Öresund Marine Joint Venture

The Øresund Link

Contract No. 2

Dredging & Reclamation

ÖRESUND MARINE JOINT VENTURE

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Öresund Marine Joint Venture was formed to tender, secure and perform the works for Contract No. 2 – Dredging & Reclamation, an integral part of the overall design and construction of the Øresund Fixed Link between Denmark and Sweden, one of the largest infrastructure projects in Europe today.

The Works, contracted at a value of 1.4 billion DKK (205 million USD) within a design and construct framework, include

- Dredging of 7 million m^3 of flint, limestone and clay till for the tunnel trench, construction and navigation channels and harbours, and hydraulic compensation areas,
- Stone works forming the 12 km perimeter revetments of an artificial island and peninsula,
- Reclamation of all dredged material for the construction of the artificial island and peninsula,
- Construction of highways, service roads and other structures on the artificial island,
- Environmental spillage monitoring and control activities.

Öresund Marine Joint Venture combines the skills and specialities of its three partners:

- **Per Aarsleff A/S** of Denmark (sponsor company)
- **Ballast Nedam Dredging** of the Netherlands
- **Great Lakes Dredge & Dock Company** of the United States of America

Öresund Marine Joint Venture (ÖMJV) relies on its partners to execute the design and construction of a defined scope of works.

The partners' scope of works is :

Stone works and civil works:
Per Aarsleff A/S

Hydraulic dredging:
Ballast Nedam Dredging

Mechanical dredging:
Great Lakes Dredge & Dock Company

For the execution of the works, the Joint Venture utilises specialised dredging and marine construction plant, in some instances purpose built or converted for the works.

The dipper dredger "Chicago", with a 22 m^3 bucket and 320,000 lbs. line force on its main hoist wire, was specially modified to dredge in shallow depths for construction channels and harbours while maintaining the capability for deep dredging in navigation channels.

The "Stenjack I" and "Stenjack II" jack-up pontoons, each equipped with a DGPS controlled 375L Caterpillar backhoe working from a 40 m long working deck, were purpose built to construct the 12 km of perimeter stone bunds for the artificial island and peninsula.

The cutter suction dredger "Castor" was specially upgraded to 5000 horsepower on its cutterhead to dredge the hard limestone and flint layers in the tunnel trench, and works with two purpose built Self Elevating Gravity Anchors each capable of generating 150 tons anchoring force on its side wires.

The vessels "Vitesse" and "Coastal Tender" were specially modified and outfitted with state-of-the-art hydraulic and sediment measuring equipment to monitor environmental spillage from the dredging activities to the strictest environmental and control standards.

With a full range of specialised dredging, marine, and civil construction plant at their disposal, combined with dedicated and experienced personnel, the Öresund Marine Joint Venture partners are especially qualified for contracting large scale, dredging and marine construction projects throughout the world.

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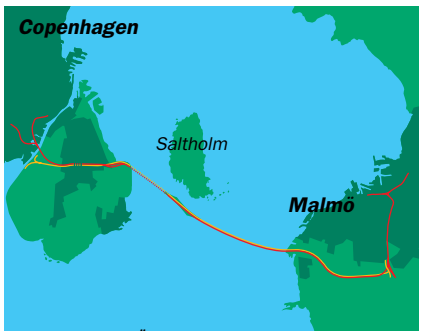
Project Overview



Alignment of the Fixed Link. The European Council has identified the Link as one of 14 priority projects in the Trans European Network programme. The construction of the Fixed Link is supported by financial grants from the EU Commission.

One of Scandinavia's largest ever investments in infrastructure, the Øresund Fixed Link will create a fixed road and rail connection between Denmark and Sweden.

The Fixed Link consists of a combined dual track railway and a four-lane motorway connecting Copenhagen, Denmark with Malmö, Sweden. This improvement in transport connections will strengthen the cultural and economic co-operation of the region by the expected stimulation in the development of a joint labour and housing market on each side of Øresund. In short, the Link is expected to further the integration of the Øresund region, thus paving the way for successful competition, with Europe's other major regional centres.

Ultimately responsible for the Fixed Link and all associated landworks is Øresundskonsortiet, A/S Øresundsforbindelsen and Svensk-Danska Broförbindelsen SVEDAB AB. A/S Øresundsforbindelsen and Svensk-Danska Broförbindelsen SVEDAB AB are owned by

Looking North across the artificial island with Saltholm island in the background –
Situation November 1998.

Photo: Jan Kofod Winther

Technical Description of the Link

The fixed motorway and railway link across Øresund will extend some 16 km between Kastrup on the Danish coast and Lernacken on the Swedish coast.

The Link's key elements are:

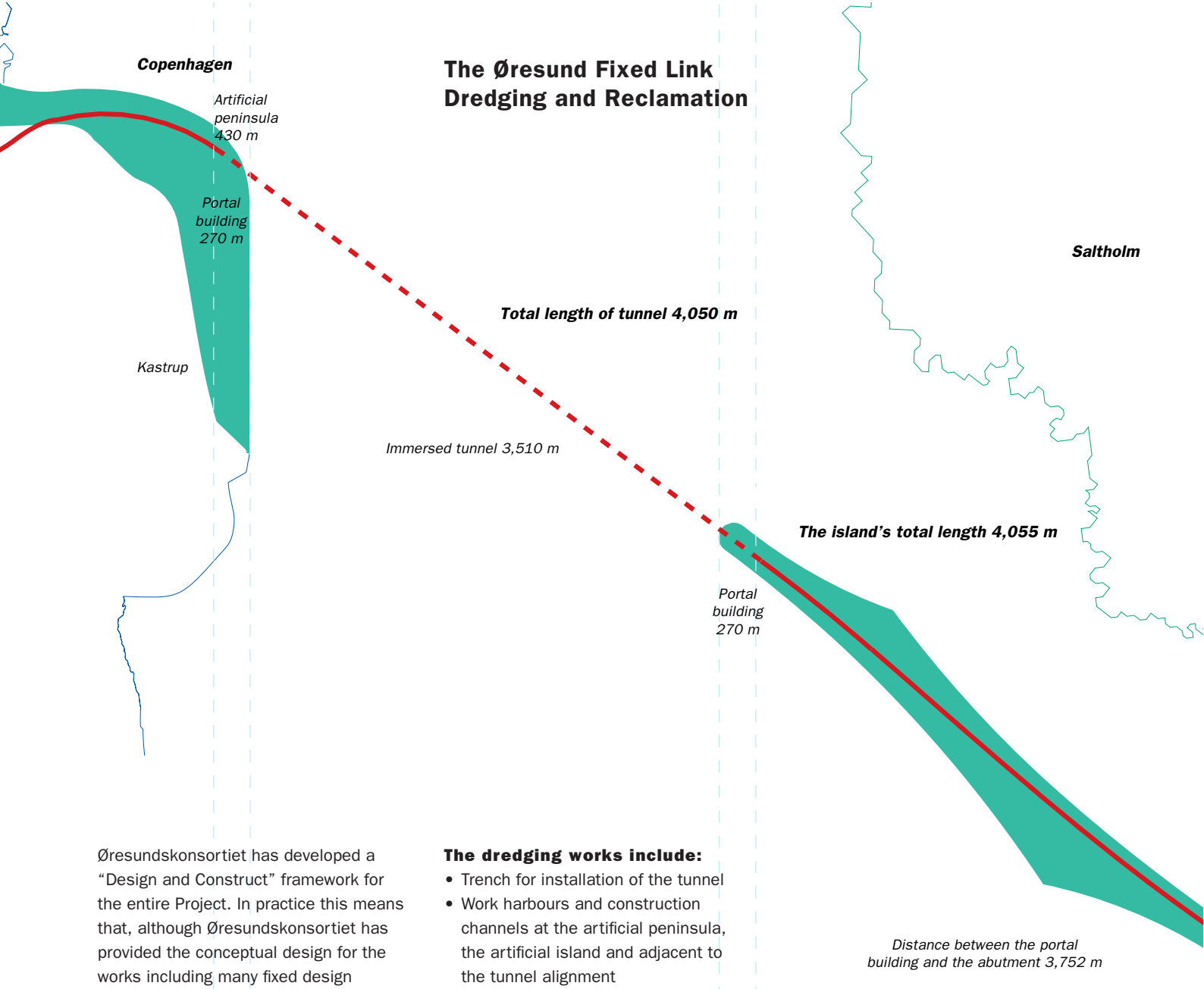
- An artificial peninsula extending 430 m from the Danish coast at Kastrup
- A 4,050 m tunnel under the Drogden Channel consisting of a 3,510 m immersed tunnel with two portal buildings
- An artificial island 4,055 m long south of Saltholm island
- A western approach bridge 3,014 m long between the artificial island and the high bridge
- A cable-stayed high bridge 1,092 m long across the Flinte Navigation Channel
- An eastern approach bridge 3,739 m long from the high bridge to the Swedish coast at Lernacken
- A terminal area with toll station and Link Control Centre located on the Swedish coast at Lernacken

the Danish and Swedish States and are each responsible for the landworks up to the two countries' coastlines. Ownership of Øresundskonsortiet is equally divided between A/S Øresundsforbindelsen and Svensk-Danska Broförbindelsen SVEDAB AB through a treaty between the governments of Denmark and Sweden. Øresundskonsortiet is responsible for the overall project design and construction of the Fixed Link between the coasts of Denmark and Sweden and exclusively holds the concession to operate the Fixed Link.

Öresund Marine Joint Venture, by contract to Øresundskonsortiet, is playing an integral and primary role in ensuring the success of the project, especially in the early, fast track stages. During the critical first two years of work, Öresund Marine Joint Venture dredged millions of cubic metres of materials and handled millions of tons of stones. ÖMJV dredged the tunnel trench for the eventual immersion of the tunnel elements, constructed the artificial island and peninsula for the connections from highway to tunnel to bridge to highway and built numerous harbours and channels – some temporary for the works and some for permanent navigational improvements to the region. Additionally, ÖMJV deepened the hydraulic compensation areas in the Øresund to ensure that the marine environment remained unchanged.

ÖMJV will remain active in the Works until project completion after the turn of the century, maintaining its commitment to quality, timely results and ensuring that the dredging and reclamation works contribute to the fulfilment of the 100 year old dream of a transportation link across the Øresund.

The Øresund Fixed Link
Dredging and Reclamation



Øresundskonsortiet has developed a "Design and Construct" framework for the entire Project. In practice this means that, although Øresundskonsortiet has provided the conceptual design for the works including many fixed design requirements, Öresund Marine Joint Venture is responsible for providing the detailed design of the reclamation works as well as the construction of the entire dredging and reclamation works.
The dredging and reclamation contract includes the initial fast track works on the Øresund Fixed Link which provide the infrastructure required for construction of the tunnel and the bridge portions of the Link. Activities commenced in August 1995.

The dredging works include:

- Trench for installation of the tunnel
- Work harbours and construction channels at the artificial peninsula, the artificial island and adjacent to the tunnel alignment
- Temporary relocation and deepening of the Flinte Navigation Channel
- Relocation of the Drogden Channel
- Compensation dredging

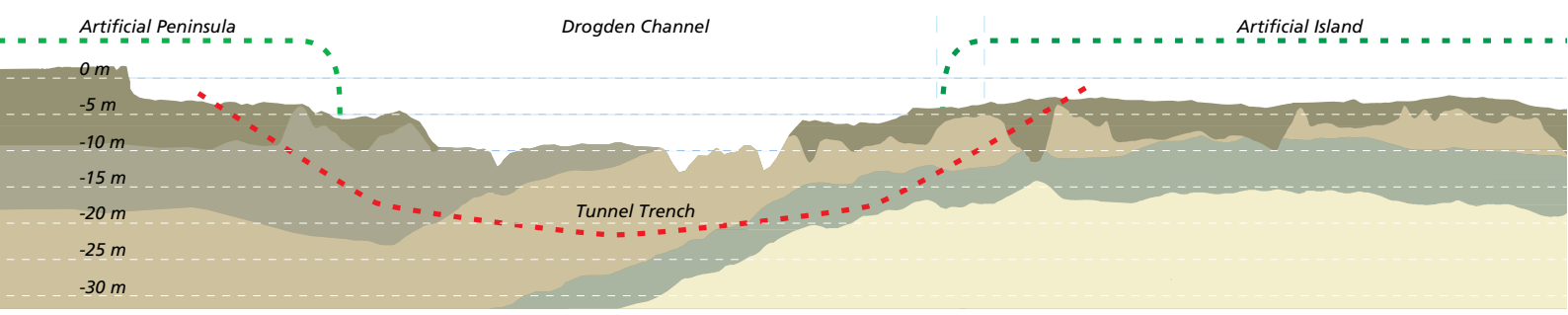
The reclamation works include:

- The artificial peninsula at Kastrup
- The artificial island south of Saltholm

Geological profile in alignment

- *Clay Till*
- *Upper Copenhagen Limestone*
- *Middle Copenhagen Limestone*
- *Lower Copenhagen Limestone*
- *Bryozoan Limestone*

The limestone layers include a matrix of limestone and flint.



Rigorous environmental requirements are in force, governing both the construction of the Link and the impact of the completed Link on the surrounding environment.

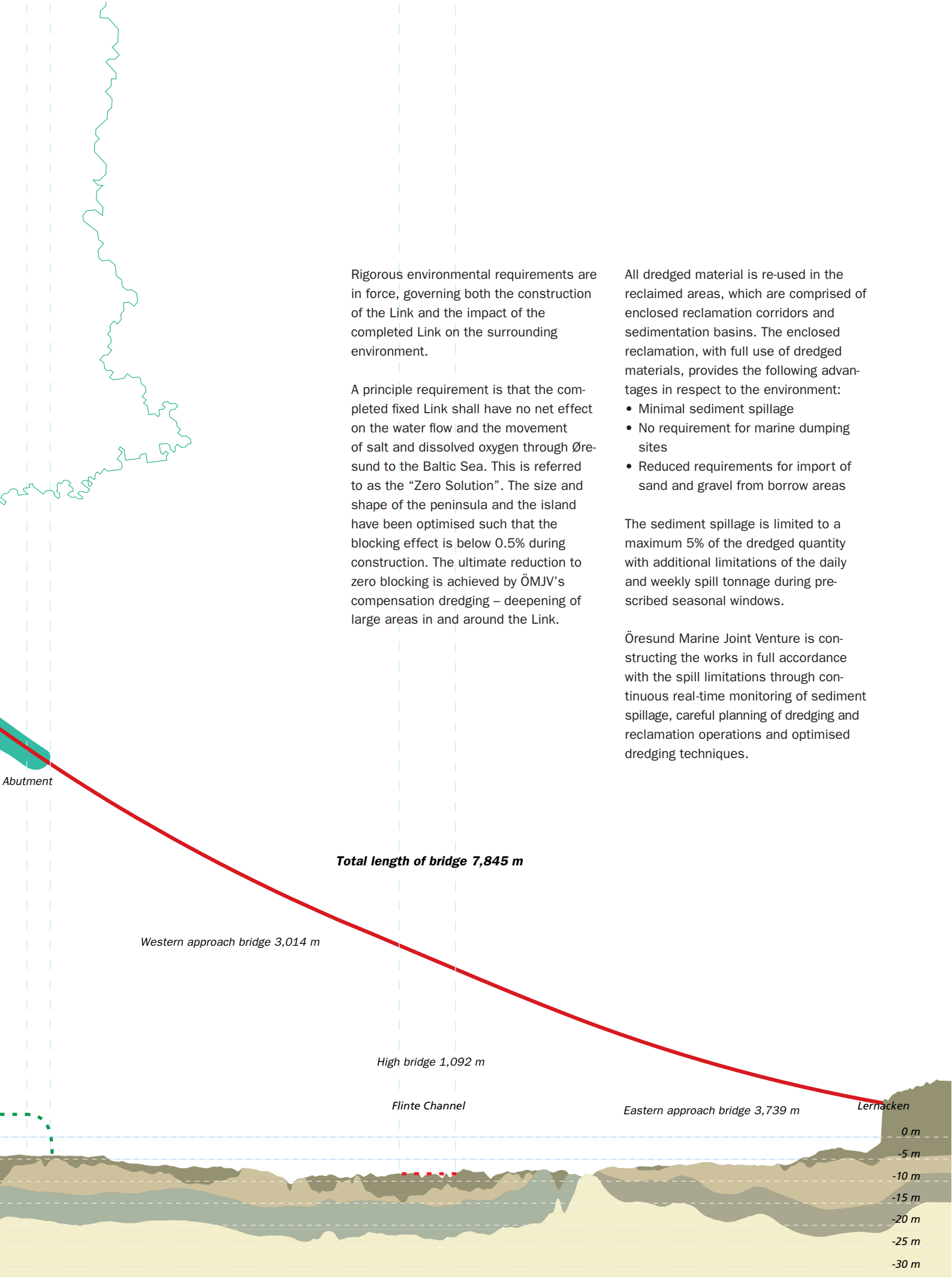
A principle requirement is that the completed fixed Link shall have no net effect on the water flow and the movement of salt and dissolved oxygen through Øresund to the Baltic Sea. This is referred to as the “Zero Solution”. The size and shape of the peninsula and the island have been optimised such that the blocking effect is below 0.5% during construction. The ultimate reduction to zero blocking is achieved by ÖMJV’s compensation dredging – deepening of large areas in and around the Link.

All dredged material is re-used in the reclaimed areas, which are comprised of enclosed reclamation corridors and sedimentation basins. The enclosed reclamation, with full use of dredged materials, provides the following advantages in respect to the environment:

- Minimal sediment spillage
- No requirement for marine dumping sites
- Reduced requirements for import of sand and gravel from borrow areas

The sediment spillage is limited to a maximum 5% of the dredged quantity with additional limitations of the daily and weekly spill tonnage during prescribed seasonal windows.

Öresund Marine Joint Venture is constructing the works in full accordance with the spill limitations through continuous real-time monitoring of sediment spillage, careful planning of dredging and reclamation operations and optimised dredging techniques.



Dredging Works

Photo: Jan Kofod Winther

To carry out the dredging works, ÖMJV deployed a wide range of specialised dredging equipment such as the dipper/clamshell dredger “Chicago”, the largest of its kind, and the cutter suction dredger “Castor”, which was especially “re-powered” for the Project.

The “Chicago” was chosen to dredge the hard clay till in the harbours, construction channels, navigation channels and compensation areas. The supply of clay till was required at a high production rate during the early stages of the project for construction of the perimeter bunds to contain the materials from the tunnel trench dredging.

The “Castor” was chosen to dredge the extremely hard limestone and flint layers in the tunnel trench to the strict tolerances required for the tunnel installation. It provided the engineered fill for the reclamation on the island and the peninsula.

With the utilisation of two such large class “overpowered” dredgers, instead of an array of smaller plant, ÖMJV provided a concise and fast track dredging programme that optimised hard material dredging, low spillage and high capacity.

The cutter suction dredger “Castor”.

Backhoe dredgers

The dipper dredger “Chicago” with a dipper bucket capacity of 22 m^3 and a daily production of 12,000 m^3, dredged the clay till and loaded 2,000 ton material barges, especially sized for transport in shallow waters. The barges were then towed to the enclosed reclamation areas for offloading behind the stone revetments. To maximise production and coverage over the relatively shallow, thin layers and to make full utilisation of her 320,000 lbs of line force, the “Chicago” was especially fitted with a wide profile dipper bucket, purpose built for the Project.

The cutter suction dredger “Castor” excavated the limestone and hard flint layers with its 5,000 hp rotating cutterhead fitted with hard alloy pick points. The loosened rock was sucked into a pipe within the cutterhead and pumped through three centrifugal dredge pumps, totalling some 8,000 hp, to the reclamation area via floating and submerged pipelines. For pumping long distances, two 5,000 hp booster stations were installed. The run-off water and suspended fines (silt and clay) were channelled to the sedimentation basins. The 23 meter deep tunnel trench was dredged by “Castor” with the exact positioning of the cutterhead monitored continuously in real-time to ensure that the profile and cross sections were dredged within tight tolerances.

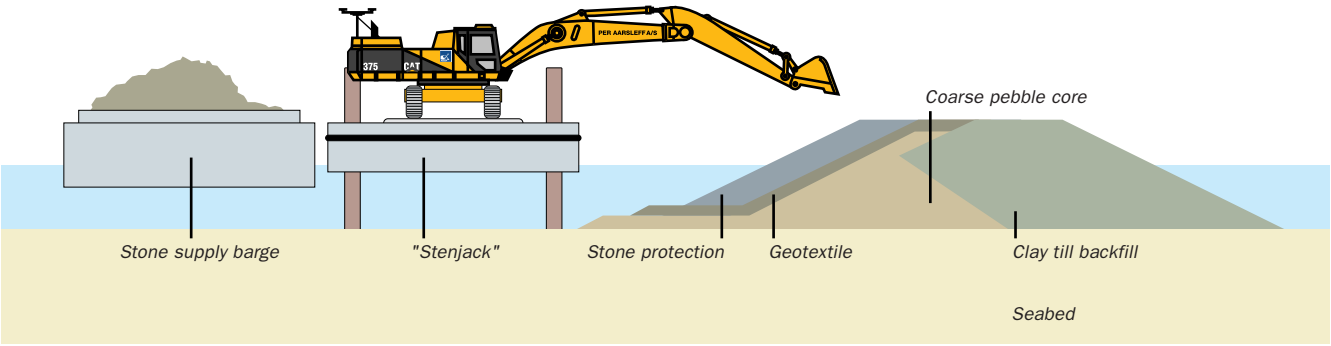
For later stages of the project with less time critical activities and for sand winning, ÖMJV utilised an additional seven dredgers including backhoe dredgers, grab dredgers, and trailing suction hopper dredgers.

Photo: Jan Kofod Winther

The dipper dredger “Chicago” dredging clay till and limestone.

Photo: Jan Kofod Winther

Backhoe dredgers operating in the Flinte Navigation Channel.



Stone Works

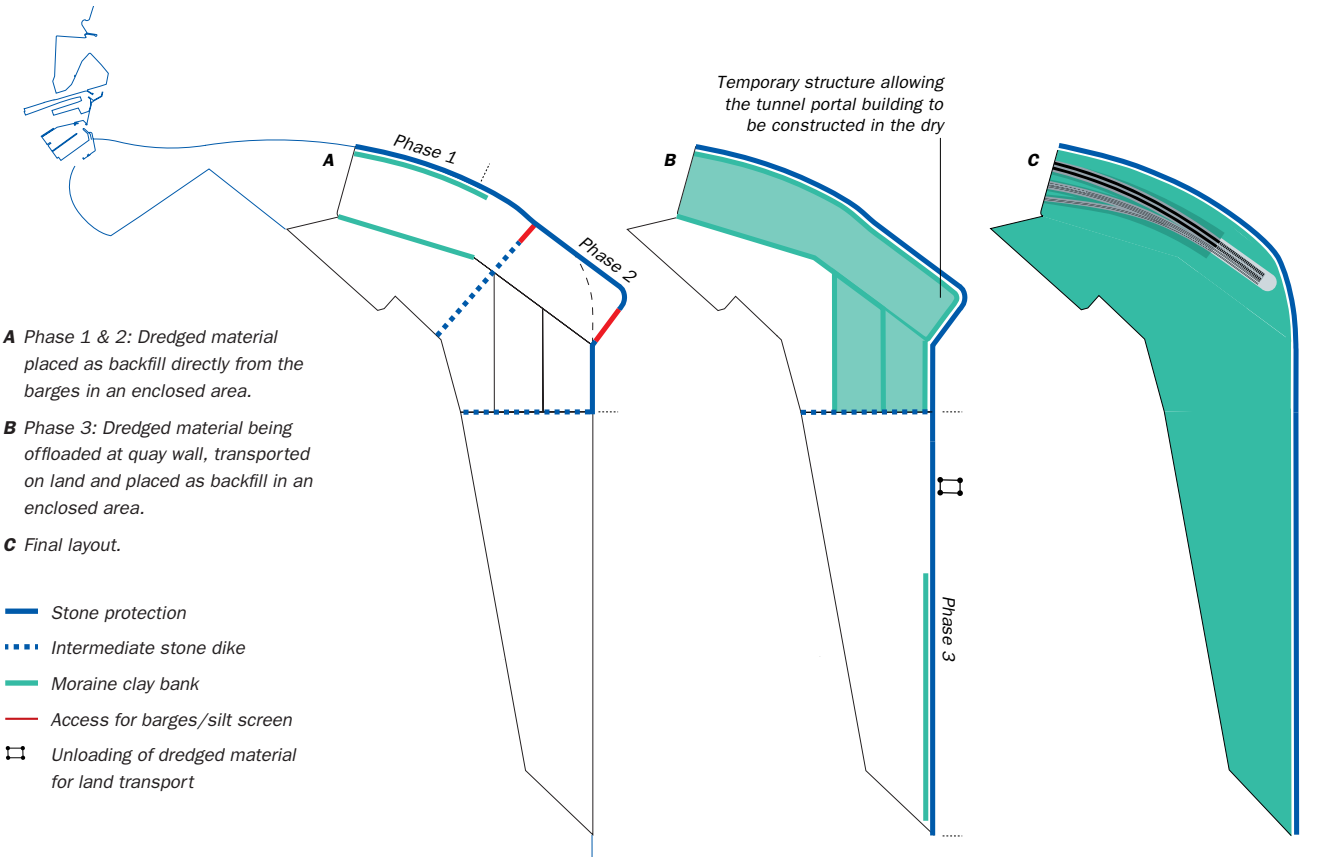
Dredging for the various channels and the tunnel trench could only proceed and continue on schedule after enclosed basins for reclamation were completed as part of the construction of the artificial island and peninsula. The reclamation of the peninsula and the artificial island was carried out in two stages, the first being the construction of the stone revetments.

The stone revetments consist of a coarse pebble core, filter stones, an interior geotextile lining and are protected from the sea by an armour stone layer. The revetments were back-filled with dredged clay till in order to provide a seal against sediment outflow.

The stone portion of the revetment was constructed as a closed cell with an access opening left for transport of the material barges to the offloading and back-filling areas. To prevent the dispersion of suspended material to the environment, the access openings were equipped with a silt screen that was only opened for the passage of barges. Once the back-filling layer was completed, the openings were sealed thus creating a completely enclosed basin ready for hydraulic reclamation.

Overall, the revetments were made up of 2,000,000 tons of stone and 1,500,000 m³ of clay backfill from the dredging operations.

The phased construction of the artificial peninsula in enclosed areas.



A *Phase 1 & 2: Dredged material placed as backfill directly from the barges in an enclosed area.*

B *Phase 3: Dredged material being offloaded at quay wall, transported on land and placed as backfill in an enclosed area.*

C *Final layout.*

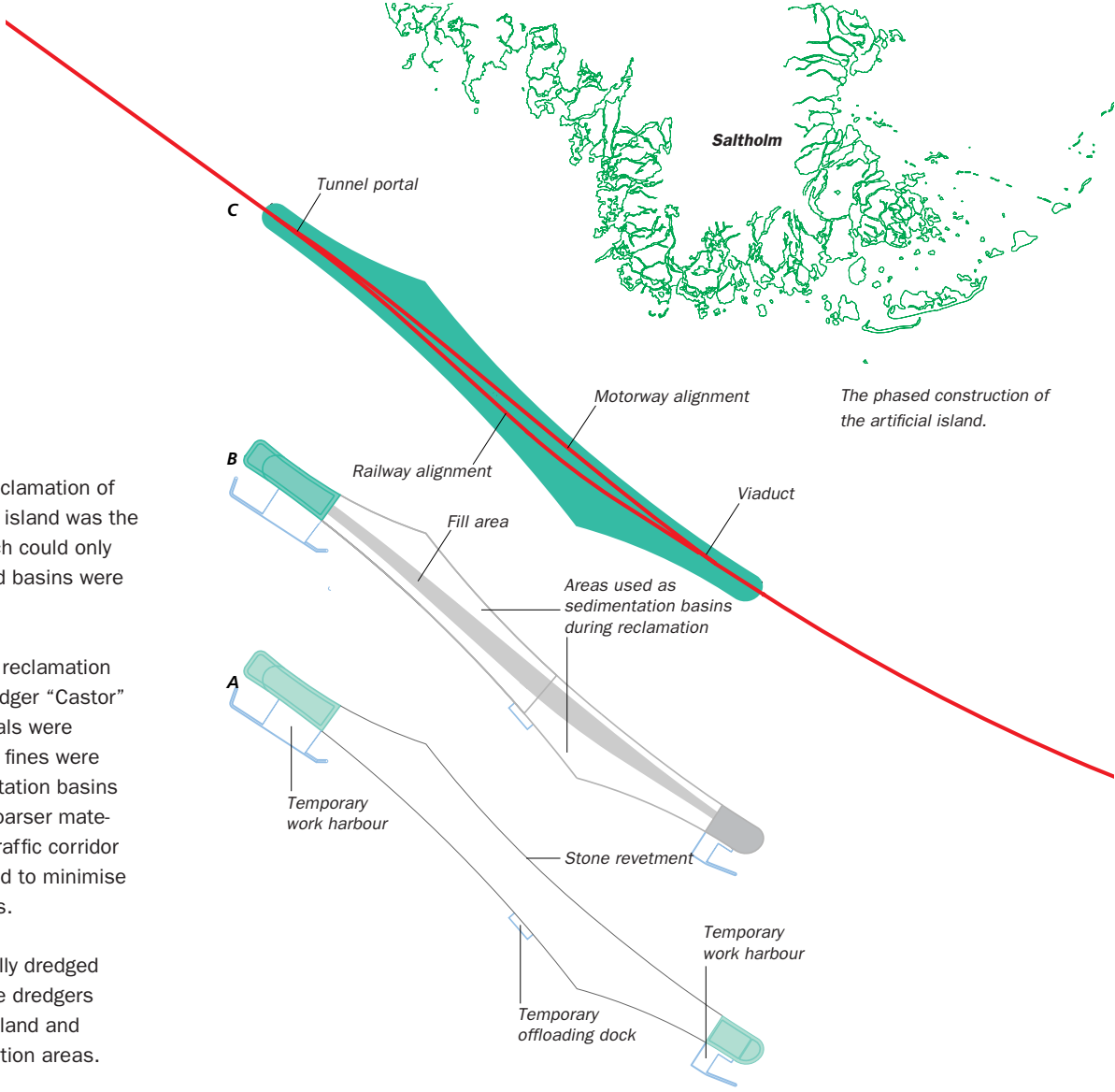
Stone protection
Intermediate stone dike
Moraine clay bank
Access for barges/silt screen
Unloading of dredged material for land transport

Reclamation

The second stage of the reclamation of the peninsula and artificial island was the hydraulic reclamation, which could only proceed when the enclosed basins were formed by the revetments.

In the process of hydraulic reclamation from the cutter suction dredger “Castor” the coarse and fine materials were separated. The suspended fines were channelled to the sedimentation basins for settling, whereas the coarser materials were retained in the traffic corridor and hydraulically compacted to minimise any differential settlements.

At later stages, mechanically dredged materials from the backhoe dredgers were off-loaded onto the island and transported to the reclamation areas.



The phased construction of the artificial island.

Dredged material being towed to the reclamation area.

One of the dredged materials off-loading harbours on the island.

Photo: Jan Kofod Winther

Construction of the artificial peninsula adjacent to Copenhagen Airport.

Artificial Peninsula

The 0.9 km^2 peninsula at Kastrup serves to reunite the passenger track from the underground station at the airport terminal with the freight track running north of the airport. The motorway along the northern edge of the peninsula joins the railway at the entrance to the Drogden tunnel. The peninsula will also accommodate a track leading to a train maintenance work area.

Photo: Jan Kofod Winther

Artificial Island

The 1.3 km^2 island south of Saltholm forms the transition between the tunnel and the western approach bridge.

Overall the island is approximately 4 km long and is protected by 9 km of stone revetments. From the tunnel portal on the western end of the island, the motorway runs along side the railway until the eastern end, where it is aligned above the tracks on a viaduct and then connects to the upper level of the bridge.

Construction of the initial stages of the artificial island.

Photo: Jan Kofod Winther

Sand from borrow areas was brought to the island for the construction of portions of the traffic corridor.

Civil Works

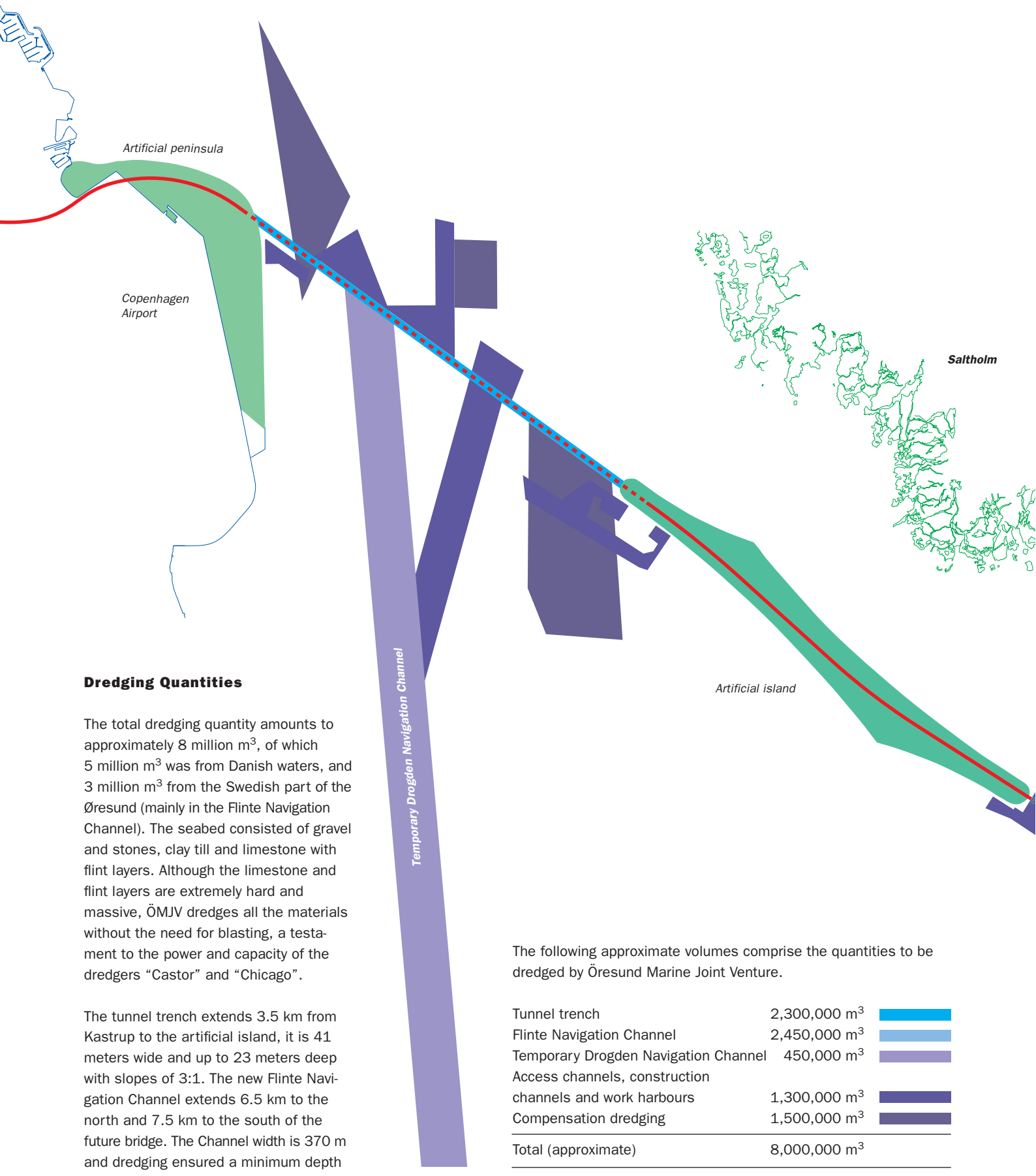
Extensive finishing works are underway on the island. The motorway corridor includes such works as final shaping, an underpass, drainage & electrical installations and finally the asphalt & safety barriers. The railway includes shaping and electrical installations. Other works include high voltage cabling across the island. Additionally, the island will have an extensive network of service roads. Landscaping will also be done to finalise the character of the island.

Looking East across the island towards Sweden. The motorway seen on the left, and railway, on the right, are taking final form.

Photo: Jørgen Weber

"Vibrowing" compaction of sand in an area sensitive to settlements.

Dredging & Reclamation Quantities



Dredging Quantities

The total dredging quantity amounts to approximately 8 million m^3, of which 5 million m^3 was from Danish waters, and 3 million m^3 from the Swedish part of the Øresund (mainly in the Flinte Navigation Channel). The seabed consisted of gravel and stones, clay till and limestone with flint layers. Although the limestone and flint layers are extremely hard and massive, ÖMJV dredges all the materials without the need for blasting, a testament to the power and capacity of the dredgers “Castor” and “Chicago”.

The tunnel trench extends 3.5 km from Kastrup to the artificial island, it is 41 meters wide and up to 23 meters deep with slopes of 3:1. The new Flinte Navigation Channel extends 6.5 km to the north and 7.5 km to the south of the future bridge. The Channel width is 370 m and dredging ensured a minimum depth of -8.33 m.

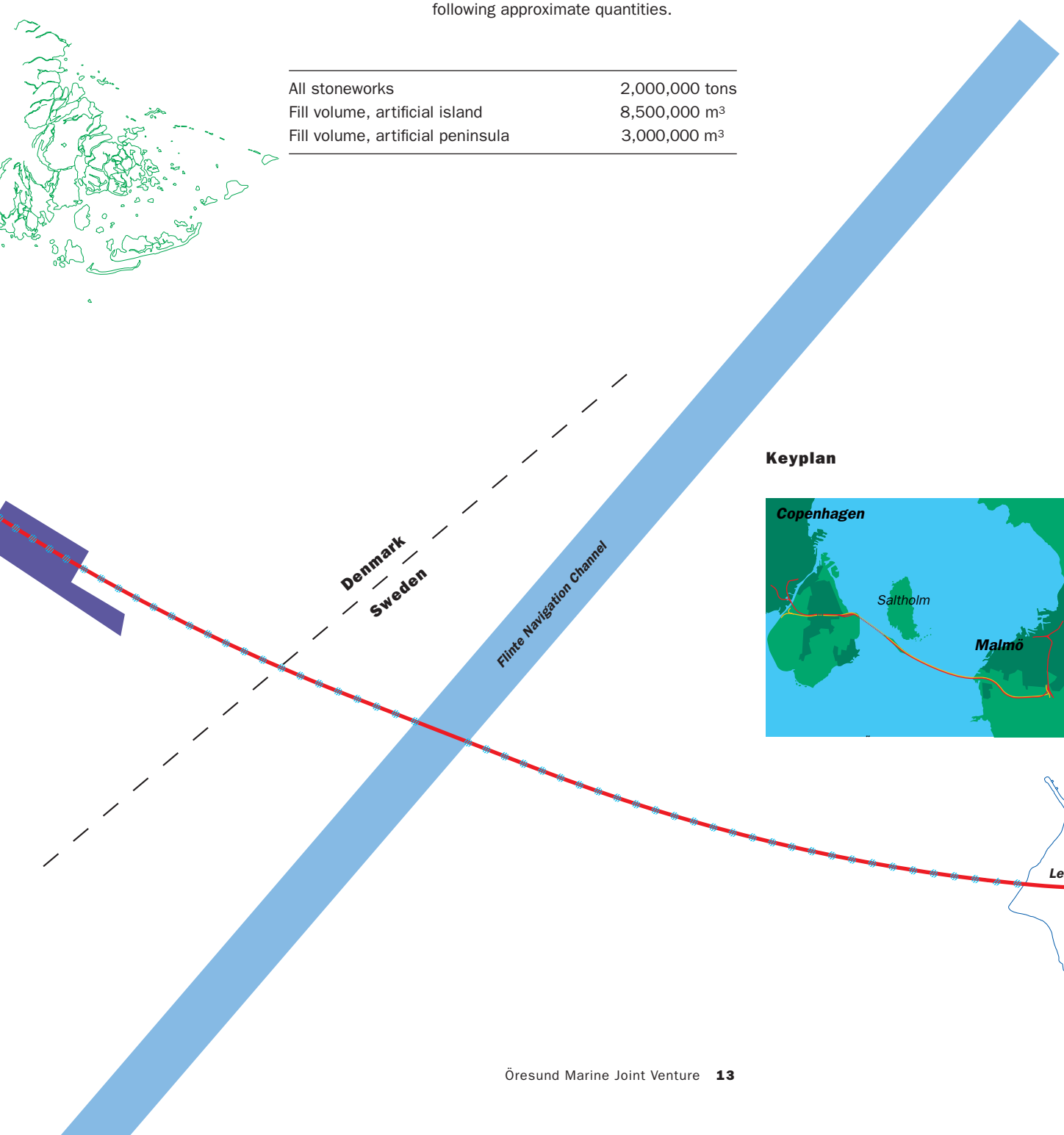
The following approximate volumes comprise the quantities to be dredged by Öresund Marine Joint Venture.

Tunnel trench	2,300,000 m^3
Flinte Navigation Channel	2,450,000 m^3
Temporary Drogden Navigation Channel	450,000 m^3
Access channels, construction channels and work harbours	1,300,000 m^3
Compensation dredging	1,500,000 m^3
Total (approximate)	8,000,000 m^3

Reclamation Quantities

The materials used for reclamation and finishing works in the creation of the peninsula and the artificial island came from a number of sources. Revetment stones from Sweden and Denmark, dredged materials from the construction area, dry fill materials from the Øresund Link landworks, sand from a borrow area in Denmark and materials for the finishing works from Sweden, Norway and Denmark. Upon completion, the 2 new geographic features will be made up of the following approximate quantities.

All stoneworks	2,000,000 tons
Fill volume, artificial island	8,500,000 m^3
Fill volume, artificial peninsula	3,000,000 m^3



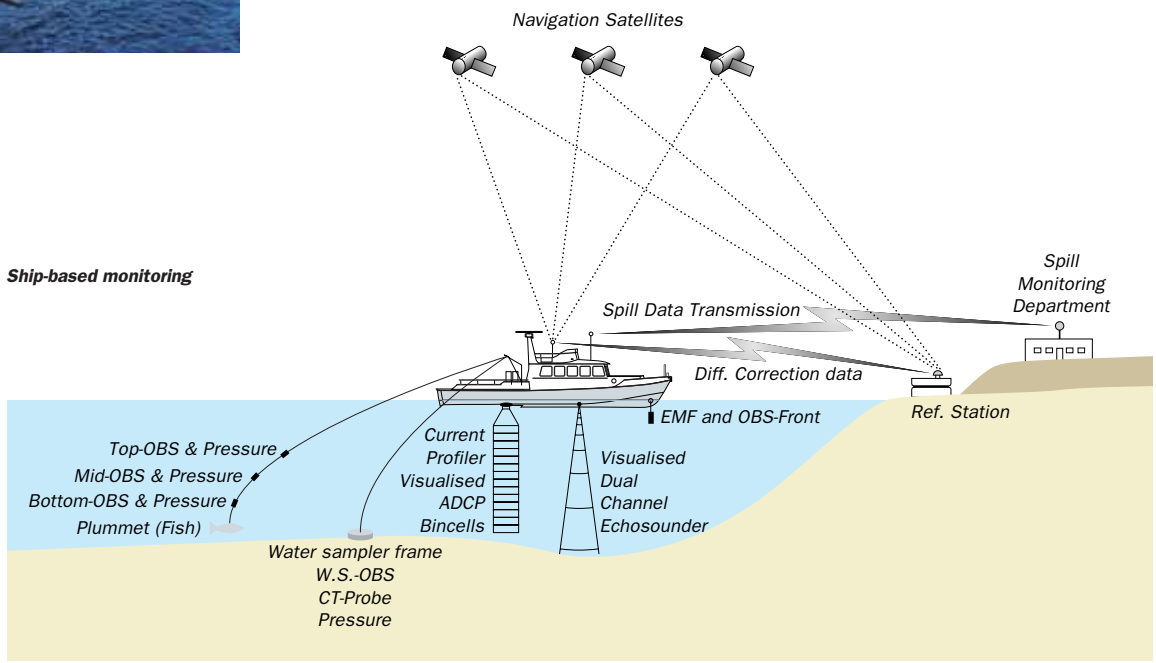
Keyplan

Spill Monitoring

It is the Environmental Authorities' demand that sediment spill from the works (sea bed materials brought into suspension by dredging or reclamation and transported out of the work zones) be limited to a maximum 5% of the dredged quantity. There were also additional limitations on the daily and weekly tonnage allowed to be spilled in defined environmental areas during prescribed seasonal windows. Öresund Marine Joint Venture was responsible for the monitoring and controlling of the spill to ensure that the works were constructed in full accordance with these requirements.

Immediately upon signing the Contract with Øresundskonsortiet, ÖMJV designed, developed and procured an advanced, purpose-built, Spill Monitoring System. The system consists of ship-based units which monitor spill leaving the offshore work zones and land-based units which monitor spill leaving the pumping stations at the sedimentation basins.

The ÖMJV Spill Monitoring Department employed three spill monitoring vessels operating 24 hours/day and 30 engineers who gathered and processed technical data about currents, concentration of suspended material, water levels and the like. The spill monitoring vessels trailed data collection streamers whilst sailing transects – predefined lines upstream and downstream of the spill source perpendicular to the current – through the spill plume, collecting current data in three dimensions and sediment concentration data in two dimensions. Such data was analysed on board to determine the raw sediment flux.



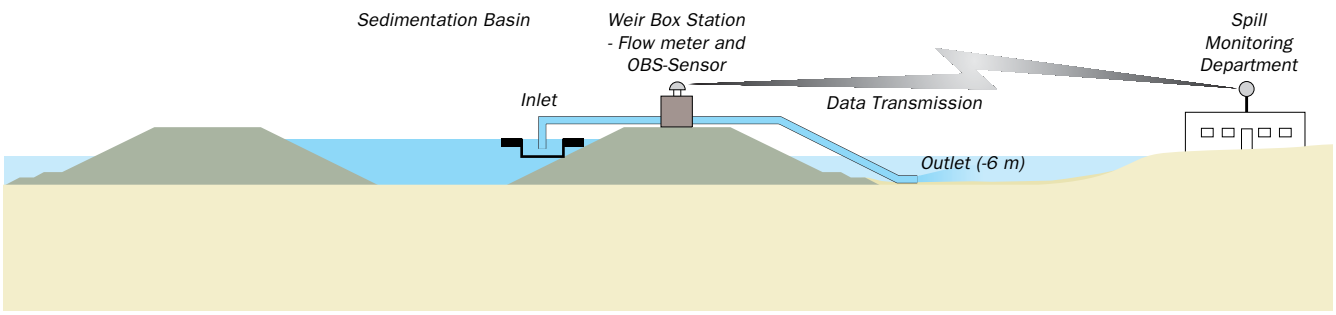
A spill monitoring vessel sailing a transect through the spill plume from the dredger "Chicago".

All data was relayed in real-time to the data processing team within the ÖMJV offices for further detailed analysis. Several hydraulic engineers performed real-time cumulative calculations of the spill to determine the final spill quantity expressed in tonnes per unit time and with production input from the dredgers, expressed as a percentage of the net quantity dredged. Each 24 hours of survey data required 12 hours of processing and analysis. The cumulative spill figures were also relayed back to the dredgers for control feedback of the dredging process, such that operations could be modified if the limitations on the daily and weekly spillage or the overall spill percentage were endangered.

The full data and resultant spill figures formed an extensive spill database which ÖMJV utilised to predict spill in new work areas and to estimate spill from short term, non-measured sources.

The Öresund Marine Joint Venture has optimised its spill monitoring and control system such that spill from ÖMJV operations is less than 4.5% of the net dredged quantity.

Land-based monitoring



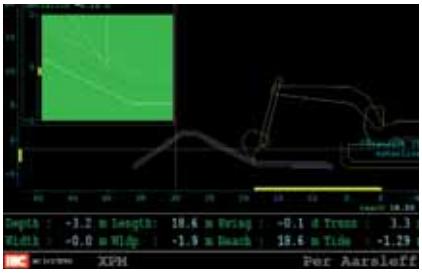
Öresund Marine Joint Venture
Innovative systems and methods

ÖMJV has developed a wide range of innovative techniques and new applications for existing technology.

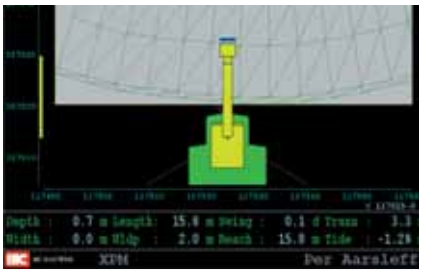
"Stenjack" during revetment construction for the artificial island.

"Stenjack I and II"
Per Aarsleff A/S designed and constructed two jack-up barges for use on the rock bund construction. Each barge has a working deck of 40 m, reducing the repositioning time considerably.

Operators view during stone revetment construction.



Stone Placing
Using IHC SYSTEMS software Per Aarsleff A/S developed a DGPS controlled on-screen computer presentation which enables the two jack-up pontoons "Stenjack I and II", both equipped with a 375L Caterpillar backhoe, to place stones fully controlled, increasing output and reducing setting out and remedial work. Rock revetment construction daily production was up to 40 m/day per unit.



"Chicago" wide profile bucket.

Wide Profile Bucket
Great Lakes Dredge & Dock Company developed a special wide profile dipper bucket for increased production and coverage in the shallow, thin dredging layers in many of the navigation channels.

"Castor" cutterhead with pickpoints.

Cutterhead and Pickpoint Systems
Ballast Nedam Dredging implemented the use of 6 new-design heavy duty rock cutterheads (30 tons) built by Vosta and utilized four Vosta D65 and two Esco D58 pickpoint systems.

SEGA.

Self Elevating Gravity Anchor
Ballast Nedam Dredging developed two containerised Self Elevating Gravity Anchors capable of generating 150 ton anchoring force. Both SEGAs were used with the cutter suction dredger "Castor".

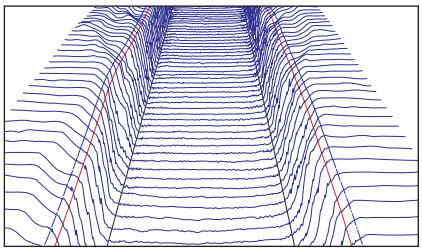
Side-wire system in place for the "Castor".

Reduced Elasticity Side-wire System
Ballast Nedam Dredging developed a steel pipe construction for the cutter suction dredging which reduced the elasticity in the side-wire. An increased longevity of cutterheads and pickpoints was the resultant benefit.

"Castor" control room with dredge computer presentation.

Dredge Computer Presentation
In order to facilitate precision dredging in the tunnel trench, Ballast Nedam Dredging developed an on board dredge profile presentation incorporating the prevailing geological conditions.

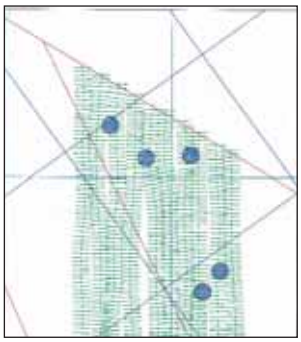
3-D view of the tunnel trench.



Multibeam Hydrographic Survey
Ballast Nedam Dredging uses multibeam survey methods to provide 100 % coverage of the tunnel trench and other dredged areas.

View indicating coverage of rail sweep.

Sweep trace
Sweep hit



DGPS and RTK Physical Rail Sweeping
Great Lakes Dredge & Dock Company developed a rail sweeping barge incorporating Digital Global Positioning and Real Time Kinetic vertical control to prove 100% coverage and full clearance in all navigation and construction channels.

On board ÖMJV spill monitoring boat "Coastal Surveyor".

Spill Monitoring System & Software
ÖMJV developed and procured a sophisticated boat-based spill monitoring system and operated up to three boats, 24 hours per day for the duration of the dredging activities. Data acquisition and presentation software were custom developed for the project.

Module in operation on the "Coastal Surveyor".

Mobile Spill Monitoring Module
ÖMJV developed in-house a mobile spill monitoring module which can be fitted on any given vessel. This module eliminates the requirement to maintain a dedicated Spill Monitoring Vessel during non-peak production periods.

ÖMJV on-site laboratory.

Laboratory
ÖMJV operates its own on-site laboratory facilities in support of its Spill Monitoring and Quality Control Programmes.

Underside of spill monitoring vessel "Vitesse" with ADCP.

Acoustic Doppler Current Profiler
For its Spill Monitoring Programme ÖMJV has made, for a duration of some 30 months, continuous use of ADCPs on its 3 spill monitoring vessels.

Steel-coated streamer cable in use.

Steel-coated Streamer Cables
ÖMJV developed in-house a steel-coated streamer cable for spill monitoring increasing the usable lifetime considerably.

Weir Box Station located on the artificial island.

Weir Box Stations

In order to measure spill volumes discharged from the reclamation areas into Øresund, ÖMJV developed fully automated, stationary spill measurement containers which continuously monitor spill discharge from the basins in real-time.

Daily use of document mangement system.

Document Management Control

ÖMJV maintains a document management system using DocsOpen Software by PC Docs.

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Print: Arco Grafisk A/S

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