 site is the presence of sand waves, which in the Baltic Sea is a rare form of active bed forms hosting a species-rich benthic fauna. The sand waves are to date subordinated to the habitat type 1110 "Sandbanks", though not yet included within the official delineation of the habitat type 1110 of the site. It is estimated that around 7% of the site's seafloor is covered by sand waves, which are located in the western part.

Habitat 1110 "Sandbanks"

Sandbanks (including different types of active bed forms like sand waves) are free from benthic vegetation. Because of the predominant current direction, the sediment spill derived from construction activities is rather low in the surroundings of the protected habitat. The increased deposition of sediment will be less than 1 mm according to the hydrodynamic models.

A threshold of 3 mm is given, above which negative impacts on benthic fauna are expected. Based on this, it is concluded that no significant impact on the structure and function of the habitat will occur. Furthermore, there are no other pressures expected in the operation phase that could impact the habitat.

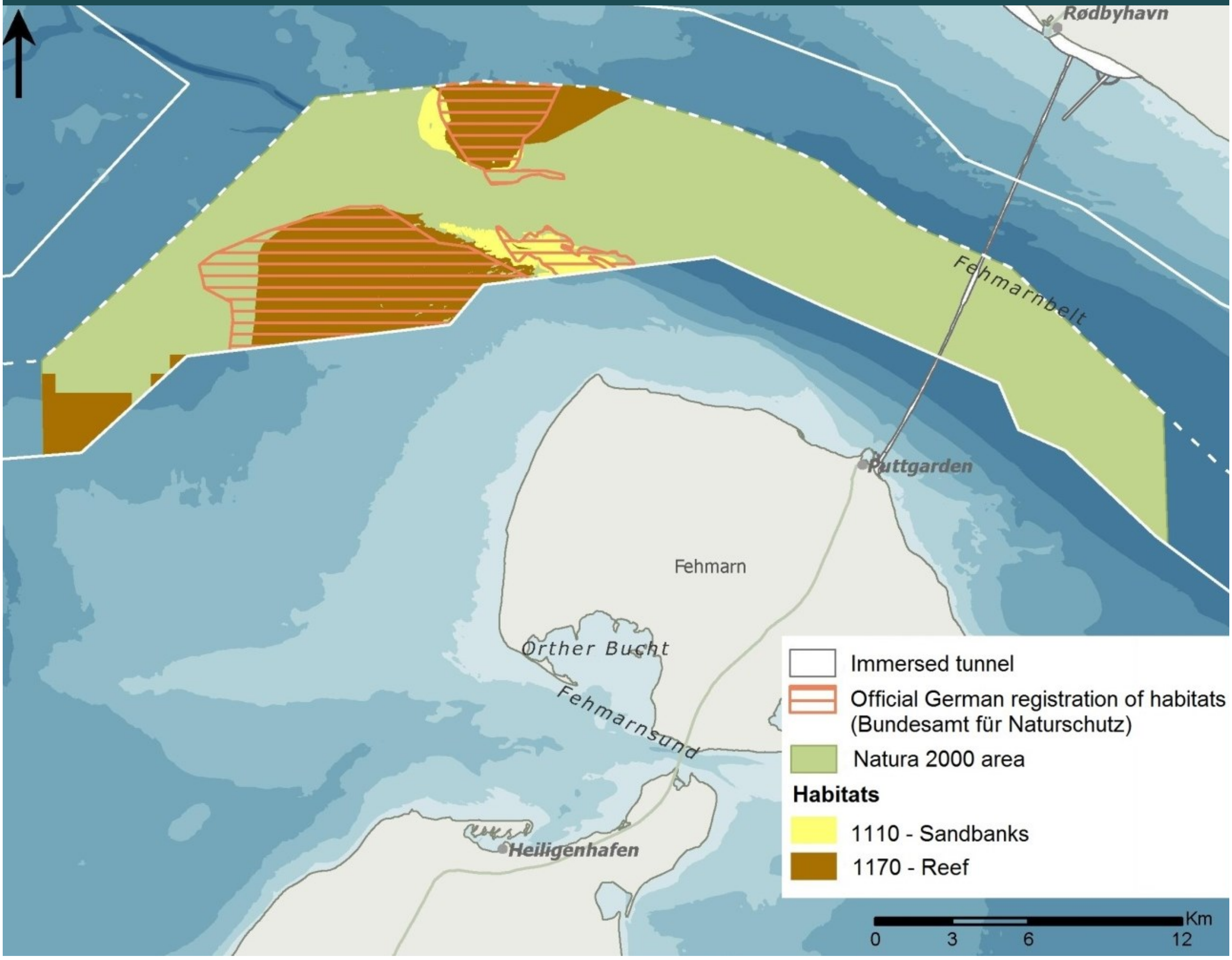
Habitat 1170 "Reefs"

Increased sediment concentration within the first year will lead to light attenuation followed by a reduced growth rate of benthic vegetation within the habitat type 1170. A reduction in biomass of 0 - 10% is expected, corresponding to a minor degree of impairment.

The total affected habitat area is calculated to amount to 82.3 ha in the first year of construction and 80.3 ha in the second year. This corresponds to around 1.3% of the total 6,210 ha reef area within the Natura 2000 site. On the basis of the investigations of the sediment spreading and deposition, possible impairment on the benthic vegetation is assessed as being insignificant.

According to the investigations, no impairment is expected for the benthic fauna of the reef areas. The expected sediment deposition amounts to less than 0.4 mm, which is well below the threshold of 3 mm that has been applied in the assessment.

FIGURE 7.17.7 Location of habitats within the SCI DE-1332-301 "Fehmarnbelt" according to FEMA 2012a-f). Hatched areas depict the delineation from German authorities (BfN 2008)



Harbour Porpoise
Four different pressures have been formulated that may lead to impairment of Harbour Porpoise. In the following, each pressure will be treated separately.

Displacement and injury because of noise from sheet piling for construction harbours
For the construction harbours on Lolland and Fehmarn the establishment of a sheet pile fortified quay wall is foreseen with a total length of 750 m and 200 m respectively. The plan is to drive the sheet piles through vibrating, which is a low-energy method associated with a lower level of noise compared to piling.

The expected range of noise levels has been predicted on the base of recent measurements on similar activities. Estimations are conservative, because the reference measurements concerned piling of sheets instead of vibrating.

The estimations show that the German obligatory noise threshold for marine construction defined by the German Federal Environmental Agency (Bundesamt für Naturschutz) – which is 160 dB re 1 $\mu Pa^2 s$ at a distance of 750 m – will not be exceeded. Since the sheet piling work is taking place at the coast, it is very unlikely that Harbour Porpoises will enter the 230 m zone, with a sound exposure level above 183 dB re 1 $\mu Pa^2 s$, where it can potentially be injured.

According to investigations, the density of Harbour Porpoise is low along both coasts. The noise from Rødbyhavn will not reach the Natura 2000 site, whereas the noise from Puttgarden will be heard by the animals in small parts of the site (SPL between 132 and 144 dB re 1$\mu Pa^2 s$). The calculations show that significant impairment of Harbour Porpoise within the Natura 2000 site, derived from under water noise, can be excluded.

Displacement and disturbance from other construction activities
Noise emissions have also been estimated for dredging activities along the marine alignment of the immersed tunnel. The trailing suction hopper dredgers, which, among others, are supposed to be deployed for the dredging work, have been used as a worst-case reference. They create an SPL of 184 dB re 1$\mu Pa^2 s$ measured 1 m from the source.

It has been calculated that the range for a medium impairment will be at maximum 660 m around the dredger (i.e. SPL 150 dB re 1$\mu Pa^2 s$ associated with disturbance and displacement). Furthermore, a range of maximum 870 m around the dredger is calculated to have a minor impairment (i.e. SPL 144 dB re 1$\mu Pa^2 s$ associated with response of Harbour Porpoise). The German threshold of 160 dB re 1$\mu Pa^2 s$ at a distance of 750 m will not be exceeded.

A calculation of the number of affected animals based upon the density of Harbour Porpoise reveals that only a few individuals will be affected. This is, however, theoretical since the Harbour Porpoise is expected to avoid an active construction site.

Barrier effect through simultaneous construction activities
For the marine construction, the plan is to work with a maximum of six dredgers. If these work at the same time and their noise ranges overlap this could in the worst-case result in an avoidance area 5.3 km long. The working plans show that this situation could last for a maximum period of 10 weeks. The 5.3 km corresponds to 30% of the cross section of the Fehmarnbelt. However, it is concluded that there will be sufficient space for the marine mammals to pass through the site at any given time during the construction phase. The impact is therefore considered insignificant.

Impairment of availability of food because of impact on fish communities
The establishment of the immersed tunnel leads to a loss of habitat within the Natura 2000 site (the footprint is 55.7 ha). Sediment deposition and turbidity will create impairment zones for fish around the alignment. The degree of impairment has been estimated on the basis of the spill scenarios and by applying threshold values for sediment deposition and turbidity for different fish species.

The impaired area within the SCI serving as feeding grounds of Cod, Whiting, Herring, and Sprat is estimated to amount to 82 ha. Furthermore, 101 ha of the nursery grounds of Cod, Herring, and Sprat will be impaired. In close proximity to the alignment (500 m), an 8% reduction of biomass of young Cod is expected. Other fish species will be less affected.

In total, the impaired area accounts for less than 1% of the SCI. The areas will recover after the seabed has been re-established. The described impairment of fish communities will not have any measurable effect on Harbour Porpoise. It is argued that the SCI comprises only a small part of the total habitat of the animals.

The Harbour Porpoises of the SCI are part of the Belt Sea population with a home range from Mecklenburg and Schleswig-Holstein through the inner Danish waters to the Kattegat. The highly mobile whales undertake long migrations, and Fehmarnbelt is believed to serve as a migration corridor (and to a minor degree, also as feeding ground). An impairment of the order of magnitude as described above does not significantly alter the availability of food for this species.

Harbour Seal

Even though Harbour Seal is listed as a conservation objective for the SCI, the area does not play an important role for this species. Investigations showed that Harbour Seals from the Rødsand Lagoon (including Vitten-Skrollen) only occasionally utilise the SCI during foraging trips.

In addition, Harbour Seals are well-adapted to forage in waters with high turbidity and will not be affected by periods with higher turbidity. Overall, it is concluded that the natural distribution and habitat of the Rødsand /Vitten-Skrollen population will not be restricted through the Fehmarnbelt Fixed Link. In the construction phase, local disturbance around active construction sites can occur, but this will not have an effect on the population. Significant impacts can therefore be excluded.

Overall, it is concluded that for none of the species or habitats and their associated biological communities will a degree of impairment occur that will change their conservation status, deteriorate the areas' integrity or impair the areas' conservation objectives.

Appropriate Assessment Germany SPA DE 1631-392 "Meeresgebiet der östlichen Kieler Bucht"

The project area of the Fehmarnbelt Fixed Link is located outside of the SPA DE 1631-392 with a minimal distance of 2 km to the eastern border of the SPA. The SPA serves the protection of marine and coastal breeding and resting birds and their habitat.

The appropriate assessment concentrates on water birds. The character of the project pressures makes it possible to exclude terrestrial species and species that only depend on the interface between land and sea (waders) from the assessment.

For the assessment of impacts on birds, a 1% criterion is applied in the sense that any impairment that concerns less than 1% of the local population is considered insignificant. If the number of affected birds exceeds 1% (see Table 7.17.4), it has to be evaluated by expert judgment whether the favourable conservation status of the species may be lost or its achievement hampered. In this case the impact is considered significant.

For each species, the number of impaired or displaced birds is calculated and the results are summarised in Table 7.17.4. As an example of how the assessment is conducted, a more detailed assessment is formulated for the Common Eider. This bird has been selected because it is by far the most important for the SPA. With a total number of up to 120,000 individuals, the area hosts 16% of the biogeographic population.

TABEL 7.17.4 Potential impacts on German Natura 2000 sites during the construction phase of the immersed tunnel

Species	Population size of SPA (local population) (standard data form)	SPA-related 1% criteria	Expulsion because of turbidity	Expulsion because of habitat change	Expulsion because of disturbance	Number of individuals affected and significance of impact
Barnacle Goose	400	4	0	0	0	no ind. impact: insignificant
Common Eider	120.000	1.200	265 (max.)	8	113	Max. 386 ind., impact in four years insignificant
Common Goldeneye	6.700	67	2 (max.)	0	1	Max. 3 ind. impact in four years: insignificant
Common Scoter	75.000	750	105 (max.)	3	45	153 ind.: insignificant
Common Pochard	4.500	45	not affected, because night active	<10 (few individuals)	<10 (few individuals)	<20 ind. impact: insignificant
Gadwall	3.500	35	0 6)	0	0	no ind. impact: insignificant
Golden Plover	1.500	15	0	0	0	no ind. impact: insignificant
Greater Scaup	5.500	55	not affected, because night active	<10 (few individuals)	<10 (few individuals)	<20 ind. impact: insignificant
Greylag Goose	4.400	44	0	0	0	no ind. impact: insignificant
Shoveler	950	10	0	0	0	no ind. impact: insignificant
Smew	110	1	0	0	0	no ind. impact: insignificant
Long-tailed Duck	35.000	350	21 (max.)	<1 (max. 1)	9	31 ind. impact: insignificant
Tufted Duck	20.800	208	not affected, because night active	<10 (few individuals)	<10 (few individuals)	<20 ind. impact: insignificant
White-fronted Goose	4.500	45	0	0	0	no ind. impact: insignificant
Whooper Swan	440	4	0	0	0	no ind. impact: insignificant

Common Eider

The standard data form lists 120,000 resting Common Eiders for the SPA. However, calculated population numbers based upon the baseline investigations indicate that up to 327,505 individuals (43% of the biogeographic population) can be found in the Fehmarnbelt, whereof 160,000 are inside of the SPA.

The Common Eider’s sensitivity towards pressures of the project has been expressed as follows:

5 Disturbance from construction vessels: high

6 Reduction of availability of food: high; Turbidity: medium

7 Barrier effect from construction vessels and collisions: low

1. Disturbance from construction vessels
Within the SPA an area of 0.50 km² has been calculated to be part of the disturbance area, which will be avoided by Common Eiders. Population modelling predicts that 113 Common Eiders will be displaced from this area. Since the construction zone for the dredging of the tunnel trench slowly moves away from the coast and into deeper water, the impact will gradually diminish.

2. Reduction of availability of food
In the assessment, project-induced habitat changes as potential reason for a reduced availability of food items have been investigated. In the first year of construction an area of 0.36 km^2 within the SPA will be affected by sediment spill and experience some reduction in biomass of benthic organisms as well as increased turbidity. According to the models, this will affect 82 Eider Ducks. It is expected that only 10% (8 individuals) of these will actually be displaced from the SPA.

The extent of areas with reduced visibility from sediment spill will change throughout the construction phase. Within the SPA, the following sequence of the size of affected areas is expected from the beginning until the end of the construction phase (years) to be: 0.87; 1.17; 1.02; 0.38; 0 km². According to the population models, a sequence of affected Common Eiders is derived from these areas: 198 (year 1 and 2 of the construction phase), 265 (year 2 and 3), 232 (year 4 and 5), and 87 (year 5 and 6).

3. Barrier effects from construction vessels and collision
Since it is expected that flying birds will be able to avoid active construction sites, only a minor impairment is derived from this pressure. The avoidance reaction automatically reduces the risk for collisions.

From Table 7.17.4 and the statements on the Eider Duck, it can be seen that only low numbers of birds will be affected by the construction of the immersed tunnel. For all assessed species the numbers are below the 1% threshold. Impacts are temporary and restricted to the construction phase. A significant impact on bird species protected in the SPA can therefore be excluded.

Appropriate Assessment Germany SPA DE 1633-491 “Ostsee östlich von Wagrien”
The project area of the Fehmarnbelt Fixed Link is located outside of the SPA DE 1633-491 with a minimal distance of 5 km to the northwestern border of the SPA. The SPA is comprised of the shallow water areas along the southeastern and southern coast of Fehmarn island, including Burger Binnensee, Sahrensdorfer See, the eastern Bay of Fehmarnsund, as well as the eastern coast of Wagrien including Großenbrode harbour.

As an overall conservation objective, the conservation of coastal habitats with high importance for international bird migration as a resting and wintering site has been formulated.

The summary of the appropriate assessment concentrates on water birds. For terrestrial breeding birds of the SPA, impacts are not expected in light of no existing overlap between project pressures and these birds’ habitats. Two of the breeding bird species, namely Red-breasted Merganser and Little Tern, are linked to the near-coast environment while foraging, and are therefore included in the assessment.

As explained in Chapter 7.16.8, the 1% criteria is applied as threshold for significant impact on staging birds. Because of the distance between the alignment and SPA, direct impacts from project activities are not expected. The assessment is therefore focused on the indirect effects from construction-related sediment spill. The results of the assessment are presented in Table 7.17.5 and Table 7.17.6.

TABEL 7.17.5 Summarised results of the appropriate assessment on breeding birds in the SPA DE 1633-491 with an indication of number of affected birds (terrestrial birds and waders are not included). BP = Breeding pairs

Species	Population size (standard data form)	Actual number of breeding pairs	Number of breeding pairs close to Project area	Impact
Red-breasted Merganser	15 BP.	28	0 (no recording exists)	minor impairment of foraging through turbidity and change of habitat: insignificant
Zwergseeschwalbe	41 BP.	44 BP	0 (no recording exists)	minor impairment of foraging through turbidity: insignificant

TABEL 7.17.6 Summarised results of the appropriate assessment on staging birds in the SPA DE 1633-491 with an indication of number of affected birds

Species	Population size (standard data form)	Site-related 1% criteria	Expulsion because of turbidity	Expulsion because of habitat change	Number of individuals affected and significance of impact
Greater Scaup	4.000	40	not affected, because night active	few individuals	<10 ind.: insignificant
Common Eider	45.000	450	73	2	75 ind.: insignificant
Long-tailed Duck	36.000	360	51	2	53 ind.: insignificant
Tufted Duck	17.600	176	not affected, because night active	few individuals	<10 ind.: insignificant
Whooper Swan	156	2	0	0	0 ind.: insignificant
Species	Population size (standard data form)	Site-related 1% criteria	Expulsion because of turbidity	Expulsion because of habitat change	Number of individuals affected and significance of impact

In Table 7.17.6 it can be seen that only low numbers of birds will be affected by the construction of the immersed tunnel. For all assessed species the numbers are below the 1% threshold. The main reason for this result is that the extent of the expected project-induced change of habitat conditions is, overall, too small to affect larger numbers of birds.

All described impacts are temporary and restricted to the construction phase with emphasis on the first two years. A significant impact on bird species protected in the SPA DE 1633-491 can be excluded.

7.17.8 Transboundary impacts for NATURA 2000

Two Swedish marine Natura 2000 sites, which are the closest sites to the area, where final deposition take place in the Arkona Basin (Falsterbo-Foteviken (SE0430002) and Falsterbo-halvön (SE0430095)), can be considered as potentially affected sites. However, both areas lie outside the deposition area (closest distance is 6.6 km) and neither direct, nor indirect impacts are expected for these sites.

Excess sediment concentrations in the water column as well as the expected amount of deposited sediment in Swedish waters are low, compared to the natural background level in the Arkona Basin, and therefore the impact is considered insignificant also outside of the Natura 2000 sites.

All other countries further east, i.e. Finland, Poland, Estonia, Latvia, Lithuania and Russia as well as Norway, and other sites in Sweden, will only receive non-measurable sediment deposition, and thus their Natura 2000 sites have not been included in the screening.

7.17.9 Transboundary impacts between Germany and Denmark

For six out of the eight Natura 2000 sites in Denmark the conclusion from the screening phase shows that significant impacts with certainty are not present, and that an appropriate Natura 2000 assessment should not be conducted. For the remaining two areas, “SCI 006X238 Hyllekrog-Rødsand” (Smålandsfarvandet North of Lolland, Guldborg Sund, Bøtø Nord and Hyllekrog-Rødsand) and “SPA DK 006X083 Coastal Zone Hyllekrog-Rødsand”, the conclusion is, however, different, as the screening indicates that an appropriate Natura 2000 assessment should be conducted for the immersed tunnel. Both areas lie within the Natura 2000 area nr. 173 (Små-landsfarvandet north of Lolland, Guldborgsund, Bøtø Nor og Hyllekrog-Rødsand). The rationale behind this judgment is that it cannot be excluded that the expected amounts of sediment during the construction phase within the Rødsand Lagoon will affect benthic communities of habitat type 1160 (shallow bays and inlets), and 1170 (reefs) through light attenuation and sediment deposition. Sediment spill may also affect food resources and feeding possibilities of breeding and staging birds.

For five out of the eight Natura 2000 sites in Germany the conclusion from the screening shows that significant impacts on the designation basis of the sites and conservation objectives can be excluded, and that an appropriate Natura 2000 assessment should not be conducted.

For the remaining three areas, SCI DE-1332-301 “Fehmarnbelt”, SPA DE 1631-392 “Meeres-gebiet der östlichen Kieler Bucht”, and SPA DE 1633-491 “Ostsee östlich von Wagrien” the screening indicates that a significant impact on the conservation objectives cannot be excluded.

An appropriate Natura 2000 assessment is therefore required for these sites. All potential impacts are related to the construction phase. Relevant pressures to be considered are related to construction of harbours and other dredging operations, with their resulting sediment spill with subsequent spreading of sediment over a large area.

Concerning the sand extraction at Krieger’s Flak a preliminary Natura 2000 screening shows that the two Natura 2000 sites, which by the nature and spread of the pressure could be affected, are ”Klinteskov og Klinteskov Kalkgrund” on Møn (DK990000254) and the German site ”Kadetrinne” (DE1339301). However, it can be excluded that there should be any significant impact on the conservation objectives.

Concerning the sand extraction at Rønne Banke, the preliminary Natura 2000 screening shows that a significant impact can be excluded on the two Danish and the four German Natura 2000 sites. Both the sediment spill as well as the other pressures are considered to be negligible, and there will be no significant impacts in the Danish habitat sites ”Adler Grund og Rønne Banke” (DK00VA261) and ”Bakkebrædt og Bakkegrund” (DK00VA310), or in the German habitat sites ”Adlergrund” (DE1251301), ”Westliche Rönnebank” (DE1249301) and ”Pommersche Bucht mit Oderbank” (DE652302) or the German bird protection site ”Pommersche Bucht” (DE1552401).

7.17.10 Significance of Impact on Natura 2000 sites

The appropriate assessment of Natura 2000 area no. 173 (Smålandsfarvandet north of Lolland, Guldborgsund, Bøtø Nor og Hyllekrog-Rødsand) concludes that the Fehmanbelt Fixed Link will neither in construction nor in operation phase affect the favourable conservation status of species, nor change the integrity or the conservation status of the habitats which constitute the conservation objectives of the area.

In Germany, the appropriate assessment of the three relevant Natura 2000 areas SCI DE-1332-301 “Fehmarnbelt”, SPA DE 1631-392 “Meeresgebiet der östlichen Kieler Bucht”, and SPA DE 1633-491 “Ostsee östlich von Wagrien” concludes that the Fehmanbelt Fixed Link will neither in construction nor in operation phase affect the favourable conservation status of species nor change the integrity or conservation status of the habitats which constitute the conservation objectives of the area.

In the Kattegat and further outside of the Baltic transition area, also including the possible sand extraction areas at Krieger’s Flak and Rønne Banke, the construction and operation of an immersed tunnel is therefore assessed to result in no impacts in Natura 2000 areas.

On the basis of the implemented Natura 2000 assessments, including both an assessment of the possible spread of the overall pressures by the project, as well as a Natura 2000 screening of 24 Natura 2000 sites and an appropriate Natura 2000 assessment of one Danish and three German Natura 2000 sites, it can be concluded that the project, including possible sand extractions on both Krieger’s Flak and Rønne Banke, neither in the construction phase nor in the operation phase will result in significant impacts on any Natura 2000 sites.

The results are summarized in table 7.17.7 below.

TABLE 7.17.7: Significance of transboundary impacts on Natura 2000 sites in the Baltic Sea, Norway, Germany and Denmark

Factor		**Significance of impacts on material assets in the Baltic Sea, Norway, Germany and Denmark**									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Natura 2000 sites	-	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.17.11 Mitigations

Proposed mitigation measures for the Natura 2000 sites that have been subject to appropriate assessments are described under the respective components in Chapter 7.

7.18 CULTURAL HERITAGE AND MARINE ARCHAEOLOGY

It is possible to find ship wrecks from all historic periods in the Fehmarnbelt in both German and Danish marine territories. It is also possible to discover finds from habitations, fishing sites and minor discoveries pertaining to hunter-gatherer societies.

Below is a description of how a fixed link can affect the cultural heritage and archaeology in the marine project area, how the topic is investigated, and results of the assessment of the transboundary impacts.

7.18.1 Environmental Baseline

Since archaeology on land only refers to German and Danish territories, no description of land-based archaeological finds has been found relevant to provide in a transboundary context (for such a description, reference is made to the Danish and the German EIAs).

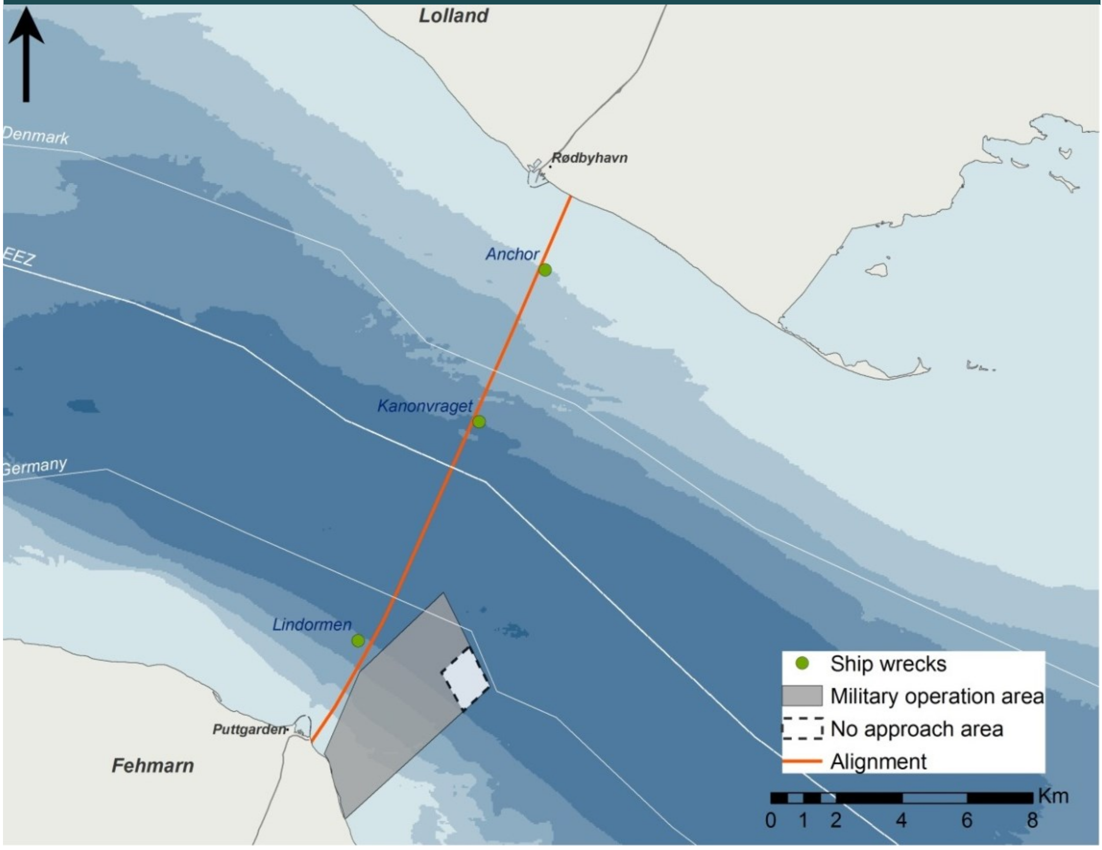
Several offshore investigations have been conducted in the area around the tunnel alignment in both German and Danish territory. The purpose was to collect information about ancient monuments and wrecks and to decide how to protect them from damage during construction and operation of the immersed tunnel. The investigations made in relation to marine archaeology in the Fehmarnbelt area are listed below:

- Geophysical investigations with a multi beam, side scan sonar, sub-bottom profiles and magnetometer in coast-to-coast alignment of 2 km width, in water depths > 6 m from Rødbyhavn to Puttgarden
- Geophysical investigations with a side scan sonar, magnetometer and sub-bottom profiles in an area along the coast 5 km east and west of Rødbyhavn, in water depths from 3 – 6 m.
- Geophysical investigations by a multi beam; side-scan sonar; sub-bottom profiles; and magnetometer due west of the earlier mentioned alignment of 2 km width
- Diving inspections and recordings by Remote Operating Vehicles (ROV) of chosen anomalies in order to localise habitations from the Stone Age, east of Rødbyhavn and east of Puttgarden
- Drilling samples in the 2 km wide corridor between coasts to investigate paleontological and ecological changes along the coast, and mapping of potential stone age settlements and ancient shorelines
- Diving inspections of shipwrecks in Danish and German territories, respectively, in the period from April to July 2012

During the investigations, three objects of interest have been identified. In Danish territory in the Fehmarnbelt a shipwreck called “Kanonvraget” has been identified. The ship is most likely a Dutch merchant ship, which was rebuilt as a warship in the early 17th century. In German territory, a wreck which is most likely “Lindormen”, a warship, has been identified. Both wrecks probably sunk during the battle at Fehmarn in 1644. Furthermore, an anchor from around 1850 – 1920 has been identified in Danish territory.

On the coast of Lolland, east of Rødbyhavn, geological investigations on land indicate that a bog from the early Stone Age might be located 2 - 5 m below surface. The age of the bog will be identified during further investigations in the area during 2013.

FIGURE 7.18.1 Location of anchor and the shipwrecks in Fehmarnbelt



Marine archaeology at Rønne Banke and Kriegers Flak

The Danish National Survey and Cadastre (Kort & Matrikelstyrelsen) has published charts showing wrecks in the Danish marine area. In addition, the Heritage Agency of Denmark (Kulturstyrelsen) holds a database of registered wrecks in the Danish marine area. Data extracted from this database (Chart no. 188) shows that no wrecks are registered within the extraction area at Rønne Banke or within the 500 m impact zone of the site, as defined by the Danish Heritage Agency. Accordingly, no wreck was observed during the side-scan study.

Settlements have not been registered within the extraction area. In addition, many metres of sand are deposited on top of the layers containing potential settlements, which will therefore not be affected by the extraction activities. Further investigations have therefore not been considered necessary.

The same method as listed for Rønne Banke has been used to identify marine archaeological sites at Kriegers Flak. Data extracted from the database from the Heritage Agency of Denmark have been plotted on Chart no. 104. The chart shows that three wrecks are registered within the extraction area and 4 wrecks within the 500 m impact area. Only two of these wrecks (The Heritage Agency of Denmark system no. 183387 and 183965/177923 - two system numbers for the same wreck) have been identified by the side-scan sonar survey. Magnetometer data have been acquired by GEUS during the survey in July 2011.

No settlements have been registered within the extraction area at Kriegers Flak. As there is four meters of littoral sand in the area, which is deposited on top of the layers with potential settlements, such settlements will not be affected by the extraction activities. Hence, further investigations are unnecessary.

Importance

Areas with marine archaeology and cultural heritage findings, such as shipwrecks and other items covered by legislation in Denmark or Germany are assessed as having special importance. Other areas with findings which are not covered by Danish or German legislation are assessed as having general importance.

7.18.2 Project Pressures

The following main pressures with respect to cultural heritage and archaeology have been identified from the construction of an immersed tunnel:

- Impacts from anchors, anchor wires and handling of anchors
- Erosion due to changing current conditions caused by the altered seabed after dredging and backfilling of the tunnel trench
- Altered seabed in the project area caused by e.g. sediment spill after dredging and backfilling of the tunnel trench, and establishment of the land reclamation (especially along the coast of Lolland)

The location of the shipwrecks in Danish and German territory can potentially be affected by construction ships, anchor blocks and anchor wires during construction.

Changes to the seabed caused by dredging or backfilling of the tunnel trench and erosion may cause an impact on the wrecks and the area surrounding them.

7.18.3 Transboundary Impacts on Marine Archaeology

The shipwreck in Danish territory is located near a work area and anchoring zone (75 m away), which stretch 440 m east of the tunnel alignment's centre line. The wreck can therefore potentially be impacted by outriggers, anchors and anchor wires from construction ships during construction. The shipwreck of "Lindormen" is located 370 m west from the centreline, which is far from the planned work and anchoring areas. However, as both wrecks will be (and are) protected by a layer of sand and singles, no impact from the construction work is expected (see section 7.18.6 on mitigations).

Changes in the seabed morphology caused by the dredging and backfilling of the tunnel trench may cause changes in the currents at the seabed, and therefore erosion, which could impact the wrecks and their surroundings. However, Femern A/S will in collaboration with German and Danish authorities make sure that both areas are strictly protected (see chapter 7.18.6 on mitigations), and therefore potential impacts induced by project pressures are kept to a minimum, if not entirely prevented.

The anchor from around 1850 is located approximately 180 m from the alignment and approximately 60 m from the planned construction area, where anchors are planned to be placed in the middle of the construction area. The construction area stretches 440 m east of the alignment. The Danish Heritage Agency will decide whether or not the anchor must be salvaged, before the construction period begins. If it is decided to leave the anchor at its present location, it is planned to be secured in the most comprehensive way.

During the operation of an immersed tunnel, no impacts are assessed to occur on either of the two shipwrecks, or on the anchor. In-situ protection of the areas and eventual follow-up mitigation measures will be decided by the German and Danish authorities.

Marine archaeology at Rønne Banke and Kriegers Flak

Since the baseline study did not observe any wrecks in the extraction area at Rønne Banke, no assessment has been found relevant for the site. Similarly, no settlements have been registered in the area, and therefore no assessment has been found relevant for this component either.

Within the extraction area at Kriegers Flak the three ship wrecks, which have been registered, are all located outside the area recommended for extraction. Actions should be taken to provide information of wreck positions to the captain of the dredger to avoid destruction by the dredging activities. Ship wrecks outside the extraction area (including the two observed by the side-scan study) will not be affected by the project, as no harmful activities influencing the seabed will take place here. Deposition of sediments is not considered problematic in this context. Furthermore, settlements have not been registered, nor will they be at risk of being affected by the sand extraction because of the deep layer of sand which has been deposited on the seabed. No impacts are therefore expected for marine archaeology in the extraction area. If wrecks are present in the Swedish part of the area, where final deposition of sediments takes place, they will not be affected by the relatively thin layers of deposited sediments.

The project pressures identified for marine archaeology from the construction and operation of an immersed tunnel, therefore, have no transboundary impacts beyond the German-Danish area, because they are all local.

7.18.4 Transboundary Impacts on Marine Archaeology between Germany and Denmark

The only potential impact on marine archaeology that could cross the borders of German territory and into Danish territory, and vice versa, is sediment spill (please see chapter 7.6 for a thorough description). However, sediment spill has not been identified as a serious project pressure in relation to marine archaeology and, as such, will not impact marine archaeology negatively. No archaeological finds have been made in the alignment of the tunnel either, so no transboundary impacts will be expected for the dredging of the tunnel trench. There are no other transboundary impacts between Germany and Denmark during construction and operation of an immersed tunnel that could affect the marine archaeology in the Fehmarnbelt area.

7.18.5 Significance of Impact for Marine Archaeology

Because the shipwreck “Kanonvraget”, in Danish territory, is located close to one of the offshore construction areas, the Danish Heritage Agency has decided that the wreck must be protected in-situ. The measures are described in the mitigation section below. As a result, no impacts are expected.

Since the wreck “Lindormen”, in German territory, is located outside the offshore construction area, no impacts on the wreck during construction are expected. Even so, the German authorities (ALSH) will most likely establish a safety zone around the wreck to make sure that the area is kept free from any kind of ship traffic.

The anchor in Danish territory will be salvaged before the construction period begins, if the authorities find it necessary, or protection of the site will be established.

The project will therefore not affect any marine archaeology sites or objects during construction.

No transboundary impacts on marine archaeology induced by project pressures are expected during the construction and operation of an immersed tunnel, because all impacts are local.

TABLE 7.18.1 Significance of transboundary impacts on marine archaeology in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on humans and health in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Marine archaeology	Shipwrecks	No	No	No	No	No	No	No	No	No	No
	Settlements	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.18.6 Mitigation Concerning Marine Archaeology

Regarding mitigation of "Kanonvraget", the Danish Heritage Agency will decide the size of the area which must be kept clear of construction activities to prevent any impacts from anchoring, anchor wires and construction ships. Furthermore, in-situ protection of the wreck has been carried out during summer 2012. This has been done by covering the wreck with 0.5 m of sand and 20 – 30 cm of singles. At the same time, this should also protect the wreck from possible illegitimate activities by scuba divers. Furthermore, a safety zone is planned to be established around the wreck and its surroundings, so that work-related and all other ship traffic has to stay clear of this area. This will also protect the wreck from construction-related activities such as anchors and anchor wires.

Even though the wreck "Lindormen" is assessed to be unaffected by the immersed tunnel, a safety zone surrounding the wreck will most likely be made to prevent impact from work-related ship traffic anchoring close to the location of the wreck.

During the construction of an immersed tunnel, control of the area and the in-situ protection will take place in order to prevent impact on the wrecks.

The Danish Heritage Agency will decide if the anchor is to be removed, before construction begins. If the anchor is to remain in Fehmarnbelt, the Agency will plan for the protection of the anchor.

Femern A/S will in collaboration with the contractors, design plans for anchor and anchor wire handling during the construction works, to ensure that the safety zones around the wrecks are not affected. The plans will be submitted to the Danish and German authorities for approval.

Should other archaeological sites or objects be revealed during the construction period, which might be protected in accordance with Danish and German law, work will be suspended, and the relevant authorities will be contacted (i.e. the Danish Cultural Agency and ALSH).

7.19 RECREATION AND TOURISM

The tourism and recreation industries in the Baltic Sea area are likely to be dependent on the state of the marine environment. A fixed link between Germany and Denmark may have different impacts on the marine environment that can indirectly affect the tourism and recreational areas in the Fehmarnbelt area.

Analyses of tourism and recreation based on interviews with stakeholders in all of the nine Baltic Sea countries indicate that mainly beach tourism, recreational fishing, and boating in all the Baltic Sea countries are depending on the marine areas and their environmental conditions. Hence, the following chapter will address:

- Offshore recreational activities (i.e. kite-surfing, water-skiing, kayaking and surfing)
- Recreational fishery
- Recreational boating

The following describes the baseline investigations on recreation and tourism on Lolland and Fehmarn and such activities taking place within the marine area of Fehmarnbelt. Possible pressures induced by an immersed tunnel and a description of how these affect the possibilities for recreation and tourism are outlined. Finally, potential transboundary impacts for recreation and tourism in those areas are assessed.

7.19.1 Environmental Baseline

Relevant literature; interviews with local citizens, organisations and visitors in the project area; and results from the assessment of impact on noise and air quality are used in identifying and mapping the recreation and tourism industry in the project area.

The recreational values in the project area have been classified by using a number of criteria such as accessibility of the area, natural experiential value, footpaths without access by motor vehicles etc. The tourism sector in the project area on Lolland has been identified by using regional and municipal plans as well as employment data from the municipality of Lolland. Fehmarn's tourism sector has been mapped by Femern A/S. The analyses made on this sector of Fehmarn (N.I.T. 2010, FFL Einflussanalyse Tourismus, Femern A/S) is the basis for the description and assessment of tourism on Fehmarn.

Interviews made in the Fehmarnbelt region indicate that the tourism industries in the Baltic Sea countries are affected by the current marine environmental conditions. The most important nuisance seems to be blue-green algae blooms, a possible adverse consequence of eutrophication, which reduces the aesthetic and recreational values in beach and coastal areas across the Baltic Sea area. However, these algae blooms have not had any significant impact on hotel and holiday house bookings or profits in the industries so far.

Recreation and Tourism on Lolland

The biggest tourist attraction in the project area on Lolland is “Lalandia” which is a “tropical” water park, with more than 700,000 annual visitors and which hosts a number of small holiday houses located near the coast, west of Rødbyhavn. Apart from this, three hotels are located in the area, which are primarily used by travellers passing Lolland on their way north or south. Also, smaller companies living off of tourism are located within the project area. Lolland and Guldborgsund municipalities together have approximately 60 companies which live off of tourism alone. In 2007, Lolland had approximately 900,000 visitors for overnight stays (i.e. at hotels, B & Bs and resorts).

Approximately 2.8% of Denmark's total number of tourists (national as well as international visitors) visited Lolland and Guldborgsund municipalities in 2007. About 3.7% (corresponding to approximately 33,000 visitors staying overnight) of those visiting Lolland in 2007 were Germans, whereas on a national scale approximately 30% of the total number of tourists were Germans.

The primary recreational areas in the Fehmarnbelt area are located near the coastline, hereunder holiday houses, harbours and beaches. These are also the areas where offshore recreational activities take place such as surfing, kite-surfing, kayaking and water-skiing, as well as boating and fishing. Especially the beaches at Bredfjed, the beach near Lalandia (both located west of Rødby Harbour) and the beach near the summerhouse area, Hyldtofte Østersøbad, are popular bathing locations.

The area also has a number of angling associations near Rødbyhavn and kayak clubs in the villages of Maribo, Sundby and Nysted. There are five marinas in the Fehmarnbelt area, located in Rødbyhavn, Lundehøje, Errindlev Havn, Stubberup and Kramnitze, respectively.

Recreation and Tourism on Fehmarn

Tourism is an important income-generating activity on Fehmarn and in 2008 the island alone had more than 3.8 million holiday visitors for overnight stays. The tourism industry on Fehmarn has increased its income and from 1981 - 2008 the number of rooms has increased by 53%. Fehmarn also receives many day-visitors from the mainland of Germany and from Scandinavia.

Fehmarn’s recreational infrastructure (footpaths, cycling paths and riding paths) together with its coastline, bathing facilities and beaches attract many visitors. Important sites are the villages Burg, Bannesdorf and Landkirchen.

Fehmarn has 24 beaches, whereof most are located on the southern part of the island. Cycling is one of the most practiced recreational activities on the island, and approximately half of the overnight-staying visitors are cyclists. The island also has a number of protected nature areas (Wallnau and Grüner Brink) and offers geological guided tours along the coast (near Presen) as well as guided horseback tours and cycling tours.

Most of the hotels and camping sites are placed in Burg and on the southern part of the island. However, one camping site and one hotel are located near Puttgarden on the northern part of the island.

Fehmarn also has five marinas placed along the southern coastline in Orth, Lemkenhafen, Femernsund, Burgtiefe and Burgstaaken, and the most-used beaches and bathing facilities are also located on the southern parts of the island near Femernsund and Gold. The bay between Orth and Strukkamphuk is a popular site for surfers.

Recreational Fishing in the Fehmarnbelt area

In the Fehmarnbelt, the German recreational fishing activities can be considered extensive all year round, while the Danish recreational fishery activities are more seasonal.

The coastline of Fehmarn Island in Germany and the southern coastline of Lolland and Falster in Denmark have a number of popular angling areas for fishing sea trout, cod, different flatfish species and other species, such as garfish, when they are seasonally abundant. Furthermore, there are many local and regional clubs in each country which have members that visit these areas on a regular basis and often during the spring and autumn when several species of interest are most abundant.

Offshore, both German and Danish anglers troll for sea trout, jig, cod and herring in small private boats, and in some areas use bait to catch flatfish within Fehmarnbelt. In Germany however, the offshore recreational fisheries in and around the Fehmarnbelt appears to be more extensive than in the rest of Denmark, mainly because of the large number of commercial angling vessels (21 vessels in 2009) that have their home harbours on or near Fehmarn Island. They fish in and near the Fehmarnbelt during the entire year.

In contrast, there are no Danish commercial angling vessels that fish in the Fehmarnbelt. Furthermore, the status of Fehmarn Island as an attractive tourist area, with the focus on and easy access to the Baltic Sea for German anglers, adds to the popularity of the Fehmarnbelt.

Almost the entire northern coastline of Fehmarn is a well-frequented angling area. The only areas where angling is not possible are the nature reserve ‘Grüner Brink’ and the ferry port of Puttgarden, located at the north side of the island.

Coastline anglers profit from a rapid increase of water depth from the shoreline and from the relatively fast and changing currents in Fehmarnbelt, which create a variety of habitats for the recreational fish of interest close to the shore. The angling areas along the north coast of Fehmarn make up approximately 25 km of shoreline, which is approximately 34% of the total coast of Fehmarn Island and 6% of the coast of Schleswig-Holstein.

In 2008, about 1,000 tourist angling licenses were sold in the northern parts of the districts of Ostholstein and Plön (Municipal administration, 2009). Of these, 558 tourist angling licenses were sold on Fehmarn and 207 in Heiligenhafen.

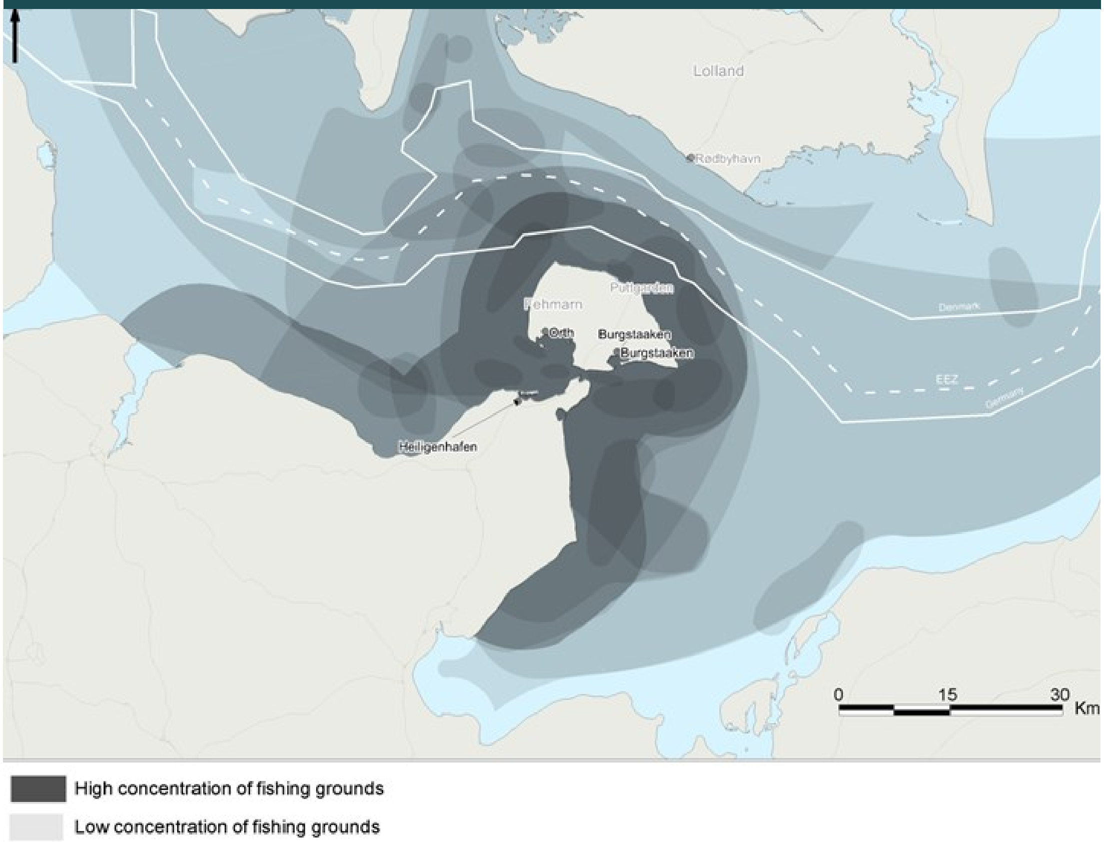
On Lolland, angling also takes place near the two piers at Rødby Harbour and from the dike near the eastern pier. Also put-and-take lakes exist on Lolland, and the Hirbo Lake and the Forrest Lake, both located east of Rødbyhavn, are used by anglers. Rødby Angler Association (Rødby Sportsfisker Forening) had sold 150 angling licenses in 2011.

Information from the main angling associations on Lolland and in the region of the Fehmarnbelt (Rødby, Nakskov, Nykøbing and Guldborgsund) indicates that these associations represent approximately 450 anglers. Many members of these associations fish along the coastline of the Fehmarnbelt on the southern coast of Lolland and Falster. Similarly, there are several members that either have small boats in the harbours of Rødbyhavn and Kramnitze or launch boats from these harbours to fish (troll and jig) in Fehmarnbelt.

In interviews with chairmen and members of the hobby fishermen associations (Organisations for Amateur Fishermen) representing southern Denmark and the Belt Region, the general opinion was that very few hobby fishermen used the Fehmarnbelt for fishing. In all, it was estimated that only 6 hobby fishermen fish in the Fehmarnbelt. It was reported that they primarily fish with gill nets and target cod and flatfish. In contrast, on the south eastern part of Lolland there were approximately 70 hobby fishermen fishing in Nysted Fjord, which opens into Nysted Nor.

The 21 registered commercial angling vessels from Heiligenhafen, Orth and Burgstaaken primarily concentrate in a zone of 5 nautical miles around the coasts of Fehmarn and the mainland (see Figure 7.19.1). According to owners of commercial angling vessels, the areas where they concentrate their efforts in the Fehmarnbelt and around Fehmarn Island depend largely on the weather, fishing seasons and success of the fisheries. In Fehmarnbelt, the majority of the angling efforts are in locations where cod, and to a lesser extent herring, is most abundant (see dark shading in Figure 7.19.1). Areas south and west of the Fehmarnbelt are locations that contain both hard- and soft-bottoms, and are therefore also good fishing grounds for flatfish and herring.

FIGURE 7.19.1 Most common fishing grounds used by German commercial angling vessels



The Danish offshore angling around the Fehmarnbelt is fairly limited, both seasonally and spatially. According to interviews with local sports fishing and boat clubs, there is only a small number of fishermen (approximately 15 - 20) in private boats that occasionally fish in the Fehmarnbelt (Figure 7.19.2). When fishing, these fishermen primarily target cod, whereas trolling after sea trout is only undertaken on occasion. In contrast, trolling in private boats is more widespread in the waters west of the Fehmarnbelt (in Langeland Belt), and east/northeast of the Fehmarnbelt; for example, in the area southeast of the Klintholm harbour on the island of Møn (location not shown in Figure 7.19.2).

There are no Danish commercial angling vessels that are active in the Fehmarnbelt between southern Lolland and Fehmarn Island. Regionally however, there is some offshore angling activity from commercial angling vessels in Langeland Belt to the west of the Fehmarnbelt and on the eastern side of Falster.

FIGURE 7.19.2 The most common fishing areas used by Danish angling boats and commercial vessels

Recreational Boating

Approximately 7,000 movements of pleasure crafts in the Fehmarnbelt area have been registered in 2010. However, the actual number of passages may be higher than this, as most pleasure crafts do not carry an Automatic Identification System (AIS). Therefore, the density of passages (i.e. the number of such vessels passing the Fehmarnbelt area) is assessed by using registered numbers of crafts using local marinas at Lolland and Fehmarn. In 2007, 52,000 pleasure crafts stayed overnight at the marinas on Fehmarn. In comparison, approximately 170,000 pleasure crafts stayed overnight at marinas located at Lolland. Among those, 8% were foreign pleasure crafts at Fehmarn and 11% were foreign at Lolland.

This indicates that the marinas at Fehmarn and Lolland are well-visited, and that the coastlines at these locations are also well-visited. Pleasure crafts using the Fehmarnbelt as a passage without stopping at the local marinas in the area are not registered though, so the actual number of passages could be higher than those listed above.

Recreational boating near Rønne Banke and Kriegers Flak can occur, but there are no marinas nearby. Furthermore, the density of recreational boating at the two locations has not been investigated. The primary reason for this is that the Automatic Identification System, AIS (a GPS based system for ship tracking), is only mandatory for vessels above 300 GT (Gross Tonnage), which makes tracking of these types of vessels difficult. Most ordinary recreational crafts do not carry AIS, as they are seldom above 5 GT. The possibility for tracking such crafts in those areas are therefore almost non-existing, even though other ships in the areas can of course see them on radar, etc. However, most recreational boating takes place along the coastlines, and as the locations of Rønne Banke and Kriegers Flak are far from any coastline, the density of these types of vessels is assessed to be low at the two locations.

Importance

Areas with marine recreational and tourism activities are assessed as having special importance. Other areas, such as areas with restricted access for sailing and fishing and military areas are assessed as having general importance.

7.19.2 Project Pressures

The following project pressures in relation to recreation and tourism on Fehmarn and Lolland have been identified from the construction of an immersed tunnel:

- Habitat loss and changes of recreational habitats also due to the new land reclamation (construction and operation)
- Physical and visual barrier effects of recreational areas and fragmentation of the landscape (construction and operation)
- Air, noise and light pollution of recreational areas (construction and operation)
- Sedimentation in the water column, which impacts the bathing water quality (construction)

7.19.3 Transboundary Impacts

The project pressures in relation to an immersed tunnel are all local; hence no transboundary impacts in relation to Recreation and Tourism will occur during operation or construction of an immersed tunnel. However, foreign visitors may be temporarily affected by the construction works offshore and near shore (this applies mainly for recreational boaters who pass the Fehmarnbelt area and for tourists visiting Lolland and Fehmarn).

The possibility for practicing recreational activities offshore in the Fehmarnbelt area is assessed to be affected to a minor degree, as there are many places where such activities can take place. As such, the offshore construction activities only take up a minor area within the Fehmarnbelt, as most of the recreational activities take place near shore.

Furthermore, the barrier effect caused by offshore construction works and an increased traffic intensity in the Fehmarnbelt will influence the area, but it is assumed that people using the Fehmarnbelt for recreational activities are already used to heavy ship traffic in the area, not least due to the 52 passages of the ferries (between Puttgarden and Rødby harbour) each day, and therefore the impact is assessed as minor (also see section 7.20.6 on mitigations).

There will be a visual and physical barrier effect caused by the offshore and near shore construction works; however, the impact is assessed as minor as it will only occur temporarily.

The offshore and near shore construction works will raise the noise level in the area. In relation to the dredging works of the tunnel trench, 104 - 115 dB near the source is expected (noise from suction hopper dredgers and other dredging machines as well as tug boats). As the background level of offshore noise in the Fehmarnbelt area is already high due to the commercial ship traffic and the ferries, the impact is considered minor. The construction works will also cause exhaust emissions offshore; however, the weather and wind conditions in the area mean that the impact from such emissions will be minor, as the spreading of emissions will occur fast. Furthermore, there are no legal regulations for emissions at sea.

Concerning light emissions, there will be no impact for recreation and tourism on Lolland and Fehmarn or in the Fehmarnbelt area, as these activities are considered not to be very sensitive to light, even if some construction works take place during the night.

The new land reclamation will change the coastline of Lolland in an area stretching 7.2 km east and west of Rødbyhavn in total. This means that the possibility for recreational fishing along this part of the coastline will be altered. However, as only two good locations for angling are present within the impacted area, and as there are many other locations nearby, which may be used successfully for such activities, the impact is considered insignificant. Concerning other recreational offshore activities (i.e. surfing, kite-surfing, water-skiing, kayaking, bathing, etc.), the land reclamation is assessed to cause a minor impact as the construction of new lagoons, beaches and recreational areas near the coastline are planned to be established and re-established during and after the construction period. The impact is therefore only temporary for such activities.

Sedimentation and bathing water quality

The frequency of background concentrations of sedimentation above 2mg/l occur at least 5 times more often than the excess frequency, due to dredging as part of the project, when considering the entire construction period. The excess frequency is largest along the coast of Lolland and inside the Rødsand Lagoon. Along the coast of Fehmarn, the excess concentration only exceeds 2 mg/l for less than 1% of the time.

Except for the period where the dredger is actually dredging in the near shore zone, the high concentration events will occur when the hydrodynamic conditions are rough. This means that at least part of the time, where the visibility limit is exceeded by excess concentration, it is simultaneous with natural re-suspension events.

It will therefore be hard to detect a visual difference in the appearance of the water, and thus the effect of dredging is considered insignificant in such cases.

Transboundary Impacts for Recreational Fishery

The impact on the recreational fisheries due to restriction zones will be on a local scale. The total loss of area for fishing possibilities by recreational fishermen and a reduction of potential catches is estimated to be minimal. Furthermore, the potential for undertaking the same recreational fisheries in adjacent areas, both to the east and west of the anticipated construction areas along the German and Danish coast and offshore, suggests that alternative nearby fishing grounds are available. Thus, the overall significance of the impact on both the coastal and offshore re-creational fisheries due to restriction zones for a tunnel is considered to be local and minor.

The time frame, for which suspended material and its sedimentation are considered to have an impact in an area, is expected to be only temporary and short-term. Consequently, it is anticipated that any avoidance behaviour by species of interest for recreational fishery will also be temporary and short-term, and it is expected that affected fish will move back into an affected area again within a short time frame.

Impacts from sediment plumes and sedimentation will only be for a limited amount of time and primarily in the local areas where dredging or land filling is taking place. Thus, the overall significance to both the coastal and offshore recreational fisheries due to sediment spills and sedimentation and temporary changes in the distribution of fish species of interest for recreational fisheries is considered to be minor.

Permanent and temporary restrictions to recreational fisheries in zones on land and offshore during construction and operation of an immersed tunnel will permanently and temporarily reduce the total amount of area available to the recreational fisheries. In practice, restrictions along the coastline will affect the availability of recreational fisheries in the local areas only, such as around ramps or harbours, where the fixed link and land meet. However, because of the relative small loss of area, restrictions to the recreational fisheries along the coast are only considered to have a minor impact.

Transboundary Impacts for Recreational Boating

Construction of an immersed tunnel involves a number of marine activities, which will affect the ship traffic in the Fehmarnbelt and the western Baltic Sea. All non-construction ship traffic is maintained throughout the construction period; i.e. commercial traffic through the T-route through Fehmarnbelt, ferry traffic across Fehmarnbelt, commercial traffic on main navigational routes in the western part of Fehmarnbelt, and additional traffic with smaller ships in the area (local commercial ships, fishing boats and pleasure crafts).

Potentially all pleasure crafts using the Fehmarnbelt area and the locations at Rønne Banke and Kriegers Flak in the western part of the Baltic Sea can be affected by marine construction works. This section therefore describes the impacts on recreational boating in these areas.

No significant impacts are expected on recreational boating in the Fehmarnbelt area during the construction period, even though there will be a higher intensity of traffic around the construction area. However, pleasure crafts in this area are supposed to be used to heavy traffic, especially because of the 52 ferry passages every day between Rødby-Puttgarden and the heavy commercial traffic. Furthermore, it is expected that approximately 100 passages will be made per day with dredged materials from the tunnel trench for land reclamations, as long as the dredging of the tunnel trench is on-going (approximately 18 months). The exact number of passages will depend on the dredging methods, the size of the barges, and actual amount of dredged materials produced per day.

Recreational crafts usually also have a good manoeuver-capability and will therefore be capable of responding quickly and easily in case of barrier effects from marine constructions works. This, together with the Vessel Traffic Service (VTS) system, which is planned to be in place from the beginning of the construction period, and the guard ships placed near the work areas, will decrease the potential for collisions between recreational crafts and construction related vessels or other floating objects (e.g. tunnel elements).

Rønne Banke

Heavy ship traffic occurs in the Baltic Sea, but all the main traffic routes pass around Rønne Banke and not through. However, a smaller amount of traffic does pass across Rønne Banke, and minor impacts may occur for this traffic, as they may have to change their sailing course to avoid the extraction area.

Between 135 - 670 cargos in total will be transported from the extraction area to the construction site. Compared to the total amount of ship traffic in the Fehmarnbelt (approximately 38,000 ships in 2010 and 34,000 crossing ferries per year), the impact is regarded as negligible. This is also the case for recreational ship traffic.

The risk of collision is regarded as low, because there is sufficient room for relocation of the traffic. The ship traffic in the area is not restricted to channels (fairways) within the extraction area, and ship traffic can change sail routes. The impact on navigation is regarded as negligible.

Kriegers Flak

Heavy ship traffic occurs in the Baltic Sea, but all the main traffic routes pass around Kriegers Flak. Sand extraction will generate between 800 and 1,428 cargos of sand between the working area for the fixed link and Kriegers Flak (120 km) in a period of 2 - 3 years that is planned to be used for the backfilling at the sides of the immersed tunnel. Compared to the current ship traffic in the Fehmarnbelt, the increase is regarded as negligible (approximately 38,000 ships in 2010 and an additional 34,000 crossing ferries per year).

A smaller amount of traffic passes across Kriegers Flak, and minor impact may occur for this traffic, as they may have to change their sailing route to avoid the extraction area. The risk of collision is regarded as low because there is sufficient additional space where the traffic can relocate to. The ship traffic in the area is not restricted to channels (fairways) within the extraction area, and ship traffic can change sail routes. The impact on navigation and recreational ship traffic is regarded as negligible.

7.19.4 Transboundary Impacts between Germany and Denmark

Transboundary effects between Germany and Denmark at the operational phase of the immersed tunnel are of no importance (noise, light and air emissions, sediment spill and barrier effects), and thus only primary construction-related project pressures are relevant. No impacts are expected in the operation phase.

The overall conclusion is that during construction the project pressures on Recreation and Tourism on the Danish side will not cause any significant impacts for these on the German side, and vice versa.

7.19.5 Significance of Impact for Recreation and Tourism

In Kattegat and further outside of the Baltic transition area the impacts addressed are assessed to be non-existing, as they are all local. An immersed tunnel is therefore found to result in negligible impacts to the Central Baltic Sea's Recreation and Tourism during construction and operation.

With no areas of impairment or loss in the Baltic Sea the assessment shows that in the construction period the immersed tunnel does not have any significance for Recreation and Tourism in the Central Baltic Sea or in the Fehmarnbelt in any way. In the figure below, the significance of impact is defined.

No impacts are expected during operation, as the impacts only occur in the construction phase.

TABLE 7.19.1 Significance of transboundary impacts on recreation and tourism in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on recreation and tourism in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Recreation and tourism	Offshore recreation activities	No	No	No	No	No	No	No	No	No	No
	Recreational fishery	No	No	No	No	No	No	No	No	No	No
	Recreational boating	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.19.6 Mitigation Concerning Recreation and Tourism

An environmental management plan for the project and its activities offshore, on Fehmarn and Lolland, where regulations for emissions, waste, cleaning, covering, watering, noise, etc. are described, will be drafted. The plan will take into account the changing weather conditions in the area.

The following mitigation measures are planned to be implemented to prevent and limit the pressures caused by the project:

Fehmarn

- Establishment of temporary recreational paths and roads during the construction, and new path and road connections across the permanent construction
- Noise, vibrations, light and air pollution during the construction of an immersed tunnel are planned to be reduced as much as possible

Lolland

- A new beach is planned to be created west of the new land reclamation. The beach is planned to be available after two bathing seasons
- Light pollution is planned to be limited throughout the construction and during the operation (by optimised design of the light sources near the tunnel entrance -- during operation)
- A noise barrier is planned to be built around the tunnel element fabric to prevent the summer cottages and residential areas from noise from the construction site (during construction)
- The land reclamation is planned to be designed in such a way that the view to the sea from the marina in Rødbyhavn remains unchanged
- The dike along the coastline is planned to be re-established after end of construction, together with the recreational path on its top
- The canal between the new lagoon, west of Rødbyhavn, and the marina is planned to be designed so that kayaking can take place between the two
- The land reclamation will create a new, large and varied recreational coastal landscape on Lolland with optimized possibilities of recreational activities in the area

Fehmarn and Lolland

- In order to prevent health problems for residents and visitors caused by noise, vibrations and air pollution during the construction of the immersed tunnel, the production of tunnel elements will take place indoors and mitigation measures regarding noise, dust and other air pollution will be in place.
- A noise barrier is planned to be constructed around the production facility in the form of an earth embankment. Concerning the outdoor workplaces at Lolland and Fehmarn, noise and dust will be reduced as much as possible.
- Dust emissions from the construction materials themselves will also be reduced as much as possible by watering.

Mitigations in relation to recreational boating and fishery

Femern A/S has in collaboration with German and Danish maritime authorities established a maritime coordination group, which will uphold and secure the navigational safety in the Fehmarnbelt area during construction of an immersed tunnel.

Some of those risk control options are active in the construction phase in order to lower the possibility for collisions. These risk control options include a temporary VTS system and guard ships in connection with each offshore work area, as well as safety zones around work areas, and creation of a work vessel coordination (WVC) centre. The WVC centre is assumed to carry out several tasks, including personnel safety, planning and overall coordination of the construction vessels.

Guard ships are planned to be connected to the work areas in order to avoid collisions between ships and equipment in the work areas, such as dredgers, immersion pontoons and tunnel elements. The guard ships are assumed to further reduce the accident frequency related to human failures on ships approaching the work areas.

7.20 MATERIAL ASSETS

The following chapter describes the baseline investigations on material assets in the Fehmarnbelt area, the possible project pressures induced by an immersed tunnel, and a description of how these can affect material assets within the Fehmarnbelt area.

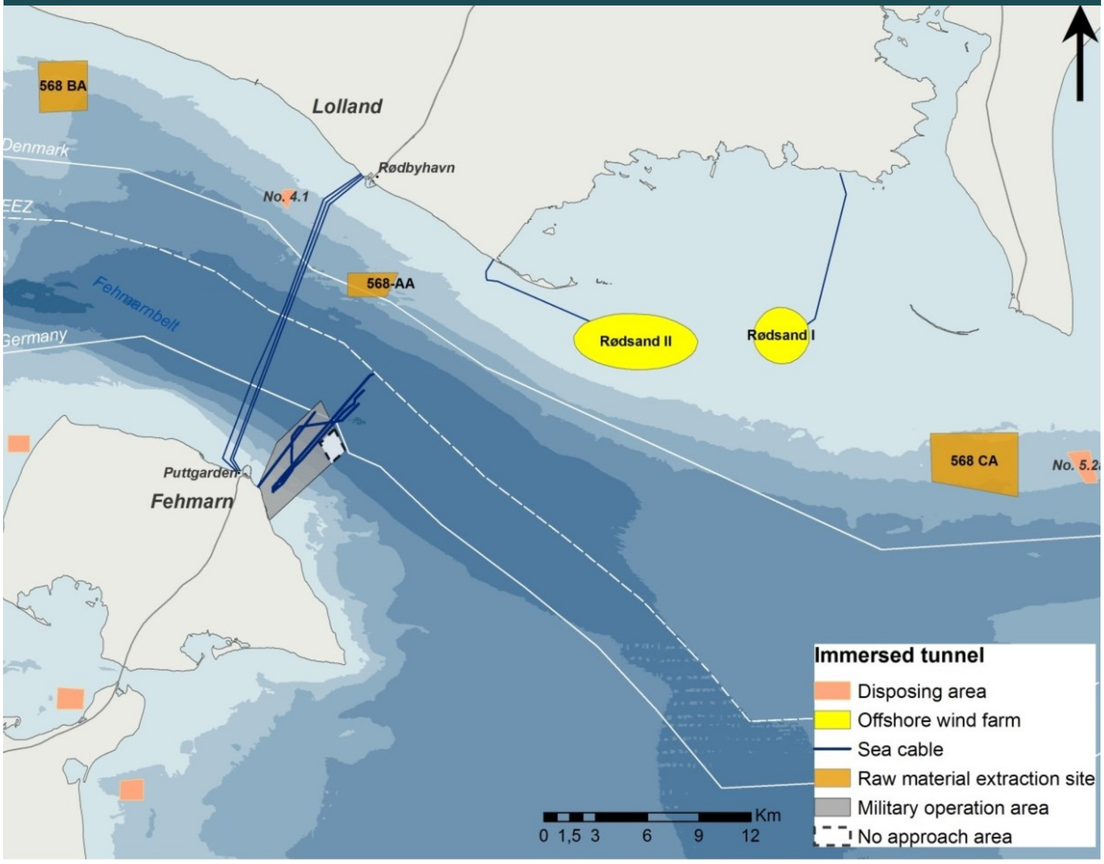
7.20.1 Environmental Baseline

The Fehmarnbelt contains several different material assets. There are two existing offshore wind parks in Danish territory (Rødsand I and Rødsand II, see Figure 7.20.1), and one offshore wind park is planned in German territory, east of Fehmarn Island. In addition, offshore wind parks are planned to be located in the central part of the Baltic Sea, among them one on Kriegers Flak. However, their location is more than 100 km away from the construction area, and potential cumulative impacts are dealt with in the chapter regarding cumulative impacts (see Chapter 7.24). There are also three telecommunication cables and two energy cables placed to the west of Rødby Ferry Harbour and Puttgarden, in connection with the two Danish wind parks. In German territory, four military related cables stretch out into the sea, east of Puttgarden.

In the Fehmarnbelt, there are also three areas for extraction of raw materials in Danish territory (used for extraction of sand and gravel) (no. 568-AA, no. 568-CA and no. 568-BA, see Figure 7.20.1). Area no. 568-AA is located close to the alignment of the immersed tunnel and is planned to be closed by the authorities if it is considered to affect safety, regarding the construction and operation of an immersed tunnel.

Five disposal areas for dredged materials are also located in the Fehmarnbelt. Two disposal areas for dredged materials are located in Danish territory and they are both active (no. 4.1, 5.2a). Three disposal areas for dredged materials are located in German territory (see Figure 7.20.1). Furthermore, a military area is located east of Puttgarden, where no public access is allowed.

FIGURE 7.20.1 Material assets and the military area in the Fehmarnbelt



Importance
Because of their value to the respective societies, material assets in the marine area have been assigned special importance in the assessment process.

7.20.2 Project Pressures

Damage to existing cables on top of and underneath the seabed may arise from impacts during construction and consist of interventions and disruptions of the seabed, as well as handling of anchors. There is also a risk that restrictions regarding future development of offshore activities and disposing areas (loss of area) comprise an impact on material assets.

Based on the above, the following main pressures with respect to material assets have been identified from the construction and operation of an immersed tunnel:

- Damage caused by construction related activities on existing cables on top of and underneath the seabed (during construction)
- Restrictions regarding future development of offshore activities and disposal areas of dredged materials (loss of area, during operation and construction)
- Restrictions on future development regarding offshore activities in the area, where the tunnel trench is located (during operation)
- Other relevant pressures, such as sediment spill, that may have transboundary impacts

7.20.3 Transboundary Impacts on Material Assets

The material assets in the marine area of the Fehmarnbelt are identified because of their societal importance, and have been assigned "special importance" in the assessment process. A qualitative assessment has been performed of the impacts induced by the project pressures causing potential damage to the material assets or their function. The focus is on the loss of area and other pressures, which construction might cause.

The results of the assessment shows that the project pressures from construction and operation of an immersed tunnel will have no impacts on material assets in the project area, as no cables, wind parks, or disposal areas for dredged materials are located near the construction area. However, there will be a permanent loss of extraction area no. 568-AA, but since there are already two existing extraction sites in the Fehmarnbelt, where the same materials are extracted (sand and gravel), the loss is assessed as insignificant. Furthermore, the authorities have decided to close the site because it collides with and poses a safety threat to the Fehmarnbelt project.

The pressures identified as relevant in relation to impacts on material assets from the construction and operation of an immersed tunnel are all related to project area activities and existing material assets within or in the vicinity of the project area. Therefore no transboundary impacts on material assets beyond the German-Danish transboundary area are expected.

Project pressures that extend into transboundary areas, i.e. more than 10 km from the alignment (such as sediment spill), during construction works offshore, are assessed as not affecting planned or existing material assets.

The assessment therefore concludes that neither the construction nor the operation of an immersed tunnel will result in significant impacts on material assets in the Fehmarnbelt. However, as mentioned above, there will be insignificant impacts on extraction sites for sand and gravel in the Fehmarnbelt.

7.20.4 Transboundary Impacts on Material Assets between Germany and Denmark

No transboundary impacts on material assets between Germany and Denmark will occur during the construction or the operation of an immersed tunnel, as only extraction site no. 568-A will be affected on Danish territory.

7.20.5 Significance of Impact for Material Assets

During construction of the Fixed Link, no intervention or disruption will occur in areas close to telecommunication or energy cables, nor the military area and connecting cables, during construction.

Area no. 568-AA for the extraction of raw material will have to be closed during the construction of the immersed tunnel. The assessment concludes that the loss of the area only has an insignificant impact.

Construction activities and pressures, e.g. the spreading of sediments which affect areas outside the local project area (10 km from the alignment), are assessed as not affecting existing or planned material assets located in transboundary areas.

Furthermore, the assessment concludes that no significant restriction will occur regarding future establishment of cables between Denmark and Germany, or any other offshore activities in Fehmarnbelt, because the alignment area can be avoided and only covers a small area of the Fehmarnbelt (approximately 180 ha).

TABLE 7.20.1 Significance of transboundary impacts on material assets in the Baltic Sea, Norway, Germany and Denmark

Factor		Significance of impacts on material assets in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Material assets	Cables and wind parks (offshore)	No	No	No	No	No	No	No	No	No	No
	Extraction sites	No	No	No	No	No	No	No	No	No	Ins
	Disposing sites	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.20.6 Mitigations Concerning Material Assets

No mitigation measures have been deemed relevant in relation to material assets in the Fehmarnbelt area.

7.21 RAW MATERIAL AND WASTE

This chapter assesses the environmental impact of raw material consumption and disposal of waste generated during construction and operation of the immersed tunnel.

Energy accounts for the handling of raw materials and waste, including dredging of sediment, are presented in Chapter 7.22 Climate and air quality.

It is assumed that all waste from the project is handled and disposed of properly in accordance with applicable legislation.

7.21.1 Method

The following assessment is based on the technical description of the immersed tunnel in Chapter 5, indicating quantities and descriptions of raw material consumption and amount of waste produced.

7.21.2 Environmental Consequences for Raw Materials

In the following Table 7.21.1 the main raw materials, i.e. concrete, steel and gravel are calculated for the project. The tables list raw materials for the whole project including the tunnel, the land reclamation, connecting railroad and highway. A more detailed overview of the need for raw materials is, as previously mentioned, described in Chapter 5.

TABEL 7.21.1 Expected total raw material consumption – immersed tunnel

Commodity Type	Quantity
Concrete	3,175,000 m^3
Steel	310,000 t
Asphalt	200,000 t
Sand, gravel and stones	8,580,000 m^3
Supplies	
Water (concrete production and staff facilities)	1,350,000 m^3
Electricity and heating in the construction phase	130 mill kWh

The concrete elements for the immersed tunnel are planned to be produced on a temporary production site situated on Lolland. The production site includes a temporary working harbour. The concrete is planned to be prepared in a mixing ratio of approximately 10 weight% cement and 76 weight% aggregate, consisting of sand and granite chippings. On this basis, the estimated composition of material consumption for the concrete used in the tunnel elements is approximately as follows:

TABEL 7.21.2 Estimated consumption of raw materials for concrete production – immersed tunnel

Commodity Type	Quantity
Cement (10%)	310,000 m^3
Granite gravel (47%)	1,485,000 m^3
Sand (29%)	930,000 m^3

Note: The amounts shown in this table are a breakdown of the total concrete consumption shown in Table 7.21.1

The tender process will determine the origin of the raw materials. For the environmental assessment it is assumed that granite can be delivered from Norway or Bornholm. Similarly, it is assumed that supply of sand can be based on Danish raw material resources.

According to data from Statistics Denmark, the total raw material extraction on land in Denmark during the period 2006 - 2011 is approximately 26.3 million m^3 (sand, gravel and stone), of which the extraction in the Region of Zealand amounted to 5.4 million m^3, corresponding to 1.08 m^3 on average per year. Furthermore, in the period from 2006 to 2011, approximately 6.7 million m^3 of raw materials was extracted at sea.

For the immersed tunnel project, the total requirement for different grades of sand, stone and gravel material is about 8.6 million m^3 over 6.5 years. Compared with extraction in Region Zealand, the requirement for raw materials corresponds to about eight years of normal abstraction. This is approximately 20% of Denmark's total average annual consumption of raw material (sand and gravel). The raw material consumption (sand and gravel) for the immersed tunnel is significant compared to the annual Danish production at both national and regional levels.

In this Environmental Impact Assessment, it is shown that the necessary resources (sand and gravel) are available at Kriegers Flak or Rønne Banke, near Bornholm. It is concluded that extracting sand and gravel will cause a temporary loss of bottom fauna habitats and a disturbance of the seabed in the abstraction area. Sea current and sediment transport will, however, ensure a rapid seabed recovery. In view of the rapid recovery and the fact that the affected area is of a relatively small size and will occur in a designated area for mining, it is estimated that there will be no lasting or significant negative impact on the benthic fauna at Kriegers Flak.

Chapter 5 shows that the production site situated on Lolland will use 1,350,000 m^3 of water in total. Water may come from groundwater resources north of the production area. Alternatively, or in combination, desalinated sea water may be used. Desalination of sea water will only cause insignificant impacts according to an assessment of environmental impacts from water desalination (Chapter 7.5 Water quality, and Chapter 7.22 Climate and air quality)

7.21.3 Import of Raw Materials

As stated above, raw materials are planned to be imported to the project area. Thus, the raw materials are planned to be imported across the border, which means, for example, sand and gravel from Kriegers Flak will be used to backfill the tunnel trench in German territorial waters.

The dredged materials from the tunnel trench are planned to be used as filler in the land reclamations at Fehmarn (1 million m^3) and Lolland (15 million m^3) – (see Chapter 5 Immersed tunnel – technical description, Table 5.2). Thus, maximum 1 million m^3 of sediment will be imported from Danish territorial waters to Germany and up to 7.5 million m^3 of sediment will be imported from German territorial waters to Denmark. The total amount of dredged materials from the tunnel trench and cut-and-cover tunnel corresponds to 15 million m^3.

The following potential impacts of the import of raw materials have been identified:

- Sediment may be spilled when building the land reclamations
- Sediment may be spilled when backfilling the tunnel trench
- Sediment may be contaminated and cause restrictions on use of the new land reclamations.

7.21.4 Method and Results

Sediment spill from construction of the land reclamations in Danish territory and sediment spill from backfilling the tunnel trench are incorporated into the dredging scenario for this report. Thus, the assessment of the impacts is addressed in Chapter 7.6 Sediment and seabed forms, Chapter 7.5 Water quality and Chapter 7.9 Benthic flora, among others.

Results of the chemical analysis for seabed sediment, including organic carbon and nutrients as well as the content of pollutants, are described in Chapter 7.5 Water quality.

The content in surface sediments (0 - 30 cm) and in the deeper sediments (30 - 100 cm) are calculated separately in order to detect any differences related to deposits made after the start of the industrialisation period (approximately 100 years ago).

Analysis of sediment samples for polycyclic aromatic hydrocarbons (PAHs), heavy metals (Cd, Cr, Cu, Ni, As and Hg, among others) persistent organic pollutants (PCBs, DDT) and tributyl tin (TBT) is evaluated against quality criteria used by the Danish and German authorities as well as internationally accepted criteria used in the U.S. and countries around the North Atlantic (Oslo-Paris Commission [OSPAR]).

The criterion ERL ("Effect Range Low") used in U.S. and Canada is based on toxicological data, and if a given sediment’s concentrations of toxic substances are below ERL values, there will be very little probability of toxic effects.

OSPAR and the German criteria are based on "background concentration" and accepted exceedence of these background levels, while the Danish criteria are based on both toxicological data and background concentrations.

The Danish authorities use two sets of criteria: low level of action (L Ac) and high level of action (H Ac), where the values of L Ac are regarded as unproblematic.

In general, the concentrations of pollutants are low. Only one sample exceeds any of the different threshold criteria. In general, the concentration of PCBs is well below the mentioned sediment standards. One surface sample (A011-1 in the middle of the Fehmarnbelt) differed from the other 14 samples (see Figure 7.21.1). The concentration of the sample observed is 85 times above the average of the other samples. Since the PCB concentration is low at the adjacent stations, it is likely that the contamination is local and may be due to material which has been spilled from a ship. The observed concentration of 74 µg / kg dry weight PCBs is above the low level of action (L Ac) and below the high level of action (H Ac).

In order to assess the depth of the pollutants at the location, which differed from the remaining samples, two sediment columns from the location were analysed in two sections that are 5 cm long, and in 1 cm long sections to a depth of 20 cm (see Figure 7.21.2). The results show that PCBs are only present in a top layer of 10 - 12 cm .of the sediment.

FIGURE 7.21.1 Depth profile of organic carbon and persistent organic pollutants in a sediment core taken at station A016

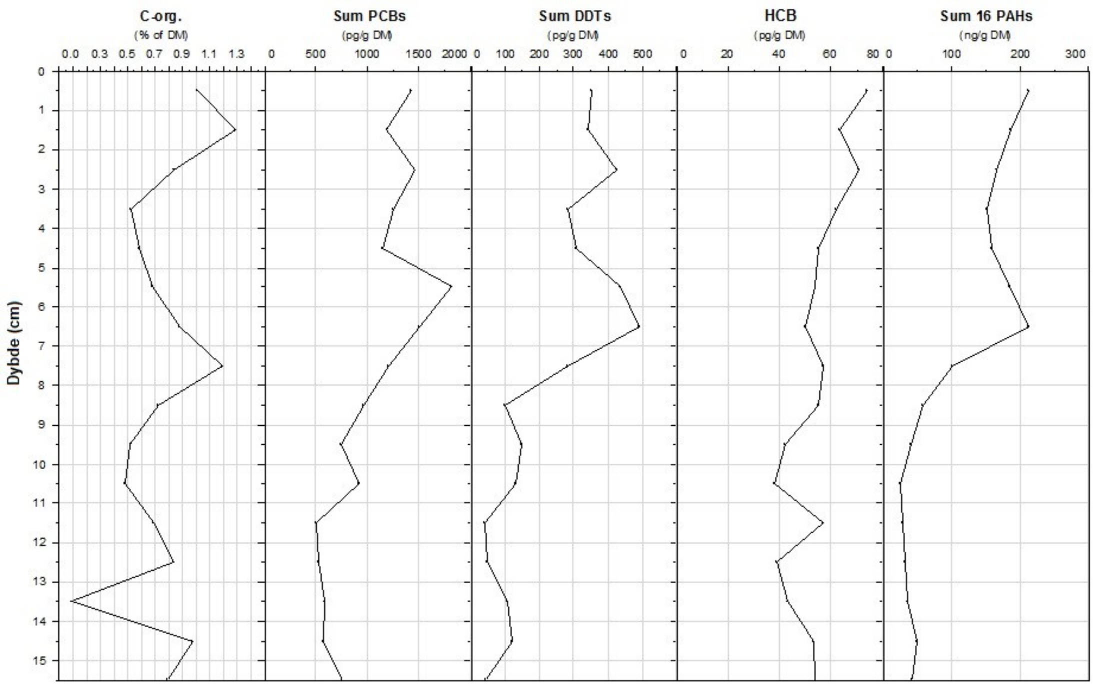
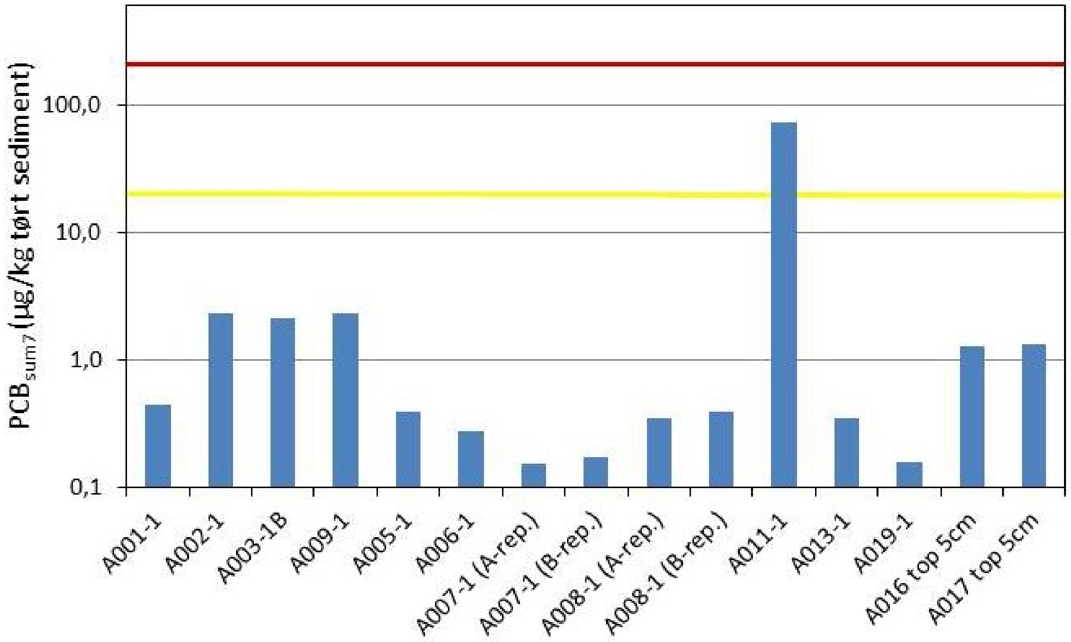


FIGURE 7.21.2 Concentration of PCBs (sum of seven compounds) in surface sediment



Note: The yellow and red lines indicate the Danish guideline values L and H Ac Ac. Note that the y-axis is log

Therefore, it is concluded that the amount of pollutants in the bottom sediment is low, and lower than national and international standards. Furthermore, the pollutants are generally limited to the upper 10 cm of the sediment surface. No impacts and restrictions on the use of sediments for the land reclamations are foreseen.

7.21.5 Environmental Consequences of Waste

The quantity of waste is described in Chapter 3 Immersed tunnel - technical description. The total waste generation and the amount of potentially recyclable materials generated during the project are relatively small compared to the waste generation at the national level.

Waste from the project will be handled in compliance with the Danish provisions of source separation, authorisation and review of construction and demolition waste in Executive Order No. 1309 of the 18th December 2012 on waste, as well as in Executive Order No. 1662 of the 21st December 2010 on the application of residues and soil for construction works and the use of sorted, uncontaminated construction waste. This will ensure that the vast majority of concrete, metal, sand/gravel and asphalt waste will be recycled. If the excavated volumes cannot be reused directly on site, the material will be sent to sorting facilities for reprocessing/recycling.

The total waste amounts from the construction phase for the fixed link project are shown in Table 7.21.3

TABEL 7.21.3 Total expected waste amount in the construction phase for the immersed tunnel

Waste fraction	Estimated waste amount	Treatment
Waste from production of tunnel elements		
Concrete for elements	40,000 m^3	Recycling
Concrete for ballast	6,000 m^3	Recycling
Concrete for portal, ramps and cut-and-cover	3,000 m^3	Recycling
Steel	150 t	Recycling
Reinforcement steel	2,000 - 5,000 t	Recycling
Household waste from campsite		
Household waste – Lolland	1,200 t per year	Incineration
Household waste – Fehmarn	60 t per year	Incineration
Waste from dismantling the production site		
Reinforcement steel	6,000 t	Recycling
Steel and metal from skeleton construction	7,000 t	Recycling
Concrete	225,000 t	Recycling
Asphalt	5,000 t	Recycling
Removal of highway		
Asphalt	5,000 t	Recycling
Gravel	3,000 t	Recycling
Dismantling of Syltholm wind farm		
Steel	3,100 t	Recycling
Fiberglass composites from wings and cabin	775 t	Landfill
Concrete foundations	2,600 m3	Recycling
Dismantling of fish farm (Dansk Klimafisk)		
Asphalt	10,000 t	Recycling
Concrete	17,000 t	Recycling
Steel	400 t	Recycling

The concrete waste from the production of tunnel elements is expected to be crushed on-site in a mobile concrete crusher and recycled in the production. When the production site is dismantled, the concrete waste produced is expected to be crushed on-site and transported by either truck or boat to a certified Danish recycling facility. The total concrete waste amounts to around 27% of the Danish concrete waste generated in 2009. The transport and recycling is considered to cause only insignificant impacts.

Steel and asphalt will be transported to a certified treatment plant. The amount of waste is relatively small compared to Danish national amounts and only insignificant impacts from transport and recycling are expected.

Dismantling and demolition of the production facilities and other constructions will be executed according to the Danish NMK 97, the Environmental Control system of the Demolition Industry of 1996. This is a prerequisite for recycling of the materials.

The total amounts of commercial household waste are estimated to be 850 - 1100 t/year. This amount equates to a maximum of 25 t/week, or on the order of five collection rounds with lorry per week. The total additional transport loads from waste is therefore considered to be insignificant.

Compliance with the provisions of Lolland industrial waste regulations concerning commercial household waste and non-recyclable waste fractions, etc. will ensure the safe collection, treatment and disposal of waste.

On Fehmarn the commercial household waste generation is relatively small and will be disposed according to local German regulations, ensuring that the waste is treated and recycled correctly.

7.21.6 Transboundary Impacts for Consumption of Raw Materials and Generation of Waste

The consumption of raw materials will only cause insignificant transboundary impacts on the environment. The majority of resources will potentially come from Kriegers Flak and Rønne Banke. The environmental assessment is integrated in this report.

Sediment from the Fehmarnbelt can be exported from Denmark to Germany, and vice versa, as the sediment generally shows low background levels of contaminants. The potential amounts are specified in Chapter 7.21.3.

Chemical analyses show that the hazardous substances are below national and international criteria, except for one sample. In this sample, PCB exceeded the Danish LAC but not HAC. All contaminants are limited to the upper 10 cm of the sediment. Therefore, no impacts are foreseen.

It is also estimated that disposal of waste can be handled without problems in Germany and Denmark, and that there are no cross-border implications.

7.21.7 Transboundary Impacts between Germany and Denmark

As indicated above, there will be no transboundary impacts due to consumption of raw materials and generation of waste between Germany and Denmark during the construction or operation of an immersed tunnel. The potential import of sediment dredged from the tunnel trench from Germany to Denmark, or vice versa, will not result in any transboundary impacts either, as mentioned above.

7.21.8 Significance of Impact

There are no transboundary environmental impacts identified by consumption of raw materials and generation of waste in Denmark to Germany, and vice versa.

TABLE 7.21.4 Significance of transboundary impacts on raw materials and waste in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on human and health in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Raw materials and waste	Raw materials	No	No	No	No	No	No	No	No	No	No
	Waste	No	No	No	No	No	No	No	No	No	No

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.22 AIR QUALITY AND CLIMATE

Construction of the immersed tunnel involves a number of activities on land and offshore, which will result in emissions of air pollutants.

This includes emissions from the marine construction activities, e.g. from dredgers, tug boats and construction vessels. Furthermore, with regard to PM_{10} and NO_2. there will be emissions of these substances from traffic going to and from the tunnel, and from the tunnel openings on Lolland and Fehmarn.

It will also result in emissions of greenhouse gases (GHG), either directly (such as exhaust from heavy equipment) or indirectly (such as electricity consumption and in the production of steel and cement used for the construction of the immersed tunnel). The emissions from construction works and operation of an immersed tunnel under the Fehmarnbelt will add to the global emissions of GHG, hence the impact from these activities is transboundary. It should be noted that GHG have no influence on the air quality, but on climate.

The calculated emissions included in the present inventory are the most significant sources of GHG emission during construction and operation. Furthermore, the energy consumption for the operation of the immersed tunnel is included in the calculations. An inventory of the greenhouse gas (GHG) emissions has been prepared, covering the construction and operation. The greenhouse gases comprise: Carbon dioxide (CO_2), methane (CH_4), nitrous dioxide (N_2O), hydro fluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

This chapter describes the calculated total emissions of pollutants and GHG emissions from construction and operation of an immersed tunnel, including the emissions from the production of building materials. Comparisons will be made with the total Danish emissions of GHGs.

7.22.1 Environmental Baseline

In the construction phase, the following are possible sources of local air pollution:

- Actual emissions from e.g. the operation of the ferries, traffic, and local industry
- Emissions during construction from entrepreneur machinery in land and off shore, trucks, and tug boats and traffic to and from the construction areas and the tunnel element factory, including transportation of employees.
- Emissions from the tunnel element factory, e.g. smoke and dust from welding, cutting processes, concrete casting and crushing plants
- Dust generation from handling of materials and driving on gravel roads
- Any small and local emissions of VOCs (volatile organic compounds) from the refuelling as well as from fuel storage

During the operational phase, the following are possible sources of air pollution in the area:

- Existing discharges from local traffic and industry
- Emissions from the tunnel opening where pollution from traffic in the tunnel will be concentrated
- Emissions from traffic along the new highway, rail and dust from re-suspension etc.
- Emissions from the ferries

The environmental baseline for greenhouse gasses for an immersed tunnel is the actual emissions of greenhouse gases. Therefore the emissions of GHG relative to the zero-alternative and the total Danish emissions have been calculated.

The methodology for the analysis has been based on the principles of a life cycle analysis as described in ex. DS/EN ISO 14040 (ISO14040) and in Corporate Accounting and Reporting Standard from World Resource Institute (WRI 2004) including the GHG-emission related to the life cycle of the immersed tunnel (i.e. production of material, transport, construction and operation of the immersed tunnel). The description of the methodology used to calculate the CO_2 emissions is divided into three parts:

- Construction of the immersed tunnel, including the main structures and construction works, temporary work sites and approach links for rail and road
- Operation of the immersed tunnel, including electricity consumption, maintenance and reinvestment, excluding traffic
- Traffic

To the extent possible, the greenhouse gas inventory covers the contribution of all greenhouse gases, expressed in CO_2 equivalents.

For the materials, the embodied CO_2 emissions will be stated in CO_2 equivalents, and will include emissions of all greenhouse gases, based on internationally accepted conversion factors.

For emissions from electricity, a CO_2 equivalent factor is calculated using global warming potential values according to IPCC.

For transport, only CO_2 emissions are included, because emissions of GHGs other than CO_2 are assessed as insignificant. The Danish National Environmental Research Institute (NERI) estimates that 95 – 99 % of the CO_2 equivalents from road transport derive from CO_2. This is also assumed the case for other transport modes and for construction machinery.

In defining the scope of the analysis, the objective has been to include significant, direct sources of emissions as well as indirect sources deriving from the construction and the operation phases.

The direct GHG emission sources include:

- Emissions from construction equipment on site
- Emissions from traffic

The indirect sources include GHG emissions from:

- Electricity production
- Production of main materials
- Transport of materials

The calculations thus include scope 1 (direct GHG emissions), scope 2 (indirect GHG emissions from consumption of purchased electricity) and scope 3 (other indirect emissions, such as the extraction and production of purchased materials, transport related activities from using vehicles, etc.) according to the Corporate Accounting and Reporting Standard from World Resource Institute (WRI 2004).

The following describes the result of the calculations concerning emissions from construction equipment, traffic, electricity consumption, and production and transport of materials.

Emissions from construction equipment

GHG emissions from construction machinery have been calculated based on estimates of the fuel consumption during construction. The final decision about use of construction machinery types, sizes, numbers, etc. will eventually be made by the contractors. Accordingly, estimates were made by the design groups based on experiences from similar types of projects.

Where the fuel consumption is not estimated by the design groups, estimates were made based on EMEP/EEA emission inventory guidebook 2009 for non-road mobile sources and machinery. The CO_2 emissions from diesel oil are based on standard factors from the Danish Energy Agency. Only CO_2 emissions have been included.

Emissions from traffic

GHG emissions from road traffic have been calculated based on the traffic prognosis (FTC, 2003) forecasted by using an annual growth in all traffic modes of 1.7 % per year. Only CO_2 emissions have been included. The emission factors for road traffic are based on assumptions for a Danish vehicle fleet composition in 2025, based on statistics and predictions about age, size and fuel distribution.

The basic source for calculation of emission factors is TEMA2010, also for trains. TEMA 2010 is a model to calculate emissions from transport based on transport method, route and distance developed by The Danish Ministry of Transport (The Danish Ministry of Transport, 2010). As the values are related to the efficiency and the technology of today, they have been projected to the year 2025 using a reduction factor taking into account improvement of train efficiency and electricity production. All trains are assumed to be fully electrified.

Electricity consumption

Calculations of GHG emissions from electricity consumption have been based on estimates of the electricity consumption during the construction phase. Electricity use for ventilation, light, pumps, compressors, etc. were provided by the design groups.

The GHG emission factor for electricity is based on information on the average Danish electricity production in the period 2015 - 2020 projected by the Danish Energy Agency. It has been assumed that the GHG emission factor for electricity is the same in Denmark and Germany.

The emission factor for CO_2 eq. pr. kWh electricity is estimated at 325 g/kWh during the construction phase and 266 g/kWh during the operation phase (average for year 2025), according to projections made by the Danish Energy Agency.

Production of construction materials

GHG emissions from construction materials have been calculated based on information about the quantities and the origin of the materials estimated by the design groups, as well as emission factors for the primary materials.

For the materials, the embodied CO_2 emission is in most cases given in CO_2 equivalents and will thus include the emission of all greenhouse gases.

The construction of the link comprises the main physical structures, the construction work activities, including temporary working sites in Lolland and Fehmarn, and the approach road and rail.

Transport of construction materials

GHG emissions from transport of materials have been calculated based on information about the likely origin of the materials, the possible destination for waste materials, and the mode of transport. For the individual mode of transport, the emission factors were identified using the figures from TEMA 2010.

Only CO_2 emissions have been included, and only the CO_2 emissions from the fuel combustion were included. No up-stream emissions were included.

7.22.2 Project Pressures

Project activities emitting air pollutants and GHG during the construction and operation phases can be summarized to the following:

- Construction of the immersed tunnel, including production of elements, the main structures and construction works, temporary work sites, and approach links for rail and road
- Operation of the immersed tunnel, excluding traffic
- Traffic

Project pressures or emission sources can be divided into direct and indirect sources. The direct GHG emission sources include 1) emissions from construction equipment and 2) emissions from traffic. The indirect sources include GHG emissions from 1) electricity consumption, 2) production of main materials and 3) transport of materials.

Construction of an immersed tunnel will cause emissions of different air pollutants, which can affect the local air quality. The main sources are:

- Construction and operation of a work harbour, tunnel element factory, camp site for workers, etc.
- Dredging of the tunnel trench and transportation of dredged materials
- Construction of the land reclamations east and west of Rødby Ferry Harbour and east of Puttgarden Harbour
- Construction of highways and railways
- Transportation of building materials by ship and trucks

A qualitative assessment has been made around the planned major construction activities, showing only local impacts (Lolland and Fehmarn).

7.22.3 Transboundary Impacts for Air Quality and Climate

Construction phase

The emissions of dust and other pollutants from construction activities in relation to the tunnel element factory will take place in closed systems, and exhaust air will be treated in filters. No problematic emissions are expected during the operation of the factory. The nearest residential area is the camp site. Furthermore, the factory is located far from other residential areas. Dust from handling, storage, and crushing of materials and driving on dirt roads will be a nuisance close to the working areas that is expected to be handled by good planning and use of necessary mitigation measures, such as cleaning, watering and covering of materials.

Emissions from the marine construction activities, e.g. from dredgers, tug boats and construction vessels are considerable, and the air quality will be affected locally. This assessment has been based on calculations of fuel consumption, and on the assumption that there are fewer demands regarding emissions from machinery than on land. As the construction activities will take place far away from residential areas and in a large area where air circulation is good, it is not expected that limit values for air quality inland will be exceeded during the construction phase.

In total, the GHG emissions from the construction of the immersed tunnel amounts to approximately 2.0 million t CO_2 equivalents (see Table 7.22.1). Embodied CO_2 in concrete is the main contributor with 46% of the GHG emissions from construction works. The emission is caused by the energy consumption in the cement production. Embodied CO_2 in reinforcement and construction steel contributes another 27%. Steel production also has relatively high energy consumption. Machinery contributes 15% and transport contributes 7%, while other sources together contribute 5%. As mentioned earlier, all GHG emissions are of a transboundary nature, so all emissions of the two phases can be considered transboundary.

The main contribution to CO_2 emissions during the construction phase is CO_2 from producing construction materials; in particular, concrete and steel because of the large quantities to be used and due to production of cement and steel, which have a high level of energy consumption compared to other sources of emissions of CO_2.

The calculated GHG emissions from the construction of the immersed tunnel account for around 3% of the total Danish CO_2 eq. emissions in 2009. If GHG emissions during construction are distributed equally over a period of 6.5 years, they correspond to annual emissions from 28,000 average Danes.

The approximately 2.0 million t CO_2 equivalents emitted from the construction of an immersed tunnel will add to the world's emissions of GHG and therefore have an insignificant transboundary impact.

Operation phase

With regard to PM_{10} and NO_2. concentrations in the operation phase, dispersion calculations show that land around the tunnel opening and up to approximately 200 m from it, in the direction away from the tunnel opening, will have elevated concentrations of these substances, which exceed the current air quality limit values for residential areas. However, there will be no permanent habitation, and the public will not have access to the outdoor area, where the concentration is above the threshold levels.

During operation of the immersed tunnel, the annual CO_2 emissions resulting from electricity consumption, maintenance and reinvestment activities amount to approximately 6,000 t.

The GHG emissions are calculated for the following three scenarios:

- Traffic scenario 2025: A scenario without a fixed link, but where the ferries still are operating (zero alternative)
- Traffic scenario 2025/50 %: An operating tunnel with ferries. It is assumed that ferries and tunnel will have an equal distribution of the traffic in 2025.

The total GHG emissions for the immersed tunnel compared with the zero alternative (scenario without a tunnel) in 2025, is shown in Table 7.22.1.

TABEL 7.22.1 Total GHG emissions compared with the zero-alternative (2025). Minus indicates a reduction

Reduction in the emission factor	Emission (t)
Construction (t, total)	1,977.254
Operation (t, annually)	5,900
Scenario 1: Traffic 2025 (t, annually) Scenario 2: Traffic 2025/50% (t, annually)	-198,500 -43,100

The largest reductions would come from closing the ferry line between Rødby and Puttgarden (scenario 1). There would also be a reduction of emissions from freight transport on road and rail. The reason for this is an expected transfer of road freight to rail and a decrease in travel distance for the rail freight. The savings will be approximately 200.000 tonnes CO_2 per year, calculated for 2025.

The 50/50 scenario where both the tunnel and ferries are operating (scenario 2) for the year 2025 will result in a reduction in CO_2 emissions compared with the zero-alternative of 43.000 tons per year. This is due to less ferry departures at the routes Trelleborg-Rostock and Gedser-Rostock, but also due to a decrease in kilometres driven by lorries and freight trains, which now use the tunnel.

As mentioned, Table 7.22.1 indicates that an immersed tunnel will result in a reduction of the emission of GHG for the year 2025 concerning traffic. This is primarily due to the closure of the ferries at Rødby-Puttgarden, but it is also presumed that freight with lorries is expected to be moved to trains instead. Furthermore, the distance for freight transport will be shorter, as more traffic types can use the immersed tunnel as a shortcut to the continent (from the continent) instead of the highway via Fyn and Jutland. Over the lifetime of the immersed tunnel (120 years), assuming the same emission and emission factors, the reduction of CO_2 emissions amounts to a total of 0.7 million tonnes CO_2.

This reduction in CO_2 emissions caused by an immersed tunnel will add positively to global CO_2 emissions and will therefore also have a positive impact within the transboundary region.

A qualitative assessment has been made of the area around the planned major construction activities, showing only local impacts (Lolland and Fehmarn).

7.22.4 Transboundary Impacts for Air Quality and Climate between Germany and Denmark

A qualitative assessment has been made of the local air quality on Lolland and Fehmarn around the planned major construction activities, showing only local impacts (Denmark and Germany)

The operation of the tunnel element factory on Lolland is planned to be regulated according to the Environmental Protection Act as a concrete factory. Most of the dust-emitting and polluting activities will take place in closed systems, and the exhaust will be emitted through filters. Therefore no major emissions are expected from the factory, hence no impact in Germany. The nearest residential area is planned to be the camp site for the workers in the tunnel element factory and the inland construction sites for ramp and highway. The production facilities are planned to be relatively far away from other residential areas.

The emissions from marine activities, being backhoe and grab dredgers, tug boats, construction vessels, barges, etc. will be considerable, and the air quality will be locally affected. This conclusion is based on calculations of fuel consumption, and the fact that there are lesser regulatory threshold values for emissions from machinery offshore compared to such regulations on land. Threshold values for air quality will not be exceeded offshore during the construction phase, as the activities will take place far away from residential areas, in a large area where the air circulation is good. This assumption is supported by dispersion calculations made for the construction year, where most construction activities will take place, resulting in highest emissions. The air pollution in the construction areas at sea is assessed to be considerable, but to not result in significant impacts for the population, animals or plants.

The production plant is placed on Lolland, Denmark and the work harbour at Fehmarn is smaller. Furthermore, the construction related traffic on Fehmarn is expected to be on a lower scale than on Lolland, Denmark.

The overall conclusion is that emissions into the air on the Danish side will not cause any impacts on air quality on the German side, and vice versa.

7.22.5 Significance of Impact for Air Quality and Climate

The overall conclusion is that emissions into the air on the Danish side will cause no impacts on air quality on the German side, and vice versa

Compared to the annual global emissions and climate, the emissions from the construction of the tunnel are insignificant. The emissions will not affect climate change in any measurable way.

Over the tunnel's lifetime (120 years), however, the tunnel will result in GHG savings. This is considered a minor positive impact for the climate.

TABLE 7.22.2 Significance of transboundary impacts on air quality and climate in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on air quality and climate in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Air quality and Climate	Air quality	No	No	No	No	No	No	No	No	No	No
	Climate	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.22.6 Mitigations concerning Air Quality and Climate

As there are no significant impacts on regional climate and air quality, hence mitigations are not relevant.

7.23 SHIP TRAFFIC AND NAVIGATION

The construction of an immersed tunnel involves a number of marine activities, which will affect the ship traffic and navigation in the Fehmarnbelt from adjacent areas. All non-construction ship traffic will be maintained throughout the construction period; i.e. commercial traffic on the T-route through Fehmarnbelt, ferry traffic across the Fehmarnbelt, commercial traffic on main navigational routes in the western part of Fehmarnbelt, and additional traffic with smaller ships in the area (local commercial ships, fishing boats and pleasure crafts). The ship traffic and the marine construction activities related to the project are also described in Chapter 5: Immersed Tunnel – technical description.

Countries that might be subjected to transboundary impacts concerning ship traffic and navigation (not in their Exclusive Economic Zones, EEZ) are Poland, Estonia, Latvia, Lithuania, Russia, Finland, Sweden and Norway and potentially other countries that use the Fehmarnbelt as a traffic route, including Germany and Denmark.

This chapter describes the impacts for ship traffic and navigation in the transboundary region in the construction phase of the immersed tunnel.

7.23.1 Environmental Baseline

The analyses were performed using data from various sources, but most analyses were based on a GPS-based system for the tracking of ships, denoted as the Automatic Identification System (AIS), which is a system mandatory for ships above 300 Gross Tonnage (GT). Other data sources include radar data, registrations from the Kiel Canal, registrations from Great Belt Vessel Traffic Service System (VTS), near miss reports from Great Belt VTS, and accident registrations and interviews.

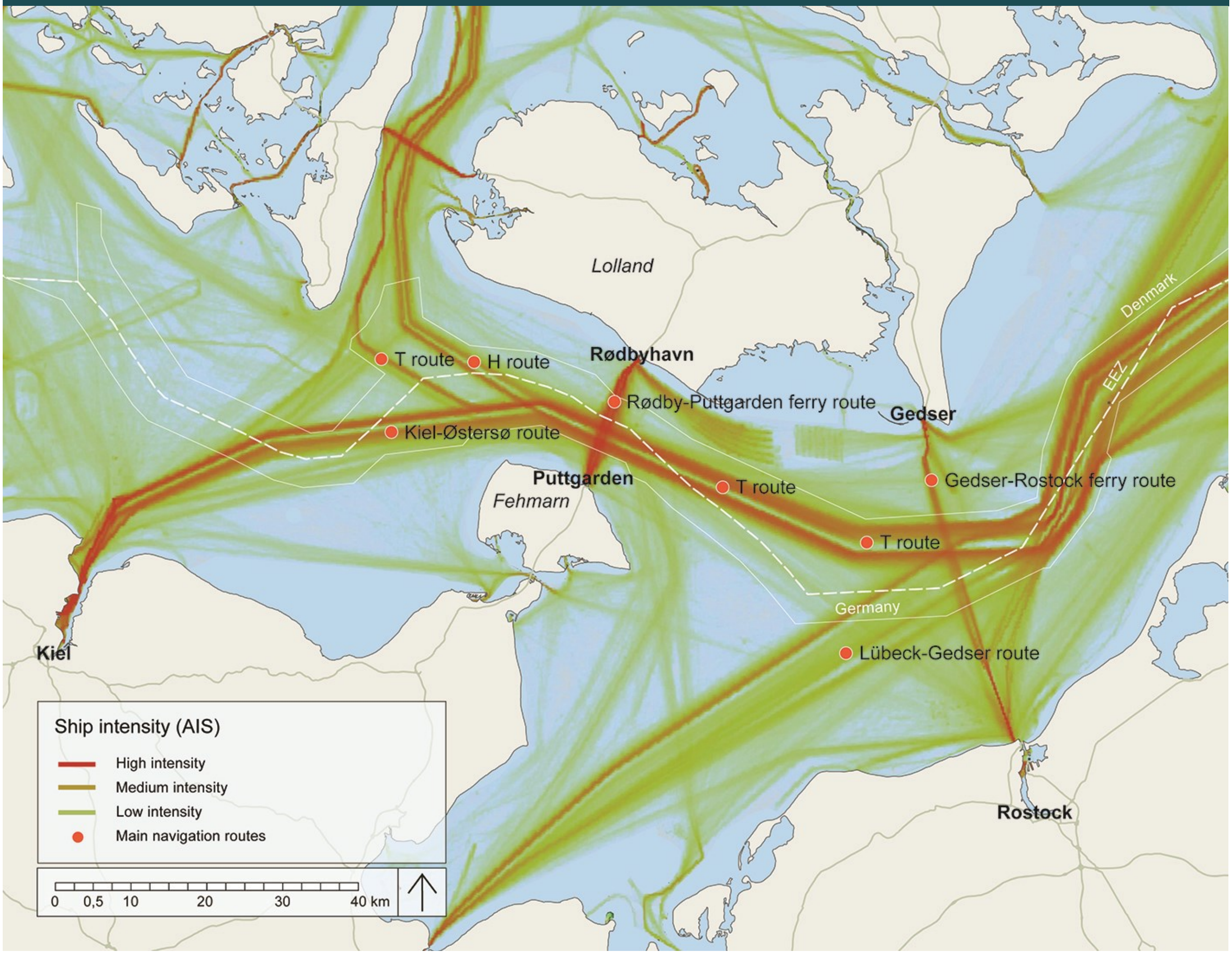
In the Fehmarnbelt, most ships sail through the T-route, the main navigation route. In the western part of the Fehmarnbelt, traffic branches out into the H-route, the deep-water route (T-DW) and the route to Kiel. The intensity plot in Figure 5.1 shows AIS tracks for ship traffic in the Fehmarnbelt area in 2010. The annual ferry traffic across the Fehmarnbelt between Rødby and Puttgarden consists of approximately 34,000 crossings.

In 2010, a total of 38,000 ships sailed on the T-route through the Fehmarnbelt. On average this amounts to slightly more than 100 ships per day. Since some of the ships can pass through

Øresund in ballast on their way to the Baltic Sea, there is a slight majority in westbound ships passing through the Fehmarnbelt. On average, 54 westbound ships and 49 eastbound ships pass through the Fehmarnbelt each day.

Traffic in the Fehmarnbelt consists mainly of general cargo ships, tankers and container ships. In 2010, around 5,000 tankers passed through the Fehmarnbelt heading west out of the Baltic Sea. Tankers travelling through the Fehmarnbelt are mainly oil tankers (90 - 95 %), some of which (35 %) are empty when passing the belt. The sizes of the ships range from small ships of around 50 m, up to large ships of 300 m, while ships above 300 m are rarely seen.

FIGURE 7.23.1 Intensity of ship traffic in the Fehmarnbelt area on different international routes



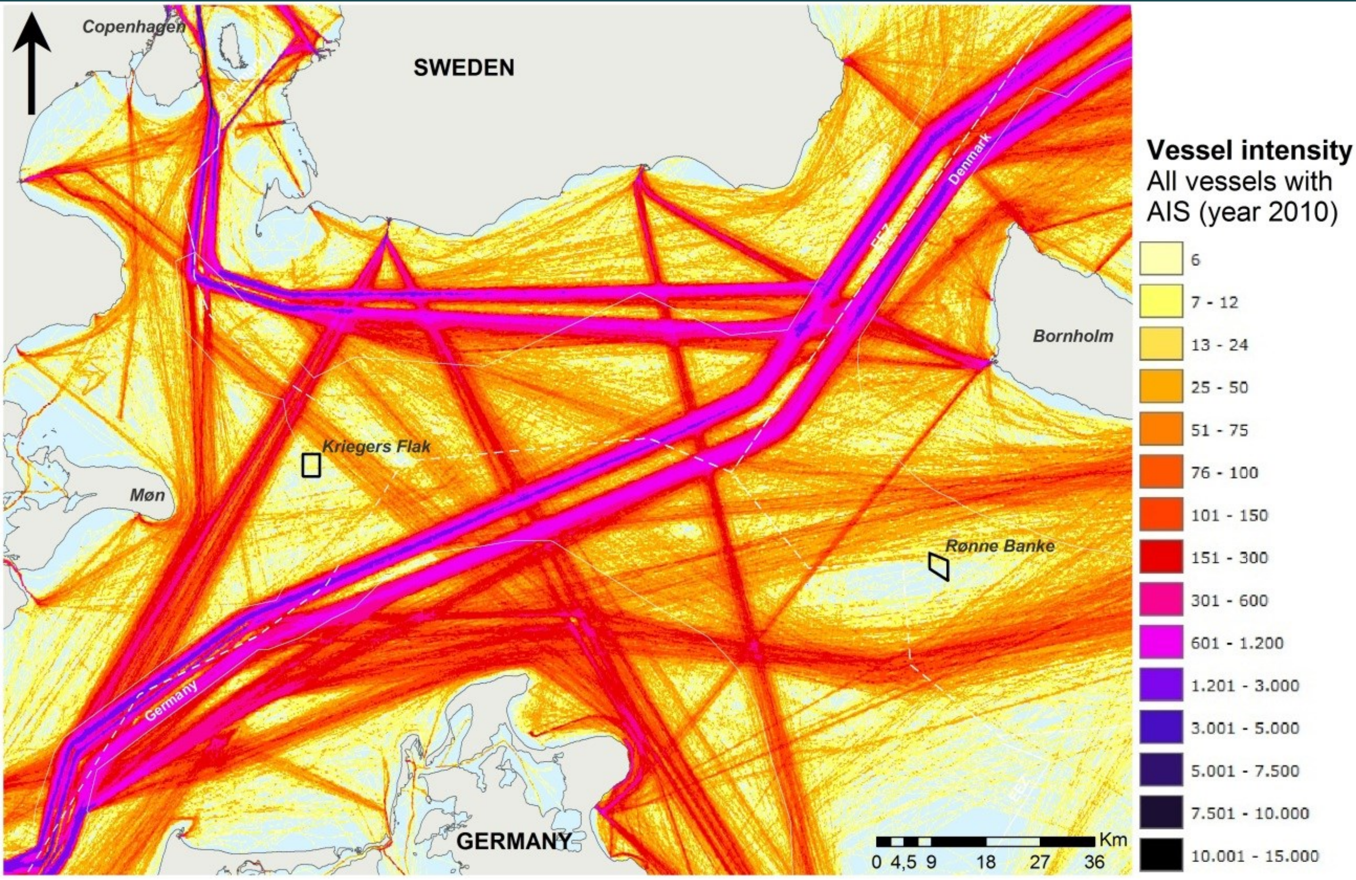
Calculations on present and future ship traffic scenarios in the Fehmarnbelt have been estimated and researched for the period from 2020 – 2030 in order to assess the possible impacts on ship traffic and navigation from an immersed tunnel during construction. These calculations show that the traffic in the Fehmarnbelt area is expected to rise to between 70,000 to 80,000 passages in year 2030, depending on the general growth of the countries around the Baltic Sea. Relevant German and Danish maritime authorities have been consulted on the data and conclusions in order to safeguard the ship traffic as much as possible during the construction of a tunnel.

As part of the baseline, it should also be mentioned that the German authorities have installed a VTS system in Travemünde, which covers the German part of the T-route. This also adds to the general ship traffic and navigation safety situation in the Fehmarnbelt.

Ship Traffic at Rønne Banke and Kriegers Flak
Only a smaller amount of ship traffic passes through Rønne Banke. The extraction activities might cause a change to the sailing routes during the extraction period, due to approximately 135 - 670 expected passages of construction related traffic.

A smaller amount of ship traffic passes Kriegers Flak, so only minor changes may occur, since ships may change their route during the extraction period (approximately 800 - 1400 passages are expected during the construction phase). The figure below shows the traffic intensity near Rønne Banke and Kriegers Flak.

FIGURE 7.23.2 **Ship traffic pattern south of Sweden and east of Bornholm. The sand extraction areas are marked in black**



7.23.2 Project Pressures

The location and intensity of the offshore construction works are essential in order to estimate frequencies and risks related to the interactions between non-construction traffic and construction equipment and ships. The project pressures in relation to ship traffic and navigation are therefore:

- The offshore construction works
- Exclusion zones
- Work areas offshore
- Barrier effects from construction works

All pressures are related to the construction phase. The tunnel elements will be towed from the work harbour to holding areas in the vicinity of the tunnel alignment. The tunnel elements are stored in holding areas until they are moved into position and immersed.

The offshore construction phase lasts for about 200 weeks and is divided into two main phases:

- Dredging phase:
  The majority of the dredging is related to the dredging of a trench across the Fehmarnbelt, where the immersed tunnel will be placed, but the works also include dredging for work harbours, access channels to work harbours, as well as for portals and ramps associated with the construction of the tunnel.
- Immersion phase:
  The immersion phase includes the placing of the foundation, immersing and connecting the tunnel elements, and backfilling of the trench. A gravel layer will first be placed in the trench. Tunnel elements are stored adjacent to the immersion location. They are then winched into position and immersed. Locking fill, back fill and a cover layer are placed once a tunnel element is correctly positioned and connected to the other tunnel elements under water.

Offshore construction related traffic is estimated to result in 130,000 trips in total during the four years it lasts (approximately 32,000 p.a., which corresponds to the present situation of the crossings that ferries make between Puttgarden and Rødbyhavn). About half of those crossings are bound to cross the international T- route in the Fehmarnbelt.

7.23.3 Transboundary impacts on Ship traffic and Navigation

A hazard identification and risk reduction workshop has been conducted to identify and describe potential hazards related to the offshore construction activities and the non-construction ship traffic in the Fehmarnbelt. A ship risk model has been developed, based on the identified hazards and used as the basis for the risk assessment of the tunnel construction phase in the Fehmarnbelt. Ship types are modelled to include the presence of different types of construction equipment. The risk assessment report describes the model plus all the modelling assumptions relating to ship traffic, work areas and construction traffic, including towing of tunnel elements, etc.

The results of the workshop were taken into account as part of the basis for the risk assessment. Moreover, general information on the geographical area and the non-construction traffic, as well as information on the offshore construction activities are included.

The results of the risk assessment are given for three risk types:

- Environment (spill of oil)
- Property (damage to non-construction vessels, construction vessels and equipment, including tunnel elements)
- Fatalities

The results include both estimated accident frequencies and risks according to the above mentioned risk types.

To illustrate how the risk reduction options impact navigational safety during the construction period, a quantitative risk assessment has been made, which estimates the risk for the construction phase and the reference scenario:

- Reference scenario (2020)
  No offshore construction works, no risk control, and continued ferry service between Puttgarden and Rødbyhavn
- Construction phase (2020)
  Offshore construction works and risk control options (see Chapter 7.23.6), and continued ferry service between Puttgarden and Rødbyhavn

The risk of collisions which involve non-construction related ships, as well as the increased risk of collisions due to the more dense traffic in the area, have been estimated.

The following figure shows the results of the risk assessment as average risk per year, measured in million Euros.

FIGURE 7.23.3 Average annual risk for construction of an immersed tunnel (in million Euros)

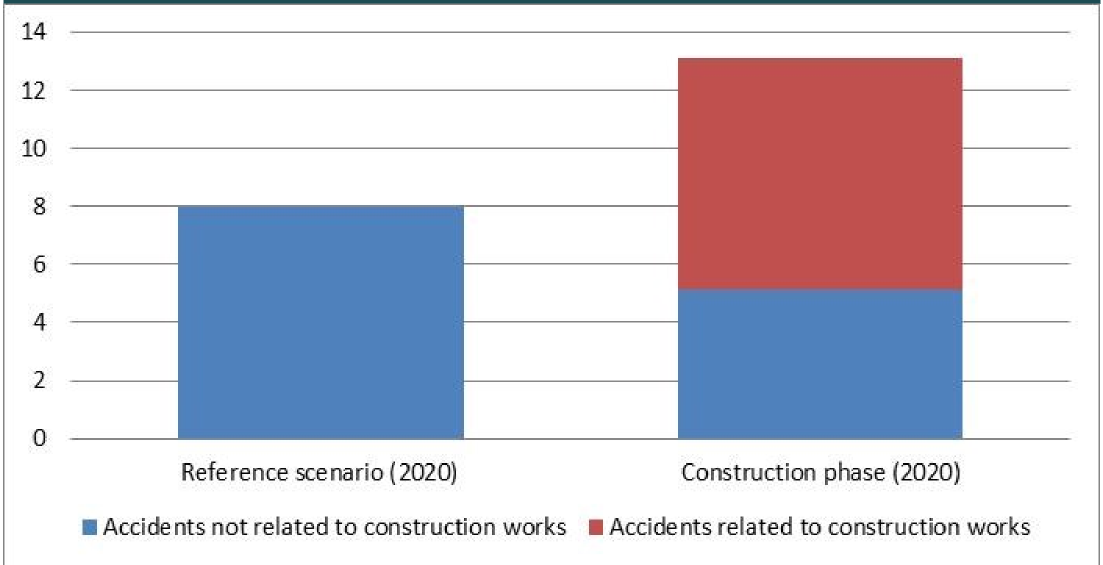


Figure 7.23.3 shows that the average annual risk of collisions during the construction phase is higher than the risk for the reference scenario. The accident frequency related to stationary equipment makes the risk higher in the immersion phase.

The most significant contribution to the higher risk in the immersion phase is collision between non-construction traffic and tunnel elements. This type of collision can happen while the tunnel elements are placed near the alignment before they are immersed. Because the tunnel elements are very expensive to repair or replace after a possible collision, costs are at their highest during this period of the construction phase. As such, even a small risk for collision will cause an increase in risk costs.

The risk of damage to property belonging to Femern A/S (construction materials and construction vessels) corresponds in average to about €6 million per year.

The average yearly environmental risk (oil spill) and the risk for personal accidents (in monetary costs) have been estimated below the reference scenario and the scenario of the construction of an immersed tunnel (Table 7.23.1). Generally, it can be concluded that the risk of oil spills and personal accidents is lower in the construction phase of a tunnel than in the reference scenario. The primary reason for this is that the most important cause of oil spills are when oil tankers collide with each other, with other elements, or go aground; and these type of accidents are expected to decrease due to the effect of the risk control measures (VTS system, guard vessels, etc.) determined to be introduced as part of the construction phase.

TABEL 7.23.1 Average yearly environmental risk (oil spill) and personal accidents based on traffic prognosis from 2010 for ship traffic in Fehmarnbelt

Yearly risk in 1,000 €		
Scenario	Reference scenario without construction	Construction of tunnel
Environmental risk	928	594
Personal accidents	613	448

Disregarding the risk of damage to property of Fehmarn A/S, the risk analysis therefore shows a decrease in risk from the reference scenario to the construction phase, including oil spills and personal accidents.

The impacts from the construction of an immersed tunnel are assessed to lead to temporary local impacts in the Fehmarnbelt, which do not extend beyond the German and Danish Exclusive Economic Zones (EEZ), and thus in the case of ship traffic, only insignificant transboundary impacts are expected to occur. However, there will be a barrier effect from the offshore construction works, but since all types of traffic can still pass through the Fehmarnbelt during the construction phase, this is only assessed as an insignificant impact. Furthermore, the effectiveness of the risk control options in operation during the construction phase (see chapter 7.23.6), will maintain a high level of safety in the construction area. During operation there will be no impacts on ship traffic and navigation from an immersed tunnel.

Rønne Banke

Heavy ship traffic occurs in the Baltic Sea, but all the main traffic routes pass around Rønne Banke and not through. However, a smaller amount of traffic does pass across Rønne Banke, and information about the extraction activities will be given to the authorities in order to provide instructions to the general ship traffic.

Between 135 - 670 cargos will be transported from the extraction area to the construction site in a period of 2 - 3 years. Compared to the total amount of ship traffic in Fehmarnbelt (Fehmarnbelt had approximately 38,000 ship passages in 2010 and 34,000 ferry crossings per year) the increase in ship traffic is regarded as negligible. The extraction area is small, the duration of the activities relatively short, and the transport of extracted sand from the extraction site to the construction sites in the Fehmarnbelt (about 240 km) will create a small increase in the ship traffic in the area.

The ship traffic in the area is not restricted to channels (fairways) within the extraction area, and ship traffic can change sail routes. The risk of collision is regarded as low, because there is sufficient room for relocation of the traffic. Compared to the total ship traffic in the area, which in Fehmarnbelt is approximately 38,000 passages per year, and approximately 34,000 ferry crossings, the impact on ship traffic and navigation by the extraction activities at Rønne Banke is assessed as not causing transboundary impacts on ship traffic.

Kriegers Flak

As for Rønne Banke, the main traffic routes pass around Kriegers Flak. However, a smaller amount of traffic does pass across Kriegers Flak, and information about the extraction activities will be given to the authorities in order to provide instructions to the general ship traffic.

Sand extraction will generate between 800 and 1,428 cargos of sand between the working area for the Fixed Link and Kriegers Flak (120 km) in a period of 2 - 3 years. Compared to the current ship traffic in Fehmarnbelt, the increase in ship traffic is regarded as negligible (Fehmarnbelt had approximately 38,000 ship passages in 2010 and an additional 34,000 ferry crossings per year). A smaller amount of traffic passes across Kriegers Flak and minor redirection may occur for this traffic, as they may have to change their sailing route to avoid the extraction area. The extraction site is small, the duration of the activities relatively short, and the transport of extracted sand from the extraction site to the construction sites in Fehmarnbelt (about 120 km) will create a small increase in the ship traffic in the area.

The ship traffic in the area is not restricted to channels (fairways) within the extraction area, and ship traffic can change sail routes. The risk of collision is regarded as low, because there is sufficient additional space, which the traffic can relocate to. Compared to the total ship traffic in the area, the impact on navigation and ship traffic by the extraction activities at Kriegers Flak is assessed to cause insignificant transboundary impacts on ship traffic.

7.23.4 Transboundary Impacts on ship traffic and navigation between Germany and Denmark

As mentioned earlier, the impacts from construction and operation of an immersed tunnel are assessed to lead to temporary, local, insignificant impacts in the Fehmarnbelt. However, there will be no transboundary impacts on the ship traffic and navigation in Germany that will lead to impacts in Denmark, and vice versa.

7.23.5 Significance of impacts for Ship traffic and Navigation

There will be no significant impacts on ship traffic during operation of an immersed tunnel.

The impact from construction of an immersed tunnel is assessed to have only an insignificant impact on ship traffic and navigation in the Fehmarnbelt, Rønne Banke or Kriegers Flak, and the transboundary region. This is mainly because the traffic is allowed to operate freely during the construction phase, and the implementation of the different risk reduction measures (mitigation) secures the on-going traffic continuously. Furthermore, no transboundary impacts on the ship traffic and navigation in Germany will lead to impacts in Denmark, and vice versa.

TABLE 7.23.2 Significance of transboundary impacts on ship traffic in the Baltic Sea, Norway, Germany and Denmark

Factor		Assessment of impacts on humans and health in the Baltic Sea, Norway, Germany and Denmark									
Component	**Sub-component**	**Swe**	**Fin**	**Rus**	**Est**	**Lat**	**Lit**	**Pol**	**Nor**	**Ger**	**Den**
Ship traffic and navigation	No subcomponent	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins

Note: Sig = Significant impact, Ins = Insignificant impact, No = No impact

7.23.6 Mitigations concerning Navigational Safety

Femern A/S has in collaboration with German and Danish maritime authorities established a maritime coordination group, which will uphold and secure navigational safety in the Fehmarnbelt area during construction of an immersed tunnel.

Some of the risk control options are active in the construction phase in order to reduce the possibility of collisions. These risk control options include a temporary Vessel Traffic Service (VTS) system and guard ships in connection with each offshore work area, as well as safety zones around work areas and a work vessel coordination (WVC) centre.

The VTS for the permanent situation in the Great Belt is able to prevent 60 – 90 % of all accidents depending on the assumed effect of increased awareness. A conservative reduction factor of 60 % is used for a VTS system in Fehmarn, including navigational assistance, when looking at the possible improvement by providing a temporary VTS system in Fehmarnbelt. The accident frequency reduction factor of 60 % is assumed for the entire area throughout the construction period. The reduction factor also includes the effect of the WVC centre, which in matters concerning navigational safety will work under the authority of the temporary VTS in the Fehmarnbelt.

Guard ships will be attached to the work areas in order to avoid collisions between ships and equipment in the work areas, such as dredgers, immersion pontoons and tunnel elements.

7.24 CUMULATIVE IMPACTS

This chapter assesses the potential for transboundary cumulative impacts associated with an immersed tunnel in the Fehmarnbelt. Cumulative impacts are defined as:

"Impacts that act together with other impacts (including those from concurrent or planned future third party activities) to affect the same resources and/or receptors as an immersed tunnel"

This chapter focuses on the potential for cumulative impacts arising from an immersed tunnel in interaction with other transboundary projects in the Fehmarnbelt area and the Baltic Sea. The potential for cumulative impacts arising from an immersed tunnel in conjunction with other projects in the Baltic Sea is considered. These impacts include cumulative impacts from projects of the countries of origin (Germany and Denmark) of the immersed tunnel and planned offshore projects/activities of third parties.

As an immersed tunnel only potentially causes cumulative impacts in the transboundary region in relation to *offshore* operating or planned projects, only planned or operating offshore projects from Germany, Denmark and third parties are assessed here. Potential cumulative impacts on land are only relevant in relation to:

- The construction of the tunnel portal and other land works towards German projects
- The construction of the tunnel portal and other land works on Lolland towards Danish projects

Thus, potential cumulative impacts on land are kept within German and Danish territories, and therefore land-based cumulative impacts have not been included in this chapter.

7.24.1 Criteria used in selection of projects with potential cumulative impacts

When several planned activities/projects within the same geographical area have an impact on environmental factors at the same time, cumulative impacts may occur. In the selection of planned projects these have to meet at least one or more of the following criteria:

- The project/activity has to be localised within the same geographical area as the immersed tunnel or in its vicinity
- The planned project/activity will have some of the same types of environmental pressures as an immersed tunnel
- The planned project will overlap with the construction phase or, in case of marine habitats, overlap with a phase of rehabilitation after the construction phase
- The planned project/activity will cause permanent impacts during operation – or construction

Projects with potential offshore cumulative impacts
Construction of new telecommunication lines, power cables and pipelines in the Fehmarnbelt area or the western part of the Baltic Sea could coincide with the construction and operation of an immersed tunnel; hence, cumulative impacts associated with pipeline/cable installation on the

seabed could arise. This could result, for example, in cumulative increases in turbidity levels in certain areas, or cumulative impacts from noise and vibration caused by the projects.

The significance of these impacts would, however, be dependent on the sensitivity of the particular environmental resources/receptors in the affected area as well as the specific character of the activities of the planned project. At the time of writing, no such activities are planned within the area of the alignment of the immersed tunnel or in its vicinity, and therefore no transboundary cumulative impacts in relation to these types of offshore projects are foreseen.

The following table shows planned and operating marine projects which have been found relevant to include in the assessment of potential cumulative impacts in relation to different environmental factors. The projects are mostly offshore wind farms, as well as the replacement of the bridge across the Storstrøm in Denmark. All planned offshore wind farms, and the bridge, are either German or Danish owned, and they are all planned within German and Danish territories.

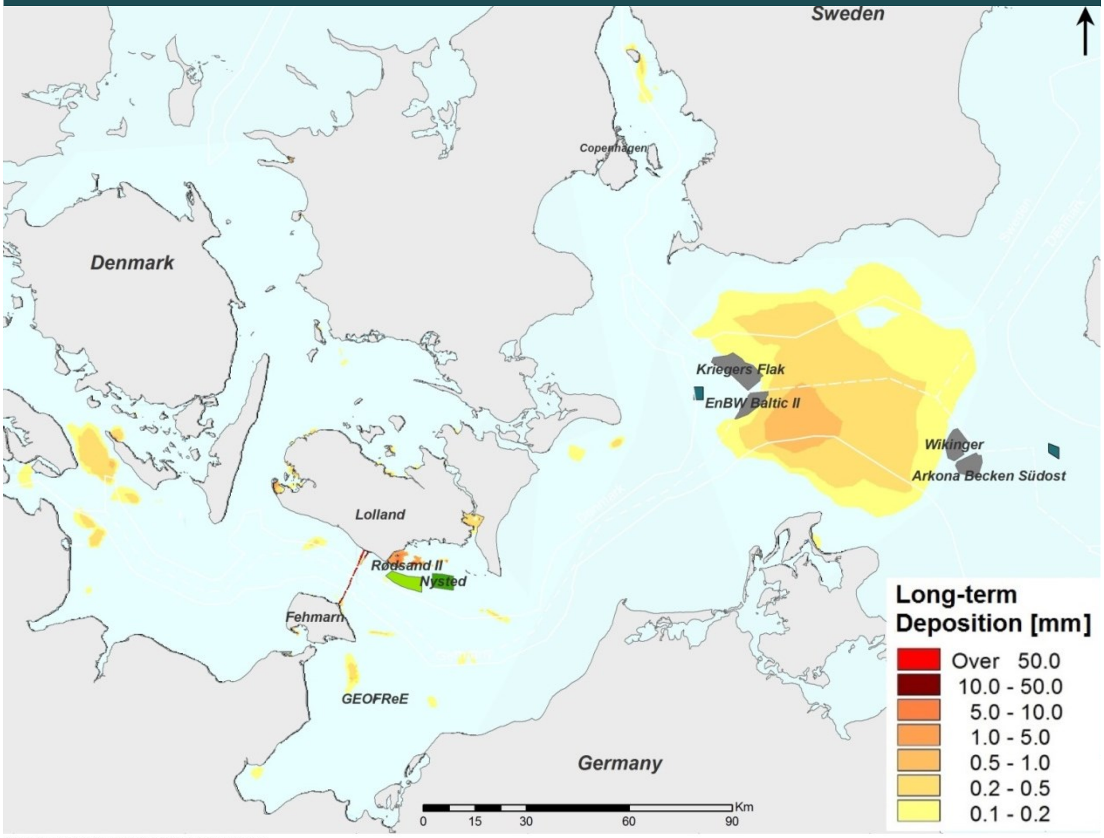
TABEL 7.24.1 Offshore planned projects which could have cumulative impacts

Project	Location	Phase	Impact from main project or extraction of raw materials	Possible interaction	Construction phase
Arkona Basin-Becken Südost	NE of Rügen (D)	Construction	Main project	Sediment spill, displacement of habitat, risk of collision, barrier effect	Expected to begin construction in 2015 (www.offshorewindenergie.net)
EnBW offshore wind farm, Baltic 2	SE of Kriegers Flak (D)	Construction	Extraction of raw materials	Sediment spill, displacement of habitat, risk of collision, barrier effect	Expected to operate in 2013 (www.windpoweroffshore.com)
Wikinger offshore wind farm	NE of Rügen (D)	Construction	Main project	Sediment spill, displacement of habitat, risk of collision, barrier effect	Start in 2015, expected completion in 2016 (www.offshorewind.biz)
Rødsand II	SE of Lolland's coast (DK)	Operation	Main project	Coastal morphology, risk of collision, barrier effect	In operation
Kriegers Flak	Kriegers Flak (DK)	Construction	Main project	Sediment spill, displacement of habitat, risk of collision, barrier effect	30 months, expected to operate in 2017 or 2018
GEOFReE	Lübeck Bight (D)	Construction	Main project	Sediment spill, displacement of habitat, risk of collision, barrier effect	Expected to begin construction in 2014 (www.offshorewindenergie.net)
Storstrøm bridge replacement	Storstrøm, Zealand – Falster (DK)	Construction	Main project	Sediment spill, displacement of habitat, risk of collision, barrier effect	Expected to be operational in 2021

Note: The wind farm at Kriegers Flak will, according to the Danish energy settlement in 2012, deliver electricity from 2017; however the farm is not expected to be in operation before 2018 according to a new settlement made in relation to the Danish strategy for solar cells (www.kemin.dk)

Figure 7.24.1 shows the projects listed in the above table as well as the extraction areas near Rønne Banke and Kriegers Flak.

FIGURE 7.24.1 Locations of the offshore wind farms Rødsand II, Nysted og GEOFReE, Kriegers Flak, EnBW Baltic II, Wikinger and Arkona Bassin Südost, the extraction sites at Kriegers Flak og Rønne Banke and modelled sediment spill from the construction of the immersed tunnel



(C) Global Offshore Wind Farms Database

Note: The wind farm Nysted was in operation when baseline investigations were made for the Fixed Link Project and is not assessed to cause future cumulative impacts, but has been considered in relation to already existing pressures. The wind farm Rødsand II was constructed and started operating at the same time as the baseline investigations in the Fehmarnbelt took place and can have a potential cumulative impact (see below).

7.24.2 Project pressures in the Marine Area

According to Table 7.24.1 there are a number of different potential cumulative impacts caused by the construction and operation of an immersed tunnel. These are: sediment spill, displacement of habitat, risk of collision, barrier effect and erosion of coastal morphology. The following seeks to explain these pressures in relation to the construction and operation of an immersed tunnel in Fehmarnbelt.

Sediment spill

Sediment spill occurs especially in relation to dredging of the tunnel trench and the extraction at Rønne Banke and Kriegers Flak. Most of the spill will occur within the first two years of the construction period. The construction activities in the Fehmarnbelt will cause sediment plumes; however, concentrations of suspended material above 2 mg/l will only occur near the construction works (i.e. within 200 - 600 m from the work areas). In other areas of the Fehmarnbelt, the suspended materials will not exceed 1 mg/l.

Spilled sand fractions will deposit within 200 - 600 m of the dredging works and are planned to be a part of the natural sand transportation at the seabed. The re-suspended sediments from the dredging works are transported for longer distances in concentrations of less than 2 mg/l at the surface and less than 10 mg/l at the seabed. At the surface, the sediment plume will not be visible, and at the seabed the concentration will not exceed maximal concentrations of the natural deposits.

The modelling of sediment spills shows that the total final settlement of fine sediments in the Arkona Basin is approximately 1 mm, which corresponds to 10% of the natural settlement rate in the Arkona Basin within the same period (Denmark, Germany and Sweden). Such a small increase in the settlement rate will hardly be detectable, and is assessed to be insignificant in Chapter 7.6 Sediment and seabed form (Figure 7.24.2).

Displacement of habitat

Permanent displacement of habitat caused by land reclamations at Rødbyhavn and Puttgarden occur locally and in relation to the footprint of the immersed tunnel. Displacement of habitat also occurs in relation to the tunnel trench and access channels to the work harbours. Calculations show that the seabed and habitats will be affected for up to 35 years. However, as explained in other relevant sections of Chapter 7, this impact is local and insignificant, as it will not affect transboundary biogeographic populations of migrating fish, birds or marine mammals.

Displacement of habitat also occurs as a consequence of sediment spill and construction-related vessel traffic in connection with the construction phase. The impacts are estimated to occur for up to two years. Displacement of habitat in relation to sediment spill and construction-related vessel traffic is assessed to have the largest impact on water birds, particularly Common Eider, Red-breasted Merganser, Wigeon, Pochard and Tufted duck. Displacement of habitat in relation to these species will occur for less than two years and will impact up to 9,000 Common Eider, 950 Red-breasted Merganser, 1,500 Wigeon, 700 Pochard and 7,000 Tufted duck. For Common Eider this corresponds to 1.2% of the bio-geographic population, while for the other species the impact is less than 1% of the biogeographic population. Modelling of the impact shows, however, that the mortality rate does not increase significantly for any of the species due to the displacement.

Risk of collision and barrier effects

These impacts are not relevant in relation to operation of an immersed tunnel, as the immersed tunnel in itself will not lead to an increase in risk of collisions or create any significant barrier effect.

The barrier effect from ships during construction has been assessed in this report. In the Fehmarnbelt, up to approximately 38,000 (2010) ships passes every year. None of the projects listed below will change this statistic in a way so that is relevant to assess potential cumulative impacts regarding ship traffic.

Coastal morphology (erosion)

It has been assessed that erosion of the coast along Lolland and Fehmarn may increase due to the construction of an immersed tunnel. However, the impact is local and within Danish territory and is confined to the southern part of Lolland's coast and stretches to the area at Rødsand Lagoon. Mitigation measures will be established to secure the coastline from erosion by using beach nourishment, and it is therefore not relevant to assess potential cumulative impacts regarding coastal morphology.

7.24.3 Transboundary cumulative impacts

The offshore wind farms Arkona-Becken Südost, EnBW wind farm Baltic 2, Wikinger wind farm and the wind farm at Kriegers Flak all lie more than 100 km from the project area of the immersed tunnel. Potential cumulative impacts in relation to these are sediment spill and displacement of habitat.

Sediment spill in relation to mentioned wind farms

For a cumulative impact to occur there has to be compliance between the construction phase, which involves dredging works at the wind farms, and the two years when the intensive dredging works during the tunnel's construction phase takes place. Apart from the planned wind farm at Kriegers Flak, all wind farms lie at least 100 km from the dredging works in the project area. The sediment spill from the extraction activities at Kriegers Flak and Rønne Banke will only consist of fine sediment at this range. Therefore the sediment will be re-suspended and non-visible and in such low concentrations that it will not affect flora or fauna significantly.

Displacement of habitat to mentioned wind farms

As mentioned, an immersed tunnel will theoretically cause a displacement of habitat in relation to some water birds within a two year period during the construction phase. The distance between the dredging works for the tunnel trench and the wind farms is more than 100 km. Since the period of displacement of habitat in relation to water birds only occurs for a period of two years, it is assessed that the construction of an immersed tunnel will not cause any transboundary cumulative impacts.

All in all, it can be concluded that no significant cumulative impacts in relation to displacement of habitat will occur between the establishment of an immersed tunnel and any of the mentioned wind farms.

Rødsand II

Rødsand II has been constructed and has started operating, while the baseline investigations of the project in the Fehmarnbelt were on-going. To the degree that erosion from Rødsand II still occurs during the construction of an immersed tunnel, a potential cumulative impact on the coastal morphology (erosion) may occur. Rødsand II has been incorporated in the hydrodynamic modelling, which forms the basis for the assessment of impacts on hydrography and coastal morphology from the immersed tunnel. Rødsand II has also been incorporated in the individual-based model (IBM) in relation to the assessment of impacts on Common Eider and other bird species. No significant cumulative impacts on birds in this respect are expected.

Coastal erosion

A cumulative impact will only occur for the coastal morphology if the coastal erosion is intensified as a consequence of the construction of an immersed tunnel. As mentioned, mitigation measures in relation to such an impact will be prevented by beach nourishment, and Rødsand II's contribution in relation to this pressure is assessed as insignificant. Hence, the construction of an immersed tunnel is assessed not to cause any transboundary cumulative impacts regarding Rødsand II.

GEOFReE

Potential cumulative impacts in relation to the GEOFReE wind farm are sediment spill and displacement of habitat. The distance between the project area of the immersed tunnel and the wind farm is more than 30 km.

Sediment spill

For a cumulative impact to occur in the construction phase, which involves dredging works at GEOFReE wind farm, there will have to be an overlap between these works and the two years during which the intensive dredging works of the construction phase of the immersed tunnel are taking place. This is, however, not the case (see Table 7.24.1).

Displacement of habitat

An immersed tunnel causes a theoretical displacement of habitat for a number of water birds within a two year period. As a consequence of the distance between GEOFReE and the project area, and this limited period of time, it has been assessed that an immersed tunnel will not cause any cumulative impacts regarding displacement of habitat. Overall, it can be concluded that there are no significant cumulative impacts in relation to the wind farm GEOFReE.

Extraction of raw material at Kriegers Flak and Rønne Banke
Sediment spill is the most significant pressure in relation to the sand extraction at Kriegers Flak and Rønne Banke. The dredging will take place in a specially designated area, where the material consists of sand and gravel. The sediment is planned to be deposited within a short period. Calculations show that most of the deposition will occur within Danish waters.

The sand extraction at Kriegers Flak has been planned to take place during a 2-year period and may be concurrent with the construction activities of the planned wind farms. Because of the distance between the activities and the local and temporary character of the pressures from the sand extraction, it is assessed that the cumulative impacts between the planned wind farms and the sand extraction to be minor and hardly existing. A more exact assessment of the potential cumulative impacts is expected to be implemented in connection with preparation of the environmental impact assessment studies of the planned wind farms.

It can be remarked that the sand extraction primarily will affect the benthic fauna communities in the area. The impacts on fish are expected to be minor and temporary. It is expected that there will be an impact on the benthic fauna communities in connection with the planned wind farms, but the impact on the benthic fauna is limited to the local areas around the wind farms.

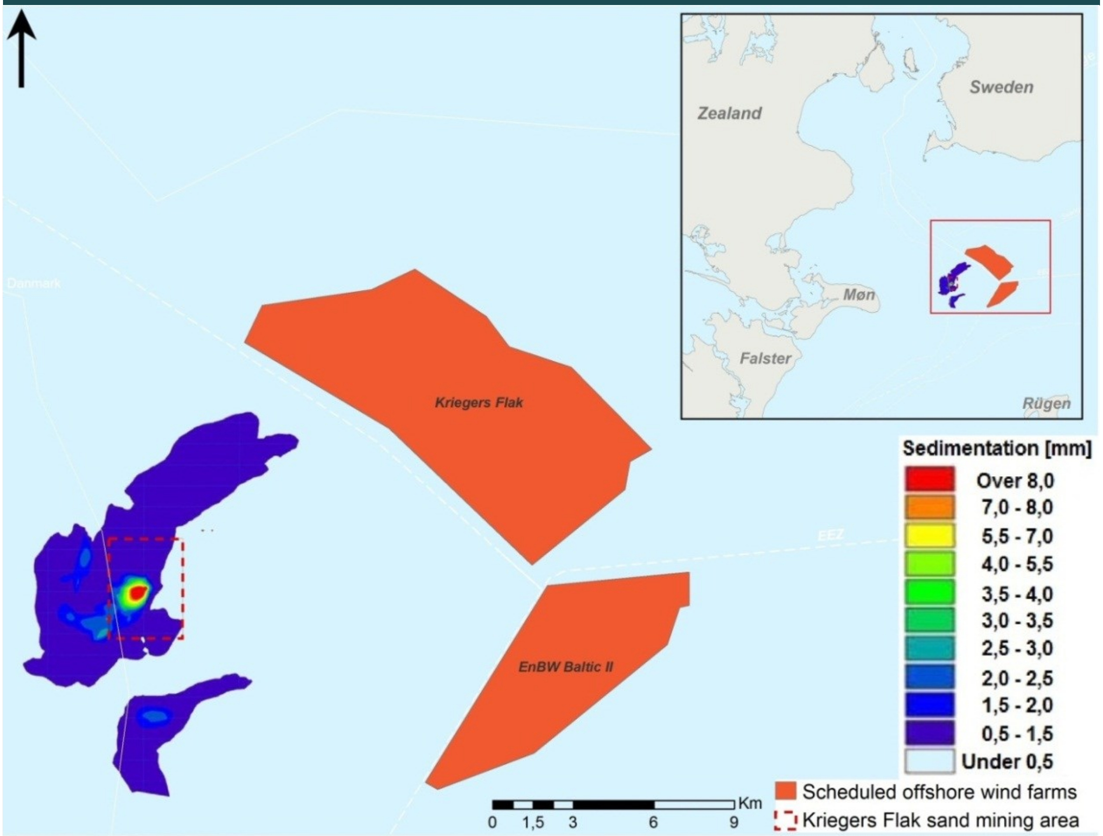
As the distance from the wind farms to the sand extraction area is long and the impacts limited, it is expected that the overall Cerastoderma community on Kriegers Flak and in the Baltic Sea will not be significantly affected, and that the ecological functionality in the area will be conserved. For the same reason it is expected that the cumulative impact on fish will be minor and insignificant.

The maximal extent of the plume from the sediment spill is about 5 km for 2 mg/l, and approximately 3 km for 10 mg/l and 2 km for 15 mg/l. Cumulative impacts from the sand extraction and the construction of the Fehmarnbelt Fixed link, which is located 130 km away, is therefore considered to be unlikely.

Concerning Rønne Banke, it has been considered to place two wind farms at Rønne Banke with a minimum distance from Bornholm of 12 km. However, no decisions have been taken concerning the detailed planning. The sand extraction will primarily affect the benthic fauna community in the area. As the distance between the planned wind farms and the extraction area is long, and the impacts on the overall Cerastoderma community at Rønne Banke and the Baltic Sea will not be affected to a mentionable degree, it is expected that the ecological functionality can be conserved. The limited extent of the impact in time and space also justifies that fish are not expected to be affected. The character of the impact likewise justifies that cumulative impacts on water birds and marine mammals are assessed to be negligible and insignificant.

The result of the model simulations of the sediment spill at Kriegers Flak can be seen in the figure below.

FIGURE 7.24.2 Modelled sediment spill for sand extraction at Kriegers Flak and location of planned offshore wind farms



(C) Global Offshore Wind Farms Database

Note: The figure shows maximum of sediment deposition for grains <63 µm, listed in mm for a whole model year (2005). Red nuances indicate the highest concentrations of sedimentation. The red rectangle shows the sand extraction area at Kriegers Flak

Storstrøm bridge

In 2013 it was politically decided to replace the old Storstrøm Bridge connecting Zealand with Falster. The bridge will be a road and double-tracked railway bridge across Storstrømmen and is expected to open at the same time as the Fehmarnbelt fixed link. Since the EIA for the Storstrøm project has not been completed yet, it is not possible to assess specific cumulative impacts. It is, however, assessed that the distance between the two projects is too large for the sediment spill to overlap. Furthermore, it is assessed that disturbance and loss of habitat will only have local impacts for the two projects, and no cumulative impacts are expected. Since the old Storstrøm bridge will be dismantled and replaced with a new bridge, no increased barrier effects are expected from the Fehmarn Belt fixed link, and no significant cumulative barrier effects are thus expected in regard to the replacement of the Storstrøm Bridge.

7.24.4 Significance of Transboundary Cumulative Impacts

For the wind farms Arkona Becken Südost, EnBW Baltic 2, and Wikinger no transboundary cumulative impacts have been identified. Concerning the Rødsand II and GEOFReE wind farms, which both lie closer to the work areas of the immersed tunnel, no transboundary impacts have been identified either.

In relation to the planned wind farm at Kriegers Flak, a model simulation of the sediment spill from the extraction activities at the site indicates that there will be no cumulative impact for this type of pressure, even though the construction of the wind farm overlaps with the period of the extraction activities at the site. However, since the exact range and type of work activities in relation to the construction of the wind farm are not known, it has not been possible to assess other potential cumulative impacts. Likewise, no cumulative impacts are expected from planned wind farms at Rønne Banke, which are also at a premature stage at this point.

The construction and operation of a new Storstrøm bridge is not expected to have any significant transboundary cumulative impact.

Overall, no transboundary cumulative impacts have been identified in relation to the construction or operation of an immersed tunnel.

8 CONTROL AND MONITORING PROGRAMME

The following chapter first outlines the general frameworks and principles for an inspection and monitoring programme for the construction and operation of the Fehmarnbelt Fixed Link. Secondly, this chapter sets out how such a programme might be organised, executed and reported on, and what focus areas might be of relevance.

8.1 STATUTORY OBLIGATIONS

The Danish EIA Statutory Order includes no formal requirement for an Environmental Impact Assessment Study to comprise a control and monitoring programme. However, the customary practice is to devise such a programme if the project entails impacts which cannot be inspected or monitored on the basis of requirements and thresholds already prescribed by public authorities.

8.2 PURPOSE

The purpose of the inspection and monitoring programme for the Fehmarnbelt Fixed Link is:

- to verify that the project is compliant with prevailing standards, requirements and thresholds for construction and operation
- to monitor that any project pressures are as assumed in the environmental impact assessments
- to monitor that mitigation and compensation measures function as expected
- to be able to implement corrective action, if necessary

8.3 PRINCIPLES OF THE CONTROL AND MONITORING PROGRAMME

- The programme will be based on the environmental impacts of construction and operation activities, the cause of which may be recognised as deriving from the project, and for which it is possible to measure an effect.
- The programme is planned to be carried out for selected activities. For activities assessed as having no impact, or where the impact is so minor that it is assessed as being of no consequence whatsoever, no inspection or monitoring will be carried out.
- The programme is planned to be based on self-inspection, where the requirements for the contractor's proof of compliance with terms and requirements, etc. will be stipulated contractually.
- The findings of the programme are planned to be reported to the authorities at regular intervals.
- Interest groups, especially affected parties and the general public, will have access to monitoring data and results.
- The programme (or parts hereof) is planned to be implemented, at the latest, by the beginning of the construction activities and is expected to be concluded during the operation phase, depending on the type of parameter monitored.

8.4 ORGANISATION

An environmental management system will be established prior to the start of the construction activities and will describe the company's organisation, and the roles and distribution of responsibilities between the company, the contractor and the authorities. The environmental management programme will also set out guidelines and procedures for carrying out the programme, indicating what is to be inspected and monitored, by whom, when and how. In addition, the format and frequency of reporting will be specified.

8.5 COMPONENT PACKAGES

The inspection and monitoring programme is planned to be based on the following main component packages:

- Requirements for inspections at the construction site in compliance with statutory environmental and occupational health requirements
- Requirements for spillage control, in the interests of verifying the spillage rates applied in the environmental assessment and compliance with contractually stipulated requirements
- Monitoring of implemented mitigation and compensation measures
- Monitoring of selected biological, physical and chemical components

8.5.1 Requirements for inspections at the construction site in compliance with statutory environmental and occupational health requirements

This would primarily relate to ordinary standards, requirements and thresholds for, for example, emissions to air (noise/vibrations, dust, and light), handling of oil and chemicals, waste management, effluent discharges, raw material consumption, etc. Inspection and monitoring of these parameters will not differ in principle from the customary practice at any construction site and will, to a great extent, be based on the contractor's own inspection and reporting to the client and the authorities (e.g. Lolland Municipality, the Danish Nature Agency, and the Danish Working Environment Authority). There will be construction sites both onshore and offshore.

The company will monitor the contractor's activities in accordance with the guidelines and procedures of the environmental management system, and persons appointed by the company to supervise the contractor are planned to be granted the requisite authority and have the right, where necessary, to implement corrective action, including suspension of work in progress.

It is expected that the different authorities will require Femern A/S to submit documentation as proof that the activities have been carried out in compliance with applicable legislation. It is also expected that the different authorities will perform their own inspections of the project.

8.5.2 Requirements for spillage control, in the interests of verifying spillage rates applied in the environmental assessment and in compliance with contractually stipulated requirements

Sediment spill control is a key parameter in relation to the potential marine impacts on, for example, flora and fauna, and is therefore also important with regard to the implementation of any preventative measures (reduction in dredging intensity or the like), which may be instituted in the event of unforeseen impacts on the marine environment. All other monitoring activities will only be able to reveal impacts after they have occurred.

Spills will occur as a result of the actual dredging of the tunnel trench, the work harbours and their access channels, and when unloading barges and draining the sedimentation basins in the planned land reclamation zones.

The potential impacts of sediment spill on marine flora and fauna – including birds – are described in earlier chapters. The spill volumes per unit of time vary according to the type of dredging equipment, the type of seabed spoil and the water depth at the site.

The contractor, who is awarded the contract for marine construction works, is intended to be contractually responsible for inspecting sediment spillage from all relevant sources at sea. For works in close proximity to the Lolland and Fehmarn coasts, the requirements for spillage control will be stricter than for works further out in the Fehmarnbelt.

The company will inspect the contractor's control measures, either by means of its own test measurements and/or by having representatives on board the contractor's vessels and at the onshore work sites.

The contractor is intended to be required to report to the company in compliance with guidelines and procedures laid down in the contracts and in accordance with the implemented environmental management system.

8.5.3 Monitoring of implemented preventative and compensation measures

Monitoring of implemented preventative and compensation measures will be performed in the interests of tracking their progress. This targeted monitoring process might also cover specially protected species.

The individual mitigation and compensation measures will mainly concern onshore factors such as the creation of a replacement lake, ponds and the Danish Nature Conservation Act's §3-areas.

The monitoring will seek to ensure that objectives for water plans prepared in accordance with the Water Framework Directive continue to be met, and that the area's ecological functionality is sustained.

In the marine area, monitoring is planned to be performed on, for example, coastal erosion and the natural reestablishment of the seabed types.

The company will undertake the monitoring, which is planned to be performed in accordance with the Environmental Management System's guidelines and procedures. The reporting is planned to be made to the different authorities, but data and results will also be made available to the public.

8.5.4 Monitoring of selected biological/chemical components

The purpose of monitoring selected biological components is two-fold: the intention is, first, to verify basic model assumptions; and second, to document the actual environmental status by means of selected parameters, which are representative of the ecosystems' function. These would consist specifically of statutory parameters, such as the Natura 2000 areas' designation basis, the Water Framework Directive's and Marine Strategy Framework Directive's requirements for good qualitative status of bodies of water and the preservation of good environmental status in marine ecosystems.

Environmental assessments in the marine area are based on 3D models, including a sediment spillage model and an ecological model. In order to verify these models and their assumptions and to promote their use in predicting the effects of the on-going dredging activities, measurements will be performed for selected parameters. These parameters will include measurements of the actual sediment spillage, the current physical conditions that are contributory to sediment transportation such as currents, wind, waves and direct effects of aqueous-phase sediment in the shape of light reduction and the subsequent effect on the distribution of vegetation.

Owing to the hydraulic conditions in the Fehmarnbelt, where the effects of a sediment spill are not detectable until up to several months after it has occurred, due to the natural sediment re-suspension, there would be no advantage in designing the marine biology monitoring programme as a feedback monitoring programme. The monitoring programmes for biological components will thus solely be for monitoring purposes to ensure that development of the areas is supervised through the construction and operation phases.

For the Habitat, Bird Protection, Marine Strategy and Water Framework directives, the environmental authorities have set goals and created monitoring and intervention programmes for the majority. It would be natural for the monitoring carried out by Femern A/S of selected biological/chemical components in connection with tunnel construction to be based on these goals and plans, their indicators, and for them to, as far as possible, support the official monitoring programmes. An example of selected components would be the monitoring of swans for which eelgrass is a food source. Eelgrass is part of the designation basis for the (H152) Hyldekrog-Rødsand habitat area, and Whooper and Mute Swans are two of the designation species for the (F83) Hyllekrog-Rødsand bird conservation area.

Regarding monitoring of selected biological/chemical parameters, Femern A/S will undertake the monitoring itself, which is planned to be implemented in accordance with the guidelines and procedures of the Environmental Management System. The reporting is planned to be made to the authorities, but data and results will also be made available to the public.

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APPENDIX 1
SUMMARY OF TRANSBOUNDARY ENVIRONMENTAL IMPACT FROM CONSTRUCTION OF AN IMMERSED TUNNEL

Transboundary environmental impact from construction of an immersed tunnel

Environmental factors		Assessment of transboundary effects in the Baltic Sea affected countries									
Component	**Sub-component**	**Sweden**	**Finland**	**Russia**	**Estonia**	**Latvia**	**Lithuania**	**Poland**	**Norway**	**Germany**	**Denmark**
People and Human Health	Air pollution	No	No	No	No	No	No	No	No	No	No
	Noise pollution	No	No	No	No	No	No	No	No	No	No
Hydrography	Water level	Ins	Ins	Ins	Ins	Ins	Ins	Ins	No	Ins	Ins
	Water exchange at Darss Sill	Ins	Ins	Ins	Ins	Ins	Ins	Ins	No	No	No
	Salinity/temp	Ins	Ins	Ins	Ins	Ins	Ins	Ins	No	Ins	Ins
	Stratification	Ins	Ins	Ins	Ins	Ins	Ins	Ins	No	Ins	Ins
Water quality	Dissolved oxygen	No	No	No	No	No	No	No	No	Ins	Ins
	Transparency	No	No	No	No	No	No	No	No	Ins	Ins
	Toxic chemicals	No	No	No	No	No	No	No	No	No	No
	Nutrients	No	No	No	No	No	No	No	No	No	No
	Coliform bacteria	No	No	No	No	No	No	No	No	Ins	Ins
Sediment and seabed forms	Seabed form	No	No	No	No	No	No	No	No	Ins	Ins
	Despositon of sediments	Ins	No	No	No	No	No	No	No	Ins	Ins
Coastal morphology	Beaches/ Unprotected coastline	No	No	No	No	No	No	No	No	No	No
	Coastal	No	No	No	No	No	No	No	No	No	No

Transboundary environmental impact from construction of an immersed tunnel

Environmental factors		Assessment of transboundary effects in the Baltic Sea affected countries									
	protection										
	Marine structures	No	No	No	No	No	No	No	No	No	No
	Special mor-phological features	No	No	No	No	No	No	No	No	No	No
Plankton	Phytoplankton	No	No	No	No	No	No	No	No	Ins	Ins
	Zooplankton	No	No	No	No	No	No	No	No	Ins	Ins
Benthic flora	Hard bottom macro-algae communities	No	No	No	No	No	No	No	No	Ins	Ins
	Furcellaria community	No	No	No	No	No	No	No	No	Ins	Sig
	Soft bottom communities	No	No	No	No	No	No	No	No	Ins	Ins
	Mixed algae-flowering community	No	No	No	No	No	No	No	No	Ins	Ins
Benthic fauna	Benthic epifauna	No	No	No	No	No	No	No	No	Ins	Ins
	Benthic infauna	Ins	No	No	No	No	No	No	No	Ins	Ins
Fish ecology	Herring	Ins	No	No	No	No	No	Ins	Ins	Ins	Ins
	Cod	Ins	No	No	No	No	No	Ins	Ins	Ins	Ins
	European eel	No	No	No	No	No	No	No	No	Ins	Ins
	Whiting	Ins	No	No	No	No	No	Ins	Ins	Ins	Ins
	Sprat	No	No	No	No	No	No	No	No	No	No
	Flatfish	No	No	No	No	No	No	No	No	No	No
	Shallow water	No	No	No	No	No	No	No	No	No	No

Transboundary environmental impact from construction of an immersed tunnel

Environmental factors		Assessment of transboundary effects in the Baltic Sea affected countries									
	species										
	Sea Stickleback	No	No	No	No	No	No	No	No	No	No
	Snake blenny	No	No	No	No	No	No	No	No	No	No
Commercial fishery	Trawl	No	No	No	No	No	No	No	No	No	No
	Gill nets	No	No	No	No	No	No	No	No	No	No
	Pound nets	No	No	No	No	No	No	No	No	No	No
	Danish seine nets	No	No	No	No	No	No	No	No	No	No
Marine mammals	Harbour porpoise, Harbour seal, Grey seal	No	No	No	No	No	No	No	No	Ins	Ins
Birds	Common Eider	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins
	Breeding waterbirds	No	No	No	No	No	No	No	No	No	No
	Other non-breeding waterbirds	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins
	Migrating birds	No	No	No	No	No	No	No	No	No	No
Migrating bats	Soprano Pipistrelle	No	No	No	No	No	No	No	No	Ins	Ins
	Nathusius Pipistrelle	No	No	No	No	No	No	No	No	Ins	Ins
	Noctules	No	No	No	No	No	No	No	No	Ins	Ins
	Other Species	No	No	No	No	No	No	No	No	Ins	Ins
Natura 2000	No sub-component	No	No	No	No	No	No	No	No	No	No
Cultural heritage and marine archaeology	Shipwrecks	No	No	No	No	No	No	No	No	No	No
	Settlements	No	No	No	No	No	No	No	No	No	No
Recreation and	Offshore recreation	No	No	No	No	No	No	No	No	No	No

Transboundary environmental impact from construction of an immersed tunnel

Environmental factors		Assessment of transboundary effects in the Baltic Sea affected countries									
tourism	activities										
	Recreational fishery	No	No	No	No	No	No	No	No	No	No
	Recreational boating	No	No	No	No	No	No	No	No	No	No
Material assets	Cables and wind parks (offshore)	No	No	No	No	No	No	No	No	No	No
	Extraction sites	No	No	No	No	No	No	No	No	No	Ins
	Disposing sites	No	No	No	No	No	No	No	No	No	No
Raw materials and waste	Raw materials	No	No	No	No	No	No	No	No	No	No
	Waste	No	No	No	No	No	No	No	No	No	No
Air quality and climate	Air quality	No	No	No	No	No	No	No	No	No	No
	Climate	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins
Ship traffic and navigation	No sub-component	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins	Ins

Transboundary Environmental Impact Assessment Documentation for the Danish Espoo Procedure (Espoo-report)

This publication has been prepared by Femern A/S

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