4th Semi-Annual Report on the Environment and the Øresund Fixed Link's Coast to Coast Installation

FIRST HALF OF 1997

Danish Ministry of the Environment and Energy

Danish Ministry of Transport

Swedish Control and Steering Group for the Öresund Link

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4th SEMI-ANNUAL REPORT ON THE ENVIRONMENT AND THE ÖRESUND FIXED LINK'S COAST-TO-COAST INSTALLATION

January-June 1997

Colophon

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Abstract:
In the semi-annual report the Danish and Swedish environmental authorities inform the governments and public of the two countries about the status of the work on control and monitoring of the establishment of the Øresund Fixed Link's coast-to-coast installation.

Key words:
monitoring; inspection; control; bridges; tunnels; installation; dredging; sediment spillage; extraction of raw materials; Øresund.

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0. Foreword

The comments to the Danish Construction Bill for the Øresund Fixed Link state that the Danish Government will submit a semi-annual progress report to the Environment and Planning Committee of the Danish Parliament regarding the environmental consequences of the construction work on the coast-to-coast section. On the Swedish side the National Environmental Protection Agency and the County Administration in the County of Skåne are to keep the Swedish Government informed about implementation of the project and control and monitoring of the construction work through the Control and Steering Group for the Öresund Link (KSÖ).

The three previous semi-annual reports, published in February 1996, September 1996 and May 1997 respectively, gave a description of the frameworks for environmental management and the individual elements of the control and monitoring programme, as well as describing the activities up to the end of 1996.

This, the fourth, semi-annual report describes the monitoring and control activities in the first half of 1997. The report, which has been prepared by the Danish and Swedish environmental authorities involved with the assistance of the Danish Ministry of Transport, is based on reports prepared by Øresundskonsortiet and consultants associated with various parts of the authorities' control and monitoring programme.

1. Summary

It is the overall impression of the authorities that the construction work is proceeding within the frameworks of the set acceptance criteria. It will not be possible to make a final assessment of some of the criteria, such as the zero solution and the temporary environmental impact in the outer impact zone, until at a later stage in the project, however. Monitoring of the effects from the construction work is therefore continuing as planned.

The various measures which were implemented to reverse the negative development in the spillage percentage from excavation of the tunnel trench in particular seem to have succeeded. Among other things, the dredging contractor chose to stop dredging work in the tunnel trench in periods with strong currents. In this way the spillage percentage was kept to approx. 4.3 during the first half of 1997 with a slight downward trend. The total permitted spillage from the construction work is max. 5%.

Approximately two thirds of the total dredging quantities were dredged between the commencement of the construction work and the end of June 1997. The spillage from the approx. 4.7 million m^3 (approx. 9.2 million tonnes) dredged so far is 4.3%, corresponding to a total of approx. 391,000 tonnes.

Øresundskonsortiet received approval for another four dredging instructions in the first half of 1997. This leaves two dredging instructions with a dredging quantity of 633,000 m^3. In autumn 1997 the Swedish Water Rights Court is to consider an application for an increase in the permitted dredging quantities on the Swedish side in Flinterenden. It is expected that an increase in the dredging quantities in Flinterenden will mean a reduction in the need for compensation dredging on the Danish side.

Øresundskonsortiet's feedback monitoring shows that, owing to the current conditions, 78% of the spilt sediment is deposited in the Øresund, particularly in the area north of Middelgrundsfortet and in the outer parts of Køge Bay. The spillage is being distributed as expected in terms of time and space.

So far monitoring of the benthic fauna has not shown any marked changes as a result of the construction work. But as far as common mussels are concerned there have been indications of reductions in the biomass in the Drogden south area. This is believed to be due to a problem with the way measuring is done rather than the construction work.

The reduction in the occurrence of eelgrass in particular in 1996 around Saltholm is considered by the authorities to have been caused by a combination of the mechanical effect of ice on the vegetation and sediment spillage from the construction work. The vegetation collected off Saltholm in summer 1997 with a view to assessing the amount of food available to swans indicates that the vegetation around Saltholm is on the increase again.

Saltholm's eiders were in significantly worse physical condition than normal, resulting in a smaller brood size. The number of nests with unhatched eggs was also twice as large as usual. It cannot be ruled out that the decline is an effect of the eiders being distributed differently to before, resulting in increased competition for food. The greylags on Saltholm have apparently not been affected by the construction work. Spring 1997 saw registration of the largest number since counting started in 1993.

In February 1997 there was one instance of reduced visibility depth in the water off Dragør's south beach which can probably be attributed to the construction work. In April there occurred a high water situation with 1.20 m above the daily water level. This was due to a special wind situation and the construction work is not considered to have been of any practical significance.

2. Introduction

The first half of 1997 was characterised by the hard winter and cold spring. The possible effects of this were discussed in relation to the distribution and biomass of the benthic vegetation in particular.

The most important excavation work was the dredging of the tunnel trench in Drogden and in the compensation dredging area south of the artificial island, both of which were carried out using CASTOR, a dredger of the cutter suction type, plus dredging of the access channel to Lernacken, which was done using conventional bucket dredgers.

In spring 1997 SEMAC Joint Venture, which carries out the authorities' control programme for water quality, benthic fauna, benthic vegetation and coastal morphology, started reporting on the 1996 studies of the individual sub-programmes, with the first reports being expected to be ready during September 1997. The programme for the second year has also been drawn up on the basis of experiences from implementing the programme for the first year.

Co-operation between the environmental authorities in Denmark and Sweden and with Øresundskonsortiet worked satisfactorily.

The following gives an account of implementation of the construction work, including developments in the dredging work and the environmental conditions in the Øresund in connection with the construction work. Finally there is an overview of future activities.

3. The construction work in the Øresund

3.1 Status of the construction work

On 1 September 1997, in accordance with its agreement with the environmental authorities, Øresundskonsortiet forwarded a report /ref. 1/ which gives an account of the construction work and the monitoring activities in the first half of 1997.

This period saw completion of the dredging work which enabled the two pylon caissons for the high bridge over Flinterenden to be positioned in April. The dredging work was nearly completed for the future approach bridge from Lernacken and to the tunnel between the artificial peninsula at Kastrup and the artificial island south of Saltholm. The first two elements for the tunnel were floated out in the dock at the tunnel factory in Copenhagen's North Dock with a view to subsequent transport to and immersion in the tunnel trench in August 1997. Casting of the tunnel portals on the artificial peninsula and artificial island is proceeding according to plan.

The bridge abutment at Lernacken has been established, while casting of the caissons and pier shafts for the approach bridges is proceeding satisfactorily in Malmö's North Dock. The SVANEN floating crane arrived in June 1997 for the purpose of transporting and positioning the bridge elements.

This means that all the contracts are well under way, with the project's overall delay of less than 6 weeks in relation to the main timetable at the end of June 1997 not giving Øresundskonsortiet reason to institute special measures.

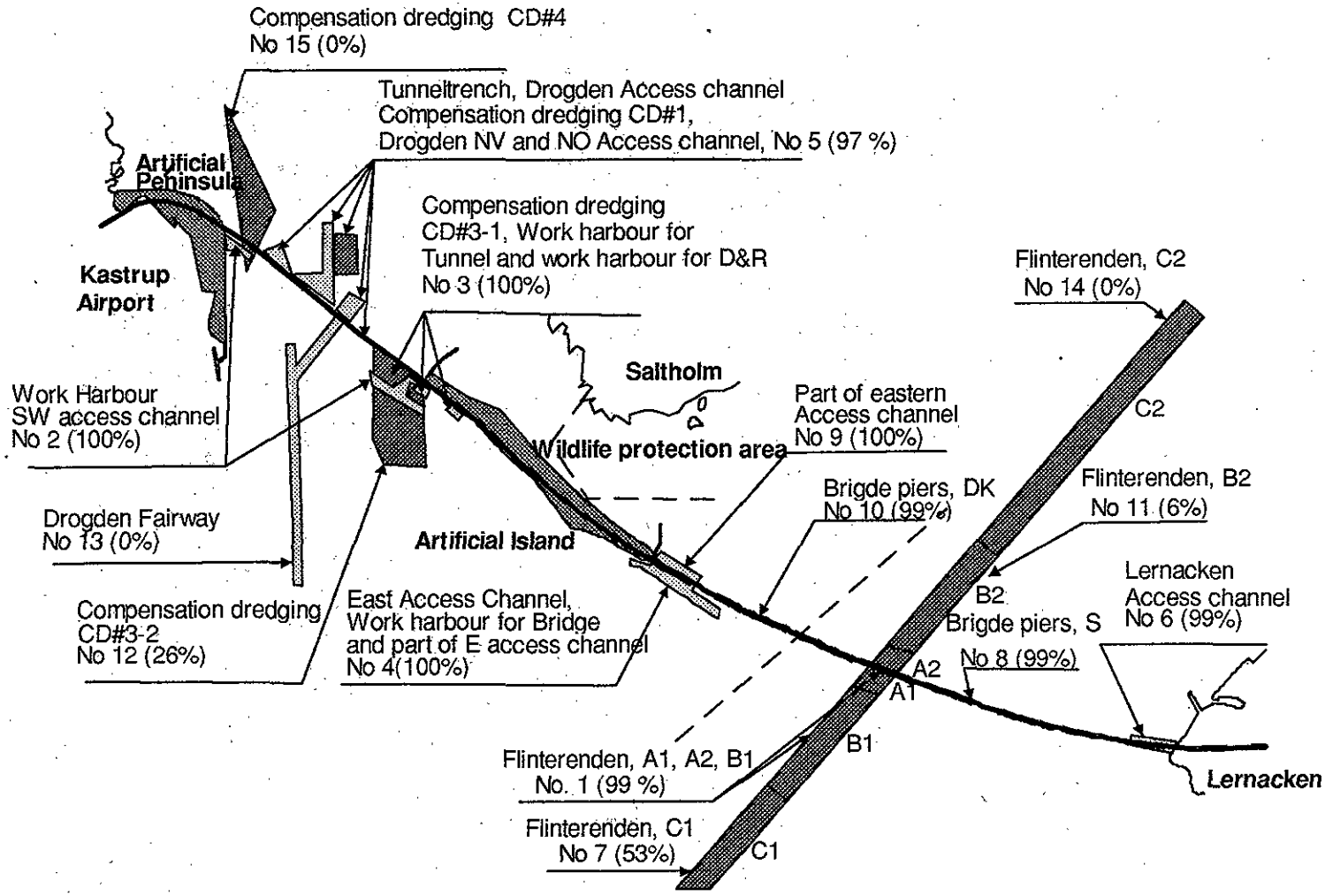

Fig. 1. Completed, ongoing and future dredging work. The numbers refer to the dredging instructions. The percentages indicate how much of the work has been done. Source: Øresundskonsortiet.

3.2 Approval of dredging instructions and spillage budget

The dredging instructions lay down detailed guidelines for how the individual dredging operations are to be carried out in practice and furthermore Øresundskonsortiet have to account for the expected spillage. The location of the approved dredging areas and the proportion dredged so far is shown in fig. 1.

The following four dredging instructions were approved in the first half of 1997, bringing the total approved so far to 13:

- Dredging Instruction No. 10 /ref. 2/ "Bridge piers on the Danish side and extension of eastern installation channel" was approved by the National Forest and Nature Agency on 11 March 1997. This dredging instruction covers a total of 74,100 m³ with budgeted spillage of 5%.
- Dredging Instruction No. 11 /ref. 3/ "Flintrännan, area B2" was approved by the County Administration in the County of Skåne on 13 June 1997. This dredging instruction covers a total of 534,000 m³ with approved spillage of 6.3%.
- Dredging Instruction No. 12 /ref. 4/ "Compensation dredging CD3-2" was approved by the National Forest and Nature Agency on 9 June 1997. This dredging instruction covers a total of 657,000 m³ with approved spillage of 5.0%.
- Dredging Instruction No. 13 /ref. 5/ "Drogden Fairway" was approved by the National Forest and Nature Agency on 2 June 1997. This dredging instruction covers a total of 230,000 m³ with approved spillage of 5.0%.

The latest revised spillage budget, valid as at 1 July 1997, is shown in table 1. The spillage budget is updated as the contractor's detailed design of the individual dredging tasks is fixed. The spillage budget contains "accounting figures" for the quantities dredged so far and the calculated sediment spillage. It can be seen from the spillage budget that an individual sub-operation may sometimes have spillage in excess of 5%, which is acceptable as long as the overall mean for the construction work as a whole is no more than 5%.

Dredging instruction no. 13 was added after it became apparent that the extensive construction activities are causing difficult navigation conditions for the heavy shipping traffic through Drogden. The shipping authorities and Øresundskonsortiet therefore wanted to improve navigating safety in the area close to the Drogden trench by straightening the fairway. Following an initial public EIA hearing in spring 1997, the Ministry of Transport gave permission for the dredging work to be carried out, while the National Forest and Nature Agency gave permission under the terms of the Danish Raw Materials Act for the dredged material to be utilised.

The fairway is being relocated in Flinterenden to ensure the safety of shipping and the bridge. This work was started in October 1995. It became apparent that it will not be possible to carry out this dredging work within the framework of the quantity of 2 million m³ originally laid down by the Water Rights Court in consequence of a precise survey of the seabed conditions and greater uncertainty (tolerance) regarding the dredging work. Therefore, in June 1997, Øresundskonsortiet applied to the Water Rights Court for permission to increase the total dredging quantity on the Swedish side to approx. 2.8 million m³ /ref. 6/. The application was made following consultation with the Swedish inspection authorities. The Danish and Swedish authorities therefore approved the spillage budget in connection with dredging instructions 11, 12 and 13 subject to the decision of the Water Rights Court. The application is expected to be heard in the autumn of 1997.

The spillage budget has mainly changed in relation to the second half of 1996 by the dredging instruction for the Drogden Fairway being added and the dredging instructions for Flinterenden being divided up and the quantity increased. The dredging requirement for the bridge contract has also been increased. The dredging quantity budget has been increased by 418,200 m³ overall in relation to the statement at the end of 1996 /ref. 7/.

No.	Area	Period	Calculated quantity						Quantity actually dredged as at 1 July 1997, calculated to the theo-retical mean level				Budget for remaining work		
			Quantity m³	Quantity tonnes	Spillage tonnes	Splg. %	Dredge spillage	Fill spillage	Quantity m³	Quantity tonnes	Spillage tonnes	Spillage %	Quantity m³	Quantity tonnes	Spillage tonnes
1	Flinterenden, central section (A1/A2 and B1)	Oct95-Aug97	197,000	372,000	16,924	4.5	4.2	0.3	157,991	298,603	12,149	4,1	39.009	73.397	4.775
2	Work harbour and SW access channel	Nov95-May96	328,000	640,000	23,000	3.6	3.2	0.4	328,000	640,000	22,811	3,6	0	0	189
3	Comp. CD#3-1, work harbour for Tunnel and work harbour for D&R	Dec95-Sep96	787,000	1,534,000	38,469	2.5	2.0	0.5	779,309	1,518,804	34,989	2,3	7.691	15.195	3.480
4	E access channel, work harbour for Bridge and part of E inst. channel	Feb96-Apr96	215,000	409,600	18,300	4.5	4.0	0.5	215,000	409,600	17,736	4,3	0	0	564
5	Tunnel trench, CD#1 and Drogden installation channel	Jul96-Aug97	2,449,400	4,638,300	251,674	5.4	4.3	1.1	2,241,172	4,254,172	212,229	5,0	208.228	384.128	39.445
6	Access channel, Lernacken	Sep96-Apr97	287,500	570,370	17,111	3.0	3.0	0.0	293,762	581,650	24,402	4,2	-6.262	-11.280	-7.291
7	Flinterenden area C1	Apr97-Sep97	348,000	858,000	49,000	7.4	7.3	0.1	183,642	347,081	6,435	1,9	164.358	310.919	42.565
8	Bridge piers for Approach Bridge and pylons/S	Oct96-Mar99	193,500	382,800	19,140	5.0	5.0	0.0	189,953	376,106	22,606	6,0	3.547	6.694	-3.456
9	Part of E Installation Channel	Mar97-Apr97	136,000	267,000	14,418	5.4	4.6	0.8	119,970	235,142	13,786	5,9	16.030	31.858	632
10	Bridge piers for approach bridge/DK	Mar97-Jun97	74,100	146,240	7,312	5.0	5.0	0.0	71,097	140,061	9,068	6,5	3.003	6.179	1.756
11	Flinterenden area B2	Jun97-Oct97	534,000	1,031,600	65,005	6.3	5.8	0.5	31,018	59,864	1,491	2,5	502.982	971.736	63.514
12	CD#3-2	May97-Sep97	657,000	1,292,500	64,625	5.0	4.8	0.2	170,158	333,509	7,126	2,1	486.842	958.991	57.499
13	Drogden Fairway	Jul97-Nov97	230,000	437,000	21,850	5.0	4.5	0.5	559	1,051	36	3,4	229.441	435.949	21.814
14	Flinterenden, area C2	Nov97-Apr98	433,000	822,700	34,320	4.2	4.0	0.2	0	0	0		433.000	822.700	34.320
15	Comp. CD#4	Apr00-Dec00	200,000	376,000	18,800	5.0	3.8	1.2	0	0	0		200.000	376.000	18.800
	Spillage from other sources - DK				7,554						6,068				1.486
	Spillage from other sources - S				11,403						0				11.403
Total	Oct95-Dec00		7,069,500	13,578,110	678,905	5.0			4,781,631	9,195,643	390,932	4.3	2,287,869	4,382,467	287,973

Table 1. *Current spillage budget as at 1 July 1997. The table shows the quantities which have actually been dredged, calculated to what is known as the theoretical mean level, and the remaining planned dredging work, together with measured and budgeted spillage. The table has been revised in relation to the budget presented in the third semi-annual report (see also section 3.2). Source: Øresundskonsortiet.*

3.3 Status of dredging instructions and spillage accounts

In the six months just ended the dredger CASTOR continued to work on dredging the tunnel trench. CASTOR was also used in compensation dredging area CD3 and the Drogden Installation Channel (fig. 1). Another seven traditional bucket dredgers were also used.

The most important parts of this dredging work were done in the new Flinterenden, the tunnel trench and compensation dredging area CD3 off the artificial island, in the installation channel for Lernacken and in the excavations for the bridge foundations on both the Swedish and Danish sides of the Øresund. The dredged material was used on the artificial peninsula and the artificial island.

In the first half of 1997 dredging work was carried out on the basis of 11 of the total of 13 approved dredging instructions (fig. 1). The excavations under dredging instructions 2 and 4 were completed in 1996. This means that Øresundskonsortiet has taken into use 13 of the 15 dredging instructions planned for the entire project /ref. 1/.

The authorities approved an increase in the weekly spillage rates in the areas west of Saltholm and in Flinterenden in the months July to October 1997 inclusive. The increased spillage rates, which concern dredging instructions 5, 7, 11, 12 and 13, are the result of an overall reassessment of implementation of the remaining dredging work. The reassessment is based on the experience gained so far with regard to dredging techniques, spillage and effects on the environment /ref. 9/. It has turned out that relative spillage is least in the summer months, when sea currents are low. Dredging more in the summer months makes it possible to achieve a greater degree of certainty that the dredging work will be able to meet the requirement for total spillage of 5%. Even if the increased spillage rates may result in a greater absolute quantity being spilt in the months July to October, this can be done without the authorities' other environmental requirements being exceeded.

The inspection authorities and Øresundskonsortiet are monitoring the spillage accounts continuously and discussing the technical aspects of calculating and measuring sediment spillage. The concluding assessment of the spillage statement up to week 6 of 1997 is in preparation /ref. 10/.

Spillage from the dredging work for dredging instructions 8, 10, 6 and 9 was higher than expected. The dredging instructions involved concern the excavations for the bridge piers in Swedish and Danish territory and the installation channels at Lernacken and the eastern part of the artificial island. Spillage from the dredging work from the other seven dredging instructions was less than expected, however /ref. 1/.

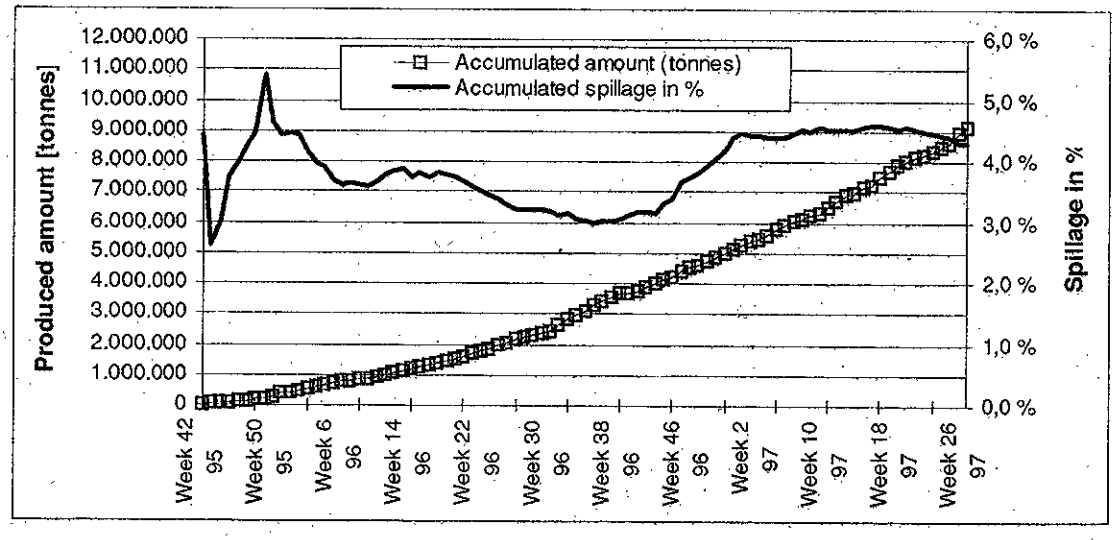

Fig. 2. Development over time of the total production quantity in tonnes and the accumulated spillage in per cent for the dredging work as a whole. Source: Øresundskonsortiet.

With so many dredgers being used, a record quantity was dredged. Thus a total of approx. 2 million m³ was dredged in the first half of 1997, mainly in the tunnel trench. The mean spillage for all dredging operations in the first half of 1997 was calculated at 4.1%.

A total of approx. 4.7 million m³ (approx. 9.2 million tonnes) was dredged between the start of the construction work and the end of June 1997, the equivalent of approx. 67% of the total planned dredging work. Spillage in the same period was approx. 391,000 tonnes (approx. 202,000 m³), corresponding to a mean spillage percentage of 4.3 for the dredging and filling work done so far.

It can also be demonstrated that the implementation in the previous six months of various measures as a result of a negative development in the spillage percentage had a positive effect /ref. 7/. The increased spillage from CASTOR, which was dredging the tunnel trench, was closely associated with periods of strong currents. The most effective tool turned out to be a warning system which the contractor used as a decision-making basis for stopping dredging work in periods with strong currents. The mean spillage from CASTOR was reduced in the spring months, bringing it under budget by the end of the period.

This means that the overall spillage percentage was kept at the same level as at the end of 1996 (fig. 2). The development over time of the total production quantity in tonnes and the accumulated spillage in per cent for the dredging work as a whole are shown in fig. 2, while the total spillage from the dredging and extraction work is shown in fig. 3.

Øresundskonsortiet has permission to extract filling sand from Kriegers Flak in the Baltic. So far approx. 1.2 million tonnes has been extracted with mean spillage of approx. 2.2%. The first half of 1997 saw the extraction of approx. 290,000 tonnes with mean spillage of approx. 1.9%.

3.4 Spillage measurement programme and bed load transport

The spillage measurements are carried out while sailing in lines across the sediment plumes and in the sediment plumes themselves. The measurements carried out in the sediment plumes are particularly useful as documentation of actual sediment distribution in the water column.

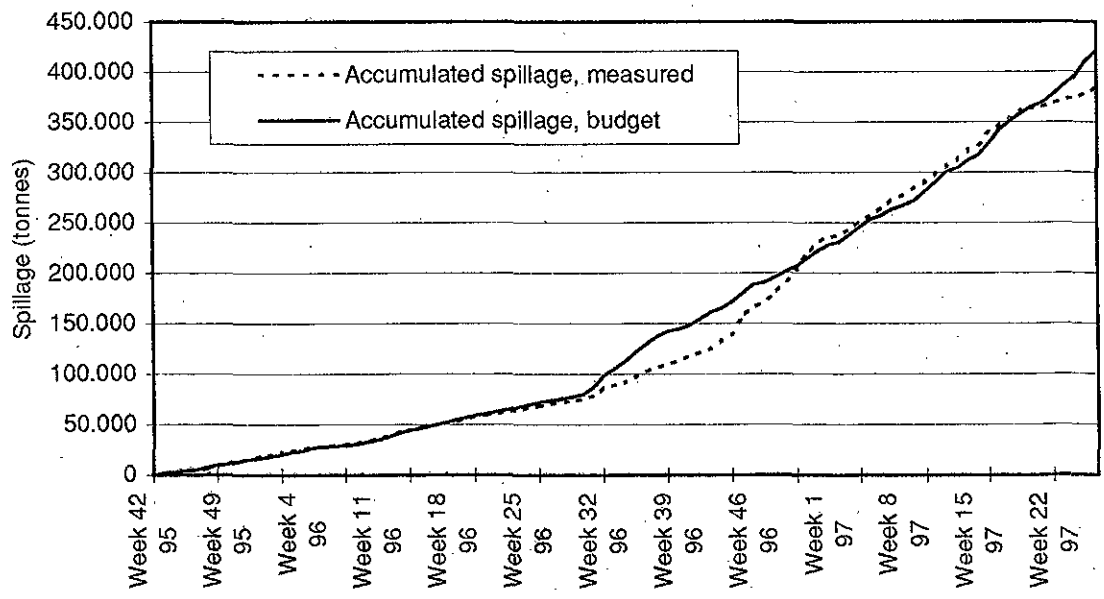

Fig. 3. *Development over time of the measured spillage from the dredging and extraction work up to the end of June 1997 in relation to the budgeted spillage for the period. Source: Øresundskonsortiet.*

Two vessels were used to measure sediment spillage around the clock in the first half of 1997. One vessel was used exclusively to measure spillage from CASTOR, while the other vessel measured spillage from the bucket dredgers by turns. The quantity of spillage coming from bucket dredgers is calculated using a combination of direct measurement of the spillage around each dredger and a model estimate of spillage based on the actual quantity dredged, also for each dredger. This method for determining the spillage was put into practice in February 1997. Øresundskonsortiet has documented that the method meets the authorities' requirements with regard to the uncertainty of spillage measurement by a good margin /ref. 1/.

Monitoring of the bed load transport of sediment from dredging operations was carried out in two stages. The first stage consists of visual observation of the seabed in and around the various dredging areas, and the second stage of more detailed investigation if spilt sediment in thicknesses in excess of 10 cm is found. Spilt sediment with thicknesses of up to 10 cm were only found in a single instance in the first half of 1997 /ref. 1/. It is estimated that the contribution made by bed load transport is in the order of 0.5% of total spillage /ref. 1/. Bed load transport from dredging in the area around CASTOR was studied using video with a so-called side-scan sonar. The first results from this investigation indicated that bed load transport out of the areas of operation is insignificant /ref. 1/.

3.5 Inspection by the authorities

Inspection by the authorities is based on discussions in technical work groups and on direct access to various data collected and processed by Øresundskonsortiet. These data are presented in the EAGLE environmental information system. The authorities also make inspection visits. The subjects discussed by the technical work groups are reported in sections 3.3 and 3.4.

The EAGLE environmental information system has given the authorities a faster access to follow the developments in environmental conditions, including developments in sediment spillage and evaluation of the effects on eelgrass and common mussels through results from the feedback monitoring. Infringements of the operational criteria (see sections 4.1.1-3) are marked separately in EAGLE so that the authorities can assess the nature of the incident directly and the action taken by Øresundskonsortiet.

The development in spillage from CASTOR in autumn 1996 led to the inspection authorities asking Øresundskonsortiet for a report on the planning of future dredging work /ref. 9/. This set the scene for a reassessment of the way in which the dredging work is controlled to ensure that the overall spillage requirements could be met. However, the spillage from CASTOR was brought under control during the spring of 1997, which together with the change in planning of the rest of the dredging work will ensure that the requirements with regard to spillage and environmental effects can in all probability be met.

In the first half of 1997 the Swedish and Danish authorities made inspection visits to the dredging contractors, Sundlink Contractors and Øresund Marine Joint Venture, on the artificial island in connection with the handling of dredged material, and to Øresundskonsortiet in connection with the model for estimating sediment spillage and calculating the uncertainty of spillage calculations. The Swedish Geotechnical Institute also went on board one of Øresund Marine Joint Venture's spillage monitoring vessels in connection with a revision of transect measurements.

4. The control and monitoring programme

An overall control and monitoring programme has been drawn up in accordance with the conditions of the Danish authorities /ref. 11/ and the judgment of the Swedish Water Rights Court /ref. 13/. The monitoring programme is primarily intended to record the state of the marine environment and form a basis for the implementation of any countermeasures which may be necessary if a construction activity has an effect which goes beyond what is expected. Once the link is ready the monitoring programme is intended to record whether the temporary effects on the water environment decrease as expected.

The responsibility for implementation of monitoring and control in connection with the construction work is divided between the contractors, Øresundskonsortiet and the Danish and Swedish environmental authorities.

4.1 Feedback monitoring

Øresundskonsortiet uses a feedback programme in connection with the individual dredging operations which involves frequent monitoring of selected parameters in the marine environment around the dredging areas. In this respect the programme differs from the more general effect monitoring programme (section 4.2). The feedback programme has the aim of insuring that early action is taken with regard to the execution of the construction work if there is any risk of the authorities' environmental requirements being exceeded. The feedback programme includes ongoing modelling work and the study of sediment in the water column and on the seabed, as well as common mussels and eelgrass. In connection with the control and monitoring programmes Øresundskonsortiet has set up what it calls its operational environmental criteria, which are stricter and more specific than those of the authorities. More intensive monitoring is normally implemented if Øresundskonsortiet exceeds the operational criteria.

In connection with the increase in spillage rates for the period July-October 1997 in two spillage areas (section 3.3) Øresundskonsortiet was instructed to draw up a plan for more intensive feedback monitoring in the period July-October /ref. 13/.

4.1.1 Sediments

In the first half of 1997 widespread sediment plumes were, as expected, recorded on both the western and eastern sides of the Øresund as a consequence of the dredging work in the tunnel trench and at Lernacken. The concentrations in the plumes were relatively low (2-10 mg/l). The plumes with concentrations in excess of 10 mg/l were largely recorded around the alignment itself /ref. 1/.

The model calculations /ref. 1/ have shown that 78% of the spilt sediment is deposited in the Øresund, particularly in the area north of Middelgrundsfortet and the outer parts of Køge Bay. The largest deposits of up to 5000 g/m^2, corresponding to a layer thickness of 5 mm, are found immediately north of Middelgrunden /ref. 1/.

In the first half of 1997 the monitoring of sediment conditions by Øresundskonsortiet did not record values which gave rise to feedback action /ref. 1/. The programme also shows that there was no simultaneous blocking in Drogden and Flinterenden in the period 15 January-15 April, when the herring migrate through the Øresund. In the period 1 April-1 May there were no concentrations which led to visibility depths of less than 1 metre in the places where the eiders feed off Saltholm.

4.1.2 Eelgrass

In the first half of 1997 eelgrass was sampled twice a month at 10-12 stations in the outer impact zone /ref. 1/. The values for the shoot density, leaf and root biomass and carbohydrate content of the eelgrass were tested against the operational criteria. In addition to this there are model calculations which can be used to assess the effects on eelgrass in the areas where field studies are not carried out.

A small reduction in carbohydrate content was recorded, but it was not significant in relation to the baseline studies. It is assumed that the low values are probably due to shading by decaying filamentous algae and/or a combination of shading by the sediment plume and decaying filamentous algae. There is good agreement between the results from the collection eelgrass and the eelgrass model except for in the area south of the artificial island /ref. 1/. Repeated sampling in this area has failed to register the major reductions predicted by the model.

The operational criterion for the root biomass was exceeded in a single instance in spring 1997 off the south coast of Amager. Subsequent sampling showed that the infringement which had been observed was probably due to the difficulty of collecting representative samples of root biomass for the eelgrass.

In the period January-June 1997 the eelgrass programme therefore showed no infringements of the operational criteria with a single exception /ref. 1/.

4.1.3 Common mussels

In the first half of 1997 mussels were sampled monthly for biomass analysis and two monthly cruises were carried out to record the occurrence of mussels by photography. Photographic registration mainly took place in the southern part of the Drogden area, where the most extensive dredging work was going on. Only very limited sedimentation on common mussels could be found. The photographic records therefore tally with the models, which show that by and large sediment is not deposited on the sea bed in the areas with common mussels /ref. 1/.

The reduction in mussel biomass by up to half which was referred to in the previous semi-annual report /ref. 7/ was, following a stagnation in the first part of 1997, replaced by an increase in the most recent series of measurements carried out in the period May-July 1997. In the first half of 1997 there were signs of the operational criterion for biomass in the Drogden south area being exceeded. An analysis of the conditions, including the use of photographic documentation, revealed that the reduction was not linked to the construction work, however. There is as good as no covering as such of the mussel banks with material from the dredging work. The problem was traced back to an unstable reference area, which started to give varying reference values for biomass in the winter months. The collection of mussels in a new reference area was started on a trial basis in the first half of 1997.

4.2 Effect monitoring

As part of their supervision of the construction work the environmental authorities apply a general programme with a view to assessing whether the observed effects of the construction work lie within the frameworks of the expected effects /ref. 14/. The programme includes monitoring within the following areas of the Øresund's environment: water quality, benthic vegetation and benthic fauna, fish, birds, beaches and coasts.

The effect monitoring is long term and is primarily aimed at identifying year-to-year effects from the construction work and changes in the environment. This monitoring also addresses a broader cross-section of the ecosystem than the feedback monitoring, which focuses on fewer variables and the immediate area around the dredging operations.

4.2.1 Water quality

The construction and operation of the Øresund Fixed Link must not lead to the release and redistribution of heavy metals, hazardous substances, nutrients or oxygen consumption to an extent which creates negative ecological effects or leads to significantly increased concentrations of heavy metals or hazardous substances in animals and plants. In critical situations involving lack of oxygen in the Øresund it must be ensured that the dredging work does not give rise to increased harmful effects on the biological conditions.

In the first half of 1997 the monitoring programme was carried out at four stations at Kullen, Ven and Drogden in the north, middle and south of the Øresund, and at Stevns to the south of the Øresund. Each sample is analysed for salinity, temperature, visibility depth and concentrations of oxygen, chlorophyll

and nutrients, among other things as support parameters to help interpret the results of the other sub-programmes. SEMAC JV carries out sampling weekly apart from in those weeks where the other

Danish or Swedish authorities (the County of Copenhagen, the Danish National Environmental Research Institute (DMU) and the Swedish Meteorological and Hydrological Institute (SMHI)) collect samples at the stations in question.

The results from the studies in 1997 will be presented in the next semi-annual report when the 1997 status report for water quality is available. Based on a provisional evaluation of the results, however, the construction work does not seem to have affected the water quality in the Øresund in the first half of 1997 as far as nutrient salts and oxygen are concerned.

For the second year of sampling in the period 1 July 1997-30 June 1998 the inspection authorities have decided that the northernmost station at Kullen should be omitted. This decision was taken on the basis that, as far as oxygen conditions are concerned, the authorities only require that the dredging work must not cause increased harmful effects on the biological conditions in the event of oxygen depletion in the Øresund. The inspection authorities assess that data from the three remaining stations will be sufficient to prove any effect on water quality in the Øresund by the construction work.

4.2.2 Benthic fauna and benthic vegetation

Permanent effects on plant and animal life are acceptable in the inner impact zone, whereas temporary effects on species composition, distribution and biomass are acceptable in the outer impact zone. A temporary reduction in animal and plant life of up to 25% is generally acceptable in the outer impact zone.

The purpose of the studies is to follow the development of benthic fauna and benthic vegetation in the Øresund with a view to documenting whether any changes fall within the frameworks of the criteria established by the environmental authorities.

Benthic fauna

A supplementary study of common mussels was carried out in 1997 to make sure that there are no systematic differences between the baseline studies and the control programme in 1996. The study showed that there are no systematic differences which prevent comparisons between the results from the baseline studies and the monitoring carried out in 1996 /ref. 15/.

As far as common mussels are concerned, the studies carried out in 1996 /ref. 15/ showed that the total area of common mussel banks in the outer impact zone, with coverage of more than 40%, was not significantly reduced in relation to the baseline studies when samples were taken in 1996. The biomass of common mussels collected at stations in the outer impact zone was not significantly reduced in relation to the baseline studies. The content of the metals cadmium and copper in the common mussels had risen in relation to the baseline studies, but, as the rise was general for the entire area studied, the results cannot explain the reason for the rise.

The mussel programme for next year will share 10 stations with Øresundskonsortiet's feedback programme by way of an innovation. Annual intercalibration will be carried out between the two programmes at these stations to ensure that the results can supplement each other.

The status report on benthic fauna in shallow water (shallow-water fauna) /ref. 16/ concludes that the time dependant changes in the area as a whole are not significant in relation to the baseline studies in 1995. The year-to-year variation in population density and biomass at the stations in the outer impact zone were of the same order as the equivalent variation at stations in the control area. The information available on shallow-water fauna thus does not show changes which can be put down to the construction work.

The benthic fauna programme for next year will combine the shallow-water and deep-water programmes in an integrated programme. Concrete information on the dispersal of sediment in time and

space will also be added. These changes have been made with a view to achieve a closer, more direct correlation with the effects of the construction work.

Benthic vegetation

The results of the first intercalibration study were further evaluated in the first half of 1997, with a new intercalibration study being carried out as a result. It showed that there are no systematic differences which prevent comparisons between the results of the baseline studies and the monitoring carried out in 1996 /ref. 17/.

The monitoring programme for benthic vegetation covers the community of eelgrass (*Zostera marina*), tassel pondweed (*Ruppia spp.*) and sea tangle (*Laminaria saccharina*) /ref. 19/. The authorities' second semi-annual report /ref. 18/ describes the content of the programmes and location of the stations in greater detail.

The monitoring shows /ref. 19/ that the development in the coverage, biomass and shoot density of the eelgrass inside the outer impact zone is not significantly different from the development in the control area, which is more than 7.5 km from the alignment. Nor is the development in the coverage of tassel pondweed in the outer impact zone significantly different from the development in the control area. Finally, the coverage and biomass of sea tangle is not significantly different from the development in the control area either.

It should be noted, however, that the data basis for sea tangle is very modest and it is not currently possible to decide whether the authorities' criteria for sea tangle have been met. Nor is the data basis for the biomass of tassel pondweed large enough for proper conclusions to be drawn after the first year.

Account has been taken of this in the revision of the monitoring programme for the second year. The programme for sea tangle will therefore include eight stations, which will be studied using video. Another intercalibration (see above) before sampling for the year begins has been agreed for use when it comes to placing the stations for the future tassel pondweed programme. The eelgrass programme will include a new element in the form of information on the concentration and dispersal of sediment at the stations used. This will give the programme a better statistical foundation as a basis for analysing the effects of the construction work.

The previous semi-annual report /ref. 7/ referred to a significant reduction in the coverage of tassel pondweed around Saltholm which was greatest closest to the construction work. Øresundskonsortiet's feedback programme does not indicate, however, that there has been a perceptible effect from sediment spillage from the construction work. The reductions may therefore be due in part to the hard winter of 1995/96, but the hard winter does not explain why the reduction was greatest close to the construction work and most marked west of Saltholm. It is therefore the opinion of the authorities that the reduction is in all probability due to the combined effect of ice and sediment. Provisional observations made in spring 1997 in connection with the swan programme indicate that the tassel pondweed vegetation on the west coast of Saltholm is on the increase, so the authorities no longer find cause for concern.

4.2.3 Fish

Situations must not occur in which sediment plumes block the migration of herring through Drogden and Flinterenden simultaneously. When this criterion was set, allowance was also made, together with the criteria for the other natural and environmental conditions, for eel, garfish, mackerel and lumpsucker, which also use the Øresund as a migration route.

In addition to the monitoring of herring migration, a separate programme concerning the occurrence of eel fry, recruitment of flatfish, etc., as required by the Swedish Water Rights Court, was also implemented.

The monitoring of herring migration through the Øresund takes the form of acoustic surveys of the size of stocks at various times during the migration process. The occurrence of herring is surveyed by means of echo sounding along a set network of survey lines throughout the Øresund. The surveys are compared with simultaneous test fishing of the surveyed stocks to establish the ratio between Rygen Herring and North Sea herring, which has the northern Øresund as the furthest reach of its area of distribution in the direction of the Baltic.

The monitoring programme for the 1996/97 migration season consisted of four monitoring cruises. The autumn monitoring showed that the herring entered the Øresund later than usual /ref. 7/. The cruises in spring 1997 showed that the herring had migrated out of the Sound in March-April as in previous years.

In April 1997 a seminar was held on herring monitoring in the Øresund with representatives from the Danish and Swedish environmental and fisheries authorities, Øresundskonsortiet and external fish experts. The seminar looked at central problems surrounding the herring's spawning migration compared with actual measurements and models of the dispersal of sediment from the dredging work.

The monitoring of the occurrence of herring in the Drogden Fairway off Nordre Røse using permanent measuring equipment showed that 10 suspected schools of herring with a width of more than 20 m were observed in October 1996. The occurrence of suspected schools of herring swimming back and forth in the area was also registered in February and March 1997. The final observations were in April /ref. 20/. The results of the programme therefore supplement the main findings from the ship-based monitoring programme.

4.2.4 Birds

A reduction of 15% in the population of eiders on Saltholm is acceptable in the construction phase, but no later than five years after the seabed work is completed the number of breeding pairs must be at least 90% of the number of breeding pairs observed during the baseline studies. As far as the other breeding waterfowl on Saltholm are concerned, there must not be a substantial reduction in numbers.

A temporary reduction in the number of feeding and resting migratory birds on Saltholm as a result of the construction work is acceptable. The number of feeding and resting migratory bids must be re-established no more than two years after construction work is completed, however. As far as greylags and mute swans are concerned, it is accepted that there is a risk of a permanent decline in the number of moulting birds.

Birds on Saltholm

The provisional results show that the *eiders* arrived on Saltholm at the end of March 1997, which corresponds to the arrival time registered for them in the three years of the baseline study, 1993-1995. As in 1996, the eiders avoided seeking food in a zone measuring approx. 300 m wide around the artificial island, and a shift was noted in the distribution of eiders looking for food around Saltholm (fig. 4). The feeding activities of the eiders off south-west Saltholm were no different from the activity registered in previous years /ref. 18 and 7/.

The possible effects of the disturbances are that the shift registered in the distribution of the eiders around Saltholm may have led to increased competition for food in areas with an increased number of birds, resulting in poorer opportunities for building up reserves of fat. This aspect will be assessed in conjunction with the monitoring in 1998.

Hatching proceeded normally at the beginning of May, but at the end of May a larger number of nests (20%) than the normal 10% or so (1995 and 1996) had not hatched on Saltholm. The mean brood size in 1997 was 3.98 eggs, which is statistically lower than the mean for 1993-1995 of 4.25 eggs. After hatching the broods moved to the raising areas off Scania and Amager as normal. No effects from the construction work on the movements of the broods away from Saltholm were registered. The survival of the ducklings was considered normal.

The *greylags* arrived on Saltholm as usual at the end of May to moult. During the period when the geese cannot fly, they are particularly sensitive to disturbances. In 1997 two cases of construction activities disturbing the moulting greylags on Saltholm were noted. In one instance a disturbance was caused by a catamaran ferry, and in the other a rowing boat caused the geese to panic. In general no disturbances caused by the construction work were registered which prevented the geese from using their preferred grazing and resting areas on the south and south-east coasts of Saltholm. In 1997 more than 12,000 geese were counted, which is the largest number registered since counting started in 1993.

Monitoring by the County of Copenhagen of breeding *waders* and *gulls* on Saltholm did not document any changes in the number of breeding birds which could be related to the construction work in 1997. A displacement of breeding waders from the southern part of Saltholm to areas in the centre and north of the island is in all probability due to the intensive use of these areas (cattle grazing, hay harvesting) and not the effects of the construction work. It is usual for there to be large fluctuations in the breeding stocks of avocets, little terns and arctic terns. It is not possible to determine the causes of the fluctuations in numbers of these species based on current monitoring.

In 1997 there was no sign of major changes in the beach ridge system on the south coast of Saltholm, which is used as a breeding site by terns and avocets. Some ridges disappeared and some new ones were created during the winter months.

Provisional results for *mute swans* indicate that their physical condition was unchanged in spring 1997 in relation to the baseline studies in 1994-95, so the swans do not seem to have had any problem finding sufficient food.

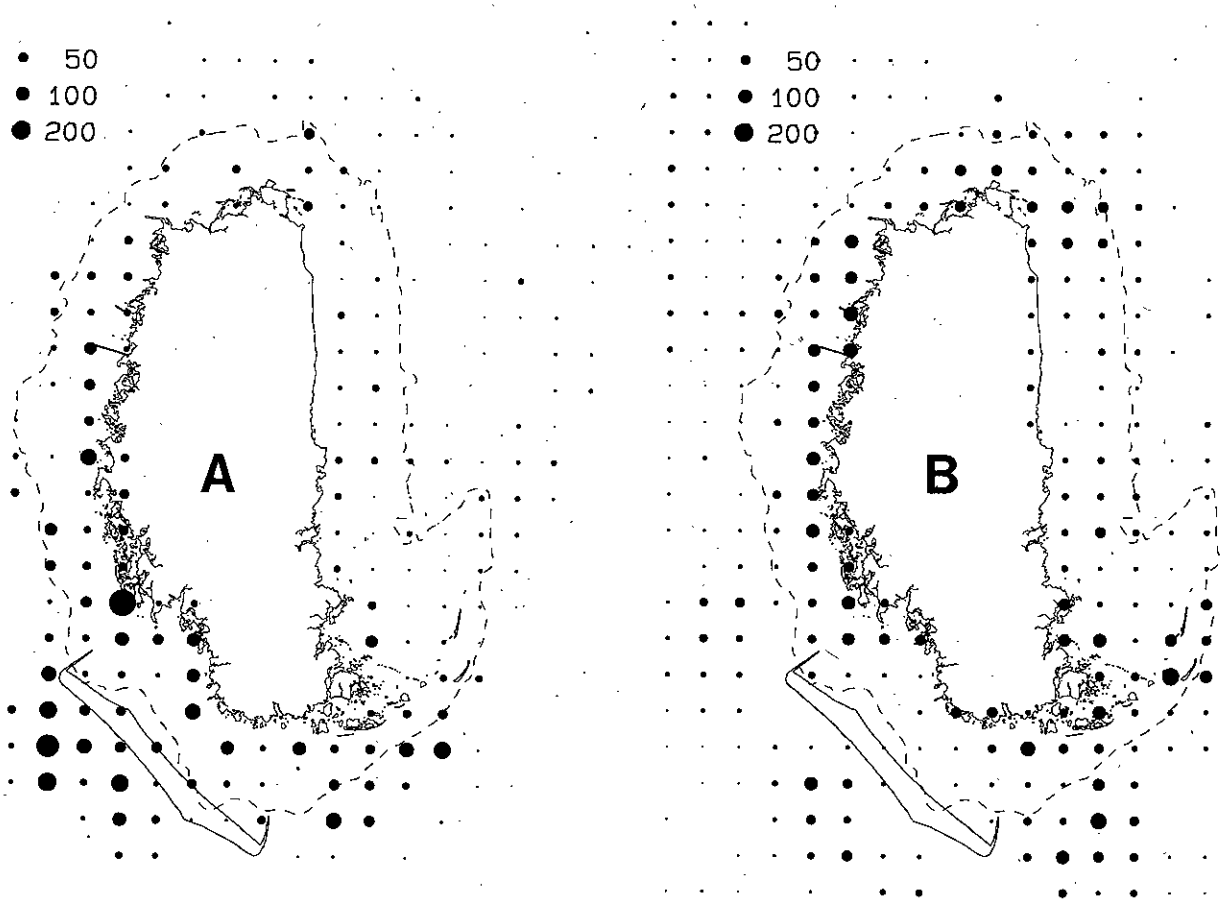

Fig. 4. Distribution of eiders around Saltholm on 30 March 1995 (A) and 14 April 1997 (B) charted on the basis of aerial photography. The charting only shows males. Source: The Danish National Environmental Research Institute.

Waterfowl on the Swedish coast of the Øresund

Bird monitoring continued in spring 1997 as set out in the programme. In the area between Limhamn north of the alignment and Måkläppen at the southern tip of the Falsterbo peninsula fewer waterfowl were observed in total than in the preceding period 1995/96. The reduction was observed in the area between Lernacken and Foteviken, while the number of waterfowl was unchanged around the Falsterbo peninsula (fig. 5).

In the area between Limhamn and Falsterbo marked differences were noted between the study years for the birds which feed in shallow water, e.g. tufted duck (*Aythya fuligula*), goldeneye (*Bucephala clangula*) and mute swan (*Cygnus olor*). In the reference area in Lomma Bay there were no differences for these three species.

For widgeon (*Anas penelope*) only minor differences between the two study periods were registered. This applies to both the reference area in Lomma Bay and for the area between Limhamn and Falsterbo.

For all species the development in the number of birds was normal up to the ice cover in the winter of 1996/97, after which much lower numbers were observed than in the winter of 1995/96. In both winters the area off Lernacken was the only ice-free area in the southern part of the Swedish Øresund coast for a time. In the winter of 1995/96 there was no construction work off Lernacken, unlike in the winter of 1996/97, when dredging was done. The decline in use of the area by waterfowl in the period with ice cover can presumably be put down to disturbances caused by the dredging work. The effect of the disturbances is limited to the local area around the alignment. Once the ice cover reduced and other feeding areas became accessible, the number of tufted ducks increased again. The number of mute swans remained low in the first half of 1997, however /ref. 21/.

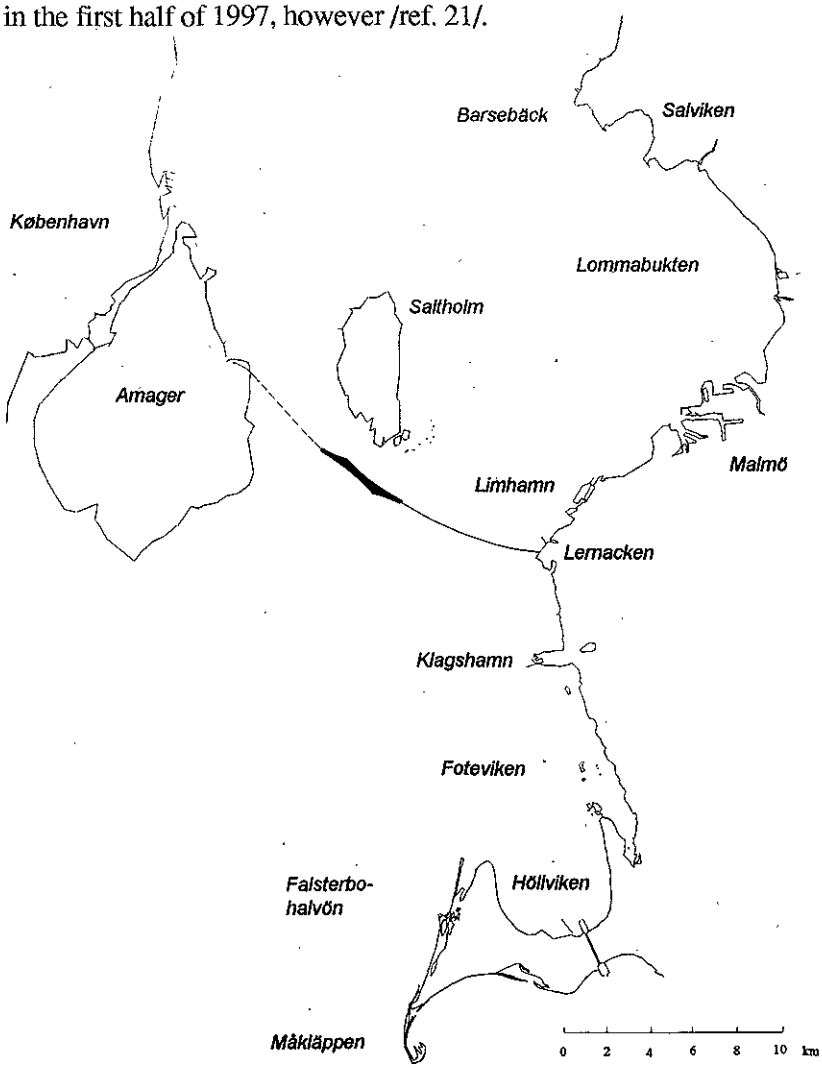

Fig. 5. *Bird locations in the southern part of the Øresund. Source: University of Lund.*

Greylags in Scania

The population of greylags (*Anser anser*) in south-west Scania, which represents a recruitment area for the moulting geese on Saltholm, continues to increase. This increase in the number of moulting geese can probably be related to fewer geese in Holland, which is normally the most important moulting area for greylags in the southern part of the Baltic /ref. 21/. In 1997 the hatching of eggs was at a normal level. Of the geese which previously bred in Scania and which were observed in Scania in the spring, 29% moulted on Saltholm compared with 11%, 10%, 2% and 17% respectively in past years.

4.2.5 Beaches and coasts

Monitoring of bathing water

The quality of beaches and bathing water along the coasts in the Øresund outside the inner impact zone must not be changed to such an extent that the quality requirements for bathing water cannot be met.

A supplementary bathing water programme is being carried out at Amager Beach and at Dragør's north and south beaches by agreement with the Municipalities of Copenhagen and Dragør.

Reduced visibility was detected at Dragør's south beach on two occasions, 4 February and 18 February 1997. Closer study of these events shows that the reduced visibility on 4 February 1997, when the current was flowing south, may have been due to a small sediment plume caused by resuspension of old spillage material, and the possibility that the western part of the sediment plume from the dredging work may have touched the south beach in the course of the day /ref. 22/. On 18 February 1997 the current was flowing north and the clouding of the water observed on that day can therefore scarcely have been due to the construction work.

On 11 April 1997 a high water situation occurred at Dragør's north beach in which the water level rose from 0.05 m at noon to 1.2 m at 6 PM, following which the water level fell again over the next 36 hours. The wind situation which caused the high water is described statistically as an event which can be expected roughly every three years, and the construction of the Øresund Fixed Link is not considered to be of any practical significance with regard to the high water level at Dragør /ref. 23/.

No abnormal conditions were observed along Amager Beach, so the Municipality of Copenhagen did not need to implement the supplementary sampling which has been agreed.

The programme for bathing water control on the Swedish side has been revised on the basis of what was learned from bathing water control in 1996. No instances of a deterioration in bathing water as a result of the construction work were registered. In 1997 the study programme for bathing water quality will therefore only be carried out at the bathing beaches in Malmö. Nothing abnormal was registered in the first half of 1997.

Monitoring of the coastal morphology

The effects of the dredging work must be limited to the immediate vicinity of the alignment. The work must not result in silting which causes the artificial island to become joined to Saltholm. There must only be insignificant changes in seabed and coastline conditions.

In 1996 studies were made of the coasts of Amager and Saltholm, as well as of the coastline between Malmö and Klagshamn. Data were collected along 65 profile lines and the aforementioned coastlines were photographed from the air. It is yet not possible to compare the results with previous studies, but such comparisons can be made in the next status report for 1997. Therefore it is not yet possible to assess whether the construction work has had any impact on coastal conditions. The assessment of this is also being made more difficult by the hard winter of 1995/96, which may have affected the coast. After studies have been carried out for several years, it will be possible to analyse the effects of hard winters, however.

The monitoring programme for next year has been designed to provide improved control on the deposition of sediment in the area between the artificial island and Saltholm, as well as on the area immediately north of Saltholm. A profile is also being extended off Lernacken so that the development of the coast can be described better. The changes in the programme mean that the number of profiles is being increased in these places, while the number of profiles is being reduced in areas which are less likely to be affected by sediment.

5. Future activities

The International Advisory Panel of Experts is holding its 7th meeting in Malmö on 10-12 November 1997. Among other things, the panel will have supplementary validation material submitted to it with a view to making a statement on whether development of the hydraulic models for calculating the zero solution is complete. The status reports from the authorities' monitoring programme will also be submitted.

The dredging work is expected to be completed on the Danish side in autumn 1997 with the exception of dredging of the western part of the Drogden Fairway, which is planned for the second quarter of 1998. Dredging of Flinterenden north of the alignment is expected to take place in autumn 1997 and spring/summer 1998 subject to the decision of the Swedish Water Rights Court.

Over the next six months the authorities will focus on the follow-up to the activities which have been started such as monitoring the effects of the dredging work and the results of the other ongoing control programmes.

6. References

/1/ Øresundskonsortiet, 1997. Semi-Annual Environmental Report for January-June 1997. 52 pp. (In Danish)

/2/ Øresundskonsortiet. The Øresund Link. Dredging Instruction No. 10. Bridge piers on the Danish side and extension of eastern installation channel. Rev. 3. March 1997. Approx. 45 pp + annexes. (In Danish)

/3/ Øresundskonsortiet. The Øresund Link. Dredging Instruction No. 11. Flintrännan, area B2. Rev. 0. April 1997. Approx. 45 pp + annexes. (In Danish)

/4/ Øresundskonsortiet. The Øresund Link. Dredging Instruction No. 12. Compensation dredging CD#3-2. Rev. 1. June 1997. Approx. 45 pp + annexes. (In Danish)

/5/ Øresundskonsortiet. The Øresund Link. Dredging Instruction No. 13. Drogden Fairway. Rev. 1. June 1997, approx. 45 pp + annexes. (In Danish)

/6/ Øresundskonsortiet. Øresundskonsortiet's application to the Water Rights Court. June 1997. (In Swedish)

/7/ Danish Ministry of the Environment and Energy, Danish Ministry of Transport, KSÖ 1996. 3rd Semi-Annual Report on the Environment and the Øresund Fixed Link's Coast-to-Coast Installation. 48 pp.

/8/ Øresundskonsortiet, 1997. Report on Environmental Consequences of Future Dredging Work Based on Changed Spillage Rates. (In Danish)

/9/ Øresundskonsortiet, 1997. Report on Planning of Future Dredging Work. (In Danish)

/10/ Øresundskonsortiet, 1997. The Øresund Link. Spillage Measurements for Weeks 31/96-06/97, 1997. Reply to Comments from the Danish and Swedish Inspection Authorities. (In Danish)

/11/ Danish Ministry of Transport, Danish Ministry of the Environment and Energy, 1995. Objectives and Criteria and the Environmental Authorities' Requirements for the Overall Control and Monitoring Programme for the Øresund Fixed Link's Coast-to-Coast Installation. 20 pp.

/12/ Växjö District Court, Water Rights Court, 1995. Permission to build the Swedish section of the Øresund Fixed Link. Judgment No. DVA 37/95, Case No. 45/92. Pronounced in Växjö on 13.07.1995. (In Swedish)

/13/ Øresundskonsortiet, 1997. Plan for Feedback Monitoring in the Period July-October 1997. (In Danish)

/14/ Øresundskonsortiet, 1995. Supplementary Assessment of the Impacts on the Marine Environment of the Øresund Link. 193 pp. (In English)

/15/ SEMAC JV, 1997. Benthic Fauna, Common Mussels, Status Report 1996 (in course of publication).

/16/ SEMAC JV, 1997. Status Report 1996. Benthic fauna - Shallow-Water Fauna (in course of publication).

/17/ SEMAC JV, 1997. Intercalibration of eelgrass (*Zostera marina*) and tassel pondweed (*Ruppia spp.*) studies. 49 pp. (In Danish)

/18/ Danish Ministry of the Environment and Energy, Danish Ministry of Transport, KSÖ, 1996. 2nd Semi-Annual Report on the Environment and the Øresund Fixed Link's Coast-to-Coast Installation. 43 pp.

/19/ SEMAC JV, 1997. Benthic vegetation. Eelgrass, tassel pondweed and sea tangle. Status Report 1996. 102 pp.

/20/ DHI/LIC Joint Venture, 1997. Acoustic Herring School Detection System. Report for the Period July 1996 - May 1997. 44 pp + annexes.

/21/ Leif Nilsson, 1997. Personal Report (report in course of publication). (In Danish)

/22/ Technical Note. Sediment Concentrations off Dragør on 4 and 18 February 1997. Feedback Monitoring Centre, 13 March 1997. (In Danish)

/23/ High Water - Dragør 11 April 1997. Letter to Øresundskonsortiet prepared by DHI/LIC Joint Venture, 1 May 1997. (In Danish)