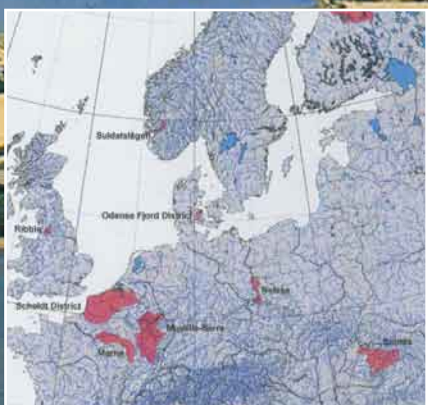
DANISH MINISTRY OF THE ENVIRONMENT

Environment Centre
Odense

Odense Pilot River Basin

Pilot project for river basin management planning

Water Framework Directive Article 13



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Foreword

The present pilot project for river basin management planning in Odense River Basin is the final step in Denmark's contribution to EU testing of the Water Framework Directive through pilot projects in Member States prior to actual implementation of the Directive. The project started in 2002 when the Danish Environmental Protection Agency (EPA) invited Fyn County to carry out the Danish pilot project. Fyn County has thus been responsible for the project on behalf of the Danish EPA, and has collaborated with and reported the project results to the EU. In connection with the 2006 reform of Danish municipal and county administrative structure, county tasks pertaining to water and nature management planning were transferred to the seven new state Environment Centres. Since 1 January 2007, responsibility for the Odense Pilot River Basin project has thus lain with the Environment Centre Odense under the Ministry of the Environment. During the latter period of the project, Environment Centre Odense/Fyn County received financial support from EU LIFE to carry out the pilot project.

The Water Framework Directive was adopted by the EU in December 2000. The Directive lays down the framework for future management of the aquatic environment in the EU Member States. The objective of the Water Framework Directive is to ensure that by 2015 at the latest, all parts of the aquatic environment, i.e. watercourses, wetlands, lakes and coastal waters, achieve "good surface water status" and the groundwater achieves "good groundwater status". This is to be achieved through river basin management plans in which each river basin is treated as a coherent entity. The Water Framework Directive integrates a number of previously adopted directives aimed at specific sources of pollution (e.g. the Wastewater Directive and the Nitrates Directive) or protection of specific waters (e.g. the Bathing Water Directive and the Shellfish Waters Directive), and combines the measures in these directives into an integrated approach.

To facilitate this integrated and ambitious reorganization of EU water policy the EU Water Directors have agreed upon a coordinated strategy for implementation of the Water Framework Directive – the Common Implementation Strategy (CIS). This strategy is subdivided into two phases. Phase I (up to 2004) primarily focused on drawing up and testing a series of EU Guidance Documents. Phase II (2005–2006/07) primarily consisted of gaining experience and developing the methods necessary for establishing monitoring programmes and river basin management plans for the pilot river basins prior to the deadlines specified in the Water Framework Directive, and of gaining experience with specific case studies focussing on selected issues, among others the relationship between the Water Framework Directive and EU Common Agricultural policy (CAP).

The reason for designating Odense River Basin as a pilot river basin was that the basin, which covers a third of Funen, encompasses a broad spectrum of Danish aquatic and terrestrial habitat types, as well as major sources of environmental pressure, e.g. Odense city, Fynsværket CHP Plant and intensive agricultural production. At the same time, the River Odense and Odense Fjord are among the most well studied water bodies in the country.

The Odense Pilot River Basin project has contributed both nationally and internationally to implementation of the Water Framework Directive through a large number of meetings, lectures, articles and reports. Of these, the following should be mentioned:

- Fyn County, 2003: Odense Pilot River Basin. Provisional Article 5 Report pursuant to the Water Framework Directive
- European Commission, Joint Research Centre, 2005: Pilot River Basin Outcome report. Testing of the WFD Guidance Documents.
- Fyn County and COWI, November 2006: Økonomisk analyse af integreret indsatsprogram for Odense Fjord-oplandet. Metodenotat (Economic analysis of an integrated programme of measures for Odense River Basin. Memorandum on methodology).
- Fyn County and COWI, November 2006: Økonomisk analyse af integreret indsatsprogram for Odense Fjord-oplandet. Virkemiddelkatalog (Economic analysis of an integrated programme of measures for Odense River Basin. Catalogue of measures).
- Fyn County and COWI, November 2006: Økonomisk analyse af integreret indsatsprogram for Odense Fjord-oplandet. Resultatrapport (Economic

analysis of an integrated programme of measures for Odense River Basin. Results).

- Environment Centre Odense, 2007: Odense Pilot River Basin. Pilot project for river basin management planning. Water Framework Directive Article 13. Layman's report.
- European Commission, Joint Research Centre, 2007: Pilot River Basin Activity Report, Phase II, 2005–06 (in preparation).
- European Commission, Joint Research Centre, 2007: Experiences in analysis of pressures and impacts from agriculture on water resources and developing a related programme of measures. Report of the Pilot River Basins Group on Agriculture. Phase II period September 2005–December 2006.

The project was carried out as an open process with the participation of two external (national and regional) advisory boards, an external technical expert group and an environmental economics expert group. A large number of stakeholders and institutions have thus followed the project, among others the Funen Municipalities, the Danish Water and Waste Water Association, Danish Agriculture, the Funen Farming Union, Funen Family Farmers' Association, the Confederation of Danish Industries, individual enterprises, the Danish Society for Nature Conservation (national and regional), the Danish Sports Fisher Association, the National Environmental Research Institute, the former Danish Institute of Agricultural Sciences (now the Faculty of Agricultural Sciences, University of Aarhus), the Institute of Food and Resource Economics, the University of Southern Jutland and consulting engineers.

The pilot project is based on the analyses in the above-mentioned Provisional Article 5 Report, which also contains provisional environmental objectives for water bodies and groundwater. Intercallibration of environmental objectives is currently being carried out at EU level to ensure that the same understanding is arrived at throughout the community as regards what is to be understood by for example the term "good ecological status". When the results of this intercallibration are available it can be expected that the criteria used in this project for the Water Framework Directive quality classes will have to be revised for use in the final river basin management plan for Odense River Basin. This will also necessitate adjustments to the choice of measures for achieving the environmental objectives.

The aim of carrying out the present pilot project has been to demonstrate and test the methodology in the Water Framework Directive, from characterization of surface water and groundwater to the establishment of environmental objectives based on reference conditions and the preparation of programmes of measures optimized on the basis of welfare economic analyses and cost-effectiveness. The river basin management plan is a technical plan that establishes the most cost-effective programme of measures for the whole of the aquatic environment within the river basin. Thus no political assessment has been made of whether the total cost of the programme of measures is considered to be disproportionate for society. Moreover, the river basin management plan does not deal with how the programme of measures is to be financed, including whether the programme is to be paid for by the water consumers, the businesses or in some other way. Furthermore, the river basin management plan does not take into account whether or not the necessary legislation is in place to ensure that the programme of measures can be realized.

Work is currently going on at committee level within the Danish Environmental Protection Agency to draw up statutory orders and guidelines establishing the necessary legislative and scientific basis for forthcoming river basin management planning in Denmark. As this was not in place when the present pilot project started, the present analyses must be considered provisional analyses that it will to some extent be necessary to adjust when work on the national legislative and scientific basis has been completed. In addition, the river basin management plan is not complete as time constraints have meant that it has sometimes only been possible to determine the magnitude of the necessary measures on the basis of expert judgement/experience.

The authors hope that the present "near realistic" example of a river basin management plan will serve as a source of inspiration for river basin district authorities in both Denmark and abroad in the coming years when they have to undertake comprehensive aquatic environment planning.

Environment Centre Odense would like to take this opportunity to thank the members of the two project advisory boards, the external technical expert group and the environmental economics expert group, as well as employees of the EU Commission and the Joint Research Centre for their great interest in the project and for inspiring cooperation throughout the project period. Finally, we wish to express our great appreciation to employees of the former Funen County who have made a considerable contribution to the project.

Ministry of the Environment, Environment Centre Odense, May 2007

1. Introduction and summary

The present pilot project for river basin management planning in Odense River Basin has been carried out pursuant to Articles 11 and 13 of the Water Framework Directive. These articles concern the preparation of programmes of measures and river basin management plans aimed at achievement of the environmental objectives specified in Article 4 of the directive. The pilot project is based on the Provisional Article 5 Report prepared during the first phase of the Odense Pilot River Basin project. Among other things, this included characterization of surface water and groundwater, provisional environmental objectives, risk assessment and economic analysis of water use.

The pilot project attempts to provide an example of how a river basin management plan can be prepared following the guidelines specified in the Water Framework Directive.

The report thus describes the river basin and the pressures on and status of the water bodies, and provides examples of environmental objectives. These sections largely summarize the Provisional Article 5 Report. The measures and interventions necessary to ensure achievement of the environmental objectives are presented for watercourses, lakes, wetlands, groundwater and coastal waters. Thereafter a catalogue of measures has been prepared that identifies more than 40 measures aimed at reducing pressure on the water bodies. The effectiveness and unit cost of each of these measures have been determined. The programme of measures for achieving the provisional environmental objectives has been arrived at on the basis of economic analyses of cost-effective measures for achieving the objectives for the water cycle in the river basin as a whole. The programme of measures is subdivided into basic measures and supplementary measures. The basic measures consist of the measures running up to 2012 that pursuant to EU directives (among others the Nitrates Directive and the Wastewater Directive), national aquatic environment plans, Regional Plans and municipal wastewater plans have already been adopted and in certain cases implemented but not completed. The supplementary measures, which comprise the actual programme of measures pursuant to the Water Framework Directive, are intended to ensure achievement of the environmental objectives by 2015. Guidelines and a timetable for implementation of the programme of measures by the authorities are also provided in the report, which rounds off with a description of the monitoring programme and a chapter describing public participation in the project pursuant to Water Framework Directive Article 13, Annex VII.

The project also includes an assessment of the measures needed to ensure achievement of the environmental objectives for terrestrial natural habitats, including Nature 2000 sites, the aim being that the programme of measures for the water bodies also contributes to achievement of the environmental objectives for terrestrial natural habitats.

The Danish Environmental Objectives Act, which legislatively implements the Water Framework Directive in Denmark, requires Municipalities to draw up an action plan to implement the management plan within their geographic boundaries based on the state river basin management plan. Annex 5 of the present report provides an example of how the programme of measures for Odense River Basin can be implemented at the municipal level in accordance with specified criteria in that it shows the calculations for basic and supplementary measures for one specific municipality in the river basin.

It is important to emphasize that the present project is a pilot project intended to demonstrate how the planning process required by the Water Framework Directive can be carried out from the initial establishment of (provisional) environmental objectives to the calculation of how the environmental objectives can be achieved most cost-effectively for the water cycle as a whole, i.e. watercourses, lakes, mires, groundwater and coastal waters. In the project, importance has been accorded to testing the methodology of the Water Framework Directive planning process. This has made it necessary to operate with provisional environmental objectives, even though the EU intercallibration process for environmental objectives has not yet been concluded. Thus no account has been taken of how the final environmental objectives are to be established. For the same reason, no account has been taken of to what extent the derogation provisions of the Water Framework Directive are to be utilized since such decisions relate to the environmental objectives and the resultant economic consequences.

The present example of a river basin management plan is intended to be as realistic as possible and the reference values and criteria for water body quality classes are therefore used without in each case specifying that the values are those proposed by the former Fyn County based on the level of protection specified in the County's Regional Plan adjusted to the classification system used in the Water Framework Directive.

1. Introduction and summary

Summary

The results of the pilot project can be summarized as follows:

- The most cost-effective programme of measures for achieving the specified (example) environmental objectives for watercourses, lakes, wetlands, groundwater and coastal waters (Odense Fjord) in Odense River Basin entails an economic cost of DKK 94 million per year, of which approx. DKK 44 million is for reducing diffuse nutrient and pesticide loading from agriculture, approx. DKK 10 million is for reducing physical pressure on watercourses and approx. DKK 40 million is for reducing pressure from point sources. The corresponding budget cost is approx. DKK 65 million per year.

- The hitherto adopted measures (EU directives, national aquatic environment plans, the Regional Plans for 2005–2013 and the municipal wastewater plans) will cost DKK 126 million per year, of which DKK 118 million is allocated to relieving pressure from point sources.

- The current total costs for water use in the river basin are DKK 612 million per year.

- The programme of measures will increase the costs of water use by 0.5–0.6% of the total production value/income in the river basin.

- For technical and economic reasons the majority of the culverted watercourses are not encompassed by the programme of measures for this plan period. The same applies to reclaimed lakes and marine waters. Based on qualitative considerations it is assessed that achievement of "good surface water status" in these water bodies during the present plan period would entail disproportionately high costs. The water bodies in question will thus remain as heavily modified water bodies during the present plan period and decisions on environmental objectives and associated measures will be postponed until the next plan period.

- There is some uncertainty regarding the establishment of reference conditions, especially for lakes, it having been shown that parameter values could be elevated locally even in for example the Middle Ages. This could be due to the early impact of society or to natural conditions. In certain cases it is therefore recommended to establish site-specific criteria for good surface water status rather than type-specific criteria.

- The programme of measures will entail taking 19% of the arable land in the river basin out of production. The proportion of the river basin under crop rotation will thus be reduced from 65% at present to approx. 52% in 2015. Approximately half of the arable land taken out of crop rotation (9%) will be converted to permanent grassland, primarily with a view to protecting groundwater in highland areas. The other half will be converted to wetland/meadows (8%) or to woodland (2%). Thus it will remain possible to utilize approximately 3/4 of the arable land taken out of crop rotation for extensive agricultural production while concomitantly increasing the proportion of uncultivated countryside from the present approx. 6% of the river basin to approx. 16%.

- A large proportion of the agriculture-related measures concern the set-aside of arable land in the river valleys for the re-establishment of wetlands and the establishment of buffer zones alongside watercourses, and in certain cases for watercourse restoration projects. These measures will concomitantly reduce nutrient loss, improve the physical state of the watercourses and enhance the contiguity of natural ecosystems.

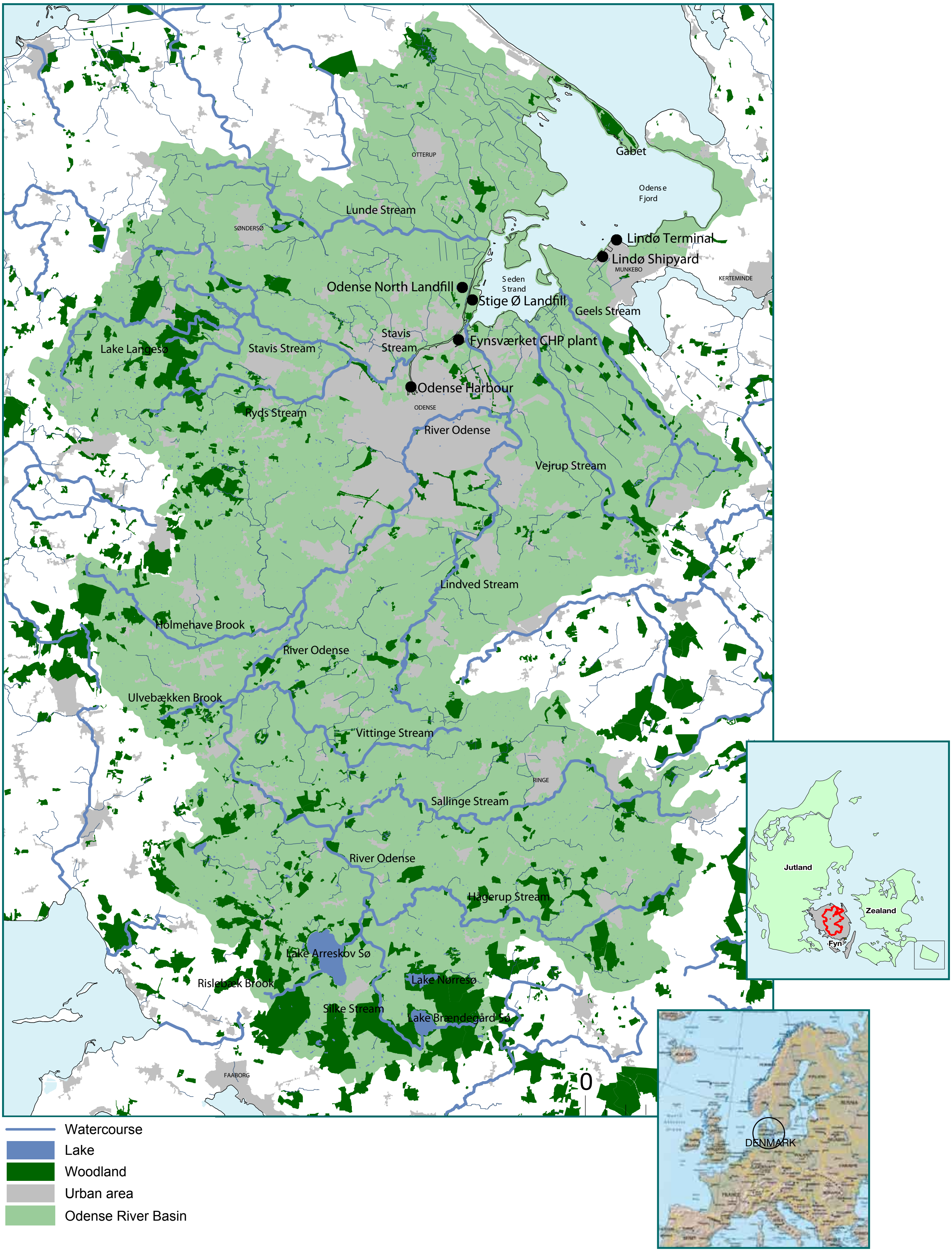
- Achievement of the environmental objective for terrestrial natural habitats (favourable conservation status) pursuant to the Habitats Directive will increase the costs by DKK 7 million per year plus the costs for reducing ammonia emissions.

- A considerable synergy effect (savings of DKK 21 million) is achieved by integrated implementation of the Water Framework Directive and Habitats Directive.

- If the value of the environmental benefits is taken into account, the economic gains can be expected to be considerable because the programme of measures creates considerable new "recreational" nature.

The northern part of Odense River Basin viewed from the south towards Odense city. The River Odense can be identified as a "green corridor" running from the lower right-hand corner up through the centre of the photograph. Odense Fjord can be seen at the top of the photograph in the distance. Photograph: Jan Kofod Winther.

Odense River Basin



2. Description of the river basin

Landscape and soil type

Odense River Basin (Figure 2.1) encompasses an area of approx. 1,050 km² and includes approx. 1,015 km of watercourse. The River Odense, which is about 60 km long and drains a catchment of 625 km², is the largest river on Funen. There are approx. 2,620 lakes larger than 100 m² in Odense River basin. Together these lakes cover an area of 1,106 ha, corresponding to approx. 1% of the river basin. By far the majority of the lakes are small, over 1,500 of them being smaller than 1,000 m² and only 21 of the lakes in the river basin being larger than 3 ha. Odense Fjord, including the inner fjord called Seden Strand, is a shallow fjord with a water surface area of approx. 60 km². The River Odense comprises by far the largest freshwater input to the fjord. The water exchange between the fjord and the adjacent marine waters takes place through the narrow opening called Gabet out towards the northern Belt Sea. The residence time in the fjord is low, the annual mean for the whole fjord being approx. 17 days.

The present landscape of Funen was largely created during the last Ice Age 11,500 to 100,000 years ago. The most common landscape feature is moraine plains covered by moraine clay that was deposited by the base of the ice during its advance. The meltwater that flowed away from the ice formed meltwater valleys. An example is the Odense river valley, which was formed by a meltwater river that had largely the same overall course as today's river.

The clayey soil types are weakly dominant and encompass approx. 51% of the river basin, while the sandy soil types cover approx. 49%. The moraine soils of Funen are particularly well suited for the cultivation of agricultural crops. Agriculture has therefore left clear traces in the landscape. Deep ploughing, liming and other practices have thus rendered the surface soils more homogeneous.

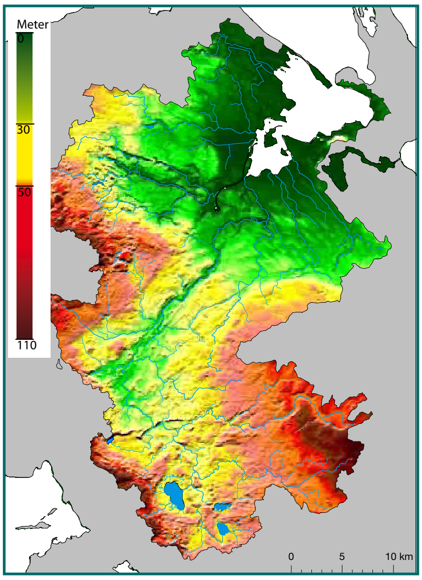


Figure 2.1
The topography of Odense River Basin.

Odense River Basin
Key figures

Catchment area 1,050 km²

Population

• Total (thousands)	246
• Density (inhab./km²)	234

Land use (percentage)

• Built-up areas	16
• Farmland	68
• Woodland	10
• Natural/seminatural countryside	6

Crops (percentage)

• Winter cereals	45
• Spring cereals	23
• Seed crops	8
• Pulses	2
• Grass/green fodder	10
• Permanent grassland	4
• Root crops	5
• Market gardens	3

Fertilizer consumption, nitrogen (tonnes N)

• Manure	5,000
• Commercial fertilizer	6,400
• Total	11,400

Fertilizer consumption, phosphorus (tonnes P)

• Manure	1,370
• Commercial fertilizer	530
• Total	1,900

Climate and hydrology (annual means)

• Precipitation (mm)	825
• Freshwater runoff (mm)	305
• Temperature (°C)	8.4

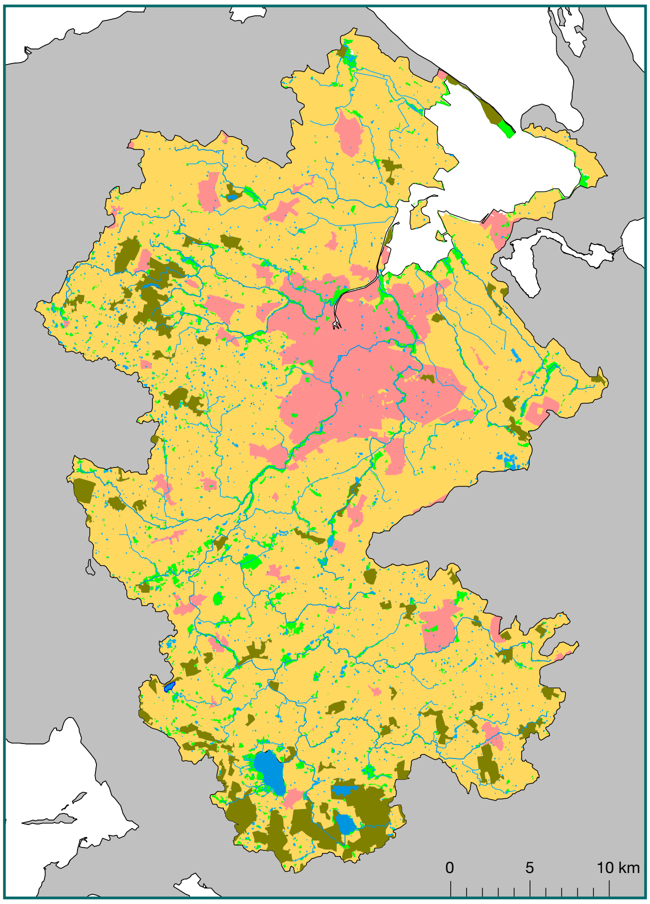


Figure 2.2
Land use in Odense River Basin.

Built-up areas
Arable land
Woodland
Inland waters (lakes, watercourses)
Natural habitats (mires, meadows, etc.)

Land use, population and wastewater

Just as elsewhere in Denmark, land use in Odense River Basin is dominated by agricultural exploitation of the soil (Figure 2.2). Farmland thus accounts for 68% of the river basin. Of the remainder, approx. 16% is accounted for by urban areas/roads, 10% by woodland, and 6% by natural/seminatural countryside (i.e. meadows, mires, dry grassland, lakes and wetlands protected by Section 3 of the Protection of Nature Act). The corresponding figures for Denmark as a whole are farmland 62%, woodland 11% and natural/seminatural countryside just over 9%.

The population of Odense River Basin numbers approx. 246,000, of which approx. 182,000 inhabit the city of Odense (Figure 2.3), which is Denmark's third largest city. Ninety percent of the population in the river basin discharge their wastewater to a municipal wastewater treatment plant. The remaining 10% of the population live outside the towns in areas not serviced by the sewerage system. A total of approx. 6,900 residential buildings are located in these sparsely built-up areas outside the sewerage system catchments.

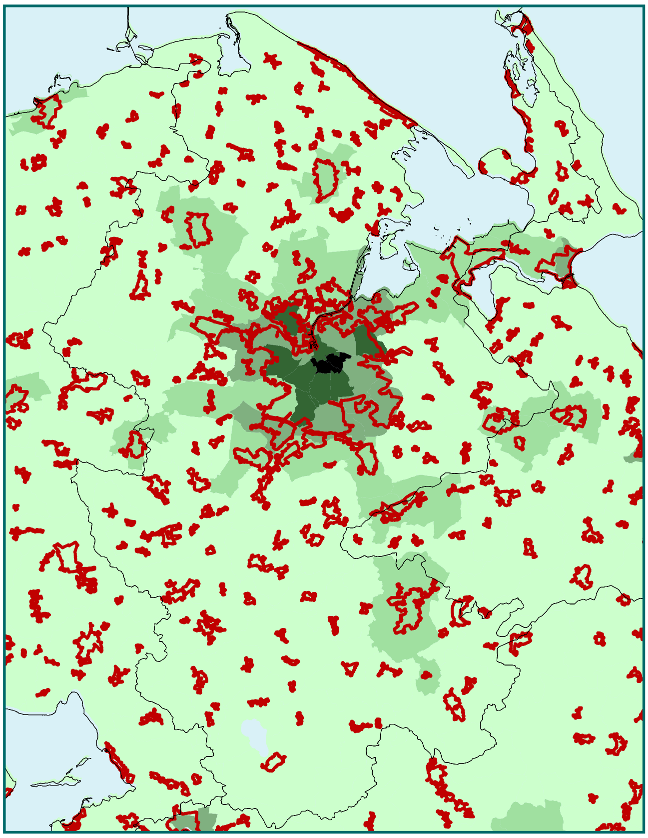
Due to the increasing industrialization and the spread of water-flushed toilets at the beginning of the 20th Century, the amount of wastewater discharged into the water bodies of Funen from towns, dairies, abattoirs, etc. increased markedly. In the 1950s, moreover, agriculture really started to pollute the aquatic environment through the discharge of silage juice, slurry and seepage water from manure heaps. Later the many dairies and abattoirs were closed down through centralization, and serious efforts were initiated to treat urban wastewater. The main progress came in the 1980s and early 1990s, which saw marked improvement in the treatment of urban and industrial wastewater and the cessation of unlawful agricultural discharges of silage juice, etc.

Figure 2.3
Population density in Odense River Basin.

Population density (inhabitants/km^2)

0	to 150
150	to 500
500	to 1,500
1,500	to 3,500
>3.500	

Urban areas



Agriculture

In 2000, there were approx. 1,870 registered farm holdings in Odense River Basin, of which approx. 960 were livestock holdings. The livestock herd in the river basin numbered approx. 60,000 livestock units (1999–2002), of which 59% was accounted for by pigs, 37% by cattle and 4% by other livestock. Livestock density averages 0.9 livestock unit per hectare farmland, corresponding to the national average. Livestock density in the individual subcatchments of Odense River Basin varies somewhat, however (Figure 2.4).

Overall, livestock production in the river basin has increased in recent years. However, this increase masks a decrease in livestock production in the cattle sector and a marked increase in pig production. Based on the applications submitted to the authorities for expansion of livestock herds and the sector's own expectations, livestock production is expected to increase further in the coming years.

The predominant crop in the river basin is cereals (approx. 2/3 winter cereals), encompassing 63% of the arable land, while 10% is permanent grassland. The concentration of market gardens is relatively high in Odense River Basin, accounting for approx. 3% of the arable land.

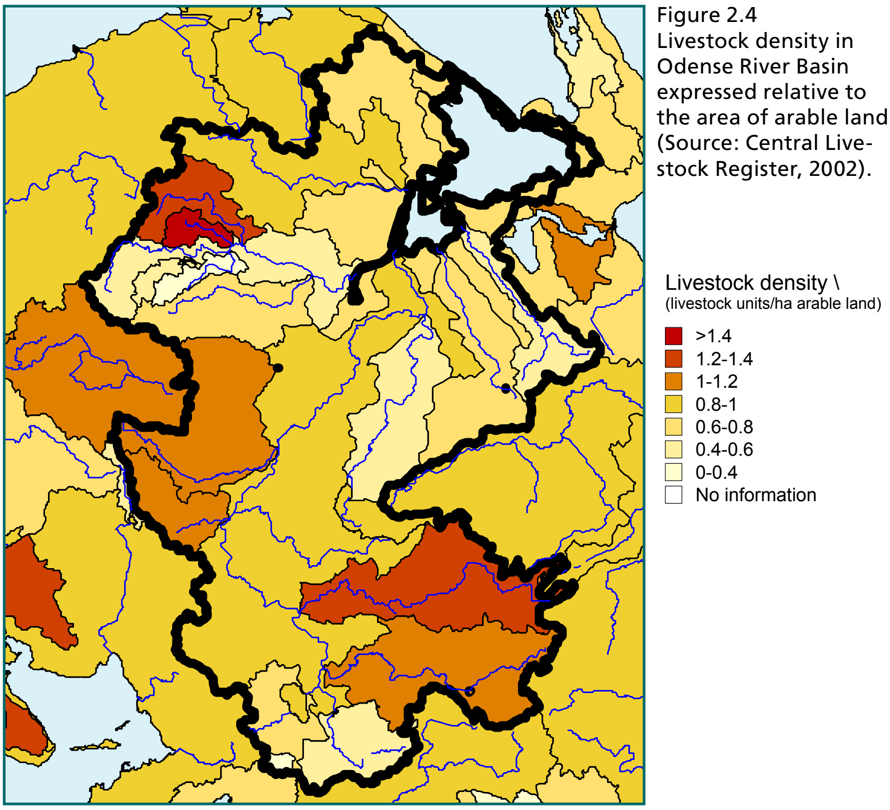


Figure 2.4
Livestock density in Odense River Basin expressed relative to the area of arable land. (Source: Central Livestock Register, 2002).

The River Odense at Borreby. Photo: Jan Kofod Winther.

Artificial drainage and land reclamation in the river basin

It is estimated that artificial drainage has been established on at least 55% of the arable land in Odense River Basin over the past 50–100 years. This has been done to ensure rapid drainage of the arable land and optimize the possibilities to cultivate it. In addition, mires, meadows, watercourses and shallow lakes and fjord sections have undergone considerable physical modification or have completely disappeared as a result of land reclamation for agricultural purposes. Thus 72% of the former large meadows and mires in Odense River Basin have disappeared over the past 100 years. A large proportion of the former meadows/mires in the river valley have been converted to arable land through watercourse regulation and regular watercourse maintenance. Thus long reaches of the River Odense are highly physically modified. Moreover, many watercourses and ditches have been culverted, and a large proportion of the watercourses have been channelized.

Correspondingly, the number of small lakes and ponds has decreased considerably. Since the end of the 19th Century, 13 large lakes in Odense River Basin have been drained. The area of water surface in Odense Fjord has decreased by approx. 30% since the 1770s, and the former fjord bed has been converted to farmland through dyking and drainage.

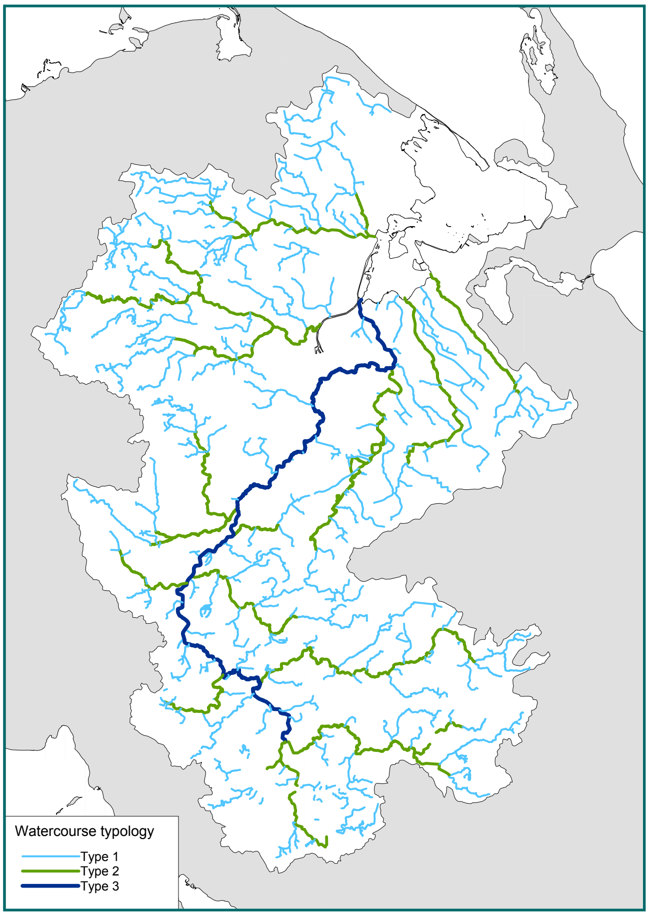
All in all, land reclamation, drainage of wetlands and the establishment of field drainage over the past decades have considerably reduced the self-cleansing ability of Odense Fjord and the river basin. However, planned and to some extent already completed re-establishment of wetlands and restoration of watercourses is expected to enhance nutrient retention and turnover in the coming years.

Pump station at Lumby Strand. Photo: Bjarne Andresen.

2.1 Location, typology and demarcation of the water bodies

This section of the report summarizes the location, typology and demarcation of the water bodies. The aim of typology is to assign the water bodies to groups having relatively uniform natural reference conditions (Section 2.2).

Figure 2.5
Chart showing the typology of watercourses in Odense River Basin.



Watercourses

The watercourses in the river basin are typical lowland watercourses (defined by a terrain elevation of less than 200 m). Viewed from the international perspective they are all very small (Table 2.1). The total length of watercourse is just over 1,000 km. The largest watercourse is the River Odense (catchment area 625 km^2), the main course of which is just under 60 km long and up to 30 m wide. Watercourse density in the river basin as a whole is currently approx. 1.0 km/km^2. The original (natural) density of the watercourse network probably used to be somewhat greater (up to 50% greater), but watercourse regulation and culverting have reduced the density. The very small watercourses account for a considerable proportion of the total watercourse network and comprise an important part of the watercourse ecosystems (Section 4.1).

The River Odense. Photo: Erik Vinther.

Odense Å. Foto: Erik Vinther.

2.1 Location, typology and demarcation of the water bodies

Watercourse size distribution			
Width (m)	≤2	2–10	>10
Length (km)	671	302	42
Proportion of total length (%)	66	30	4

Table 2.1
Summary of the size distribution of watercourses in Odense River Basin.

Watercourse typology		
Typology	No. of km (water bodies)	%
Type 1	662 (225)	65 (71)
Type 2	216 (45)	21 (14)
Type 3	53 (11)	5.2 (3.5)
Type a	84 (35)	8.3 (11)
Total	1,015 (316)	-

Table 2.2
Summary of the typology criteria used to assign the watercourses to types. The watercourses in the river basin all lie east of the glacial boundary.

Watercourse typology		
Typology	No. of km (water bodies)	%
Type 1	662 (225)	65 (71)
Type 2	216 (45)	21 (14)
Type 3	53 (11)	5.2 (3.5)
Type a	84 (35)	8.3 (11)
Total	1,015 (316)	-

Table 2.3
Summary of the typology (reach length and number of water bodies) of watercourses in Odense River Basin.

The watercourses are subdivided into types according to criteria that include watercourse width, catchment area and distance to source (Table 2.2). The size distribution of watercourses in Odense River Basin is shown in Table 2.1 and the typology in Figure 2.5 and Table 2.3. In addition to types 1–3, the designation “a” is used for watercourses that are artificially constructed and which therefore fall outside the normal typology. The watercourse network is further subdivided into 316 water bodies (Table 2.3), each of which encompasses reaches with a relatively uniform ecological state. The individual riverine water bodies in the river basin vary in length from under 1 km to 15 km (Figure 2.6).

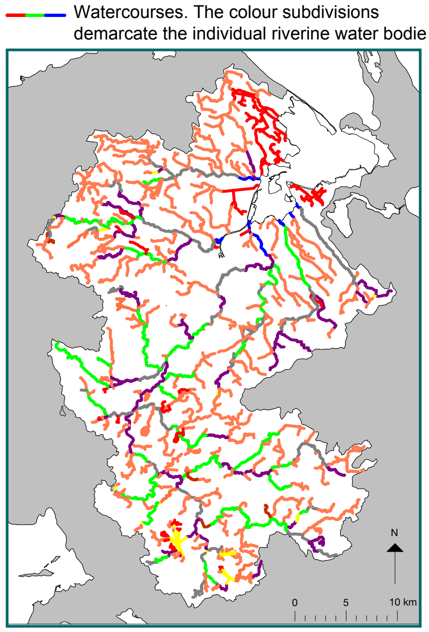


Figure 2.6
Chart showing the subdivision of the watercourses in Odense River Basin into water bodies.

The River Odense downstream of Brobyværk. An unregulated reach. Photo: Jan Kofod Winther.

Lakes

There are a total of 2,620 lakes larger than 100 m^2 in Odense River Basin. Together they cover an area of approx. 11 km^2, corresponding to 1% of the total area of the river basin. All lakes larger than 100 m^2 are encompassed by the river basin management plan, but the emphasis is on the large lakes. Fourteen of the lakes are larger than 5 ha, with the 317 ha Lake Arreskov being the largest. The size distribution of the lakes is shown in Table 2.4.

Pursuant to the Environmental Objectives Act the lakes are subdivided into types based on their alkalinity, humic content, colour, salinity and mean depth[1]. The typology has been determined for 17 lakes in the river basin. Their location and typology are shown in Figure 2.7. By far the majority (14) belong to the high alkalinity, low humic content, freshwater, shallow type of lake. In addition, one high humic content lake (Lake Sortesø) and two deep lakes (both gravel quarry lakes) have been identified.

Lake Brahetrolleborg Slotssø arose as a mill pond in the River Silke. In the Provisional Article 5 Report it is therefore characterized as a heavily modified water body.

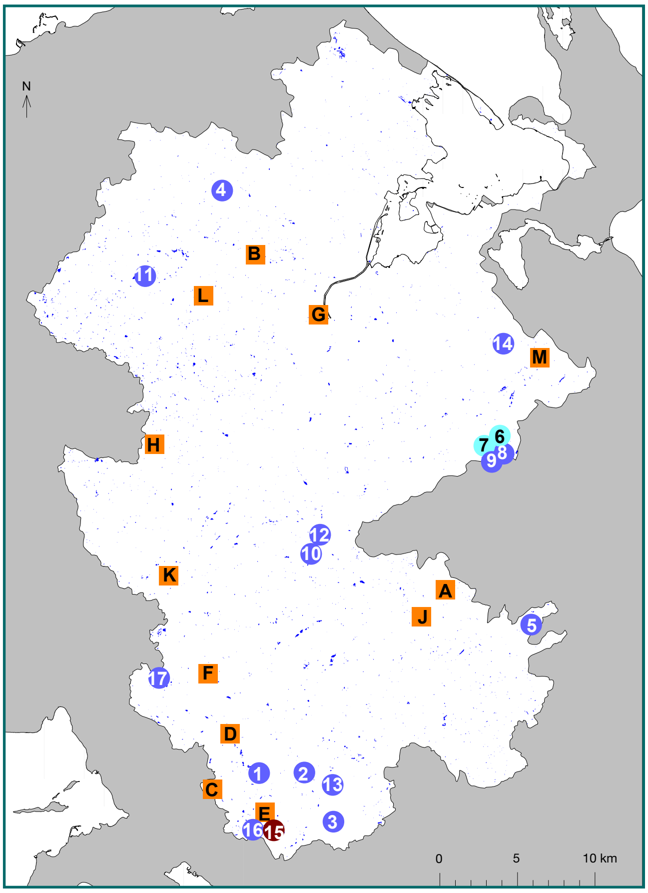
Another 12 former lakes that have been drained since the 19th Century are also characterized as heavily modified water bodies (Figure 2.7). Two of these have subsequently been partially re-created as part of nature restoration projects (Lake Hammerdam north of Faaborg and Lake Ringe Sø).

Søer Størrelsesfordeling

Lake size distribution				
Size	**No.**	**Total area (ha)**	**Investigated No.**	**%**
>5 ha	14	606	11	79
>3 ha	21	639	11	52
>1 ha	97	767	20	21
>0.5 ha	228	858	27	12
>0.1 ha	1,058	1,032	50	5
>100 m²	2,620	1,106	63	2

Table 2.4
Number and total area of lakes of various size classes in Odense River Basin.

Lakes in OPRB indicating lake type



Name:

1 Lake Arreskov Sø
2 Lake Brahetrolleborg Slotssø
3 Lake Brændegård Sø
4 Lake Dallund Sø
5 Lake Fjellerup Sø
6 Gravel quarry lake No. 1
7 Lake Davinde Sø (gravel quarry lake No. 1.1)
8 Gravel quarry lake No. 7.1
9 Gravel quarry lake No. 7.9
10 Lake Hovlung v. Nr. Søby
11 Lake Langesø
12 Lake Nr. Søby Sø (Søby Søgård Sø)
13 Lake Nørresø
14 Lake Sellebjerg Sø
15 Lake Sortesø
16 Lake Store Øresø
17 Lake Søbo Sø

A Lake Breddam
B Lake Broby Sø
C Lake Hammerdam
D Lake Hellebjerg Dam
E Lake Langedam
F Lake Nydam
G Lake Næsbyhoved Sø
H Lake Ravedam
J Lake Ringe Sø
K Lake Sølung Sø
L Lake Trøstrup Sø
M Lake Urup Dam

Lake type
- Type 9: High alkalinity, low humic content, freshwater, shallow
- Type 10: High alkalinity, low humic content, freshwater, deep
- Type 6: Low alkalinity, high humic content, freshwater, deep
- Drained lake
- Other types of lake

Figure 2.7
Seventeen lakes in Odense River Basin indicating the lake type. Numerous small lakes of unknown lake type are also indicated, as are 12 lakes that have been drained since the 19th Century.

Lake Langesø. Photo: Bjarne Andresen.

1] Statutory Order No. 811 of 15/07/2003 on the characterization of water bodies, determination of pressures and charting of water resources.

Wetlands

Odense River Basin presently contains 2,203 ha of mire, 1,743 ha of freshwater meadow and 481 ha of coastal meadow distributed over 1,500 localities (Figure 2.8). Compared with the country as a whole the wetland habitat types are relatively weakly represented in Odense River Basin.

Studies performed by Fyn County show that the area of mire, freshwater meadow and coastal meadow has decreased by approx. 70% since the 1940s and currently only accounts for approx. 5% of the river basin. As a result of this trend the large contiguous areas of natural countryside have become much smaller and lie isolated from each other separated in particular by arable land. Approx. 55% of the localities are thus smaller than 1 ha. Small, isolated areas of natural countryside are unable to maintain the same flora and fauna as large contiguous areas of natural countryside. Since the end of the 19th Century, moreover, numerous plant species associated with wetland habitats have died out on Funen.

Odense River Basin contains many of the types of mire found on Funen and some of the most valuable mires on Funen. These include the only two raised bogs on Funen – Storelung and Nybo Mose – as well as the largest and best developed rich fen – Urup Dam. These three mires are all located within Natura 2000 sites.

Alongside Odense Fjord there are small areas with a naturally elevated seabed and large dyked-in areas where the remains of coastal meadows and rich fens can be found. Kærby Fed in the southern end of the fjord is an example of a large dyked-in coastal meadow. There are a few coastal meadows that are not affected by drainage/reclamation, for example the coastal meadows at the base of Enebærodde Spit and on the eastern side of Stige Island.

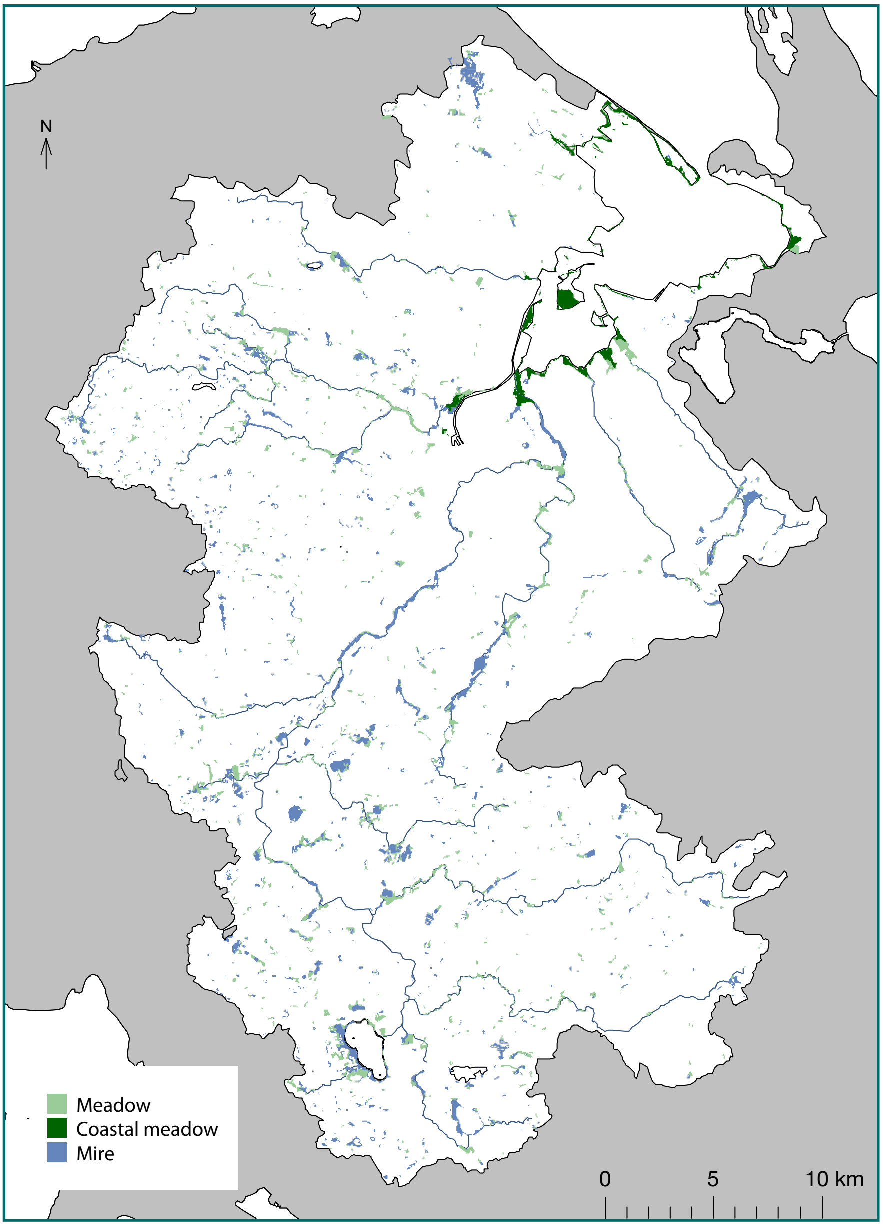


Figure 2.8
Distribution of mires, freshwater meadows and coastal meadows in Odense River Basin.

Coastal meadows are typically located on the coast and are subject to regular tidal flooding. Some coastal meadows have arisen as dyked-in marine waters that have been drained by pumping. The coastal meadows are often grazed by cattle or sheep. If grazing ceases, the coastal meadows become overgrown with common reed and sea club-rush, and a reed swamp develops. The photograph shows a grazed coastal meadow with tidal channels. Photo: Leif Bisschop-Larsen.

Mires are wet terrestrial natural habitats such as raised bogs, reed swamps, swamp forests and various types of fen, some of which are maintained with the help of grazing. The photograph shows a grazed rich fen containing many specimens of western marsh orchid. Photo: Leif Bisschop-Larsen.

Freshwater meadows are damp terrestrial natural habitats that are typically exploited for grazing or haymaking. They can contain a diversity of species, but some "cultural meadows" are both drained and fertilized and only contain a few plant species. The photograph shows a freshwater meadow in the foreground at Urup Dam. Photograph: Erik Vinther.

2.1 Location, typology and demarcation of the water bodies

Coastal waters

Odense Fjord is located in the area of the northern Belt Sea, which is part of the transitional zone between the world's largest estuary, the brackish Baltic Sea (salinity 3–8 PSU) and the salty North Sea (salinity 32–35 PSU).

Odense Fjord, which has a water surface area of approx. 60 km^2, is generally shallow (mean depth approx. 2.25 m) and consists of a small inner fjord (Seden Strand) and a larger outer fjord. A shipping fairway runs from Odense Harbour on through the outer fjord to the small outlet of the fjord at Gabet (Figure 2.9).

Water exchange mainly takes place through Gabet, which is a prolongation of a small 7–11 m deep shipping fairway from Odense Harbour. Most of the fresh water entering the fjord derives from the River Odense. The high freshwater input, the tide and the currents created by the difference in the salinity of the fjord and that of the open sea together result in very dynamic water exchange. The residence time of the fjord water is thus relatively short – around 7 days during the winter and higher during the summer when freshwater input is low.

The two water bodies that comprise Odense Fjord differ in typology. Seden Strand is characterized by fresh water (mesohaline, salinity 5–18 PSU) and is fully mixed. The outer fjord is more salty (polyhaline, salinity greater than 18 PSU) and stratified. In addition, Odense Fjord as a whole is highly affected due to the freshwater runoff, for example by high nutrient loading. As a consequence of these various factors, Seden Strand is classified as type M4 and the outer fjord as type P3[1].

Together with Seden Strand, the western part of the outer fjord has been designated as an international protected area (Natura 2000 site). The fjord can thus be subdivided into three large water bodies – Seden Strand and the western and eastern parts of the outer fjord. In addition, there are 17 heavily modified water bodies (harbours, dyked-in areas, shipping fairways, etc.) giving a total of 20 water bodies in all (Figure 2.9).

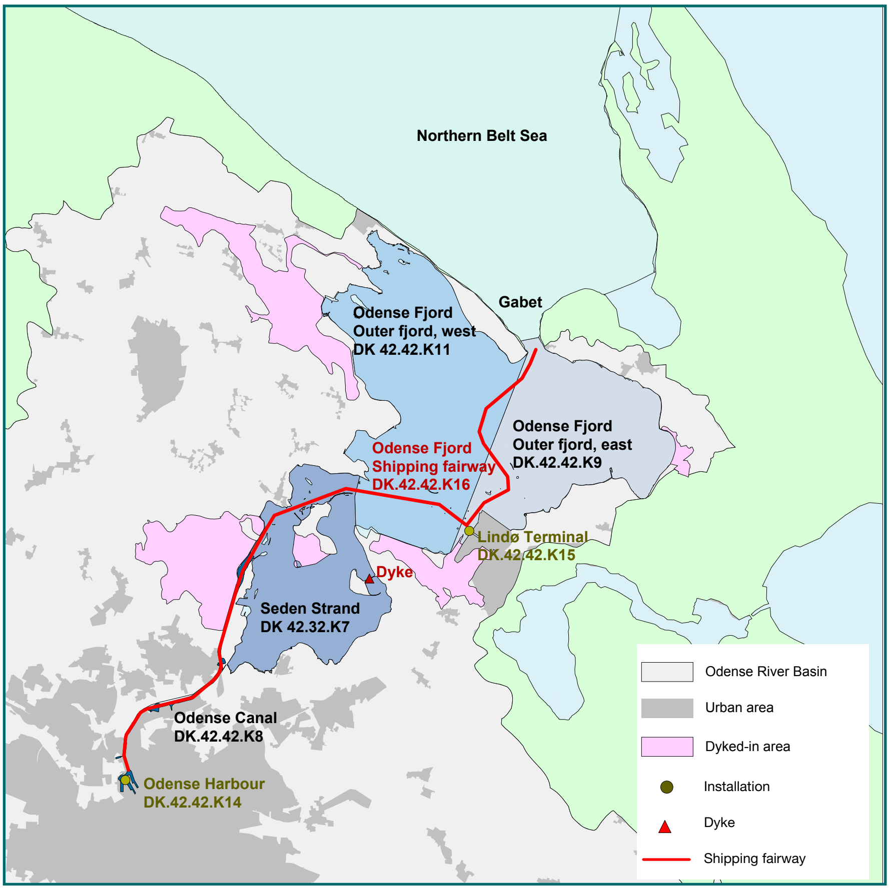


Figure 2.9
Water bodies in Odense Fjord, including identified heavily modified water bodies.

1] Danish EPA Guideline No. 2/2004. Characterization of water bodies and determination of pressures.

Odense Canal. Coal transport to Fynsværket CHP Plant. Photo: Nils Daell Kristensen.

Odense Fjord viewed towards Boels Bro hill. Photo: Birgit Bjerre Laursen.

Odense Fjord. Morning atmosphere at Klintebjerg. Photo: Bjarne Andresen.

2.1 Location, typology and demarcation of the water bodies

Groundwater

Thirty-six groundwater bodies have been identified within Odense River Basin: Together these cover an area of 722 km², corresponding to 69% of the total area of the river basin (Figure 2.10).

Nearly all the groundwater bodies are located in sand aquifers.

The majority of the groundwater bodies (29) are in contact with surface waters, typically with lakes and watercourses. As a consequence, the quality and quantity of the groundwater can influence the quality and environmental status of the surface water bodies.

Of the groundwater bodies that are in contact with surface waters, 26 are in contact all year round, and the remaining three are only in contact during the winter period.

Aquifers

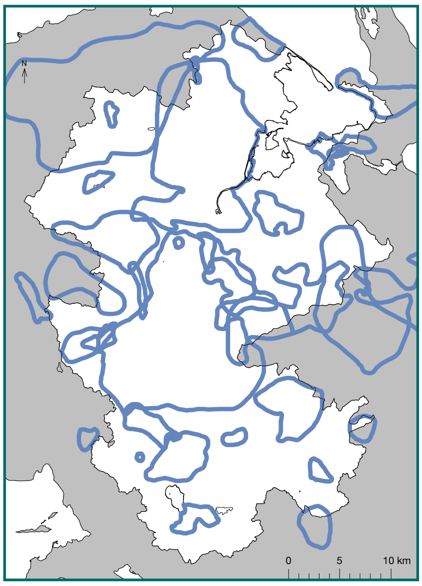


Figure 2.10
Groundwater bodies identified in Odense River Basin.

Water well. Photo: Troels Kjærgaard Bjerre.

2.2 Reference conditions for the various types of water body

Reference conditions for a water body define the status that the water body would have if it were unaffected by human activities. This status is to be used as the basis for classifying the water body's present ecological status (high, good, moderate, poor or bad, cf. the definitions in Chapter 5).

Watercourses

The data for describing the reference status of Danish watercourses is generally flimsy. Comparison of the historic data and current data for macroninvertebrates in Funen watercourses shows for example that there are clear differences between the old (historical) and new data sets. Thus it is not possible – even at the most pristine of the stations – to find a macroinvertebrate fauna that is fully comparable to the fauna present in the past. The reason for the lack of suitable reference data is that the flora and fauna have become considerably impoverished as a result of man's activities, especially over the past 100 years (see Chapter 3).

A good initial proposal for reference conditions for Funen watercourses is therefore the conditions pertaining in reaches with a natural course, good hydraulic contact with the surroundings, no or only very extensive exploitation of the surrounding land, generally varied physical conditions in and around the watercourses, clean water with a low content of nutrients and easily degradable organic matter (Table 2.5), and a natural varied flora and fauna both in and around the watercourses. The plants, macroinvertebrates and fish considered to be characteristic for the various types of reference watercourse on Funen are listed in Annex 1.

Classified on the basis of the macroinvertebrate fauna, a reference watercourse will belong to fauna class 7 (scale 1 to 7). Classified on the basis of physical conditions, a reference watercourse will have a physical index close to 1 (relative scale from 0 to 1).

The Traunskov outlet, which flows into Lake Lange, is a small watercourse of type 1.
Photo: Frank Gert Larsen.

Watercourses – Reference values	
Parameter (unit)	Value
NH_x-N (mg/l)	<0.05
NO_x-N (mg/l)	<0.8
Total-N (mg/l)	<1.0
PO_4-P (mg/l)	<0.020
Total-P (mg/l)	<0.030
BOD_5 (mg/l)	<0.5
Fauna class (DSFI)	7
Physical index (0–1)	0.81–1.0

Table 2.5
Reference values for watercourses.

Lakes

All the lakes in Odense River Basin are to a greater or lesser extent affected by human activity and therefore differ from the reference conditions. The lakes that are closest to reference conditions as regards water chemistry are relatively newly excavated gravel quarry lakes that have filled with groundwater and do not receive nutrient-rich surface water from the surroundings. The groundwater can also be affected, though, for example by a raised nitrate concentration.

Thus nothing is known about reference conditions for the majority of the lakes in the area. Based on conditions in clean Danish and foreign lakes, the National Environmental Research Institute has drawn up proposed values for reference conditions in three types of Danish lake (larger than 1 ha) (see Table 2.6).

In many cases the reference conditions correspond to the conditions pertaining in the lakes prior to 1850. Studies of plant and algal remains in the sediment of a number of Funen lakes (palaeolimnological studies[1]) indicate that reference conditions can sometimes differ from the values shown in Table 2.6. Until the end of the Bronze Age, for example, the phosphorus concentration in Lake Dallund Sø seems to have been 0.020–0.040 mg/l, whereafter it increased in connection with cultivation of the catchment. It decreased again to the same low level, but increased again in the Middle Ages in connection with renewed intensification of agricultural production. Far back in time, the nutrient concentration in the lake was thus elevated due to human activities such as cultivation and deforestation in the catchment and use of the lake for hemp retting.

In Lake Nørresø the phosphorus concentration around 1850 was approx. 0.030 mg/l. In Lake Langesø the phosphorus concentration was already high (0.135 mg/l) in 1850 due partly to the presence of a large farm close to the lake. Studies indicate, though, that the phosphorus concentration in the lake was also high before 1850, perhaps due to inflow of naturally phosphorus-rich groundwater. In that case the reference concentration of phosphorus could be considerably higher than the value given in Table 2.6.

Based on measurements made in pristine watercourses on Funen and elsewhere in Denmark it is believed that the natural background concentration of phosphorus in unaffected watercourses on Funen is typically 0.050 mg P/l. If the water that flows into the lakes has this phosphorus concentration it can be calculated using simple models that the background concentration of phosphorus in these lakes will typically lie between 0.030 and 0.040 mg P/l, and will only be lower in special cases. The lowest measured phosphorus concentration in a lake on Funen is 0.023 mg P/l (summer mean) in a gravel quarry lake. The indication is thus that the reference concentration of phosphorus in the lakes will often be higher than the value shown in Table 2.6.

Assessment of lake status pursuant to the Water Framework Directive is primarily to be based on biological quality elements (vegetation, fauna). At the present time, however, the scientific background for characterizing the biological content under reference conditions is inadequate. From the purely qualitative point of view, though, reference conditions are typically characterized by clear water and a widespread and diverse submerged macrophyte flora out to a depth of 3–7 m.

Table 2.6
Reference values for three types of lake (greater than 1 ha) classified according to their mean depth and alkalinity. Summer means. Adapted from the National Environmental Research Institute[2].

Lakes – Reference values			
Lake type	**Low alkalinity, shallow**	**Alkaline, shallow**	**Alkaline, deep**
	<3 m, <0.2 meq/l	<3 m, >0.2 meq/l	>3 m, >0.2 meq/l
Total-P (mg/l)	0.010	0.015	0.008
Total-N (mg/l)	0.37	0.4	0.38
Chlorophyll *a* (µg/l)	2.5	3.7	3.9
Secchi depth (m)	4.1	3.8	5.4

Lake Sortesø. Photo: Erik Vinther.

1] The Water Framework Directive and Danish lakes. Part 2: Palaeolimnological studies (in Danish). Technical Report No. 476, National Environmental Research Institute.

2] Fredshavn, J. & Skov, F. 2005: Assessment of reference conditions (in Danish). Technical Report No. 548, National Environmental Research Institute. http://www.dmu.dk/International/Publications/NERI+Technical+Reports/

Wetlands

Lake Arreskov Sø together with the adjoining wetlands has been designated as a Natura 2000 site. On the western side of the lake there are grazed-down rich fens with very diverse vegetation. Since the 1920s, however, a number of mires and freshwater meadows in the catchment of Lake Arreskov Sø have disappeared and many rich fens are becoming overgrown. The latter entails the risk that several low-growing plant species, including the orchids western marsh orchid and the marsh helliborine, risk disappearing. Photo: Erik Vinther.

Reference conditions for open terrestrial natural habitat types are defined as the best conditions attainable given the habitat type's area, structure, function and species diversity[1]. With many terrestrial natural habitat types, reference conditions also include human exploitation in the form of grazing or haymaking as the Danish cultural landscape lacks sufficient natural grazers. The reference conditions for a specific habitat type are thus established on the basis of the habitat types as we know them today and which can be sustainably maintained in the long term.

Under reference conditions, wetlands are characterized by an optimal (often natural) hydrology that is unaffected by abstraction, drainage and reclamation. Some wetland habitat types can have arisen as a result of lowering of the water level, however. These areas have structures that are characteristic for the various habitat types, for example a well-developed system of tidal channels to transport the tide in the wet coastal meadows. Under reference conditions the wetland habitat types are unaffected by fertilizers or pesticides. In this connection the critical loads established for the habitats are an important aid when assessing reference conditions.

Coastal meadows meeting reference conditions must have a natural hydrology that is unaffected by land reclamation or drainage. In addition, they must contain coastal morphological features such as tidal channels, beach ridge systems, spit formations and coastal lagoons. This definition does not take into account whether the coastal meadows have developed along a natural or an artificial coastline. In addition, the grazed down coastal meadows must have a long continuity, as expressed, for example, by the presence of anthills of the yellow meadow ant and the occurrence of characteristic coastal meadow plants. The vegetation must not bear signs of the use of fertilizer or pesticides.

Mires and springs meeting reference conditions must in principle have a natural hydrology and contain features such as upwelling groundwater, active peat formation, etc. In addition, rich fens and open springs must be grazed down and the vegetation must be relatively low and diverse without any signs of the use of fertilizer or pesticides.

Freshwater meadows meeting reference conditions must in principle have a natural hydrology. In addition, they must be grazed down and the vegetation must be relatively low and diverse without any signs of the use of fertilizer or pesticides.

Surveys performed by Fyn County show that a number of plant species have disappeared from Funen's mires, freshwater meadows and coastal meadows [2],[3], among other reasons because the area of the habitat types in question has decreased by approx. 70% since the 1940s. It has been calculated 2,[4] that preservation of the present species diversity in mires, freshwater meadows and dry grasslands would require the area of each of these habitat types to be doubled. It is therefore important that reference conditions for wetland habitat types also specify the minimum total area of each habitat type. One proposal for such reference conditions is the area and to some extent the distribution of these wetland habitat types in the 1890s (see Figure 3.2), at which time the major drainage projects had not been completed.

1] Fredshavn, J. & Skov, F. 2005: Assessment of reference conditions (in Danish). Technical Report No. 548, National Environmental Research Institute. http://www.dmu.dk/International/Publications/NERI+Technical+Reports/.
2] Vinther, E. & Tranberg, H. 1999: Nature quality in coastal meadows on Funen. Before and after 1980 (in Danish). Fyn County.
3] Vinther, E. & Tranberg, H. 2002: Nature quality in mires on Funen. Before and after 1980 (in Danish). Fyn County.
4] Vinther, E. & Tranberg, H. 2002: Nature quality in dry grasslands on Funen (in Danish). Before and after 1980 (in Danish). Fyn County.

Coastal waters

The reference conditions for Odense Fjord have been established on the basis of historical data from around 1900 combined with modelling calculations and expert judgement as no coastal water bodies judged to be pristine or virtually pristine exist in Denmark. The proposed reference conditions for Odense Fjord are thus the relatively pristine biological conditions that prevailed around 1900.

It is believed that the outer part of Odense Fjord was only negligibly affected by human activities around 1900, while the inner fjord, Seden Strand, was affected by wastewater from the city of Odense. Based on an historical survey performed by the Danish Biological Station in Odense Fjord and other Danish fjords it is surmised that under reference conditions the depth distribution of eelgrass would be up to 4 m in Seden Strand and 6 m in the outer fjord (Figure 2.11).

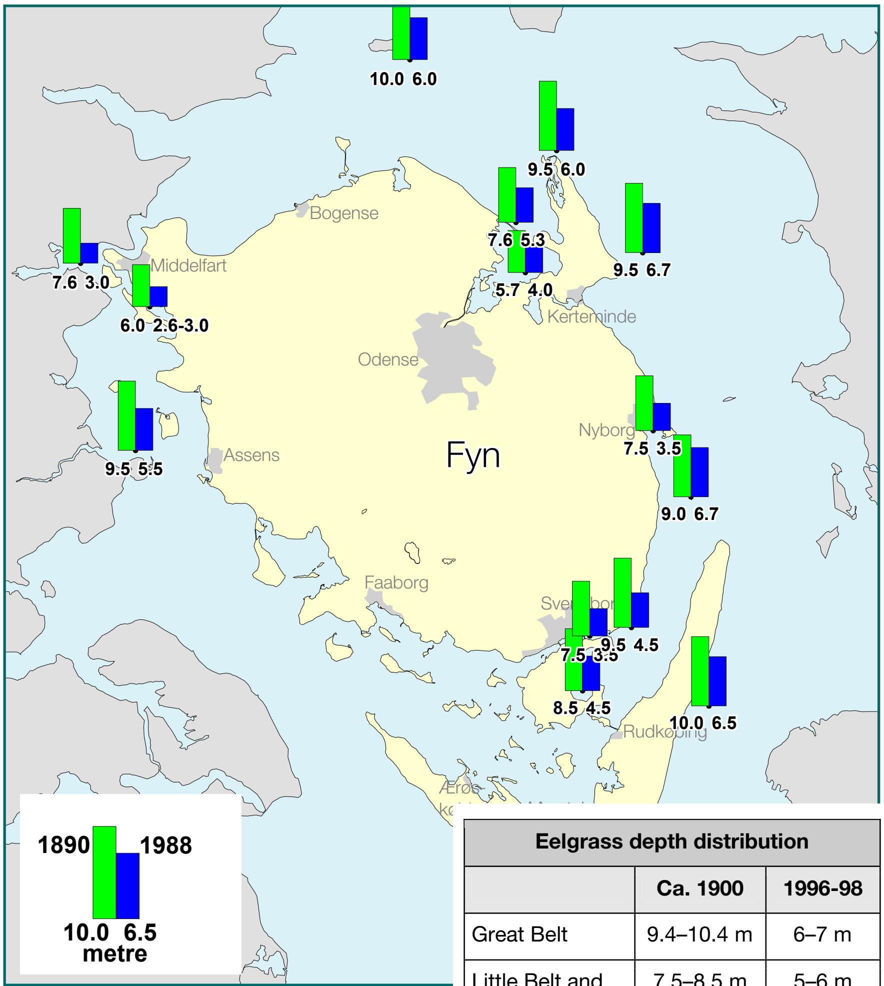
The maximum depth at which eelgrass can grow depends on light penetration of the water provided that the other physical conditions for growth are fulfilled (suitable bottom substrate, etc.). One of the main determinants of light penetration is the amount of phytoplankton, which in turn is closely related to the concentration of nutrients. The depth distribution of eelgrass is therefore also related to the concentration of nutrients. This (logarithmic) relationship is used to calculate the nitrogen concentrations that would apply under reference conditions given the above-mentioned depth distributions of eelgrass – i.e. 666 µg N/L in Seden Strand and 374 µg N/l in the outer fjord (annual mean total nitrogen concentrations).

In the case of phosphorus the modelling calculations show that the reference concentrations are 29 µg P/l in Seden Strand and 22 µg P/l in the outer fjord (annual mean total phosphorus concentrations).

The above reference values are those for the quality elements that serve as the basis for determining what measures need to be taken to reduce the nutrient load.

In addition, reference conditions in Odense Fjord are characterized by a Secchi depth of 7.2 m in the outer fjord, by the presence of an eelgrass population and, in the upper water zone (0–1.5 m water depth), by dense growths of seagrass, and by the rapidly growing macroalgae (sea lettuce and freely floating filamentous algae) being restricted to minor occurrences in the immediate vicinity of the main freshwater inflows.

Eelgrass. Photo: Nanna Rask.



Eelgrass depth distribution		
	Ca. 1900	1996-98
Great Belt	9.4–10.4 m	6–7 m
Little Belt and the South Fyn Archipelago	7.5–8.5 m	5–6 m
Odense Fjord	5.7–7.5 m	2.5–4 m
Nyborg Fjord (inner)	7.5 m	3.5 m

Figure 2.11
Eelgrass depth distribution – past (approx. 1900; Ostenfeld, 1908) and present (1988 and 1996–98).

2.3 Protected areas

The water bodies in Odense River Basin are to varying extents encompassed by international conventions, national legislation and regional regulations.

International protected areas

There are seven Natura 2000 sites located in Odense River Basin. The sites have been designated in order to protect specific habitat types and species. Three of the sites have also been designated as Special Protection Areas pursuant to the Birds Directive in order to protect selected bird species (Figure 2.12). The Natura 2000 sites cover a total area of approx. 8,000 ha, of which half is accounted for by marine areas.

Other international protected areas are groundwater bodies used for the water supply, i.e. groundwater bodies from which water is abstracted at a rate of more than 10 m^3 per day or to supply more than 50 persons, and groundwater bodies intended for such use. These protected groundwater bodies are shown in Figure 2.13.

Shellfish waters, which are international protected areas in the sea, are not present in Odense Fjord.

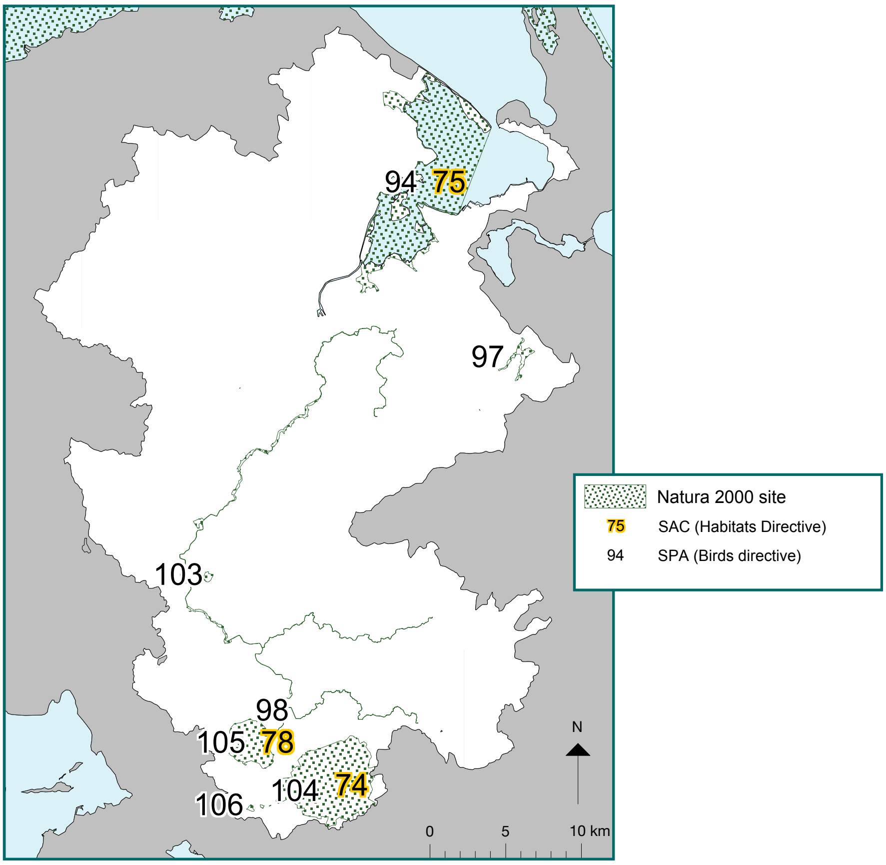


Figure 2.12
Natura 2000 sites in Odense River Basin. See Annex 2 for the basis for the designation of each site.

Special Protection Areas (Birds Directive)
No. 74 Lake Brændegård Sø, Lake Nørresø and the forests at Brahetrolleborg
No. 75 Odense Fjord
No. 78 Lake Arreskov Sø

Special Areas of Conservation (Habitats Directive)
No. 94 Odense Fjord
No. 97 The mires Urup Dam, Brabæk Mose, Birkende Mose and Illemose
No. 98 River Odense with River Hågerup, River Sallinge and River Lindved
No. 103 Storelung
No. 104 Forests and lakes south of Brahetrolleborg
No. 105 Lake Arreskov Sø
No. 106 Lake Store Øresø, Lake Sortesø and Lake Igle Sø

Lake Nørresø in Special Protection Area (SPA) No. 74 and Special Area of Conservation (SAC) No. 104. Photo: Erik Vinther.

2.3 Protected areas

National protected areas

The wet habitat types mires, freshwater meadows and coastal meadows are protected under Section 3 of the Protection of Nature Act along with lakes and watercourses. As a consequence, their state may not be changed. These three wetland habitat types account for 5.2% of the river basin. In addition, there are 706 km of watercourse.

Within Odense River Basin there are large areas that have been designated as national protected areas. The largest of these are the River Odense river valley, Lake Arreskov Sø, Lake Nørresø/Brændegaard Sø and the area around Enebærrodde Spit. Together these account for 2% of the river basin.

There are no bathing waters in Odense River Basin. The whole of Odense Fjord and the northern end of Lake Arreskov Sø are designated as game reserves.

Regional nature areas

The Fyn County Regional Plan for 2005–13 designates areas of special scientific interest and specifies quality objectives for coastal waters, lakes and watercourses, and for the terrestrial natural habitat types. Following the recent reform of Danish municipal and county administrative structure the Regional Plan has been accorded legal status through a National Planning Directive.

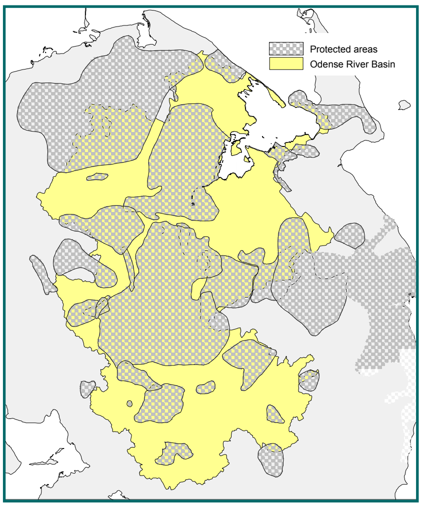


Figure 2.13
Protected groundwater bodies used for the water supply in and near Odense River Basin.

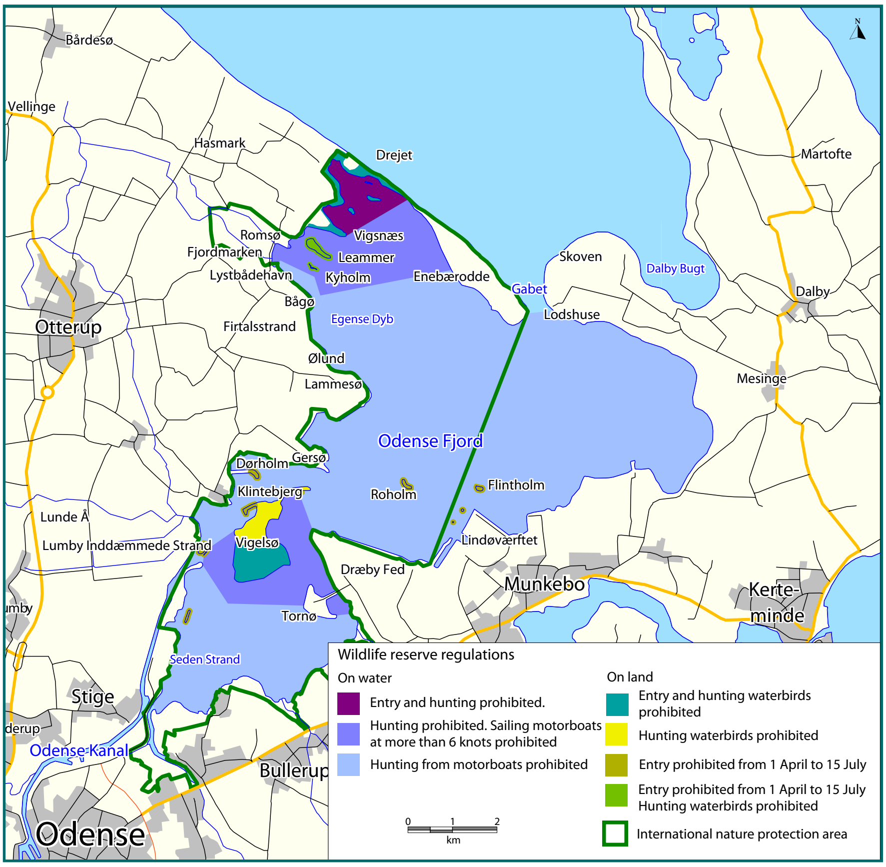


Figure 2.14
The international Natura 2000 site (Special Area of Conservation and Special Protection Area) and wildlife reserves on water in Odense Fjord.

Seden Strand and Odense Fjord viewed facing north. Odense Canal is seen on the left of the photograph, and the mouth of the River Odense in Seden Strand is seen on the lower left. Photo: Jan Kofod Winther.

3. Pressures

The pressure on the water bodies are both natural and anthropogenic in origin. The pressures encompass input of pollutants, for example nutrients and hazardous substances, and physical pressures on the water bodies, for example land reclamation, drainage, watercourse maintenance, abstraction and shipping (Table 3.1). Input of pollutants takes place via both water and the air from diffuse sources (e.g. nutrient leaching from farmland) and point sources (e.g. wastewater discharges from households and industry, atmospheric emissions from industry and agriculture and leaching from disused landfills). The various pressures on the water bodies and terrestrial natural habitats in Odense River Basin are summarized in Table 3.1.

Pressures on water bodies and terrestrial natural habitats		
	Pollutants	**Physical pressures**
Watercourses	● Organic matter and oxygen-consuming substances ● Sediment discharges ● Hazardous substances ● Pathogenic bacteria and viruses ● Acidifying substances.	● Regulation and culverting of watercourses, watercourse maintenance and drainage of river valleys • Activities primarily resulting from the desire to cultivate river valleys ● Obstructions to the free passage of fauna • Among other things to harness water power and to meet former needs for meadow watering. ● Water abstraction ● Dyking of watercourses • To hinder flooding of farmland and towns in the river valleys, etc. ● Navigation and fishery
Lakes	● Nutrients ● Hazardous substances ● Pathogenic bacteria and viruses ● Internal loading from phosphorus accumulated in lake sediment.	● Damming of lakes to harness water power ● Reclamation of shallow areas for agricultural purposes ● Fishery
Coastal waters	● Nutrients ● Hazardous substances ● Pathogenic bacteria and viruses ● Internal loading from phosphorus accumulated in fjord sediment ● Thermal pressure from cooling water discharges	● Shipping and fishery ● Dredging/maintenance of shipping fairways into the fjord harbours ● Reclamation of shallow areas for agricultural purposes ● Harbours
Groundwater bodies	● Nitrate leaching ● Hazardous substances from contaminated industrial sites, pesticide use, etc. ● Pathogenic bacteria and viruses	● Water abstraction ● Raw materials extraction
Terrestrial natural habitats (meadows, mires and dry grasslands)	● Nutrients, especially from agriculture ● Hazardous substances	● Water abstraction ● Drainage ● Land reclamation

Table 3.1
Summary of pressures on the individual types of water body and terrestrial natural habitat.

3.1 Wastewater from households and industry

Wastewater pressure on the water bodies derives from wastewater treatment plants, stormwater outfalls from separate and combined sewerage systems and from sparsely built-up areas and industry. The pressure on the water bodies is primarily attributable to the wastewater content of organic matter (BOD5), nitrogen, phosphorus, hazardous substances, heavy metals and pathogenic bacteria and viruses.

After treatment the wastewater is typically discharged to surface waters or into the ground via soakaways. Since the end of the 1980s the total amount of BOD5, nitrogen and phosphorus discharged into Odense River Basin with wastewater has decreased considerably. The decrease mainly reflects improved treatment at the wastewater treatment plants, all major treatment plants now having been upgraded to include nitrogen and phosphorus removal.

At present the sparsely built-up areas are the main point source of BOD5 loading, the wastewater treatment plants are the main point source of nitrogen loading and stormwater outfalls and sparsely built-up areas are the main point sources of phosphorus loading (see Table 3.2).

Relative to total point-source and diffuse loading of Odense River Basin, point sources account for a considerably greater proportion in the summer half-year than during the winter half-year. In the case of nitrogen, point sources account for an average of approx. 20% of the total load in the summer half-year and approx. 10% in the winter half-year. The corresponding figures for phosphorus are approx. 45% and 25%, respectively.

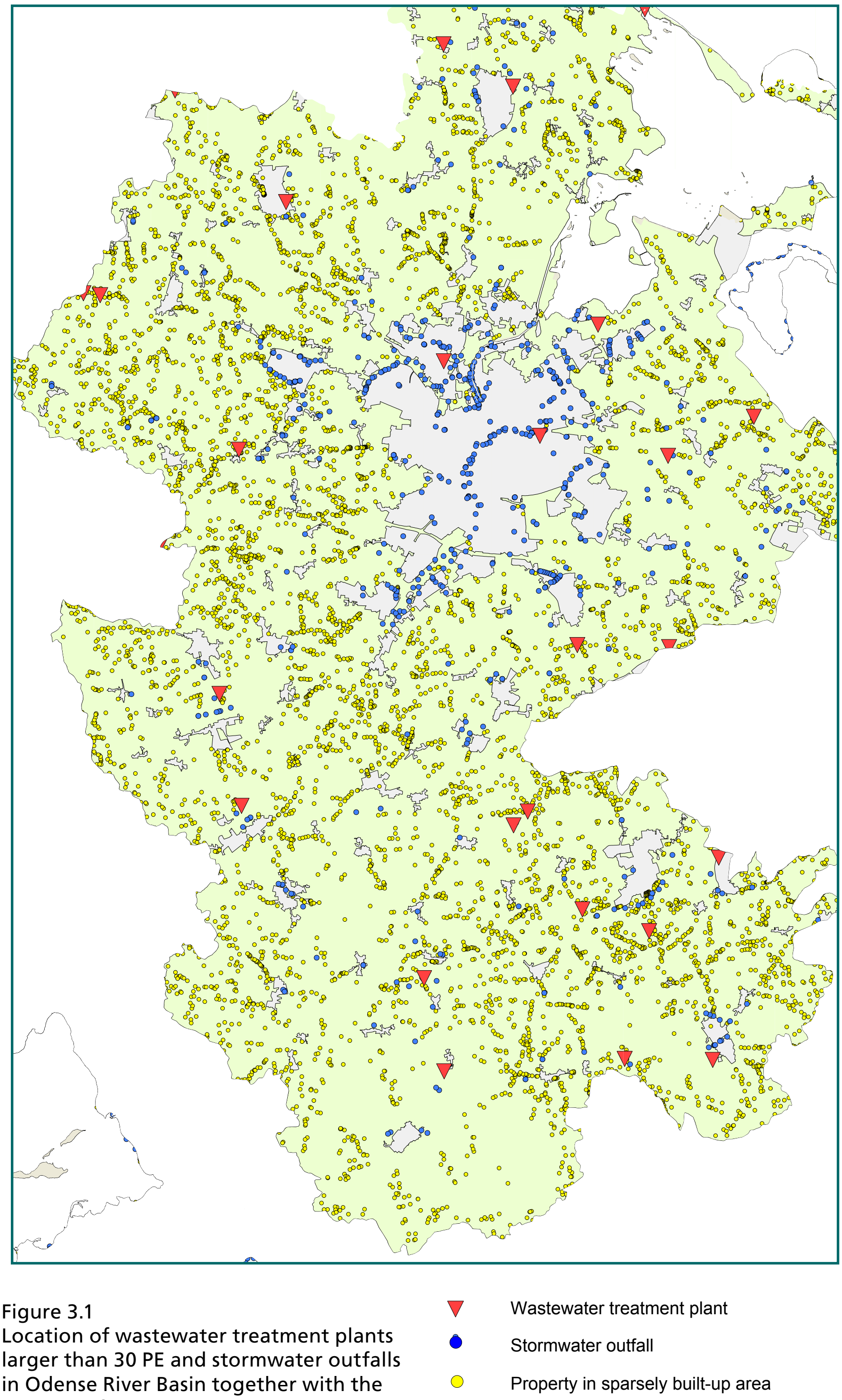


Figure 3.1
Location of wastewater treatment plants larger than 30 PE and stormwater outfalls in Odense River Basin together with the location of individual properties in the sparsely built-up areas of the basin.

3.1 Wastewater from households and industry

There are a total of 25 wastewater treatment plants larger than 30 person equivalents (PE) in Odense River Basin. The location of these plants is shown in Figure 3.1. Ten of the wastewater treatment plants in the river basin are smaller than 100 PE, while eight of the plants are larger than 10,000 PE. The largest is Ejby Mølle Wastewater Treatment Plant, which has a capacity of 325,000 PE. This plant treats nearly three quarters of all the wastewater that is discharged into the public sewerage system in the river basin. The magnitude of treated wastewater discharges depends on the amount and intensity of precipitation during the year. The total discharges in 2002 are shown in Table 3.2.

There are 489 registered stormwater outfalls in Odense River Basin (Figure 3.1). Of these, 204 are outfalls from combined sewerage systems and 285 are outfalls from separate sewerage systems. The discharges vary from year to year depending on the precipitation. The total discharges in 2002 are shown in Table 3.2.

There are approx. 6.900 properties located in sparsely built-up areas of Odense River Basin (Figure 3.1). The former Regional Plan for Funen designates areas in which special measures have to be taken to address wastewater discharges from such properties. As a consequence, the municipal wastewater plans include decisions to improve wastewater treatment at approx. 4,300 properties in the sparsely built-up areas in question. The discharges to surface waters from sparsely built-up areas are shown in Table 3.2.

The former waste depository Stige Ø Landfill was established in 1965 without a bed membrane, and it is therefore possible for nitrogen, hazardous substances and heavy metals to leach from the landfill into Odense Fjord/Odense Canal. A system for draining the landfill was completed in 2006, however. Estimated leaching from the landfill is shown in Table 3.2.

The River Odense has been shown to be affected by stormwater outfalls resulting in exceedance of national and international limit values for heavy metals and PAHs in particular.

In addition, Fynsværket CHP Plant discharges considerable amounts of cooling water to the River Odense/Odense Canal. The temperature of the discharged cooling water can be up to 8ºC (mean 2–3 ºC) higher than that of the water in the recipient water bodies. This results in elevation of the temperature in Seden Strand, thereby creating the conditions for enhanced growth of phytoplankton and rapidly growing macroalgae such as sea lettuce.

Odense River Basin also contains numerous contaminated sites attributable to past activities. They are typically contaminated with oil/petrol/BTEX, heavy metals, PAHs/tars or organic solvents. As of 2003, 283 contaminated sites had been identified in Odense River Basin. As with the remainder of Funen, the primary cause of contamination is oil/petrol/BTEX. The density of contaminated sites is very high in the vicinity of Odense city in particular.

Ejby Mølle Wastewater Treatment Plant. Photo: Jan Kofod Winther.

Point-source loading of surface water bodies			
Source	**BOD_5 (tonnes/yr)**	**Nitrogen (tonnes/yr)**	**Phosphorus (tonnes/yr)**
Wastewater treatment plants	63	137	6
Stormwater outfalls	116	40	10
Sparsely built-up areas – to surface water	141	36	8
Industry (Stige Ø Landfill)	26	164	2
Total	346	377	26

Table 3.2
Point-source loading (organic matter and nutrient) of the surface water bodies in Odense River Basin.

3.2 Agriculture

Agricultural production affects terrestrial natural habitats and the aquatic environment in several ways. Crop cultivation results in the loss of nitrogen, phosphorus, etc. Ammonia is lost to the air from livestock housing and manure stores, thereafter to be deposited locally on water bodies and terrestrial natural habitats or transported away and deposited beyond the borders of Odense River Basin. Neighbours to farms can be affected by odours from manure. The use and handling of pesticides can cause environmental problems, as can the pharmaceutical residues and pathogenic bacteria and viruses present in the manure spread on the fields.

Application of slurry with trailing hoses. Photo: Bjarne Andresen.

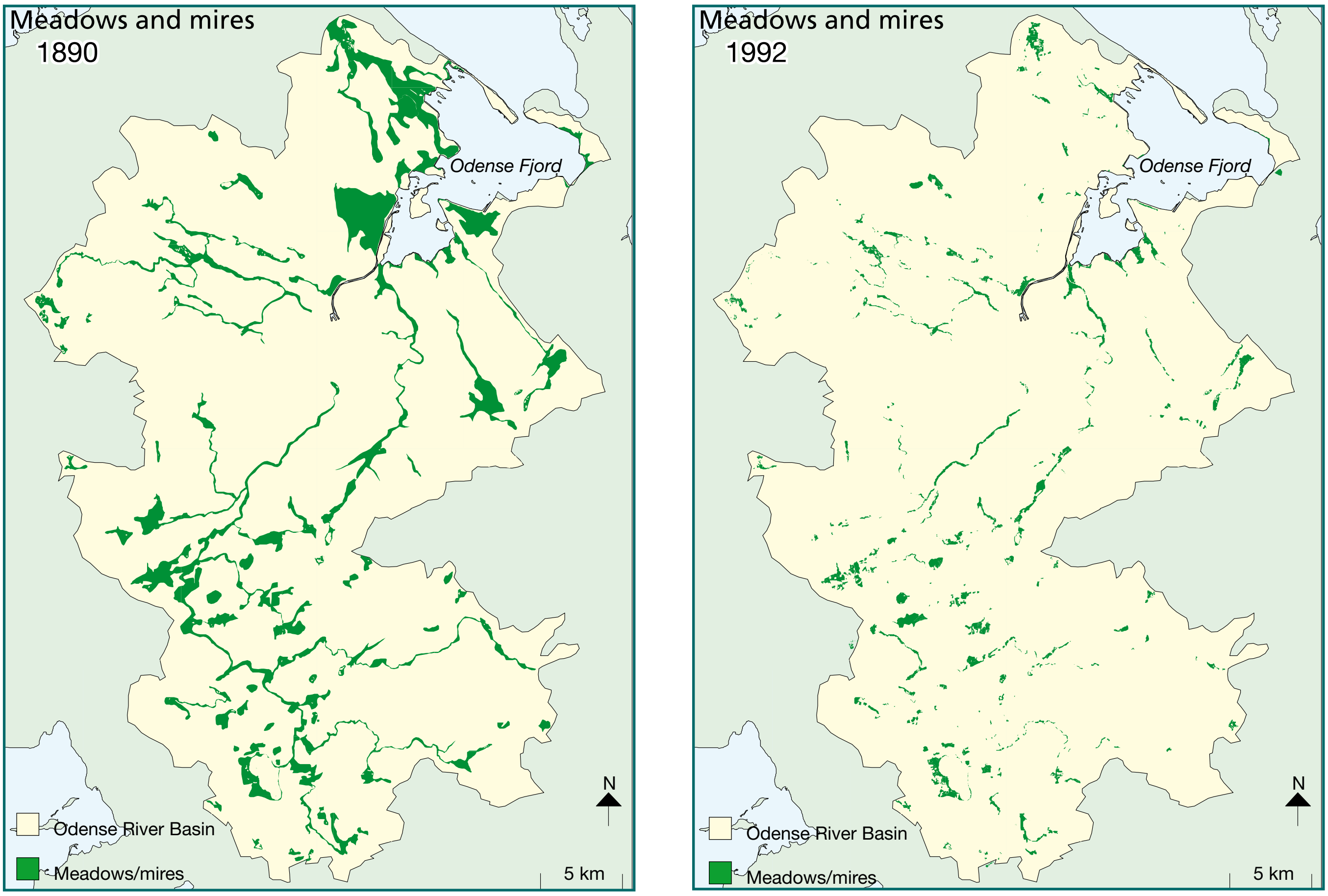


Figure 3.2
Distribution of mires, freshwater meadows and coastal meadows in Odense River Basin in 1890 and 1992. Prepared on the basis of maps from 1890 (1:20 000) and the National Survey and Cadastre map from 1992 (1:25 000). The water bodies in 1890 only encompass those larger than 5 ha. The change from 1890 to the present time is primarily the result of land reclamation and drainage activities.

Reclamation of former wetlands (meadows and mires in the river valley and elsewhere, shallow lakes and fjords), drainage, watercourse regulation and regular watercourse maintenance have been carried out over the years to meet agricultural requirements for arable land. These activities have enhanced physical pressure on the water bodies, however, especially on the watercourses and wet habitats, as well as enhanced nutrient loading of lakes and coastal waters due to reduced natural turnover of the nutrients that leach from the fields. The lower the level of land reclamation and drainage activity, the greater the self-cleansing ability of the wetlands and hence the greater the natural turnover of leached nutrients and the lower the level of nutrient loss to the surface waters.

National plans such as the Action Plans on the Aquatic Environment and the Pesticide Action Plan have reduced agricultural pressure on terrestrial natural habitats and the aquatic environment. Thus monitoring of the Danish aquatic environment shows that diffuse nitrogen runoff (primarily from agriculture) in the watercourses in the river basin has decreased by 20–30% (2005) relative to the period prior to adoption of Action Plan on the Aquatic Environment I in the mid 1980s. The situation with phosphorus is that more phosphorus is presently applied to the fields in the form of fertilizer than is removed in the crops. In 2002, the phosphorus surplus applied to the fields averaged approx. 10 kg P/ha arable land. Continued excessive application of phosphorus to the fields will eventually result in enhanced loss of phosphorus to the aquatic environment.

Over the period up to 2015 the third Action Plan on the Aquatic Environment is expected to further reduce nitrogen loading of the aquatic environment by approx. 15% and the phosphorus surplus applied to fields by around 50%.

Agricultural activities are the dominant source of nitrogen pressure on terrestrial natural habitats and the aquatic environment, both with regard to waterborne loading and airborne loading. Thus agriculture accounts for approx. 70% of total waterborne nitrogen loading of surface waters in the river basin (2003-2004) and half or more of atmospheric deposition of nitrogen on water bodies and terrestrial natural habitats. As regards phosphorus loading of the water bodies, agricultural activities account for approx. 25% of all waterborne phosphorus loading of the water bodies (2000–2004). Nowadays, agricultural application and handling of pesticides only rarely cause environmental problems in the surface waters. Pesticide residues that can be attributed to public and agricultural use of pesticides are found in approx. 22% of the groundwater bodies.

A large proportion of the watercourses in the river basin are regulated, primarily to meet the need for arable land. Thus at least 25% of the watercourses are culverted. Of the remaining open watercourses, 60% are estimated to be regulated (straightened, deepened, etc.). The watercourses were previously maintained in order to ensure drainage, without taking environmental aspects into consideration. Since adoption of the revised Watercourse Act in 1982, watercourse maintenance practice takes into account both the needs for agricultural drainage and consideration for the environment. Maintenance nevertheless still results in unstable conditions in many watercourses, to the detriment of the flora and fauna and nutrient turnover.

Reclamation and drainage of former wetlands have resulted in the disappearance of more than 70% of the large meadows and mires over the past 100 years (see Figure 3.2). As regards the coastal areas, Odense River Basin is among the areas on Funen where the most extensive land reclamation has been carried out, with low-lying coastal areas and some marine areas having been dyked-in and reclaimed. The shoreline of Odense Fjord has thereby been reduced from approx. 150 km to the present approx. 67 km, and 22 islands have disappeared from the fjord.

Freeland pig. Photo: Bjarne Andresen.

Field spraying. Photo: Bjarne Andersen.

3.3 Atmospheric deposition


Odense Canal at Fynsværket CHP Plant. Photo: Bjarne Andresen.

Atmospheric pollutants are deposited in the form of either wet deposition or dry deposition. The pollutants emitted to the atmosphere from among other sources industry, power stations, households, traffic and agriculture will eventually be deposited on the land or a water surface. Some pollutants emitted to the atmosphere will be deposited locally close to the source of pollution, while others will be transported afar and perhaps deposited on the sea or in other countries. Ammonia emitted from agricultural sources is an example of an atmospheric pollutant that is largely deposited locally, whereas nitrogen oxides emitted from power stations and traffic are an example of atmospheric pollutants that are largely transported afar.

The atmospheric pollutants that are deposited on terrestrial natural habitats and the aquatic environment in Odense River Basin thus derive both from local sources and from more distant sources. It has been calculated that by far the majority of the nitrogen oxides deposited on the Funen landmass derive from foreign sources, whereas approx. half of the ammonia deposition derives from Danish sources. Moreover, the amount of ammonia-N emitted from agricultural sources on Funen is more than double the amount deposited on the Funen landmass, thus indicating that a considerable proportion of the local ammonia pollution is transported afar and deposited on water bodies and terrestrial natural habitats further away, and that exports of ammonia pollution from Funen are greater than imports of ammonia pollution to Funen.

Certain airborne pollutants (especially sulphur dioxide, nitrogen oxides and ammonia) have an acidifying effect on terrestrial natural habitats and the aquatic environment in areas where the buffering capacity of the soil is low. This poses only a minor problem in Odense River Basin and Denmark as a whole as the buffering capacity of the soil is generally good. In contrast, it poses a far greater problem when these pollutants are deposited in the neighbouring country Sweden, where the buffering capacity of the soil is low in many areas.

Total atmospheric deposition of nitrogen (N) and phosphorus (P) on the Funen landmass is calculated to be approx. 20 kg N/ha/yr and approx. 0.20 kg P/ha/yr (mean values for 2000–2003). Deposition on the Funen coastal waters is calculated to be just under 12 kg N/ha/yr and approx. 0.15 kg P/ha/yr. Mean deposition of sulphur on the land mass in 2002 is calculated to be approx. 6 kg S/ha. These mean values mask considerable local variation depending on local differences in atmospheric emissions and differences in the roughness of the land and water surfaces. Due to the differences in roughness the deposition of pollutants is generally greater on terrestrial natural habitats and woodland than on farmland, and the deposition on water surfaces is less than on land surfaces.

Nitrogen deposition derives almost solely from anthropogenic sources, of which ammonia emissions from agricultural activities are the dominant source accounting for more than half of all nitrogen deposition. Phosphorus deposition derives from both anthropogenic and natural sources. The anthropogenic sources are primarily emissions of particulate phosphorus from the combustion of coal and straw, including the burning of field stubble. The natural sources of phosphorus deposition are primarily soil dust and organic matter whirled up by the wind. The majority of the sulphur compounds derive from the combustion of fossil fuels.


Bulk sampler at Årslev. Photo: Bjarne Andresen.

3.4 Total nutrient loads

The total riverine nitrogen and phosphorus loads have been determined for all large water bodies in Odense River Basin since the late 1970s based on measurements of nutrient runoff in watercourses and nutrient discharges from all major municipal wastewater treatment plants. In areas and at localities (point-source discharges) for which no measurements are available, the loads have been determined by modelling based on the characteristics of the areas and localities. The organic matter load (BOD_5) has also been determined for the water bodies.

Annual riverine nitrogen and phosphorus loading of Odense Fjord is shown in Figure 3.3 apportioned by diffuse sources (e.g. leaching from fields) and point sources (e.g. wastewater). As is apparent from the figure, diffuse loading in particular varies considerably from year to year, primarily due to interannual variation in precipitation and runoff.

Corrected for the influence of interannual variation in runoff, riverine phosphorus loading of the fjord has decreased by approx. 80% since the beginning of the 1980s, and nitrogen loading has decreased by 30–35%. The reduction in phosphorus loading is attributable to the fact that the wastewater is now treated far more effectively than previously. The reduction in nitrogen loading is the combined result of improved wastewater treatment and reduced leaching from arable land due to implementation of the Action Plans on the Aquatic Environment.

The mean precipitation and freshwater runoff in Odense River Basin correspond to the national average. Mean freshwater runoff to the fjord is approx. 305 mm per year, although there is considerable precipitation-dependent interannual variation (Figure 3.3). Mean annual precipitation in the river basin is 825 mm.

From the source apportionment of riverine nitrogen loading of Odense Fjord (Figure 3.4) it can be seen that agriculture is the main source of diffuse loading, accounting for approx. 70% of the total load. Point sources account for approx. 13%, and the natural background load accounts for approx. 18%.

The source apportionment of phosphorus is quite different. Just over 30% of the riverine phosphorus load is accounted for by natural background loading. Agriculture accounts for approx. 25%, while the remaining 45% of the phosphorus load is accounted for by wastewater discharges from sparsely built-up areas, stormwater outfalls and municipal wastewater treatment plants.

The present account of riverine nutrient loading from Odense River Basin describes the conditions both as they apply to Odense Fjord and as they apply to the other water bodies in the river basin as a mean for the river basin as a whole. There are local deviations from this general picture depending on differences in land use and the natural conditions.

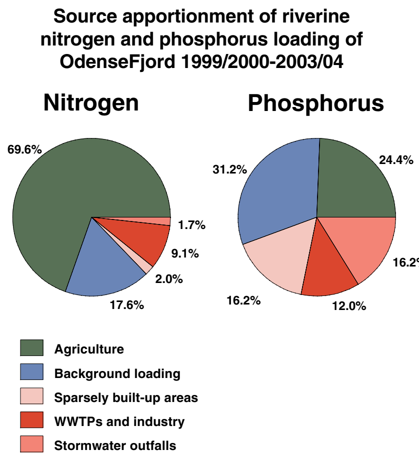


Figure 3.4
Source apportionment of riverine nutrient loading of Odense Fjord. Mean for the period 1999/2000–2003/2004.

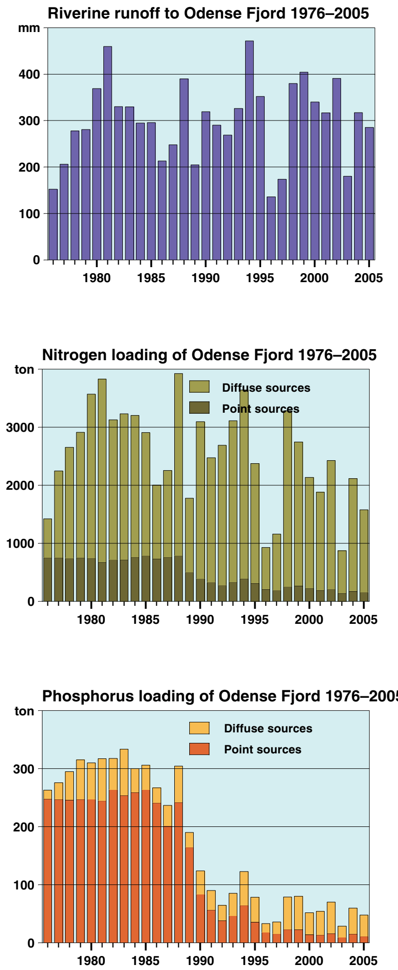


Figure 3.3
Trend in riverine nitrogen and phosphorus loading of Odense Fjord from Odense River Basin over the period 1976–2005 apportioned between diffuse sources and point sources. Freshwater runoff to the fjord during the same period is also shown.

3.5 Quantitative pressures on the water cycle

The water cycle can be affected in a large number of ways. When water is abstracted for use by households, agriculture, market gardens and industry, groundwater and surface water are removed from specific water bodies (aquifers, lakes or watercourses). The abstracted water is returned to the water cycle, sometimes to the same place as it was abstracted from, and other times to other water bodies.

The natural transport pathways for water can also be changed, for example by abstraction or by culverting of watercourses. In large areas, infiltration of the precipitation down into the soil is severely reduced due to drainage or the establishment of paved surfaces such as roads, buildings, etc. This water is instead led to watercourses either directly or via wastewater treatment plants.

Water is thereby redistributed between various water bodies with the result that certain water bodies may not be able to meet their environmental objectives.

In Odense River Basin, virtually all the water abstracted is groundwater. This applies both to abstraction for the public water supply and abstraction for use by industry, market gardens and agriculture. The reason for this is that the groundwater is cleaner than surface water (lakes, watercourses, etc.), and that abstraction of surface water has major undesirable effects on the inland waters.

The possibilities for abstracting groundwater are limited by the fact that in the long term it is only possible to abstract the same amount of water as percolates down into the ground from the precipitation and that in many areas it is not possible to find an aquifer from which water can be abstracted in sufficient quantities.

Moreover, abstraction of groundwater can result in changes in its chemical composition. Thus the concentrations of sulphate and nickel may rise as a result of oxidation of sulphide-containing minerals in the soil strata.

Overexploitation of the groundwater resource can also result in an increasing chloride content, either due to intrusion of seawater or because the younger groundwater becomes mixed with ancient seawater located in a part of the aquifer where groundwater flow is minimal.

Measuring the groundwater level in a waterworks well. Photo: Peder Lerche Jensen.

3.6 Other pressures

A number of other activities affect the environmental status of the water bodies, either directly or indirectly.

Over the years, dams and weirs have been established in the watercourses to facilitate exploitation of water power and meet former needs for irrigation of meadows. Among other things these dams and weirs obstruct the natural passage of migratory fish up through the watercourses. In recent decades, especially in the large watercourses, watercourse restoration projects have been carried out that have removed a number of these obstructions, thereby establishing free passage for fauna from the mouths of the watercourses in the coastal waters and far on up into the watercourse systems. Numerous obstructions still exist, though, that hinder the free migration of watercourse fauna in the watercourse systems.

A detailed map of obstructions in the river basin is available at: www.odenseprb.ode.mim.dk.

In large areas the percolation of precipitation into the ground is markedly reduced due to drainage and the establishment of paved areas. Stormwater from paved areas markedly affects the water bodies due to the large pulse discharges that occur during precipitation events.

Fishery in the form of trawling for mussels and fish has marked physical effects on the seabed. Mussel fishery is not presently carried out in Odense Fjord as consumption of mussels from the fjord is banned due to their high content of hazardous substances. Fishery for fish is carried out in the fjord using passive gear. In former times, considerable shell mining was carried out in the innermost part of the fjord. As a consequence, the seabed was constantly disturbed.

The shipping fairways and harbours in Odense Fjord are regularly dredged and deepened. Changes in the water depth due to deepening can result in changes in water exchange in the fjord. There are no sites in the fjord for dumping dredged materials, and no raw materials extraction is carried out. Beach nourishment was undertaken on the Kattegat coast at Enebærodde Spit in 1999 and 2001. Apart from the physical effects on the benthic fauna and vegetation, dredging and beach nourishment reduce the clarity of the water and enhance the release of pollutants from the sediment to the water phase.

Canoeing on a watercourse. Photo: Stig E. Pedersen.

Navigation on lakes, the sea and in the watercourses can disturb the fauna and physically affect the sediment (especially the rotating screws of large vessels). In addition, the vessels can release pollutants directly into the water.

No fish or mussel farming is performed in Odense River Basin. Duck stocking is undertaken on a large scale in lakes and ponds to support hunting. Food remains and faeces from the ducks can markedly affect the water. Moreover, the ducks have a negative impact on the breeding success of amphibians and on the bank vegetation.

Water mill with obstruction. Photo: Bjarne Andresen.

The River Odense – a regulated reach. Photo: Jan Kofod Winther.

4. Status of the water bodies

4.1 Watercourses

Over the past 100 years in particular, the watercourses have been markedly affected by man's activities. Thus they have become polluted, and the physical conditions in and around the watercourses have been changed in connection with intensive agricultural production in the river valleys, increased abstraction of water (including groundwater) and various forms of exploitation of water power (see Chapter 3). Around 70% of the natural watercourses on Funen have thus been regulated (or culverted) to a greater or lesser extent and have therefore lost their original form. Moreover, they have been maintained very intensively such that the water flows away from the surroundings as fast as possible. As a consequence of these pressures the flora and fauna in the watercourses and riparian areas have become markedly impoverished.

Since the end of the 1980s the environmental status of the watercourses has improved considerably, however, especially in the case of the large watercourses. This is reflected in both analyses of water quality and assessments of their environmental status based on the macroinvertebrate fauna (see Figures 4.1 and 4.2). The main reason for the improvement is that many small wastewater treatment plants have been closed down, and the wastewater instead led to larger, more effective treatment plants. In addition, agriculture has made great efforts to stop unlawful discharges of pesticides and silage juice, seepage water, etc. Finally, more environment-friendly maintenance practices have been

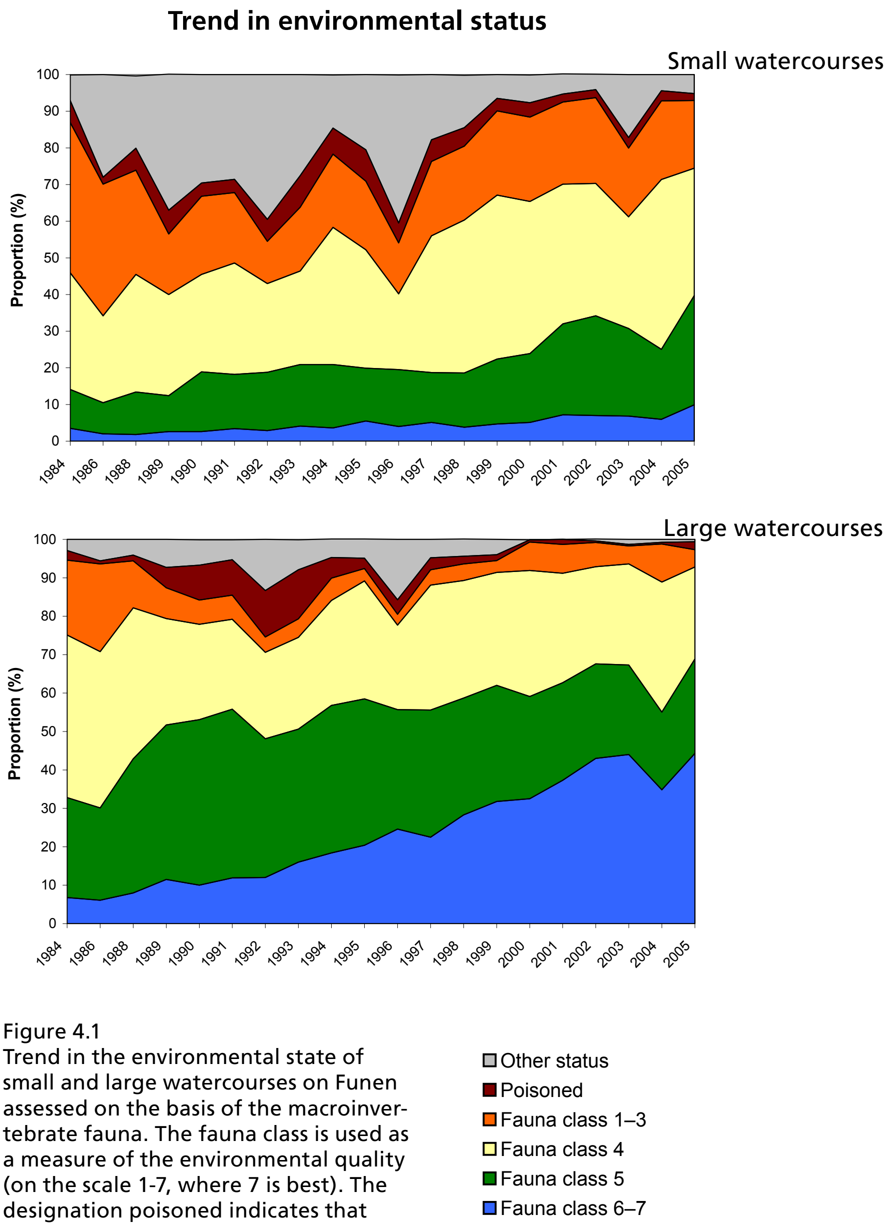


Figure 4.1
Trend in the environmental state of small and large watercourses on Funen assessed on the basis of the macroinvertebrate fauna. The fauna class is used as a measure of the environmental quality (on the scale 1-7, where 7 is best). The designation poisoned indicates that the watercourses are highly affected by pesticides.

introduced in many watercourses, and in certain places watercourse restoration has been carried out.

Nevertheless, many watercourses – especially small watercourses – are still in a poor condition, mainly because they receive wastewater from sparsely built-up areas and stormwater outfalls, and because the physical conditions are very homogenous due to watercourse regulation and maintenance. Moreover, the upper ends (including the spring where the watercourse starts) are often culverted. Finally, especially in the small watercourses, there are many obstructions to the free passage of fauna upstream and downstream in the watercourse systems.

From monitoring it is known that it is presently the small watercourses that are in the worst state (Figure 4.1). They comprise a very important part of the watercourse system, however, containing just as many species of macroinvertebrates as the large watercourses (including very special species as well), and often comprising important spawning and nursery waters for salmonids. Improvement in the state of small watercourses will therefore have many "rub off" effects on the state of the other watercourses.

The River Odense at Vibæk. Photo: Frank G. Larsen.

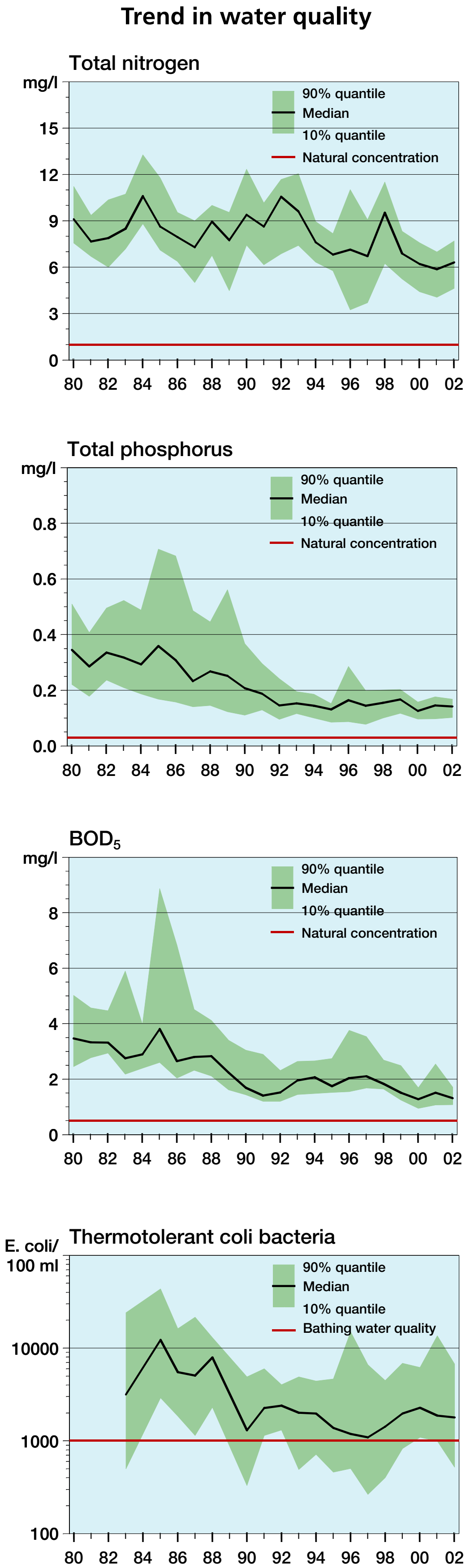


Figure 4.2
Trend in the concentrations of nutrients (nitrogen and phosphorus), easily degradable organic matter (BOD5), and coliform bacteria in Funen's watercourses. The natural background concentrations (reference conditions – see Section 2.2) are indicated, as is the bathing water limit value for coliform bacteria.

4.2 Lakes

By far the majority of lakes in the river basin have become severely polluted with nutrients over the years. Some of the lakes have received inputs of urban wastewater, and many lakes are affected by inputs of nutrients from agriculture and wastewater from sparsely built-up areas. This has resulted in enhanced algal growth, blooms of potentially toxic blue-green algae, shading out of the submerged macrophytes and impoverishment of the lake fauna (benthic invertebrates, fish and birds). Since the 1980s a concerted effort has been made to stop or reduce the discharge of urban wastewater into the lakes, and in recent years measures have also been initiated to deal with the problem of wastewater discharges from small urban communities and households outside the sewerage system catchments.

Even though the status of many lakes has improved as a result of the above-mentioned measures, the general picture of the lakes is still characterized by the occurrence of algal blooms – often of blue-green algae – and the absence or decline of submerged macrophytes. In addition, the fish stocks are too highly dominated by roach and bream and contain too few of predators such as perch and pike.

The reason for this is partly the current level of nutrient loading, especially from agriculture, and partly former loading that has resulted in the accumulation of nutrients in the lake sediment and which still affects the state of the lakes through enhanced nutrient release from the sediment.

On the other hand, the lakes seem to be only slightly affected by hazardous substances such as pesticides and heavy metals.

Nutrient concentrations, algal composition and submerged macrophyte distribution in 16 of the largest lakes in the river basin are summarized in Table 4.1.

Lakes – Environmental status

Lake	**Lake type**	**Physico-chemical conditions**				**Phyto-plankton**			**Submerged macrophytes**			**Period**
		Total phosphorus	Total nitrogen	Secchi depth	pH	Chlorophyll *a*	Blue-green algae	Problem species	No. of species	Depth distribution	Coverage	
		mg/l	mg/l	m		µg/l	%	*n*		m	%	
Arreskov Sø	9	0.097	1.82	1.24	9.0	73	100	14	9	2.75	47	2004–2005
Brahetrolle-borg Slotssø	9	0.900	1.87	>0.61	8.1	65			0		0	2003
Brændegård Sø	9	1.50	4.34	>0.51	8.8	175	86	13	2	0.2	<5	2003
Dallund Sø	9	0.107	1.74	0.54	8.4	103	76	5	0		0	1998–2005
Fjellerup Sø	9	0.215	2.20	0.37	8.3	87	68	12	0		0	2000–2005
Gravel quarrey lake No. 1	10	0.032*	1.48*	2.44*	8.1*	14*						1992
Gravel quarrey lake No. 7.1	9	0.023	0.54	3.33	8.3	11			12	5.7	48	2005
Gravel quarrey lake No. 7.9	9	0.040*	0.65*	3.38*	9.0*	7*			6			1992
Hovlung	9	0.303*	2.03*	0.40*	8.7*	281*						1998
Langesø	9	0.182	1.82	1.13	8.6	134	82	10	0		0	1997–2004
Nørre Søby Sø	9	0.52	5.97	0.21	8.5	281	12	15	0		0	2001–2003
Nørresø	9	0.098	1.38	1.07	8.5	56	49	10	3	0.25		1999–2003
Sellebjerg Sø	9	0.061	1.02	2.13	8.1	16			7	2.5	95–100	2005
Sortesø	6	0.094	1.58	0.32	5.1	98			0		0	2005
Store Øresø	9	0.042	1.61	>0.76	9.0	12			2	0.8	50–75	2003
Søbo Sø	9	0.091	1.26	1.21	8.6	84	9	8	4	3.5	3	1998–2003

Table 4.1
Physico-chemical and biological parameters for 16 of the largest lakes in the Odense River Basin. Summer mean values (at least 4 measurements) for physico-chemical parameters and phytoplankton, together with submerged macrophyte species number, depth distribution and coverage. * indicates summer mean values based on 1–3 measurements. Problem species are species of blue-green algae known to be potentially toxic. The year or the period from which the data derive are given. See Figure 2.7 for a definition of the lake types.

4.3 Wetlands

Studies carried out by Fyn County show that the total area of coastal meadows, freshwater meadows and mires on Funen decreased by approx. 70% over the period 1940–1992, primarily due to land reclamation for agricultural purposes. In addition, the remaining wetlands are highly influenced by factors that negatively affect their hydrology and diversity, such as draining, drainage, abstraction, nitrogen loading and overgrowth.

Draining and drainage comprise a major threat to the remaining mires and freshwater meadows in the river basin. Around 50% are considered to be directly affected by drainage in the form of drainage ditches, drain pipes, etc. Moreover, a further approx. 2,500 ha of mires and freshwater meadows are assessed as being affected by lowering of the water table as a result of regulation of adjacent public watercourses.

Like draining and drainage, water abstraction can lower the water table in mires and freshwater meadows and reduce upwelling of groundwater in the springs. Model calculations show that approx. 75% of the springs, 65% of the mires and 70% of the freshwater meadows are located in areas where abstraction for the water supply has lowered the groundwater pressure potential. The risk therefore exists that the water table has lowered in these wetlands.

In the case of coastal meadows, the most destructive of the modifying interventions are drainage and dyking. Of 37 registered coastal meadows encompassing a total area of 476 ha, 23 (353 ha) are affected by drainage and/or dyking.

Nutrient loading (especially nitrogen) is particularly a problem for the mires. Of the 772 mires (2,183 ha), the critical load for nitrogen is considered to be exceeded by atmospheric deposition alone in 641 (1,972 ha), corresponding to 90% of their total area. With coastal meadows the critical load for nitrogen is exceeded at 11 of 29 examined localities (206 ha out of a total of 400 ha, corresponding to 50% of the examined coastal meadow area. The calculations are based on the lowest critical load.

Overgrowth due to the cessation of grazing is particularly a problem in mires. Unpublished data from Fyn County show that in the 1990s, grazing took place on approx. 40% of the coastal meadows and 10% of the mires on Funen. In 2003, grazing subsidies were granted for approx. 9%, 52% and 20%, respectively, of the area of mires, coastal meadows and freshwater meadows in Odense River Basin. It is estimated that these subsidized areas are virtually identical with the total grazed area of the habitat types in question. Thus large areas of mire, coastal meadow and freshwater meadow are not grazed and are becoming overgrown.

Lake Arreskov Sø together with the adjoining wetlands has been designated as a Natura 2000 site. On the western side of the lake there is grazed-down rich fen with very diverse vegetation. Since the 1920s, however, a number of mires and freshwater meadows in the catchment of Lake Arreskov Sø have disappeared, and many rich fens are becoming overgrown. The latter entails the risk that several low-growing plant species, including the orchids western marsh orchid and the marsh helliborine, risk disappearing. Photo: Erik Vinther.

The reduction in area and the negative pressures on the remaining wetland areas have resulted in a decrease in their biodiversity. Thus as shown by Fyn County, Red-listed species have disappeared from 70% of their former habitats in mires and freshwater meadows and from 50% of their former habitats in coastal meadows. Moreover, several common species have disappeared from Funen. The same trend is believed to apply to Odense River Basin.

The basis for selection of the Natura 2000 sites in Odense River Basin consists of the following wetland habitat types:

- 1310 Salicornia and other annuals colonizing mud and sand
- 1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
- 6410 Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)
- 7110 Active raised bogs
- 7120 Degraded raised bogs still capable of natural regeneration
- 7140 Transition mires and quaking bogs
- 7150 Depressions on peat substrates of the Rhynchosporion
- 7220 Petrifying springs with tufa formation (Cratoneurion)
- 7210 Calcareous fens with Cladium mariscus and species of the Caricion davallianae
- 7230 Alkaline fens
- 91D0 Bog woodland
- 91E0 Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae).

The environmental objective for these habitat types is that their conservation status within the Natura 2000 sites should be favourable. At the present time, however, their conservation status has not been assessed. The greatest threats to these habitat types are identical to the above-mentioned general threats to mires, coastal meadows and freshwater meadows.

4.4 Groundwater

The groundwater is primarily formed in the winter half-year, during which only a very limited proportion of the precipitation evaporates or is taken up by plants. As the precipitation moves down through the soil its chemical composition changes. If the precipitation passes through pollution on the surface or in the soil, the groundwater can become contaminated.

The whole of the water supply in Odense River Basin is based on groundwater. The groundwater has normally been forming for many years before it is abstracted by the waterworks. Any contamination present in the groundwater that is abstracted today can thus be attributable to human activity that took place many years ago.

Nitrate

Nitrate contamination of the groundwater is still limited at present. In some locations the nitrate concentration is elevated in the groundwater abstracted for the water supply. So far, high concentrations of nitrate have primarily been detected in wells located in near-surface aquifers.

Pesticides and other hazardous substances

Analyses for pesticides and other hazardous substances performed by the waterworks and under the groundwater monitoring programme reveal that the groundwater in many locations is contaminated with hazardous substances.

Of the 31 groundwater bodies in the river basin for which data is available, 13 are contaminated with hazardous substances. Eight of the groundwater bodies are contaminated with pesticides and 12 with other hazardous substances, 7 of which are contaminated with both pesticides and other hazardous substances. When detected the pesticides are usually present in concentrations below the limit value for drinking water (0.1 µg/l). Occasionally, pesticides are detected at the waterworks in the water supplied to consumers in concentrations exceeding the limit value for drinking water. This problem is usually solved by taking the contaminated well in question out of production. No overall trend is detectable as regards pesticide contamination. Other factors could explain the variation detected in the wells, for example periods of high precipitation surplus that can influence the residence time and flow patterns.

The groundwater resource

The magnitude of groundwater recharge depends on the amount of precipitation that falls in the winter half-year. In wet years much groundwater is formed, whereas in dry years little groundwater is formed. The variation in annual precipitation is therefore reflected in the groundwater table. For example, the groundwater table fell markedly in the dry years 1996 and 1997. Since then the amount of precipitation has normalized the groundwater table again. The amount of precipitation has thus varied markedly in recent years with a resultant relatively great variation in the groundwater table.

The majority of the groundwater that is formed eventually ends up in watercourses, lakes and the sea. The remainder is abstracted. The majority of abstraction takes place at public and private waterworks, and the remainder by individual households, industry and for field irrigation, etc.

Over the period 1988–2003, the total amount of water abstracted by the waterworks has fallen, and per capita consumption of water has decreased markedly, primarily due to the installation of water meters and levies on tap water. In addition, the water metres have provided the waterworks with a better idea of loss in the supply system, which has helped reduce leakage. As a consequence, water losses by the waterworks have also decreased markedly. This trend has resulted in more sustainable exploitation of the groundwater resource and has saved the waterworks having to expand water treatment plants and well fields.

4.5 Coastal waters

Odense Fjord has a large catchment area – approx. 1/3 of the size of Funen – characterized by intensive agriculture and a high population density. As a result, the fjord has become very polluted with nutrients over the years. This has had a fundamental negative impact on the chemical and biological cycles in the fjord, which is thus classified as eutrophic. In addition, the fjord is affected by input of hazardous substances and heavy metals from wastewater treatment plants, separate industrial discharges and shipping, as well as by physical pressures, especially dredging and deepening work in connection with harbours and shipping fairways.

The nutrient loading of Odense Fjord has resulted in marked growth of rapidly growing annual algae such as sea lettuce (in Seden Strand) and various species of filamentous algae (in the outer fjord), and the decline of perennial anchored macrophytes such as sea grass in Seden Strand and eelgrass in the outer fjord measured at the depth limit for growth. The abundance of these so-called eutrophication-dependent macroalgae peaked in the 1980s when particularly the enormous amounts of sea lettuce in Seden Strand posed a problem. In step with the decrease in point-source nutrient loading at the end of the 1980s and a subsequent smaller decrease in diffuse nutrient loading and associated decrease in the nitrogen and phosphorus concentrations in the fjord (Figure 4.3), the amount of sea lettuce and filamentous algae has declined considerably.

In Seden Strand the abundance of sea grass has increased again, but the nitrogen load, especially from agriculture, remains so high that considerable amounts of sea lettuce still grow there each year. In the outer fjord the abundance of perennial, slowly growing brown algae such as bladder wrack and toothed wrack has increased considerably, whereas eelgrass has fluctuated markedly, most recently having declined. The depth distribution of eelgrass is presently only approx. 3 m.

The diverse benthic fauna in Odense Fjord is dominated by filter feeding species of polychaete, mussel and crustacean. The filtration capacity is consequently high, and the water volume in the fjord can potentially be filtered more than once per day. Combined with the low residence time of the fjord water this means that the phytoplankton biomass in the fjord is relatively low seen in relation to the level of nutrient loading. The phytoplankton biomass has therefore only decreased slightly in response to the decrease in nutrient loading. Phytoplankton blooms still occur, though, including blooms of potentially toxic species.

The fjord is generally so shallow and the water so well mixed that oxygen deficit is rare. The episodes of oxygen deficit that occurred in Seden Strand in connection with the decomposition of the large sea lettuce populations in the 1980s are rare nowadays. On the other hand, short-lasting episodes of oxygen deficit regularly occur in summer/autumn in the deeper parts of the fjord around the shipping fairway, primarily when tongues of saline and often oxygen-deleted bottom water from the northern Belt Sea penetrate into the fjord along the shipping fairway.

A number of hazardous substances have been detected in Odense Fjord in the sediment and in mussels, fish and birds, in some cases in concentrations exceeding the effect criteria specified in international conventions, for example TBT, PAH, PCB (which has long been banned) and copper. Due to the relatively high loading of the fjord with hazardous substances, serious effects are detectable in the fjord fauna, e.g. reproductive disturbances in gastropod molluscs and mussels and enhanced levels of detoxification enzyme activity and malformation in mussels and eelpout. The high levels of TBT in common mussels in Odense Fjord has resulted in the Danish Veterinary and Food Administration imposing a ban on mussel dredging for consumption in Odense Fjord. The hazardous substances probably also have an effect on the fjord's plant communities.

In conclusion, Odense Fjord is characterized by a continued high level of nutrient loading such that environmental conditions remain unstable despite certain improvements compared with the situation previously. Moreover, the fjord is subject to hazardous substance loading and physical pressures that affect the fjord flora and fauna.

Due to the high level of nutrient loading the aquatic flora, which here consists of eelgrass and bladder wrack, is often encrusted with diatoms. Photo: Nanna Rask.

Sea lettuce still dominates in Seden Strand despite the reduction in wastewater loading. Photo: Søren Larsen.

Trend in environmental state

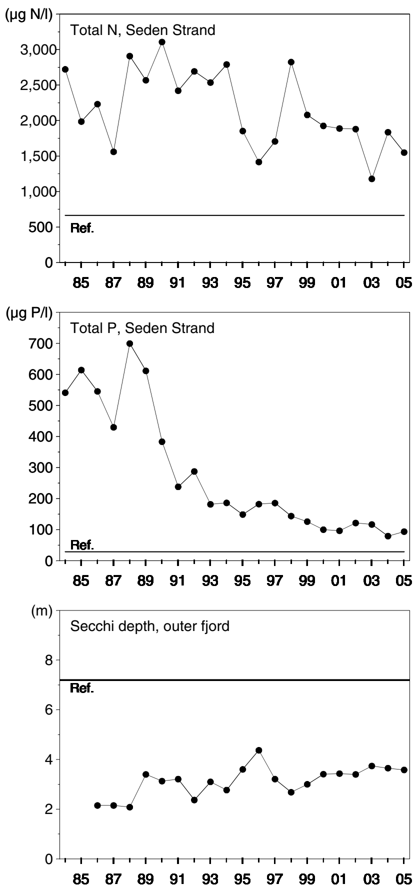


Figure 4.3
Time-weighted annual mean concentration of nitrogen and phosphorus in Seden Strand and time-weighted summer mean Secchi depth in the outer fjord over the period 1984–2005. Calculated values for reference conditions are also shown.

5. Environmental objectives and measures required

The Water Framework Directive requires that all surface water bodies be classified on the basis of their ecological status into one of five classes ("High", "Good", "Moderate", "Poor" and "Bad"). Groundwater bodies are to be classified using two status classes ("Good" and "Bad"). The status classes are to be established on the basis of reference conditions for the water bodies defined as "no, or only very minor, anthropogenic alterations" compared with "undisturbed conditions". The objective is that all water bodies should achieve "Good status" before the end of the year 2015. In addition, any deterioration in the existing status of both surface waters and groundwater is to be prevented.

The Environmental Objectives Act further requires that any increase in direct or indirect pollution of a surface water body must be prevented unless this restriction leads to increased pollution of another water body.

Pursuant to the Water Framework Directive the ecological status of a surface water body is to be described on the basis of its biological, hydromorphological and physico-chemical quality elements. The biological quality elements must encompass phytoplankton, macrophytes, macroinvertebrates and, in the case of fresh waters and transitional waters, also fish. The supporting hydromorphological and physico-chemical elements include such parameters as water level, water flow, water temperature, nutrient concentrations, oxygenation conditions, Secchi depth, salinity, BOD5 concentration, etc. Groundwater is described on the basis of its quantitative status and chemical status.

As regards hazardous substances, the Water Framework Directive requires Member States to implement measures to progressively reduce pollution from substances included on the Commission's list of priority substances and – in the case of priority hazardous substances – to ensure their phase-out by 2025.

The Water Framework Directive's general definitions of ecological quality for surface waters are shown in Box 1. The extent to which the individual status classes may acceptably deviate from the reference conditions can vary between the individual quality elements. For example, a specific percentage deviation may be acceptable for phytoplankton in order for a water body to be classified as fulfilling "Good status", while a different percentage deviation may be acceptable for BOD5.

Box 1
The Water Framework Directive's general definitions of ecological quality for surface waters

High status

There are no, or only very minor, anthropogenic alterations to the values of the physico-chemical and hydromorphological quality elements for the surface water body type from those normally associated with that type under undisturbed conditions. The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion. These are the type-specific conditions and communities.

Good status

The values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions.

Moderate status

The values of the biological quality elements for the surface water body type deviate moderately from those normally associated with the surface water body type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status.

5. Environmental objectives and measures required

The Water Framework Directive's general definitions of good quality for groundwater are shown in Box 2.

In special circumstances the Water Framework Directive permits the following general derogations from its provisions pertaining to the general objective of "Good status" and the deadline of 2015:

More stringent environmental objectives
With certain surface water bodies it is permissible to set a more stringent environmental objective than "Good status".

Less stringent environmental objectives:
With certain surface water and groundwater bodies it is permissible to set a less stringent environmental objective than "Good status".

Extension of deadlines:
Under certain circumstances the deadline of 2015 can be extended for the purpose of phased achievement of the environmental objectives.

Artificial and heavily modified water bodies:
A surface water body can be designated as artificial or heavily modified.

In the text that follows the conditions applying to any water bodies that derogate from the general provisions are described separately. In general though, water bodies that under the previous Danish system for establishing quality objectives were designated as "Reference areas of scientific interest" are assigned the corresponding environmental objective "High ecological status".

Box 2

The Water Framework Directive's general definitions of good status for groundwater

Good quantitative status

The level of groundwater in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction. Accordingly, the level of groundwater is not subject to anthropogenic alterations such as would result in:

- **failure to achieve the environmental objectives specified under Article 4 for associated surface waters,**
- **any significant diminution in the status of such waters,**
- **any significant damage to terrestrial ecosystems which depend directly on the groundwater body,**

and alterations to flow direction resulting from level changes may occur temporarily, or continuously in a spatially limited area, but such reversals do not cause saltwater or other intrusion, and do not indicate a sustained and clearly identified anthropogenically induced trend in flow direction likely to result in such intrusions.

Good chemical status

The chemical composition of the groundwater body is such that the concentrations of pollutants:

- **as specified below, do not exhibit the effects of saline or other intrusions**
- **do not exceed the quality standards applicable under other relevant Community legislation in accordance with Article 17**
- **are not such as would result in failure to achieve the environmental objectives specified under Article 4 for associated surface waters nor any significant diminution of the ecological or chemical quality of such bodies nor in any significant damage to terrestrial ecosystems which depend directly on the groundwater body.**

5.1 Environmental objectives and criteria for compliance

The environmental objectives for the individual types of water body are presented below. A detailed map showing the environmental objectives for each individual water body is available at www.odenseprb.ode.mim.dk

Watercourses

Criteria for ecological quality classes
Suitable tools (indicators) have not yet been developed in Denmark for describing the quality elements macrophytes and fish. In contrast, indicators are available for describing environmental quality on the basis of the macroinvertebrate fauna (the Danish Stream Fauna Index, DSFI) and the physical conditions (the physical index). These indicators have hitherto been used as a measure of environmental quality in the river basin (Table 5.1). The physical index is included because the relationship between it and future indicators based on macrophytes and fish is expected to be close, and because the DSFI is considered to inadequately reflect the overall ecological status.

Environmental objectives
The environmental objective set for most watercourses in the river basin is that they should achieve good ecological status before the end of 2015. The following exceptions apply:

- *Water bodies assigned high ecological status:*
  Some watercourses have been assigned a more stringent objective than good status. The environmental objective is set at high ecological status if the present status of the water body is better than good, if it has previously been assigned the highest quality objective in the Regional Plan (Reference area of scientific interest), or if it has been designated as a Special Area of Conservation pursuant to the Habitats Directive. This applies to much of the River Odense and its tributaries the River Lindved, River Sallinge and River Hågerup (99 km in all). The reason for designating this area is the occurrence of a number of the species listed in Annex II of the Habitats Directive, i.e. Desmoulin's whorl snail (Vertigo moulinsiana), the common river mussel (Unio crassus), the brook lamprey (Lampetra planeri) and the spined loach (Cobitis taenia), combined with an ample presence of habitat types such as 3260 (Watercourses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation), 6430 (Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels) and 7220 (Petrifying springs with tufa formation (Cratoneurion)).
- *Water bodies designated as artificial:*
  A total of 84 km of watercourse have been designated as artificial (canals and ditches established in connection with land reclamation). These water bodies have been assigned the environmental objective "Good ecological potential" (clean water, sufficient water, unrestricted passage to fauna and environmentally friendly maintenance), but no requirements have been set regarding actual physical improvements to the watercourses themselves in the form of restoration projects, etc.

The River Odense. Photo: Bjarne Andresen.

- *Water bodies for which the deadline has been extended:*
  There are presently 236 km of culverted watercourse in the river basin. The majority of the culverted reaches are located in the upper reaches of the watercourse systems (including the source springs). Daylighting, laying out of gravel/stones and remeandering are performed wherever possible – especially in watercourse systems assigned a high quality objective. Due to environmental, technical and socioeconomic considerations, though, it is not considered possible to plan and carry out measures to ensure good ecological status in these water bodies by 2015. For these water bodies, decisions on environmental objectives and associated measures for achieving them will thus be postponed until the next plan period. Restoration in the form of daylighting of the upper reaches of the watercourses can be beneficially carried out as an alternative to the relaying of the culverts that has in any case to be carried out at regular intervals. However, the water that flows in the culverts must always be so clean that it does not compromise compliance with the objective for downstream reaches (that has to be achieved by 2015).

Watercourses – Criteria for ecological status classes		
Ecological status	**Physical index**	**Fauna class** (DSFI)
High	0.81–1.00	7
Good	0.60–0.80	5–6
Moderate	0.40–0.59	4

Table 5.1
Overview of the physical and biological quality indicators used to characterize ecological status. The physical index has been converted from a normal to a nominal scale ranging from 0 to 1 (1 is the highest quality).

Lakes

Criteria for ecological quality classes

The general criteria for the ecological quality classes are shown in Table 5.2. The criteria stipulate the nitrogen and phosphorus concentrations in the lake water, whereas the Water Framework Directive requires that the quality classes should be described with the help of biological quality elements such as phytoplankton, macrophytes, benthic invertebrates and fish. However, the stipulated nutrient concentrations are considered to be the precondition for achievement of good and high ecological status in the biological sense (cf. National Environmental Research Institute[1]). Moreover, a knowledge of the nitrogen and phosphorus concentrations related to the ecological status classes is a precondition for being able to assess the measures necessary to achieve the environmental objectives as the measures will typically aim at reducing the input of these nutrients.

Environmental objectives and criteria for compliance with them

The environmental objectives and the associated criteria for compliance with them are shown for 12 of the lakes in the river basin in Table 5.3.

Due to the natural conditions pertaining the criteria for phosphorus concentration given in Table 5.3 sometimes differ from the general criteria given in Table 5.2 (Lake Arreskov Sø, Nørresø, Sortesø and Store Øre Sø). This is because the calculated background concentration (cf. Chapter 2.2) is higher than the general criteria. The criteria given in Table 5.3 have been calculated based on the following assumptions (Fyn County[1]):

1. The background concentration (corresponding to the concentration in pristine watercourses) of phosphorus in the tributaries is 0.050 mg/l.
2. The phosphorus concentration in the lakes may maximally be 15% higher than the calculated background concentration.

Lake Brahetrolleborg Slotssø was formed by damming the River Silke. In the Provisional Article 5 Analysis it is therefore designated as a heavily modified water body. The lake functions as a natural flushed lake and should be preserved due to its biological and historical value. In Table 5.3 the lake has therefore been assigned the environmental objective "Good status" just like a natural lake.

In addition to the lakes covered by Table 5.3 there are just over 2,600 other lakes larger than 100 m^2 in the river basin. These lakes are assigned the environmental objective "Good ecological status".

Water bodies assigned high ecological status

Lakes assigned the quality objective "Areas of scientific interest" in Fyn County's 2005–2013 Regional Plan are assigned the environmental objective "High ecological status" because of their special natural qualities. They are all Natura 2000 sites and thereby encompassed by international protection. The environmental objective pursuant to the Water Framework Directive concomitantly aims to ensure achievement of the Habitats Directive objective of favourable conservation status for the species and habitat types for which the site was designated. No assessment has yet been made of the conservation status of the various lake types, but it is believed that high ecological status will concomitantly ensure favourable conservation status. For a description of the sites and the species/habitat types for which they were designated, see the Natura 2000 baseline analysis[2]. In brief the main habitat type that Lakes Arreskov Sø, Brændegård Sø, Nørresø and Store Øresø were designated to protect is 3150 "Natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation". Lake Fjordmarken could develop towards the same habitat type, although it is not part of the basis for its designation as the types of plant in question are not presently found in the lake. Lake Sortesø was designated to protect habitat type 3160 "Natural dystrophic lakes and ponds".

Some lakes are designated as Special Protection Areas pursuant to the Birds Directive. The main species that Lake Arreskov Sø is designated to protect are the Grey lag goose (Anser anser), the Tufted duck (Aythya fuligula) and the Shoveler (Anas clypeata), while those that the lakes at Bra-

Lakes – Criteria for ecological status classes		
Ecological status	**Criteria**	
	Deep lakes (type 10)	**Shallow lakes (type 9, 11 and 13)**
High	P <0.013 mg/l N <0.75 mg/l	P <0.025 mg/l N <0.75 mg/l
Good	P: 0.013–0.025 mg/l N: 0.75–1.0 mg/l	P: 0.025–0.050 mg/l N: 0.75–1.0 mg/l
Moderate	P: 0.025–0.050 mg/l N: 1.0–1.4 mg/l	P: 0.050–0.10 mg/l N: 1.0–1.4 mg/l

Table 5.2
The River Basin Management Plan's general criteria for lake ecological status. The nitrogen and phosphorus concentrations are summer means and are based on a report by the National Environmental Research Institute[3]. So as not to delay achievement of the environmental objectives it is important to speed up measures to reduce phosphorus loading. Decisions on possible needs for lake restoration should be postponed to the next plan period. It is permissible to derogate from these general criteria if knowledge of specific conditions in the individual lakes speaks in favour of doing so.

1] Odense Pilot River Basin, Phase II: Preliminary note on the Programme of Measures for lakes. Memorandum of 12 May 2005 (in Danish).

2] Natura 2000 baseline analysis (in Danish). Fyn County, 2006.

3] Søndergaard, M., Jeppesen, E., Jensen, J.P., Bradshaw, Skovgaard, H. & Grünfeld, S., 2003: The Water Framework Directive and Danish lakes. Part 1: Lake types, reference conditions and ecological quality classes (in Danish). Technical Report No. 475. National Environmental Research Institute, 2003.

Lakes – Environmental objectives and criteria for compliance						
Lake	International protection (Natura 2000)	Environmental objective for ecological status	Criterion for phosphorus content (mg/l)	Current phosphorus content (mg/l)	Criterion for nitrogen content (mg/l)	Current nitrogen content (mg/l)
Arreskov Sø	Yes (H105, B78)	High	<0.039	0.097	0.75	1.82
Brahetrolleborg Slotssø	No	Good	? 1)	0.90	1.0	1.87
Brændegård Sø	Yes (H104, B74)	High	? 1)	1.45	0.75	3.34
Dallund Sø	No	Good	<0.05	0.107	1.0	1.74
Fjellerup Sø	No	Good	<0.05	0.215	1.0	2.20
Fjordmarken	Yes (H94, B75)	High	<0.025	?	0.75	?
Langesø	No	Good	<0.05	0.182	1.0	1.82
Nørre Søby Sø	No	Good	<0.05	0.522	1.0	5.97
Nørresø	Yes (H104, B74)	High	<0.036	0.098	0.75	1.38
Sortesø	Yes (H106)	High	<0.030	0.094	0.75	1.58
Store Øresø	Yes (H106)	High	<0.050	0.042	0.75	1.61
Søbo Sø	No	Good	<0.050	0.091	1.0	1.26

Table 5.3
International protection, environmental objectives, hitherto provisional criteria for compliance and current nutrient levels in 12 of the largest lakes in Odense River Basin. International protection: H and B indicate that the lake is encompassed by the Habitats Directive or Birds Directive, respectively. The number is that of the designated areas that encompass the lakes. (H94: Odense Fjord; H104: Forests and lakes south of Brahetrolleborg; H105: Lake Arreskov Sø; F74: Lake Brændegård Sø, Lake Nørresø and forests at Brahetrolleborg; F75: Odense Fjord; F78: Lake Arreskov Sø),
1) Phosphorus concentration naturally elevated due to the presence of a cormorant colony at Lake Brændegård Sø.

hetrolleborg (Lake Nørresø and Lake Brændegård Sø) are designated to protect are the Grey lag goose (Anser anser), the Tufted duck (Aythya fuligula) and the Common pochard (Aythya farina). Lake Fjordmarken is a dyked-in part of the Odense Fjord Special Protection Area designated to protect such species as the Mute swan (Cygnus olor), the Whooper swan (Cygnus Cygnus) and the Coot (Fulica atra). In these cases too, achievement of high ecological status in the lakes will ensure conservation of the habitats for the species for which the sites have been designated as far as concerns water quality and hence the presence of large stands of submerged vegetation (the Coot and the Mute swan). In addition, the Birds Directive typically requires that the sites must provide the birds with undisturbed conditions. With Grey lag geese, moreover, adjoining fields and meadows have to be available where the birds can forage, and with Common terns there has to be access to small uninhabited islands and islets in the lake and an abundant supply of fish.

Water bodies with less stringent environmental objectives

In connection with Action Plan on the Aquatic Environment II a number of new lakes have been established (for example Lakes Hammerdam and Geddebækken upstream of Lake Arreskov Sø) to increase the turnover of nitrogen in the water flowing through the lakes from farmland and thereby reduce nitrogen loading of downstream water bodies. These lakes have typically arisen in former wetlands, for example where lakes have previously been located, and can be or become of great natural value. As the lakes are primarily established with a view to enhancing nitrogen turnover, they will generally not be required to achieve good ecological status. Thus any measures taken in the catchment of these lakes will not be aimed at these water bodies but rather at upstream or downstream water bodies. Thus the quality of the water that flows from the lakes will have to be sufficiently good to enable achievement of the environmental objectives in the downstream water bodies.

Water bodies designated as heavily modified

No existing lakes have been designated as heavily modified water bodies. However, the river basin contains a number of dried-out lakes that were designated as heavily modified water bodies in the Provisional Article 5 Report (see Figure 2.7). Two of these (Lakes Hammerdam and Lake Ringe Sø) have since been completely or partially re-established. No decision has been made as to whether all or some of these dried-out lakes are to be re-established during the present plan period or in the next plan period.

Water bodies for which achievement of the environmental objectives can be delayed

Even once the measures to reduce nutrient inputs to the lakes have been implemented there will still be a risk that some of them will be unable to achieve good ecological status by 2015 due to nutrients accumulated in the sediment. These can continue to be released into the water for many years unless costly lake restoration is undertaken to remove the lake sediment or chemically bind the phosphorus in the sediment. Such measures are not included in the present programme of measures (Chapter 6) as socioeconomic constraints mean that it is not generally possible to carry out such measures within the present plan period. Decisions on the need for lake restoration should be postponed to the next plan period. So as not to delay achievement of the environmental objectives it is important to speed up measures to reduce phosphorus loading.

Wetlands

Odense River Basin contains 44 coastal meadows (481 ha), 879 freshwater meadows (1,743 ha) and 977 mires (2,203 ha). Pursuant to the Water Framework Directive these wetlands should be assigned the environmental objective “Good status” as wetlands follow the objective for the adjoining water bodies (watercourses, lakes and coastal waters). In addition, the river basin contains seven Special Areas of Conservation designated to protect the wetland habitat types:

- 1310 Salicornia and other annuals colonizing mud and sand
- 1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
- 6410 Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)
- 7110 Active raised bogs
- 7140 Transition mires and quaking bogs
- 7150 Depressions on peat substrates of the Rhynchosporion
- 7120 Degraded raised bogs still capable of natural regeneration
- 7220 Petrifying springs with tufa formation (Cratoneurion)
- 7210 Calcareous fens with Cladium mariscus and species of the Caricion davallianae
- 7230 Alkaline fens
- 91D0 Bog woodland
- 91E0 Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae).

The Habitats Directive requires that measures be taken to ensure that these habitat types are restored to or maintained in a state of “Favourable conservation status”.

Meadows alongside the River Odense. Photo: Bjarne Andresen.

Criteria for good status
No description of environmental objectives exists for coastal meadows, freshwater meadows and mires, although the National Environmental Research Institute[1] has established a number of measurable parameters for assessing habitat status, including “Good status” of open terrestrial natural habitats. The assessment system is based on the data that the Counties collected when characterizing 18 habitat types located in the Special Areas of Conservation. The five status classes used are the same as those used in the Water Framework Directive.

The National Environmental Research Institute[2] has also established decisive criteria for determining whether the conservation status of a habitat type is favourable.

Based on the National Environmental Research Institutes assessment system and criteria the following parameters are decisive when determining whether a wetland habitat type has “Good status”:

- Nutrient loading (including nitrogen)
- Hydrology
- Farming practice/nature management
- Area and fragmentation
- Pesticide loading.

Nutrient loading, hydrology, area and pesticide loading are important parameters as regards the Water Framework Directive, the Habitats Directive and the Regional Plan, while farming practice/nature management is primarily of significance regarding the Habitats Directive and the Regional Plan. Farming practice is also of significance regarding nutrient turnover in the wetlands and thereby for loss of nutrients to the water bodies.

The close association between the water

1] Fredshavn, J. R. & Skov, F., 2005: Assessment of the status of natural terrestrial habitats (in Danish). Technical Report No. 548. National Environmental Research Institute.
2] Søgaard B. et al. 2003: Criteria for favourable conservation status. Habitat types and species encompassed by the Habitats Directive and species encompassed by the Birds Directive (in Danish). Technical Report No. 457. National Environmental Research Institute.

bodies and the adjoining wetlands (coastal meadows, freshwater meadows and mires) is of decisive significance for loading of the water bodies with nitrogen and other nutrients as the wetlands remove part of the nutrients lost to them. The most vulnerable of the wetlands will be negatively affected if nutrient-rich drainage water, etc. is led into them in connection with a project in which the wetland is to serve as a nitrogen filter.

It is considered that the individual coastal meadows, freshwater meadows and mires in Odense River Basin will have "Good status" if they meet the following criteria:

- No direct application of fertilizer or pesticide may take place. Indirect input of nitrogen, including atmospheric deposition, must be below the lowest critical load for the habitat type in question.
- The wetland's hydrology must be optimal, which in many cases can be identical to "natural hydrology".
- Coastal meadows, freshwater meadows and mires such as rich fens must generally be grazed down. The intention is that the following percentage of each habitat type within the river basin should be grazed down: Freshwater meadows 100%, coastal meadows 80% and mires 50%.
- No criteria have been set regarding the minimum area of the three habitat types or the minimum proximity to similar habitat types. The intention is to double the total area of these habitat types within the river basin.

The critical load for nitrogen input to the habitat types is presently the only parameter for which values are available that can be considered a measure of when the habitats can be expected to achieve "Good status". The deposition of nitrogen expressed relative to the critical load is shown in Table 5.4.

Wetlands Atmospheric deposition of nitrogen shown in relation to the critical load								
Exceedance of critical load (kg N/ha/yr)	No. of localities		No. in percent		Area in hectare		Area in percent	
	Mires	Coastal meadows	Mires	Coastal meadows	Mires	Coastal meadows	Mires	Coastal meadows
Not exceeded	131	18	17	63	211.2	193.7	10	48
Exceedance ≤1 kg N	87	0	11	0	102.2	0	5	0
Exceedance 1–≤3 kg N	303	1	39	3	564.5	5.5	26	1
Exceedance 3–≤4 kg N	70	0	9	0	161.1	0	7	0
Exceedance 4–≤6 kg N	52	0	7	0	323.2	0	15	0
Exceedance >6 kg N	129	10	17	34	820.8	200.5	37	51
Total	**772**	**29**	**100**	**100**	**2,183.0**	**399.7**	**100**	**100**

Table 5.4
Deposition of nitrogen expressed relative to the critical load for 772 mires (2,183 ha) and 29 coastal meadows (400 ha) in Odense River Basin. The critical load for the individual mires and coastal meadows has been established taking into account their quality objectives in the Regional Plan. Exceedances are expressed relative to the lowest critical load applying to the individual types of mire and individual coastal meadow.

European fire-bellied toad. Photo: Leif Bisschop-Larsen.

More stringent environmental objectives

The Water Framework Directive requires that the wetland habitat types achieve "Good status". More stringent environmental objectives can be set for the wetland habitat types and their associated species in the Natura 2000 sites if they are among the habitat types and species that the sites were designated to protect since the Habitats Directive and/or Birds Directive require that these habitat types and species achieve "Favourable conservation status".

The nature of such more stringent environmental objectives will not be known until the Danish Ministry of the Environment issues a statutory order on environmental objectives for Natura 2000 sites some time in 2007.

5.1 Environmental objectives and criteria for compliance

Groundwater

The environmental objectives for groundwater are based on Fyn County's 2005–2013 Regional Plan. This stipulates the following overall objectives for the groundwater:

- Present and future requirements for an adequate supply of water of satisfactory quality for the public and enterprises shall be assured while concomitantly respecting the environmental objectives for terrestrial natural habitats and surface waters.
- The drinking water supply is to be based on pure groundwater without the need for more than simple treatment.
- The groundwater resource must be safeguarded against overexploitation.
- The groundwater must be protected against contamination.

On the basis of these overall objectives, more operational objectives for the groundwater's quantitative and chemical status have been determined.

Quantitative status
The use of the groundwater resource has been prioritized such that use for the water supply is accorded highest priority and nature interests are accorded second-highest priority.

As far as possible, though, abstraction by the waterworks has to be planned in such a way as to take into account achievement of the environmental objectives for watercourses, lakes and wetlands. Thus abstraction must not conflict with watercourse, lake and wetland interests.

Based on the overall objectives and the more operational objectives stipulated in the Regional Plan, the following criteria can be formulated for *"Good quantitative status"* pursuant to the Water Framework Directive:

- Groundwater abstraction from the groundwater body must not exceed the long-term groundwater recharge
- In accordance with the above-mentioned prioritization, the groundwater level must not be so affected by anthropogenic alterations as to hinder achievement of the environmental objectives for associated watercourses, lakes and wetlands or to result in any diminution in the status of such water bodies or any significant damage to terrestrial ecosystems which depend directly on the groundwater body.

At Tarup-Davinde east of Odense the groundwater exudes from the surface in the gravel quarries. On the slopes one can see what a sand aquifer looks like. Photo: Gunnar Larsen.

Chemical status
Nitrate: The objective for nitrate stipulated in the Regional Plan is:

- To ensure that the water supplied to the population only contains nitrate in natural concentrations.
- To ensure that the natural nitrate concentration (less than 1 mg/l) remains unchanged. In areas where the groundwater is subject to nitrate contamination, the concentration should not exceed an average of 25 mg/l.

As the Regional Plan's overall objectives for the groundwater focus on abstraction for the water supply, this objective for nitrate applies to groundwater bodies utilized for the water supply. In the case of all other groundwater bodies the Nitrates Directive's more general limit level of 50 mg/l applies.

Pesticides and other hazardous substances (chemicals, oils, etc.): The objective stipulated for these substances in the Regional Plan is:

- Pesticides and other hazardous substances must not be present in the groundwater that is used for the drinking water supply.

As with nitrate, this objective applies to groundwater bodies used for the drinking water supply. The Groundwater Directive's general limit level of 0.1 µg/l for pesticides applies to all other groundwater bodies.

A further requirement is that the pollutant content of groundwater must not be such as to hinder achievement of the environmental objectives for watercourses, lakes and coastal waters.

Coastal waters

Criteria for ecological quality classes
The ecological status of the coastal water bodies in Odense River Basin is assessed using both biological (eelgrass depth distribution) and chemical (water phase concentration of total nitrogen and phosphorus) quality elements. The latter quality elements are the foundation for determining the necessary measures, and thereby open up the possibility for operationalization of the establishment of environmental objectives. The criteria for high, good and moderate ecological status based on the above-mentioned quality elements (Table 5.5) are defined respectively as a 15%, 25% and 40% deviation from the previously described reference conditions for Odense Fjord (Section 2.2).

As regards hazardous substances, the criteria for compliance with the environmental objective is that the content of these substances in sediment, water and biota should always fully comply with the applicable national and international limit values.

Environmental objectives
Seden Strand and the western part of the outer fjord is designated as a Natura 2000 site pursuant to the Habitats Directive and the Birds Directive. In addition to having to achieve "Good ecological status" by 2015 (Table 5.5), this part of Odense Fjord also has to achieve "Favourable conservation status" in relation to the habitats and species it was designated to protect. The part of Odense Fjord that has not been designated as a Natura 2000 site – the eastern part of the outer fjord – also has to meet the requirement of "Good ecological status".

Water bodies with high ecological status
Under the former Danish system for environmental quality objectives the north-western part of the outer fjord (see Figure 2.9) was designated as a reference area of scientific interest. This more stringent objective is carried forward as corresponding to the achievement of "High ecological status" (Table 5.5) by 2015.

Water bodies designated as heavily modified
Seventeen heavily modified water bodies have so far been designated in Odense Fjord. Of these, five contain harbours, bridges and shipping fairways and, in accordance with the provisions of the Water Framework Directive regarding "technical feasibility or disproportionate cost", will consequently remain heavily modified, but will be assigned the environmental objective "Good ecological potential".

Water bodies for which the deadline has been extended
The remaining 12 heavily modified water bodies are dyked-in or drained areas. Due to environmental, technical and socioeconomic constraints, though, it is not considered possible to plan and carry out measures to ensure good ecological status in these water bodies by 2015. For these water bodies, decisions on environmental objectives and associated measures for achieving them will thus be postponed until the next plan period.

Arctic tern. Photo: Leif Bisschop-Larsen.

Water bodies for which achievement of the environmental objectives can be delayed
Due to the high level of phosphorus loading of Odense Fjord in the past, large amounts of phosphorus have accumulated in the fjord sediment. From there it can be slowly released into the water phase. As a consequence, the measures taken to reduce phosphorus loading may not result in achievement of the environmental objective by 2015, especially in Seden Strand, but first some years later. Likewise, a number of hazardous substances are persistent in the environment and can have accumulated in the fjord sediment and elsewhere. In order to minimize the risk of a delay in achieving the environmental objective it is important to speed up measures to reduce phosphorus loading in particular.

Coastal waters – Criteria for ecological status classes						
Ecological status	**Eelgrass depth distribution (m)**		**Total nitrogen (µg/l)**		**Total phosphorus (µg/l)**	
	Seden Strand	**Outer fjord**	**Seden Strand**	**Outer fjord**	**Seden Strand**	**Outer fjord**
Reference	>4	>6	<666	<374	<29	<22
High (15% dev.)	3.4	5.1	826	464	33	25
Good (25% dev.)	3	4.5	976	548	36	28
Moderate (40% dev.)	2.4	3.6	1,312	737	41	31

Table 5.5
Criteria for reference conditions and high, good and moderate ecological status for eelgrass depth distribution and the associated concentrations of total nitrogen and total phosphorus (based on fjord modelling) in Odense Fjord (Seden Strand and the outer fjord). As the relationship between eelgrass depth distribution and total nitrogen concentration is logarithmic, the resultant percentage deviations in total nitrogen concentration differ from those shown. The values for eelgrass depth distribution are seasonal maximums, while those for total nitrogen and phosphorus concentrations are annual means.

5.2 Objective compliance and measures required

Watercourses

The current assessment is that more than 90% of the riverine water bodies do not presently comply with the objective of at least good ecological status (Table 5.6). Moreover, the status of a large proportion of the watercourses (32%) is unknown because the watercourses in question have not been investigated.

The assessment was based on the criteria discussed in Section 5.1. No separate assessment has been made of the conservation status of species and habitat types encompassed by the Habitats Directive. A number of conclusions can nevertheless be drawn concerning the riverine habitat types. Thus the greatest present threat to habitat type 3260 (Watercourses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation) is physical disturbance in the form of maintenance (weed clearance and dredging) and former regulation, which keep the watercourses in a poor physical state. Habitat type 6430 (Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels) is mainly threatened by maintenance and loading with nutrients and hazardous substances (various pesticides). Finally, habitat type 7220 (Petrifying springs with tufa formation (Cratoneurion)), which encompasses the sources of the watercourses and the surrounding vegetation, is mainly threatened by regulation, maintenance (dredging) and water abstraction, as well as by nutrient loading and overgrowth. The improvements discussed in Chapter 6 will contribute significantly to ensuring good conservation status for the special species and habitat types associated with watercourses, however.

Aerial photograph of Tørringe Brook in the Odense River system indicating the remeandering project.

Considering watercourses as a whole, lack of compliance with the environmental objective is mainly due to physical pressure from regulation and watercourse maintenance (approx. 85% of the reaches that do not comply with the environmental objective), as well as pressure from pollutant discharges (approx. 65% of the reaches that do not comply with the environmental objective). The pollution mainly derives from sparsely built-up areas (a total of 4,300 properties) and stormwater outfalls (especially 131 outfalls from combined sewerage systems). Moreover, levels of bacteria, viruses, parasites and hazardous substances are elevated in watercourses that receive wastewater from large wastewater treatment plants (a total of seven in the river basin). Achievement of the environmental objective will require measures directed at all of these pressures.

The measures considered necessary to achieve the environmental objective for physical conditions and water quality are quantified in Table 5.7. See also Chapter 6.

Table 5.6
Overview of the present ecological status of the riverine water bodies in Odense River Basin. The values shown are the total length in kilometres with the number of water bodies in parentheses and the corresponding percentages.

Watercourses – Current ecological status relative to their environmental objectives					
Ecological status	**Type 1 (small)**	**Type 2 (medium)**	**Type 3 (large)**	**Type a (artificial)**	**All rivers**
High – Good %	18 (8) ***3 (4)***	42 (6) ***19 (13)***	2 (1) ***4 (9)***	0 (0) ***0 (0)***	62 (15) ***6 (5)***
Moderate - Poor	406 (83)	161 (31)	42 (7)	21 (5)	630 (126)
Unknown	238 (134)	13 (8)	9 (3)	63 (30)	323 (175)
All classes	662 (225)	216 (45)	53 (11)	84 (35)	1015 (316)

Watercourses – Need for improvement of physical conditions and water quality					
Physical improvements	**Type 1 (small)**	**Type 2 (medium)**	**Type 3 (large)**	**Type k (artificial)**	**Total**
▪ Total length of watercourse in the catchment (km)	662	216	53	84	1,015
▪ Open watercourses, total (km)	426	216	53	67	762
▪ Estimated length of open watercourse without good status (km)	339	156	39	-	534
▪ Need for removal of obstructions (estimated number)	175	45	0	3	220
▪ Need for reduced maintenance (km)	339	156	39	-	534
▪ Need for reduced maintenance (% of open watercourse length)	79	72	74	-	70
▪ Need for establishment of cultivation-free buffer zones[1] (ha)	1,000	1,500	1,100	-	3,600
▪ Need for remeandering[2] (km)	155	54	18	-	227
▪ Need for remeandering (% of open watercourse length)	36	25	34	-	30
▪ Daylighting of culverted reaches[3] (km)	236	0	0	-	236
Water quality improvements	**Type 1 (small)**	**Type 2 (medium)**	**Type 3 (large)**	**Type A (artificial)**	**Total**
▪ Need for wastewater treatment[4] (estimated km)	260	105	20	30	415

1 The calculations assume 15-, 50- and 150-m uncultivated buffer zones alongside each bank of type 1, 2 and 3 watercourses, respectively. Only part of this land is presently cultivated, though, so the amount of land that needs to be set aside is less, corresponding to just over 2,200 ha (see Chapter 6).
2 The calculations assume a need for remeandering in reaches where the physical state is poor/bad.
3 The calculations assume a need for stone/gravel to be laid out (and possibly for remeandering) as well as the establishment of at least 5-m wide buffer zones alongside the watercourses.
4 Reaches affected by discharges of wastewater and/or hazardous substances.

Table 5.7
Calculated requirements for improvement in physical conditions and water quality in the watercourses in Odense River Basin. The first row gives the total length of each type of watercourse in the river basin.
Notes:

Fish pass at Brobyværk in the River Odense. Photo: Bjarne Andresen.

5.2 Objective compliance and measures required

Lakes

All the 12 lakes listed in Table 5.3 (Section 5.1) are at risk of failing to meet their environmental objective. Based on the environmental objectives, nitrogen and phosphorus reduction requirements have been calculated for 11 of the lakes. Due to inadequate information on pressures and status it has not been possible to calculate the reduction requirements for Lake Fjordmarken. The amount by which annual nitrogen and phosphorus loading will have to be reduced in order to enable the lakes to achieve their environmental objectives is shown in Table 5.8.

The reduction requirements have been calculated using empirical models for the relationship between phosphorus and nitrogen loading of the lake and the concentration of the respective nutrient in the lake water. In the cases where measurements of nutrient transport to the lakes are unavailable, phosphorus and nitrogen loading are calculated based on knowledge of the point sources in the catchment and estimated diffuse loading. The latter was calculated using models for the relationship between on one hand land use and precipitation and on the other hand runoff of water and nutrients.

In some lakes it will be necessary to carry out lake restoration measures such as sediment removal or chemical binding of the nutrients in the sediment if their environmental objectives are to be achieved by 2015. Lake restoration requirements will be evaluated in the next plan period, cf. Section 5.1.

The majority of the ponds and small lakes in the river basin are at risk of failing to achieve the environmental objective of good ecological status. No specific needs for intervention have been calculated for the individual small lakes but as a general rule, improved wastewater treatment including phosphorus removal will have to be implemented at properties in lake catchments, and 10-m wide uncultivated buffer zones will have to be established alongside the lakes. This is expected to improve their status. Experience from studies of ponds and small lakes shows that wastewater from sparsely built-up areas comprises the greatest threat to the environmental state of small lakes[1]. In certain cases, moreover, it can be necessary to reduce/stop duck rearing in order to ensure achievement of the environmental objective.

Lake Sortesø. Photo: Leif Bisschop-Larsen.

Lakes – Required reduction in nutrient loading

Lake	Current loading		Required reduction	
	Phosphorus (tonnes/yr)	Nitrogen (tonnes/yr	Phosphorus (tonnes/yr)	Nitrogen (tonnes/yr)
Arreskov Sø	0.56	28.8	0.28	13.6
Brahetrolleborg Slotssø	0.57	22.4	0.27	15.8
Brændegård Sø	0.39	13.9	0.18	4.9
Nørresø	0.09	3.9	0.03	0.6
Dallund Sø	0.08	2.3	0.03	0.5
Fjellerup Sø	0.02	0.9	0.01	0.4
Langesø	0.22	8.8	0.10	5.0
Nørre Søby Sø	0.32	10.2	0.21	5.8
Søbo Sø	0.07	2.5	0.03	0.6
Sortesø	0.002	0.03	0	0
Store Øresø	0.03	0.9	0.02	0.3

Table 5.8
Present nutrient loads and reduction requirements (objective) in 11 of the largest lakes in Odense River Basin. The present loads are the means for the period June 1999–May 2003.

Note:
When calculating the nutrient reduction requirements in the present pilot project, resource constraints have necessitated making a number of simplifications and generalizations that will have to be reconsidered in the final river basin management plan. Thus no account has been taken of special local factors such as the cormorant colony at Lake Brændegård Sø, the possibility of a naturally elevated phosphorus concentration in the water flowing into Lake Langesø and the fact that Lake Dallund Sø seems to have been affected by agriculture for several hundreds of years, cf. Chapter 2.2.

1] Fog, A. and P. Wiberg-Larsen, 2002: Environmental state of small lakes and ponds on Funen 1997–2000 (In Danish). SØovervågning i Fyns Amt No.10, June 2002. Fyn County, 63 pp.

Wetlands

It is estimated that 30–70% of the coastal meadows in Odense River Basin and at least half of the mires and freshwater meadows (including springs) do not meet their environmental objectives, mainly due to loading with nitrogen, other nutrients and pesticides, draining and drainage, and overgrowth. In order to achieve the environmental objectives for the wetlands the following measures will be required:

- A 50% reduction in ammonia emission from livestock holdings >35 LU[1]
- Deactivation of around 300 km of drains/ditches
- A doubling of the area of natural terrestrial habitats, i.e. establishment of approx. 2,400 ha of mire/freshwater meadow and 450 ha of coastal meadow.
- Clearance of growth on approx. 360 ha of mire
- Grazing down of approx. 2,400 ha of mire, freshwater meadow and coastal meadow.

Pond surrounded by grazed freshwater meadow and dry grassland. The pond is shallow and clean and serves as a breeding ground for several species of amphibians, but only remains in existence due to grazing. Photo: Birgit Bjerre-Laursen.

Groundwater

Nitrate

A number of measures have been implemented since 1988 that will reduce nitrate contamination in the future. The measures in question result from Action Plans on the Aquatic Environment I, II and III.

The analysis results for the upper oxic groundwater collected from the groundwater monitoring sites in Denmark have been reported by the Geological Survey of Denmark and Greenland (2004). The oxic groundwater is the youngest groundwater, but represents groundwater of different ages. The general trend is that the nitrate concentration has remained unchanged at an average of 45–50 mg/l since 1999. By far the majority of the analysed groundwater was formed prior to 1990. As a consequence, any effect of the measures implemented as part of the Action Plans on the Aquatic Environment cannot be expected to have a detectable effect on the mean nitrate concentration in the groundwater before 2015.

This is underlined by the analyses of the newly formed groundwater (0–6 m b.g.s) from the national agricultural monitoring catchments in Denmark. No significant change has been detected in the nitrate content of the upper groundwater over the period 1998–2003. In sandy areas the mean nitrate concentration exceeded 50 mg/l in most years, while it fluctuated between 37 and 49 mg/l in the clayey areas.

Likewise, the National Environmental Research Institute has determined the trend in the nitrate content of the root zone water and the upper groundwater over the period 1990/91–2002/03 for Denmark as a whole. The findings show that the nitrate concentration in the root zone water has decreased in both sandy areas and clayey areas, but still exceeds the EU limit value

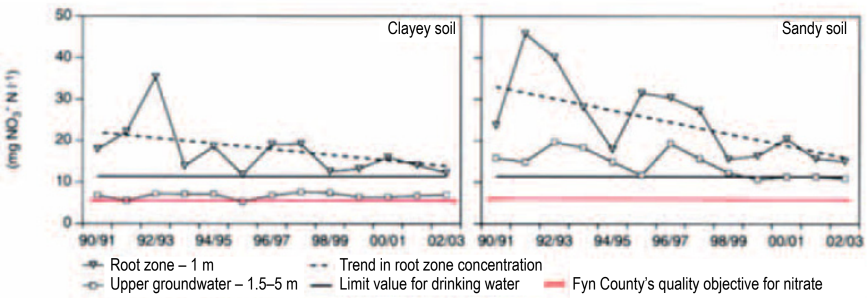


Figure 5.1
Tend in measured nitrate concentrations in the root zone water and upper groundwater (National Environmental Research Institute). Note that the concentration is expressed as NO3--N in the figure but as NO3- in the text.

1] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

of 50 mg/l for drinking water. Over the same period the nitrate concentration in the upper groundwater (1.5–5 m b.g.s.) has decreased in sandy areas, although not since 1998/99, and is now around the limit level for drinking water (Figure 5.1). In clayey areas no statistically significant change in nitrate concentration is detectable over the period, but the nitrate content has been below the limit value for drinking water throughout the period (cf. abovementioned analysis by the Geological Survey of Denmark and Greenland).

Over the whole period the nitrate concentration in the upper groundwater has exceeded the quality criterion for nitrate specified for both clayey soil and sandy soil in the Funen County Regional Plan. As a consequence, the groundwater will become contaminated in those areas where the soil is no longer able to metabolize nitrate, thereby preventing achievement of the environmental objective. These areas have not yet been precisely identified, but based on the information available the nitrate-vulnerable areas total approx. 18,000 ha. From experience with charting of the vulnerable areas it can be expected that it will be necessary to implement groundwater protection measures in approx. 1/3 of this area.

Hazardous substances

Hazardous substances contaminating the groundwater primarily derive from point sources. Further contamination is usually combated through preventative measures and inspection of potential sources of contamination. With a number of the hazardous substances, measures have been implemented to hinder further contamination. The primary example is the petrol additive MTBE, although this is rarely used nowadays.

To the extent that it is financially feasible, known sources of contamination are charted and remedial measures are initiated aimed at cleaning up the contamination or preventing it from spreading further. The location of the contaminated sites is not fully known, but previous experience and statistical analyses indicate that there should be 107 contaminated sites at which measures need to be taken.

A number of the pesticides have been banned, thereby reducing the risk of future contamination. As the transit time of the groundwater is long relative to the time period up to 2015, the above measures cannot be expected to change the status of the groundwater to any great extent within the coming years.

Approved pesticides may still be used, but specially designed surveillance programmes have revealed that some of these pesticides can leach to the groundwater. Thus the possibility that pesticide contamination of the groundwater will also occur in the future cannot be excluded. It is therefore necessary to protect areas in the vicinity of waterworks wells where pesticide contamination has previously been detected. This means that it is necessary to protect a total of approx. 2,000 ha of land in the vicinity of waterworks wells from pesticide leaching.

Coastal waters

The failure of Odense Fjord to meet its environmental objective is due to excessive nutrient loading, especially from agriculture, the presence and effects of hazardous substances, and physical pressures such a dredging and deepening activities in connection with shipping fairways and harbours. These pressures are concomitantly the greatest threats to attainment of favourable conservation status for the marine habitat types that the Natura 2000 site in Odense Fjord was designated to protect, namely habitat types 1110 (Sandbanks which are slightly covered by sea water all the time), 1140 (Mudflats and sandflats not covered by seawater at low tide) and 1160 (Large shallow inlets and bays).

The required reductions in nitrogen and phosphorus loading have been calculated based on the ecological status criteria presented in Table 5.5 for eelgrass depth distribution and the concentrations of nitrogen and phosphorus. As far as concerns nitrogen, a model has been established for the relationship between loading and the concentration in the fjord. From this it is possible to determine the maximum nitrogen load that can be input to the fjord while still permitting achievement of the environmental objectives "Good ecological status" and "High ecological status".

In Seden Strand, "Good ecological status" can be achieved provided the nitrogen load is no more than 900 tonnes N. The same maximum load will permit achievement of "High ecological status" in the western part of the outer fjord.

As far as concerns phosphorus, it is estimated that provided the load does not exceed 35 tonnes P, "Good ecological status" can be achieved in Seden Strand and "High ecological status" can be achieved in the western part of the outer fjord.

It should be noted that meeting these loading targets will raise the status of the eastern part of the outer fjord from the minimum requirement of "Good ecological status" to "High ecological status".

Based on the present riverine nutrient inputs to Odense Fjord – 2,100 tonnes N and 55 tonnes P (2004 level) – the reduction requirement can be calculated to be 1,200 tonnes N and 20 tonnes P.

Achievement of these reduction targets will concomitantly ensure achievement of the environmental objective of "Good ecological potential" in the water bodies designated as heavily modified (i.e. harbours, bridges and shipping fairways).

In addition to the measures already implemented it will be necessary to further reduce inputs of hazardous substances and heavy metals to Odense Fjord.

Dredging and deepening activities in the fjord will have to be undertaken gently through the use of suitable methods and materials.

A lucky and happy seatrout angler. Photo: Bjarne Andresen.

6. Programme of measures and economic aspects

The analyses presented in Chapter 5 show that in order to ensure achievement of the environmental objectives it is necessary to implement a number of measures to reduce anthropogenic pressures on water bodies and terrestrial natural habitats and ensure the survival of species and habitat types.

The failure of the various types of water body to meet their environmental objectives is in principle attributable to two main types of pressure:

1. Pollutant pressure due to loading with nutrients, hazardous substances, etc.
2. Physical pressure due to interventions such as watercourse maintenance, land reclamation, etc.

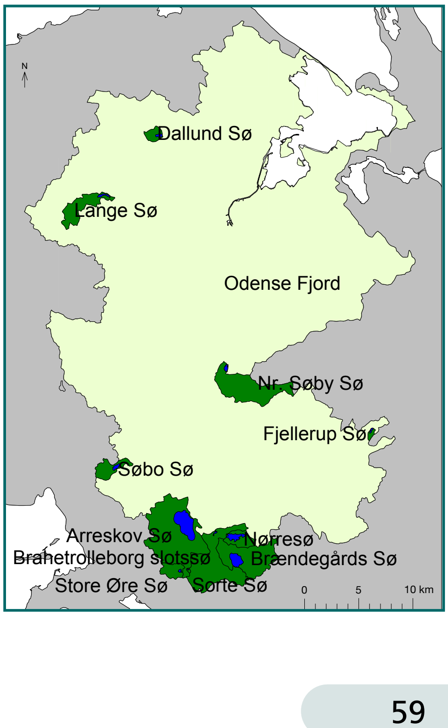
The programme of measures is dimensioned on the basis of the determined operational objectives and quantified reductions/improvements specified in Chapter 5.2 as being necessary to reduce pressure on the various water bodies and natural terrestrial habitats. The reduction requirements are in turn based on the situation in 2004 taking into account the expected effects of the measures already adopted (in 2004), but not yet fully implemented, pursuant to EU directives such as the Nitrates Directive and the Wastewater Directive and regional/national action plans such as the Regional Plan, the Municipal Wastewater Plans and Action Plan on the Aquatic Environment III (see Section 6.2). These measures are termed "basic measures", while the remaining measures needed to ensure achievement of the environmental objectives, i.e. those initiated pursuant to the Water Framework Directive, are termed "supplementary measures".

Based on a cost-effectiveness analysis, a programme of measures has been drawn up for the catchments of 11 of the largest lakes in Odense River Basin and for the remainder of the river basin (Figure 6.1) containing a balanced combination of measures that will together ensure that the water bodies and the terrestrial natural habitats meet their environmental objectives.

The programme of supplementary measures is comprised of measures aimed at reducing point-source pressures, physical pressures and diffuse nutrient loading from agriculture (see Section 6.3). The programme of measures for the water bodies is integrated with Natura 2000 planning such that the programme of measures for water bodies also contributes to some extent to achievement of environmental objectives pursuant to the Habitats Directive – not just regarding aquatic habitats, but also regarding terrestrial natural habitats. Thus the river basin management plan contains measures that increase the area of terrestrial natural habitats and enhance their contiguity, among other reasons to ensure that they attain "favourable conservation status" as required by the Habitats Directive. The analyses have shown that a considerable synergy effect can be achieved by integrating measures to meet the objectives of the Water Framework Directive and the Habitats Directive because certain types of measure/intervention concomitantly affect different types of water body and terrestrial natural habitat (see Section 6.1).

The programme of measures presented here is expected to ensure achievement of the environmental objectives in the large majority of the water bodies in Odense River Basin. During the first plan period, though, the programme of measures will leave a number of water bodies in the same state as now, i.e. highly physically modified. The water bodies in question are largely the uppermost culverted reaches of watercourses and drained lakes and fjord sections (land reclamation), where the environmental objectives cannot be achieved during the first plan period due to lack of temporal, economic and societal constraints.

Figure 6.1
Odense River Basin shown subdivided into the 11 lake catchments (dark green) for which the programme of measures is specified separately in Annexes 3 and 4 together with that for the remainder of the river basin (light green).



6.1 Measures – summary

The pressure reductions required to ensure achievement of the environmental objectives for the water bodies will necessitate implementing many different types of measure. These measures can be subdivided into the following main groups:

- Measures to reduce pressures from diffuse inputs of pollutants (among others, nutrients from agriculture)
- Measures to reduce pressures from point sources (among others, wastewater from households and industry)
- Measures to reduce physical pressures on the water bodies (among others, from watercourse regulation and maintenance, shipping, etc.).

A number of measures have been identified that differ in environmental impact and cost-effectiveness. Each of these measures is not necessarily aimed at reducing pressure on one particular type of water body, for example a lake, but the measure can concomitantly have an effect on several types of water body and terrestrial natural habitat, for example a downstream fjord, and/or a beneficial effect on the quality of terrestrial natural habitats, for example by increasing their area and enhancing their contiguity. When selecting cost-effective measures to fulfil the environmental objectives one cannot solely focus on each individual type of water body and terrestrial natural habitat in isolation, but must consider the need for measures in an integrated manner, focussing concomitantly on the need for measures related to all water bodies and terrestrial natural habitats in the river basin.

The various cost-effective measures that can together help ensure achievement of the environmental objectives are summarized in Table 6.1. The type of water body and terrestrial natural habitat at which the measures are aimed is also indicated. Some of the measures are multifunctional, for example the measure "Set-aside of farmland – lowland/river valleys; Land for re-establishment of wetlands". This measure concomitantly reduces nutrient loading of surface waters, reduces physical pressure on watercourses and re-establishes new natural habitats that can help ensure the necessary dispersal corridors in the cultural landscape and halt the decline in biodiversity.

Other measures aim to reduce a specific type of pressure, for example the measure "Environmental optimization of crop production – lowland/river valleys", which reduces nutrient pressure on the water bodies, or improved wastewater treatment in the form of "UV and ozone treatment", which reduces pressure from hazardous substances and pathogenic bacteria and viruses.

Ejby Mølle Wastewater Treatment Plant. Photo: Jan Kofod Winther.

Summary of measures
Measures to fulfil environmental objectives in Odense River Basin

Pressures and measures to reduce them	Target pressures that are reduced or removed. Effect of the measures	Water bodies and terrestrial natural habitats affected by the measure				
		Coastal waters	Lakes	Water-courses	Ground-water	Terrestrial natural habitats
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] *Nitrogen* • Additional 5% higher utilization of the N content of manure • Catch crops: Increased area • Reduced N fertilization norm (-10%) *Phosphorus* • P fertilization regulation: Balance between applied and removed phosphorus at field level • P fertilization regulation: Reduced P fertilization of soil with a high P index (P_t>4)	• Nitrogen leaching (N) • Phosphorus leaching (P)	+	+		++ (N)	
Environmental optimization of crop production – lowland/river valleys *Nitrogen* • Additional 5% higher utilization of the N content of manure • Catch crops: Increased area • Reduced N fertilization norm (-10%) *Phosphorus* • P fertilization regulation: Balance between applied and removed phosphorus at field level • P fertilization regulation: Reduced P fertilization of soil with a high P index	• Nitrogen leaching (N) • Phosphorus leaching (P)	++	++			
Set-aside of farmland – upland[1] • Land for afforestation (broadleaf) • Permanent grassland • Restrictions on cultivation of land potentially subject to erosion	• Nitrogen leaching (N) • Phosphorus leaching (P) • Sediment loss • Re-establish the dry grassland habitat types and reduce/reverse the decline in species diversity in these habitats	+	+		++(N)	++
Set-aside of farmland – lowland/river valleys • Land for re-establishment of wetlands • Permanent grassland on farmland • 5-m buffer zone alongside watercourses in lake catchments • 10-m buffer zone around ponds in lake catchments	• Nitrogen leaching (N) • Phosphorus leaching (P) • Sediment loss • Re-establish the mire and meadow habitat types and reduce/reverse the decline in species diversity in these habitats	++	++	++		++
Groundwater protection measures *Set-aside of arable land:* 1. Permanent grassland kept unfertilized 2. Afforestation *Environmental effectivization of arable land:* 3. Pesticide-free cultivation of arable land 4. Increased area of spring cereals, fertilization with 60% N norm and increased use of catch crops	• Nitrogen leaching (N) • Pesticide leaching (Pest)	+(N)	+(N)		++	++ (1,3)
Reduction of physical pressure						
Removal of obstructions for fish migration	• Reintroduction and protection of migratory fish			++		
Cessation of watercourse maintenance in conjunction with extensification of cultivation in river valleys (establishment of uncultivated buffer zones)	• Restore natural hydromorphological conditions, N and P leaching	+ (N, P)	+(N, P)	++		++
Remeandering of watercourses, laying out of spawning gravel, stones, etc.	• Restore natural hydromorphological conditions			++		
Daylighting of culverted watercourses and establishment of 5-m buffer zones alongside both banks	• Restore natural hydromorphological conditions and ensure dispersal possibilities for plants and animals			++		+
Removal or reduction of water abstraction/supplies	• Restore natural hydromorphological conditions			+		+
Reduction of pressure from point sources						
Sparsely built-up areas – improved wastewater treatment	• BOD, nitrogen and phosphorus	+	+	++		
Stormwater outfalls – detention volume	• BOD, nitrogen and phosphorus • Sand transport and hydraulic disturbances	+	+	++		
Wastewater treatment plants – improved wastewater treatment • (UV and ozone treatment)	• Hazardous substances • Bacteria and viruses	+	+	+		
Contaminated sites	• Hazardous substances	+	+	+	++	
Enterprises	• Improved water quality	+	+	+		
Special measures – terrestrial natural habitats						
New terrestrial natural habitats (coastal meadows, mires/freshwater meadows and dry grassland)	• Stops decline in biodiversity	+	+	+	+	++
Reduced ammonia emission from agriculture	• Critical loads not exceeded	+	+			++
Nature management • Grazing down etc. of present natural habitats • Clearance	• Hinders overgrowth and thereby reduces the decline in species diversity					++
Improved hydrological conditions (decommissioning of ditches/drains)	• Re-creates natural hydromorphological conditions	+	+	+		++

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Where is the effect greatest?

A measure can have different effects on a water body depending on how the measure is implemented. For example, measures that reduce leaching from farmland have a greater effect on nutrient loss to watercourses, lakes and coastal waters if they are implemented in river valleys (lowland) rather than in upland farmland (in this report defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place). This is due to the fact that retention and turnover of nutrients in the soil are greater during the longer transport of the water from the upland fields to the surface waters via the soil. Conversely, measures implemented in the river valleys to reduce nutrient leaching will have no effect as regards reducing pressure on the aquifers as virtually all movement of water in the river valleys is directed towards the watercourses rather than towards the aquifers. Moreover, measures implemented on sandy soils, which are not usually drained, will have less effect on pressure on the surface waters than if they were implemented in clayey soils, which are typically drained. The reason for this is that turnover of nutrients flowing from drained clayey soils to surface waters is lower than that of nutrients flowing from undrained sandy soils.

In relation to reducing pressure on surface waters one thus gets "better value for the money" by implementing environmental effectivization measures in "lowland" farmland (the river valleys) than in "upland" farmland. Moreover, measures implemented in the river valleys will also yield a synergy effect by reducing nutrient pressure and physical pressure, while concomitantly meeting the need to enhance the area of terrestrial natural habitats and ensure more contiguous dispersal corridors in the cultural landscape.

For this reason, the measures directed at reducing diffuse nutrient pressure from agriculture are collated for each of the three types of farmland: Lowland farmland in the river valleys, upland farmland in nitrate-vulnerable areas used for groundwater abstraction, and the remaining upland farmland (Figure 6.1).

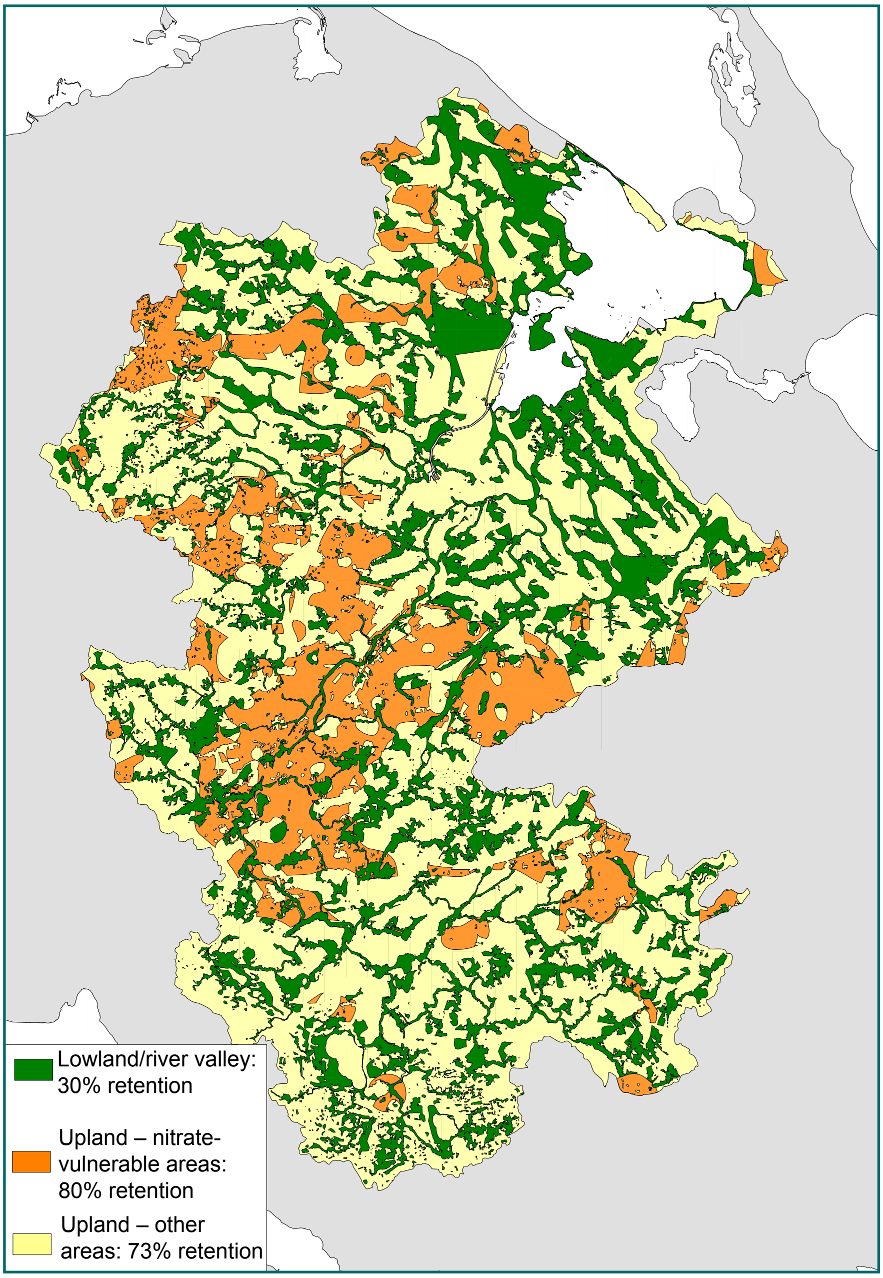


Figure 6.2
Odense River Basin subdivided into retention zones, i.e. areas differing in ability to retain (metabolize) nutrients lost to the surface waters from farmland. A retention of 30% means that 30% of the nitrogen leaching from the fields is metabolized before it reaches the watercourses. "Lowland" means arable land elevated less than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place, while "Upland" means arable land elevated at least one metre above the same reference level.

Photo: The River Odense at Tørringe Brook. Stig E. Pedersen.

6.2 Basic measures and assumptions

Independently of the Water Framework Directive a number of measures have been adopted in Odense River Basin pursuant to EU directives such as the Nitrates Directive and the Wastewater Directive and regional/national action plans such as the Regional Plan, the Municipal Wastewater Plans and Action Plan on the Aquatic Environment III that will further reduce pressure on the water bodies after 2004, which is the year used to calculate the requirements for reduction in pressures. These basic measures, some of which have not yet (2004) been fully implemented, are collectively referred to as "Baseline 2015" (Table 6.3).

The expected situation after implementation of "Baseline 2015" is the foundation for determining what supplementary measures (Section 6.3) are needed to ensure fulfilment of the environmental objectives specified in the Water Framework Directive and the Habitats Directive.

Effects

The effects and costs of these basic measures and the assumptions made are given in Table 6.3. It can be seen that the basic measures are together expected to reduce annual nitrogen loading by 330 tonnes N and phosphorus loading 5 tonnes P. Point-source discharges of oxygen-consuming substances and ammonia will also be reduced. The measures will also result in improvement in the physical condition of watercourses in connection with the re-establishment of wetlands, the elimination of thermal pressure on the River Odense from the cooling water discharge from Fynsværket CHP Plant, and a reduction in hazardous substance loading from contaminated sites.

Economics

The economic cost of the basic measures are calculated to be around DKK 126 million per year, of which by far the majority is for measures directed at point sources (approx. DKK 118 million per year).

The economic analysis of water use in Odense River Basin prepared for the Provisional Article 5 Report shows that the present total costs of water use in the river basin amount to approx. DKK 612 million per year. The costs are shown apportioned by sector together with the income and production value in Table 6.2. Expressing the costs of water use relative to the income and production value provides a rough indication of the proportion of household income and total business production costs is comprised by water and wastewater costs and thereby of the significance of water use as a production factor.

	Expenses for water use (DKK million/yr)					
	Water	Wastewater disposal	Levies, VAT, etc.	Total	Income and production value	Expense in % of income and production value
Households	80	140	130	**350**	33,750	1.0
Industry and services	54	158	6	**218**	80,050	0.3
Agriculture	34	2	8 (APAE II)	**44**	2,800	1.6
Total (WFD Article 5 analysis)	**168**	**300**	**144**	**612**	**116,600**	**0.5**

Table 6.2
Expenses for water use, etc. in Odense River Basin.

Assumptions

When assessing the effects and costs it has been assumed that the agricultural measures pursuant to Action Plan on the Aquatic Environment III are equally distributed throughout Denmark, either in relation to the amount of farmland in the local areas or in relation to the size of the livestock production when relevant. In the case of the measure "Set-aside of land for wetlands" it has been assumed that the presently ongoing (2004–2007) set-aside of a total of 603 ha for wetland pursuant to Action Plan on the Aquatic Environment II/III will be fully implemented. This means that the measure will be used to a greater extent in Odense River Basin than in the country as a whole, where a total of 8,000–12,500 ha of new wetland are to be established under Action Plan on the Aquatic Environment II.

It is also assumed that any changes in livestock production on livestock holdings inside or outside the river basin will not enhance losses of nutrients, etc. to the environment or diminish the effect of the measures already adopted to reduce pressure on water bodies and terrestrial natural habitats.

If the above-mentioned assumptions fail to hold in practice, it will be necessary to adjust the dose of the supplementary measures to fulfil the environmental objectives, cf. Section 6.3 and Table 6.4. The river basin management plan thus incorporates a follow-up on the basic measures to assess whether the assumptions on which they are based remain valid. For example, if the Municipalities change the way they administer livestock holdings locally and permit an increase in pressure from agricultural production it will be necessary to implement further measures to achieve the environmental objectives. Correspondingly, it can be necessary to adjust the programme of measures if the local environmental impact of the general environmental regulation of agricultural production fails to meet the assumptions (see Table 6.3).

Table 6.3 **Baseline 2015 – Assumptions**

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc.

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Physical Pressure** - Reduction	**Natural habitats** Re-establish-ment and improve-ment of quality	Other	Economic cost (DKK 1,000/yr)
Diffuse nutrient and pesticide loading – agriculture ***(Total cultivated land in the river basin: 68,421 ha)***							
Action Plan on the Aquatic Environment III Catch crops: Increased area	3,216 ha	47	0				1,000
5% higher utilization of the N content of manure	68,421 ha	29	0				2,100
EU agricultural reform (CAP) + improved utilization of the N content of fodder	68,421 ha	51					0
Structural development (reduction in area relative to 2003)	2,824 ha	40					0
Agri-environmental measures – buffer zones and wetlands	90 ha	8		+			600
Set-aside of land for afforestation (upland[1])	586 ha	6			+		2,000
Set-aside of land for wetlands (APAE II+III)	603 ha	131	0.6	+	+		2,500
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	4,291 properties	8	2			Reduced discharge of oxygen-consuming substances and ammonia	32,000
Wastewater treatment plants – improved wastewater treatment through optimization of operation	13 WWTPs	2	0				0
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	131 localities	5	2			Reduced discharge of oxygen-consuming substances and ammonia	41,700
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	4 localities	<1	<1			Reduced discharge of oil residues, precipitates, etc.	200
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	1 locality	?3	?			Reduced discharge of hazardous substances	15,200
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	1 locality					Reduced temperature pressure from cooling water	
Contaminated sites – remediation	107 localities					Hazardous substances – reduced loss to the environment	29,200
COMBINED EFFECT AND COST		**330**	**5**				**126,500**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

The basic measures that the river basin management plan assumes will be implemented in the catchment of each of the 11 largest lakes in Odense River Basin and in the remainder of the river basin as a whole are specified and quantified in Annex 3.

6.3 Programme of measures – supplementary measures

The programme of measures (supplementary measures) and associated dose of each measure needed to ensure achievement of the environmental objectives for the water bodies in Odense River Basin is summarized in Table 6.4. The measures were selected and dosed using economic optimization, cf. Section 6.4. That the measures were selected on the basis of a cost-effectiveness analysis ensures that the environmental objectives for the water bodies are achieved as cheaply as possible. The measures are distributed throughout the river basin in the dose indicated.

The annual economic cost of the programme of measures for the water bodies in Odense River Basin amounts to approx. DKK 94 million. To this should be added the supplementary measures to fulfil the environmental objectives in the Natura 2000 sites cf. the Natura 2000 plans.

The programme of measures contains supplementary measures with four main aims:

1. Reduction of diffuse pressure from agriculture – nutrients and pesticides:
   a. Environmental optimization of crop production (upland)
   b. Environmental optimization of crop production (lowland/river valleys)
   c. Set-aside of farmland (upland)
   d. Set-aside of farmland (lowland/river valleys)
   e. Groundwater protection measures (upland in nitrate-vulnerable areas)
2. Reduction of physical pressure on watercourses
3. Reduction of pressure from point sources
4. Special measures for terrestrial natural habitats.

Many of the measures used have an effect on several types of pressure and an effect on several water bodies and terrestrial natural habitats, cf. Table 6.1. These diverse effects are taken into account in the programme of measures.

The programme of measures for the catchment of 11 of the largest lakes in the river basin is shown in Annex 4 together with that for the remainder of the river basin. An example of subdivision of the programme of measures at the municipal level is shown in Annex 5.

Reduction of diffuse pressure from agriculture – nutrients and pesticides

Nitrogen losses

Nitrogen loading of surface waters will be reduced by just over 900 tonnes N per year upon implementation of the supplementary measures. Approx. 1/3 of this reduction will be achieved through environmental optimization of crop production. The remainder of the reduction will be achieved by the set-aside of arable land in the river valleys, among other things with a view to re-establishing wetlands that can retain part of the nutrients lost from farmland. In all, approx. 85% of the necessary reduction in nitrogen loss to the surface waters will be achieved through measures in the river valleys. The remaining 15% of the reduction in nitrogen loss to surface waters will be achieved through measures in upland farmland as a side effect of groundwater protection in nitrate-vulnerable groundwater abstraction areas.

The most effective measures to reduce pressure on the surface waters are "Set-aside of land for re-establishment of wetlands", "Catch crops" and "Reduced N fertilization norm" (Table 6.4, measures 13, 1 and 7). In addition to reducing nutrient loading of surface waters the measure "Set-aside of land for re-establishment of wetlands" (measure 13) will concomitantly help reduce physical pressure on watercourses and help enhance the area of the wetland habitat types mire and freshwater meadow and thereby contribute to fulfilling the environmental objectives for the Natura 2000 sites.

As regards reducing the nitrate contamination of the aquifers, the programme solely focuses on the set-aside of farmland as permanent grassland (approx. 7% of the total area of farmland). This measure will concomitantly help enhance the area of the dry grassland habitat types and thereby contribute to achievement of the environmental objectives for the Nature 2000 sites.

To reduce pressure on terrestrial natural habitats from airborne nitrogen, ammonia emissions from livestock holdings larger than 35 livestock units are to be reduced by 50% as the local contribution to ensuring that the critical load for nitrogen is not exceeded in these habitats. This measure will concomitantly help reduce nitrogen loading of the water bodies.

All in all, 12,480 ha of farmland will be set aside corresponding to 19% of the area of farmland in 2004.

Phosphorus losses

Phosphorus loading will be reduced by a total of 8.5 tonnes P per year through measures to reduce diffuse pressure from agricultural production (65% of the total reduction) and point-source pressure from sparsely built-up areas (35%). A further reduction will be obtained through the measure "Reduced P fertilization of soil with a high P index" (Table 6.4, measure 4), although it has not been possible to quantify the reduction. Moreover, the measure "Balance between applied and removed phosphorus at field level" (measure 3) will ensure that phosphorus loss from farmland does not increase in the future as a result of the accumulation of phosphorus in fields due to overfertilization with phosphorus.

The reduction in phosphorus loss from farmland is primarily expected to result from the set-aside of farmland in the river valleys for wetlands and the presently unquantifiable effects of the measure "Reduced P fertilization of soil with a high P index" (measure 4).

Table 6.4

WFD Programme of Measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and terrestrial natural habitats in Odense River Basin

Measure		Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Economics** Economic cost (DKK 1,000) /yr
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	11,482 ha	115	0			3,358
2. Additional 5% higher utilization of the N content of manure	41,548 ha	17	0			632
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	30,745 ha	0	No loss increase			?
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	10,802 ha	0	Reduction not quantified			?
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	4,656 ha	121	0			1,362
6. Additional 5% higher utilization of the N content of manure	13,116 ha	14	0			199
7. Reduced N fertilization norm (-10%)	12,953 ha	32	0			909
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	9,706 ha	0	No loss increase			?
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	3,410 ha	0	Reduction not quantified			?
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	1,532 ha	16	0.153		+	5,255
11. Permanent grassland	304 ha	3	0.030		+	981
12. Restrictions on cultivation of land potentially subject to erosion	258 ha	3	0.026	+	+	832
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	3,185 ha	319	3.185	+	++	13,503
14. Permanent grassland on farmland	541 ha	14	0.054	+	++	1,744
15. 5-m buffer zones alongside watercourses in lake catchments	17 ha	0.9	0.017	+	+	72
16. 10-m buffer zone around ponds in lake catchments	10 ha	0.5	0.010	+	+	43
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	4,598 ha	44.1	0.092		++	14,832
18. Pesticide-free cultivation of farmland around water supply wells (300-m zone) (no pesticide leaching)	2,056 ha	-	-		+	?
Reduction of physical pressure on watercourses						
19. Removal of obstructions to fish migration	220 localities	-	-	++		2,415
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys through the establishment of on average 15, 50 and 150 m wide buffer zones alongside small, medium and large watercourses (incl. re-establishment of wetlands corresponding to measure 13)	2,035 ha 534 km	204	2.035	++	++	6,772 -6,287
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	227 km	-	-	++		7,438
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	1,516 properties	7.8	2.945			11,324
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	7 WWTPs	0	0	-	-	28,581
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (coastal meadows, mires/freshwater meadows and dry grassland) • Carried out integrated with measures 11–18	Coastal meadows: 450 ha Mires/meadows: 2400 ha Dry grasslands: 600 ha	+	+	+	++	See Table 6.7
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	450 properties (2003)	25			++	
26. Nature management – Grazing down, haymaking etc. on present terrestrial natural habitats	2,450 ha				++	
27. Nature management – Clearance	360 ha				++	
28. Improved hydrological conditions (decommissioning of ditches/drains)	300 km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**926**	**8.5**			**94,000**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Reduction of pressure from pesticides

The programme of measures encompasses only a single measure to reduce pressure from pesticides: "Pesticide-free cultivation of farmland around water supply wells" in a 300-m zone around 211 water supply wells, corresponding to a total area of 2,056 ha (Table 6.4, measure 18).

Reduction of physical pressure on watercourses

The measures to reduce physical pressure on watercourses (Table 6.4, measures 19–21) include the removal of 220 obstructions in watercourses in order to restore free passage for fish, "Cessation of watercourse maintenance combined with extensification of cultivation in river valleys" in 534 km of watercourse and "Re-meandering of watercourses, laying out of spawning gravel, etc." in a further 227 km of watercourse. Extensification of cultivation in river valleys encompasses the establishment of on average 15-, 50- and 150-m wide buffer zones alongside each bank of small, medium and large watercourses, respectively. The aim of extensification of agricultural production is to enable watercourses to find their own course and to re-establish hydrological balance between the watercourses and the riparian areas in order to limit the input and transport of sand/sediment and to ensure the greatest possible habitat diversity and the best possible habitat conditions for aquatic organisms, some of which spend part of their lives on land.

Reduction of pressure from point sources

The programme of measures includes two measures to reduce pressure from point sources (Table 6.4, measures 22 and 23). "Sparsely built-up areas – improved wastewater treatment", aims to reduce phosphorus loading of small lakes and coastal waters and inputs of oxygen-consuming substances and ammonia loading to small watercourses. The small watercourses in question encompass watercourse reaches that have not been assigned an individual quality objective (status unknown) in the Regional Plan, as well as reaches assigned an "eased" quality objective, including reaches that do not even meet the "eased" quality objective.

The second measure, "Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment)", which will be applied at the seven largest wastewater treatment plants in the river basin, aims to reduce pressure on watercourses and coastal waters from hazardous substances, bacteria, viruses and parasites.

Special measures for terrestrial natural habitats

In order to achieve the environmental objectives for the terrestrial natural habitats (mires, meadows and dry grasslands) the river basin management plan and the statutory Natura 2000 planning, which in Denmark has to be carried out concomitantly with the river basin management plans, include implementation of the following four types of measure:

- Re-establishment of terrestrial natural habitats corresponding to a doubling of the total area in order to halt the decline in biodiversity. Re-establishment of terrestrial natural habitats is coordinated with the measures to improve the aquatic environment and is thus carried out in such a manner as to concomitantly reduce diffuse pressure on the water bodies from nutrients and pesticides and reduce physical pressure on the watercourses.
- Measures to reduce ammonia loss from farm holdings locally, nationally and internationally, primarily to ensure that the critical load for nitrogen is not exceeded in the terrestrial natural habitats. At the local level the measures consist of an overall 50% reduction in ammonia emissions from local farm holdings. This measure will concomitantly reduce loss of nitrogen to the water bodies.
- Nature management measures to prevent overgrowth of the open terrestrial natural habitats as compensation for the absence of natural grazers in the present-day cultural landscape.
- Removal or decommissioning of 300 km of drains and ditches to ensure sufficiently natural hydrological conditions in the terrestrial natural habitats.

For further information about Natura 2000 planning in Denmark, see www.skovognatur.dk/emne/natura2000/english

Seagrass threatened by filamentous algae in Odense Fjord. Photo: Nanna Rask.

6.4 Cost analysis

The economic assessment of the programme of measures is based on a cost-effectiveness analysis of the economic cost, i.e. it is based on how the predefined objectives can be realized at the lowest costs to society. In the analysis the cost estimates are expressed in terms of both budget cost and economic cost. The budget cost analyses calculate the costs at sector level, for example for the agricultural sector, while the economic cost analyses calculate the change in society's total possibilities for consumption.. The economic cost estimates are based on the budget cost estimates, which consist solely of the operating costs. The economic costs are generally higher than the budget costs, among other reasons because the former include levies and VAT. The result of the analysis is thus a budget cost of DKK 65 million per year as compared with an economic cost of DKK 94 million per year.

In a cost-effectiveness analysis the costs of a particular environmental measure are expressed in monetary units, while the environmental effect of the measure is expressed in physical units such as the number of tonnes reduction in nitrogen or phosphorus loading of the aquatic environment. In an economic cost analysis the non-water related side effects resulting from the measures should in principle be assigned a cost or value, for example the environmental benefits of reduced greenhouse gas emissions, ammonia volatilization, enhanced/changed biodiversity (terrestrial natural habitats), etc. In principle, calculation of the economic costs necessitates determining the cost/value of all environmental consequences over and above the one being assessed. A cautious estimate of the non-water related environmental benefits of reduced greenhouse gas emissions and ammonia volatilization as a result of the programme of measures (Table 6.4) is approx. DKK 9 million per year.

This cost-effective solution considers all water bodies as a whole, thereby taking into account any effects on water quality in downstream water bodies. Among other things this means that what for example appears to be the most cost-effective solution for a lake when viewed in isolation, is not necessarily the most cost-effective solution when the water bodies are considered as a whole.

Dosing the measures

Some of the measures stipulated in the programme of measures have been selected and dosed on the basis of the cost-effectiveness analysis. Other measures have been selected solely on the basis of expert judgement.

With some types of pressure, alternative and equally effective measures have been identified to regulate them. This applies in particular to measures to reduce nitrogen leaching from fields, and to a certain extent also to measures to reduce phosphorus leaching. Determination of the most cost-effective programme of measures for this type of pressure is based on a cost-effectiveness analysis of the identified alternative measures.

The remaining types of pressure have been selected and dosed solely on the basis of expert judgement based on a knowledge of the measure and the water bodies. With this type of measure, no alternative and equally effective measures have been identified. This applies for example to measures to reduce pressure from point sources, measures to reduce physical pressure on watercourses and measures to ensure phosphorus balance and reduced phosphorus fertilization on soils with a high phosphorus index. Thus unlike the measures to reduce nitrogen loading, the measures included in the programme of measures for these types of pressure have not been selected on the basis of a cost-effectiveness analysis. The combined economic cost of the above-mentioned non-cost optimized measures amounts to approx. DKK 59 million per year, of which measures directed at point sources account for the majority – just under DKK 40 million.

Unit costs

For each measure, a unit cost has been estimated with regard to nitrogen. The cost-effectiveness is thus calculated solely on the basis of their nitrogen-reducing effect in the river basin. Nearly all the measures that reduce nitrogen loading are related to agricultural activity. The unit costs are calculated as constants, i.e. no account is taken of the fact that the costs can depend on the size of the dose of a particular measure or that of a closely related measure. In the case of the agriculture-related measures, the estimated costs are primarily based on estimates prepared when drawing up Action Plan on the Aquatic Environment III (www.vmp3.dk).

The cost-effectiveness of the nitrogen-reducing measures and their potential for reducing nitrogen loading in the river basin is summarized in Table 6.5 together with the maximum area, etc. to which the measure can be applied in the river basin. The total reduction potential is achieved if the measure is applied in the maximum dose. The potential dose of the individual measures is not constant in the analysis but depends on the use of closely related measures. For example, the potential for using a given measure depends on what other measures are used in the same catchment.

It can be seen that the use of measures in lowland areas (river valleys) is generally more cost-effective than the use of the same measures in upland areas. Similarly, measures based on environmental optimization of crop production are generally more cost-effective than measures based on the set-aside of farmland. However, as the reduction potential of the optimization measures is lower than that of the set-aside measures there remains a need to set-aside farmland in order to achieve the environmental objectives.

Measures ranked according to cost-effectiveness	Locality 	Cost-effectiveness (DKK/kg N)	Potential dose (ha)	Potential reduction (tonnes N)	Unit cost (DKK/ha)
Catch crops: Increased area	Lowland	11	4,889	126.6	293
Additional 5% higher utilization of the N content of manure	Lowland	14	19,597	20.6	15
Reduced N fertilization norm	Lowland	29	18,683	45.8	70
Catch crops: Increased area	Upland[1]	29	12,180	121.7	293
Cessation of watercourse maintenance and extensification of cultivation in river valleys	Lowland	33	2,035	203.5	3,328
Additional 5% higher utilization of the N content of manure	Upland	38	48,824	19.8	15
Set-aside of arable land for wetlands	Lowland	42	13,201	1,320.1	4,240
Reduced N fertilization norm	Upland	74	46,546	44.0	70
Set-aside: 5-m buffer zones alongside watercourses	Lowland	85	457	22.9	4,240
Set-aside: 10-m buffer zone around ponds	Lowland	85	10	0.5	4,240
Set-aside: Permanent grassland	Lowland	121	19,597	521.3	3,226
Increased area of organic crop farming	Lowland	240	19,150	268.1	3,358
Reduced livestock production	Lowland	251	19,597	148.2	1,895
Set-aside: Permanent grassland	Upland	314	3,787	38.9	3,226
Restrictions on cultivation of land potentially subject to erosion	Upland	314	3,787	38.9	3,226
Set-aside: Land for afforestation	Upland	334	25,425	260.9	3,430
Permanent grassland kept unfertilized in groundwater protection areas	Upland	336	18,390	176.5	3,226
Afforestation in groundwater protection areas	Upland	357	18,390	176.5	3,430
Buffer zones in connection with daylighting of culverted watercourses	Lowland	366	236	11.8	4,240
Increased area of spring cereals, fertilization with 60% N norm and catch crops in groundwater protection areas	Upland	455	18,390	132.4	3,276
Increased area of organic crop farming	Upland	622	47,709	257.6	3,358
Reduced livestock production	Upland	650	48,824	142.4	1,895
Sparsely built-up areas – improved wastewater treatment		1,037	5,237[2]	37.7	7,469
Sparsely built-up areas – improved wastewater treatment in the catchments of small lakes		2,075	434[2]	1.6	7,469

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] No. of properties

Table 6.5
Cost-effectiveness of the measures as regards reducing nitrogen loading shown together with the potential dose and the nitrogen reduction potential in upland and lowland areas of the river basin. "Lowland" means arable land elevated less than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place, while "Upland" means arable land elevated at least one metre above the same reference level.

The measures to reduce physical pressure from point sources are generally very expensive compared with other measures to reduce nitrogen loading. It should be noted, though, that the main aim of the point-source measures is not to reduce nitrogen loading but rather to achieve the environmental objectives in relation to pollution of water bodies with oxygen-consuming organic matter, phosphorus, hazardous substances, etc.

The measures "Increased area of organic crop farming" and "Reduced livestock production" have not been employed in the present programme of measures (Table 6.4) due to their relatively low cost-effectiveness in relation to nitrogen.

Meadow at Brahetrolleborg. Photo: Erik Vinther.

Cost summary

The economic cost of implementing the Water Framework Directive in Odense River Basin is summarized in Table 6.6 apportioned by type of measure. The total cost is approx. DKK 94 million. Given that the present total expenses for water use in the Odense River Basin amount to DKK 612 million compared with the total income and production value of DKK 116,600 million (see Table 6.2), the programme cost thus corresponds to an increase in the total expenses for water from 0.5% to 0.6% of total income and production value.

A large proportion of the cost of the programme of measures is accounted for by measures directed at point sources (43%), while the remainder is accounted for by agriculture-related measures and nature restoration (56%). Of the agriculture-related measures, set-aside of arable land accounts for the greatest proportion of the total costs (23%), with the majority (16%) of this being accounted for by set-aside in lowland areas, and concomitantly accounts for 38% of the reduction in nitrogen loading. The measures aimed at environmental optimization of crop production account for just 7% of the total costs yet account for fully 32% of the reduction in nitrogen loading, thereby illustrating the high cost-effectiveness of these measures, especially when applied to arable land in the river valleys. Set-aside for groundwater protection costs just under DKK 15 million per year corresponding to 16% of the total costs.

WFD Programme of measures Annual economic cost apportioned by main programme components		
Main components	**1,000 DKK/yr**	**%**
Diffuse nutrient and pesticide loading – agriculture	*43,723*	*46*
• Environmental optimization of crop production – upland[1]	3,990	4
• Environmental optimization of crop production – lowland /river valleys	2,471	3
• Set-aside of farmland – upland[1]	7,068	7
• Set-aside of farmland – lowland/river valleys	15,362	16
• Groundwater protection measures	14,832	16
Reduction of physical pressure	*10,338*	*11*
Reduction of pressure from point sources	*39,904*	*43*
TOTAL	***93,965***	***100***

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place

Table 6.6
Overall results of the economic analysis.

Sensitivity analyses show that the costs of measures in which farmland is taken out of production or is set-aside for grazing/permanent grass can be overestimated. The present reform of the agricultural support scheme entails that these areas can probably continue to receive financial support, thereby reducing the cost of using these measures. The sensitivity analysis shows that the cost of implementing these measures could actually be DKK 16 million less than assumed in the economic analysis.

In addition to the measures aimed at environmental optimization of crop production the programme of measures entails the set-aside of a total of 12,480 ha – corresponding to 19% of the farmland in the river basin (67,142 ha after implementation of the basic measures, i.e. Baseline 2015 – see table 6.3) – as forest (2%), wetlands (8%) and permanent grass (9%). Moreover, pesticide-free cultivation will be implemented on 2,000 ha of farmland around water supply wells. As a consequence, the proportion of the river basin comprised by terrestrial natural habitats will increase from 6% to approx. 16%. In addition, some 1,532 ha of farmland will be converted to forest. The area of arable land in the river basin will thereby be reduced from 65% of the river basin prior to implementation of Baseline 2015 (excluding roads, hedgerows, etc) to 52% of the river basin in 2015, although it will remain possible to utilize approx. 3/4 of the set-aside land for extensive agricultural production.

Structural consequences for agriculture in Odense River Basin	
Cultivated area	68,421 ha
Cultivated area after Baseline 2015	67,142 ha
Farmland converted to other uses (WFD)	12,480 ha
Converted farmland as a percentage of the cultivated area (WFD)	19%
New use of set-aside farmland:	
• Woodland	2%
• Wetland/meadow	8%
• Permanent grassland (predominantly in highland areas for groundwater protection)	9%

Terrestrial natural habitats Programme of Measures – summary			
Measure	**Dose**	**Cost** (DKK million /yr)	**Cost when carried out integrated with WFD programme of measures** (DKK million/yr)
New terrestrial natural habitats (coastal meadows, mires/freshwater meadows and dry grasslands)	Coastal meadows: 450 ha	1.9	0
	Mires/meadows: 2,400 ha	17.0	0
	Dry grassland: 600 ha	1.9	0
Reduced ammonia emission (-50%) from livestock holdings >35 LU[1]	450 properties (2003)	(95.7)	(90)
Nature management – Grazing down, haymaking, etc. of existing natural habitats	2,347 ha	2.5	2.5
Nature management – Clearance of existing natural habitats	380 ha	1.3	1.3
Improved hydrological conditions (decommissioning of ditches/drains)	300 km	3.2	3.2
Total		**27.8** (123.5)	**7** (97)

[1]LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc

Table 6.7
Programme of measures for terrestrial natural habitats indicating the dose and costs when carried out alone or integrated with the programme of measures under the Water Framework Directive.

Integration with measures to improve terrestrial natural habitats

The economic cost of achieving the environmental objectives for terrestrial natural habitats pursuant to the Rio Convention on Biological Diversity, the Habitats Directive and the Birds Directive and the 2005 Regional Plan for Funen is calculated to be around DKK 28 million per year. Of this, approx. DKK 21 million could be avoided by the synergy effect obtained by integrating achievement of the objectives for terrestrial natural habitats with the programme of measures for water bodies. Achievement of the environmental objectives for terrestrial natural habitats would thereby only cost DKK 7 million (see Table 6.7). To this should be added the cost of reducing ammonia volatilization from agriculture. This is difficult to estimate, among other reasons due to the rapid structural development in agriculture in the direction of considerably fewer but larger holdings, which will considerably affect the cost of introducing new technology to limit ammonia emissions. The programme of measures will lead to a minor reduction in ammonia emissions in itself.

A synergy effect can be achieved by the fact that the requirement for enhancing the area of terrestrial natural habitats to meet their environmental objectives can be met by the land set aside under the programme of measures as wetlands and permanent grass. Thus the programme of measures sets aside a total of 5,220 ha as wetlands and extensification in the river valleys, where mire/meadow habitats could potentially develop, and 4,598 ha of upland farmland as permanent grass to protect the groundwater, where – in the long term – dry grassland habitats could potentially develop, thereby fulfilling an important precondition for fulfilling the environmental objective for this habitat type. The overall assessment, therefore, is that provided careful consideration is given to the placement of the new natural habitats, including coordination with soil conditions and the occurrence of existing natural habitats, it is possible to benefit nature in a manner that helps achieve the environmental objectives for both water bodies and terrestrial natural habitats.

The peat moss Sphagnum rubellum in the raised bog Nybo Mire in Odense River Basin at Brahetrolleborg. Photo: Erik Vinther.

6.5 Guidelines

When issuing permits for discharges of wastewater and for other activities that affect the state of the water in Odense River Basin the following guidelines apply:

1. Any deterioration in the status of either surface waters or groundwater is to be prevented.

2. No increase in direct or indirect pollution of surface waters is permissible unless this restriction leads to enhanced pollution of other water bodies.

3. The status of watercourses, lakes, coastal waters, wetlands and groundwater must comply with the environmental objectives stipulated in Chapter 5 and the detailed map on www.odenseprb.ode.mim.dk. Water bodies whose environmental objective is not directly apparent from the detailed map – primarily the approx. 2,600 lakes between 100 m^2 and 5 ha in size – are in principle encompassed by the Water Framework Directive objective that they should achieve at least "Good ecological status" by 2015.

4. The measures stipulated in the programme of measures – or environmentally equivalent measures – must be implemented by 2012 at the latest. Any obligatory measures must however be implemented as described. This applies to both basic measures and supplementary measures.

5. The measures should be implemented and prioritized in accordance with the timetable specified in Table 6.8.

6. Under exceptional circumstances it is permissible to stipulate less stringent environmental objectives than specified in Chapter 5 and the detailed map in the immediate vicinity of wastewater outfalls.

7. All wastewater discharges to lakes and other still water bodies should as far as possible be avoided.

8. Draining of lakes and other still water bodies is to be avoided.

9. Culverting of watercourses should as far as possible be avoided.

10. When issuing new permits for the discharge of wastewater in the river basin the following limit values (controlled according to the regulations described in Danish Standard DS2399) must not be exceeded:

Discharge size (PE)	Parameter and limit value			
	BOD_5 (mg/l)	Total N (mg/l)	Total P (mg/l)	NH_3-N (mg/l)
30–999	10	8	1,0	3
1,000-49,999	8	8	0,7	3 (2*)
>50,000	8	8 (6*)	0,5	3 (2*)

* recommended limit value during the summer period

11. Discharges of mixed wastewater from combined sewerage systems should in principle be reduced to a maximum of 10 discharge events per year. If a concrete assessment of the impact on the recipient water body indicates that it is necessary, the discharge frequency must be reduced further. Apart from reducing the frequency of discharge events other measures with an environmentally equivalent effect may be implemented.

12. Stormwater outfalls from separate sewerage systems must be fitted with an overflow basin of a volume equivalent to a minimum of 23.6 m^3 per hectare paved area or alternatively with a fat separator having a 98% efficiency at a storm flow of 18 l/sec/ha.

13. The Municipalities in the river basin are responsible for ensuring that measures are implemented, for example establishment of a contingency unit, to prevent or reduce the impact of accidental pollution.

When issuing permits for the abstraction of groundwater the following guidelines apply:

14. The amount of groundwater abstracted must not exceed the long-term groundwater recharge in the individual aquifer.

15. The abstraction of groundwater must not affect the groundwater level so much that the associated surface water systems and terrestrial ecosystems cannot achieve their environmental objectives.

16. In areas where the groundwater resource is insufficient to meet all needs for abstraction and for achieving the environmental objectives in the associated surface water systems and terrestrial ecosystems the following prioritization may be applied following a socio-economic assessment:
    1. The public water supply
    2. Maintenance of an environmentally acceptable state in terrestrial natural habitats
    3. Other purposes – industry and the irrigation needs of the agricultural sectors.

6.6 Timetable

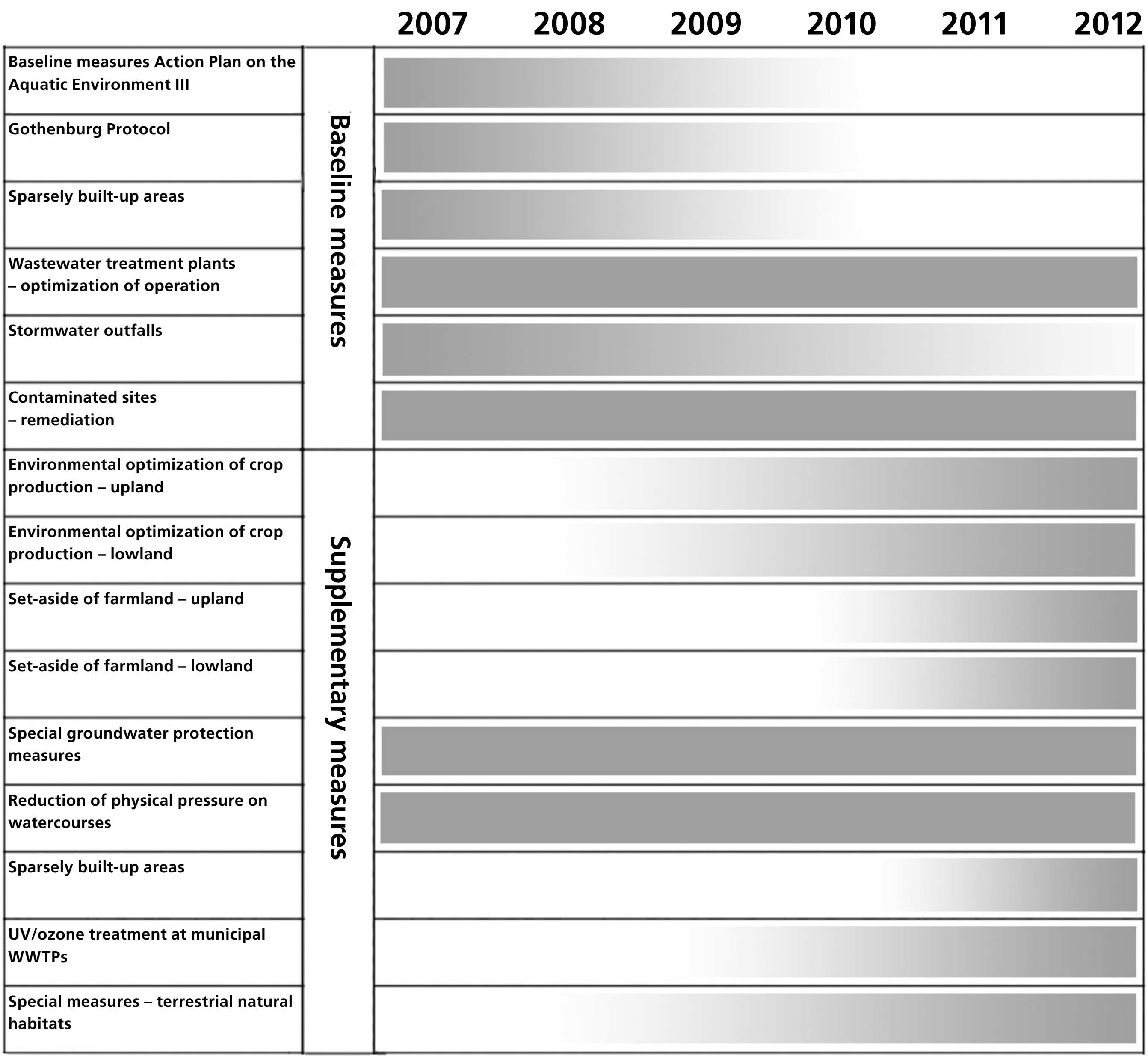
The timetable for implementation of the programme of measures is presented in Table 6.8.

Several of the basic measures are initiatives that have already been initiated and which are continued in the plan period. Certain measures in the wastewater area are encompassed by recommended deadlines specified in the Regional Plan for Funen and are carried forward in the present timetable.

With other measures, especially those related to agriculture, the assumption is made that the necessary legislation will be adopted beforehand.

Pursuant to the Water Framework Directive, all the measures have to be implemented by the end of 2012.

Table 6.8
Timetable for implementation of the basic measures and supplementary measures.



The River Odense at Hillerslev Bridge surrounded by cultivated fields. Photo: Erik Vinther.

7. Monitoring programme

The Water Framework Directive operates with three levels of monitoring: Surveillance monitoring, operational monitoring and investigative monitoring.

- *Surveillance monitoring* is intended to provide a picture of the general ecological and chemical status of the water bodies, including the long-term changes herein.

- *Operational monitoring* aims at establishing the status of those water bodies identified as being at risk of failing to meet their environmental objectives. As the objectives are met, monitoring of the water bodies in question will be reassigned to surveillance monitoring.

- *Investigative monitoring* is carried out when the reason for a water body failing to meet its environmental objective is unclear.

An overall monitoring programme has been prepared for the water bodies in Odense River Basin based on the previously existing monitoring programme, although adjusted in some respects to meet the above-mentioned requirements. The programme is summarized in Table 7.1 and is comprised of the first two elements of the Water Framework Directive principles for monitoring.

In addition, a programme has been established for monitoring pressures on surface waters and groundwater (see Section 7.6). A detailed map showing the locations at which the monitoring is performed is available at www.odenseprb.ode.mim.dk.

The monitoring programme for each type of water body is described below.

Odense Pilot River Basin – Frequency of surveillance and operational monitoring

Aquatic media	Biological		Hydromorphological		Physico-chemical	
	Quality element	Frequency /interval	Quality element	Frequency /interval	Quality element	Frequency /interval
Watercourses	Macrophytes	1 / 2	Hydrology	Continuously[1]	Organic matter, nutrients	4 / 2
	Macroinvertebrates	1 / 2	Continuity	1 / 6	Priority substances and other hazardous substances	4 / as needed
	Fish	1 / 2	Morphology	1 / 2		
Lakes (>5 ha)	Phytoplankton - chlorophyll - species	7 / 2 7 / 0–2	Hydrology	12 / 0-2	Temperature, oxygenation, salinity, alkalinity	7–19 / 2
	Macrophytes	1 / 2	Morphology	1 / as needed	Nutrients	7-19 / 2
	Macroinvertebrates	1 / 0–1			Priority substances and other hazardous substances	6 / as needed
	Fish	1 / 0–1				
Lakes (<5 ha)	Phytoplankton - chlorophyll - species	6 / 0–1 -	-		Temperature, oxygenation, salinity, alkalinity	6 (1) / 1
	Macrophytes	1 / 0–1			Nutrients	6 (1) / 1
					Priority substances and other hazardous substances	As needed
Coastal waters	Phytoplankton	35 / 6	Water level	Continuously	Temperature, oxygenation, Salinity	35 / 6
	Macroalgae	1 / 4			Nutrients	35 / 6
	Angiosperms	2 / 6			Priority substances and other hazardous substances	1 / 2–6
	Benthic invertebrates	1 / 6			Effects of hazardous substances on biota[2]	1 / 4–6
Groundwater	-				Nutrients, trace elements, other substances	1 / 1–2

[1]Only water bodies with a catchment area >50 km^2
[2]Biota: mussels, gastropod molluscs and fish

Table 1
Summary of the proposed surveillance monitoring and operational monitoring programmes for Odense River Basin. The frequency indicates the number of annual measurements, and the interval indicates the number of years that the measurement is carried out over a 6-year period. The table does not indicate the number of stations at which the individual measurements are made. For information on the monitoring of pressures, see Table 7.4.

7.1 Watercourses

Of the 316 riverine water bodies (total 1,015 km) in Odense River Basin, only 15 (62 km) presently fulfil the environmental objective of at minimum good surface water status (see Section 5.2.1). Pursuant to the Water Framework Directive, all the other riverine water bodies must therefore undergo either operational monitoring (objective not met) or investigative monitoring (reason for not meeting objective unclear).

Surveillance monitoring

A few of the riverine water bodies in the river basin are presently included in the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA), which is intended to meet the requirements for surveillance monitoring (cf. the National Environmental Research Institute's Technical Guidelines No. 21). This applies to 21 water bodies and involves 23 monitoring stations. Among these, two stations (two water bodies) already fulfil at least good surface water status, which roughly corresponds to the proportion of riverine water bodies in Odense River Basin that meet their environmental objectives. The small watercourses (especially type 1) are considerably underrepresented in the NOVANA programme, however. As the intention with the surveillance monitoring is to obtain a representative picture of the ecological and chemical status of the watercourses in the river basin as a whole, the monitoring under NOVANA is supplemented with an additional 22 stations primarily located in small watercourses (Table 7.2).

Table 7.2
Number of watercourse monitoring stations in Odense River Basin for surveillance monitoring (NOVANA plus supplementary surveillance investigations) and for operational monitoring (DEVANO plus supplementary operational investigations). Figures in parentheses indicate the percentage coverage of the total number of water bodies for surveillance monitoring and operational monitoring.:

	Surveillance monitoring	Operational monitoring
NOVANA (2004–2009)	23	-
DEVANO (2007)	-	11
Supplementary investigations	22	59
Total	45 (14) [1]	70 (23) [2]

[1] Type 1: 30; type 2: 9, type 3: 6.
[2] Type 1: 47; type 2: 16; type 3: 7 (of which 5 a
pursuant to the Habitats Directive)

The Water Framework Directive specifies minimum requirements for the choice of monitoring parameters and monitoring frequency. The parameters and monitoring frequencies utilized in the river basin are summarized in Table 7.1.

Operational monitoring

In 2007 a national programme (DEVANO) was established for decentralized monitoring of the aquatic and terrestrial environments and this includes 11 stations in riverine water bodies in Odense River Basin that fail to meet their environmental objective. The DEVANO monitoring programme will contribute to the operational monitoring. The stations have been selected representatively, i.e. they realistically reflect anthropogenic pressures and the effects of the environmental measures that the Municipalities are to implement in the coming years. It is not feasible to monitor all water bodies, however. The number of water bodies considered necessary to meet the operational monitoring requirements is as follows: 15% of the type 1 watercourses, 30% of the type 2 and 70% of the type 3. This means that in practice, 50 riverine water bodies are monitored, of which some have more than one monitoring station, at a total of 65 stations. In addition, there are a further five stations located in SAC H98 (the River Odense and tributaries), where the habitats and character species for which the site was designated have not yet attained favourable conservation status. The total number of stations at which operational monitoring is carried out is therefore 70.

The parameters and monitoring frequencies utilized in the river basin are summarized in Table 7.1. The DEVANO programme does not presently specify quality criteria for plants, but it would be desirable to include these in future in the open watercourses, especially where the plants are affected by weed clearance.

Within SAC H98 (the River Odense and tributaries) it is also necessary to perform special monitoring of the common river mussel (Unio crassus), the spined loach (Cobitis taenia)

and the brook lamprey (Lampetra planeri), as well as habitat types 3260 (watercourses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation) and 6430 (hydrophilous tall herb fringe communities of plains and of the montane to alpine levels). The details of this monitoring will be finalized with the statutory preparation of Natura 2000 plans in 2007–2009.

Investigative monitoring

Investigative monitoring is carried out when the reason for a water body failing to meet its environmental objective is unclear (including water bodies where the status and/or the pressures are unknown). In 2007, it is expected that physical conditions and the macroinvertebrate fauna will be investigated at 200 stations in such riverine water bodies. The possibilities for fish to pass selected obstructions/fish passes will also be investigated. This type of monitoring is need-oriented and intended to support and supplement the operational monitoring. Thus it could also be used when the need arises for a more detailed analysis of the effects of restoration work or special pollution incidents in riverine water bodies.

7.2 Lakes

Surveillance monitoring

In principle, surveillance monitoring requirements are met by the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA). Eight of the 14 lakes larger than 5 ha in Odense River Basin are encompassed by the programme, namely Lake Arreskov Sø, Lake Nørresø, Lake Dallund Sø, Lake Langesø, gravel quarry lake 7.1, Lake Fjellerup Sø, Lake Store Øresø and Lake Søbo Sø. Among the smaller lakes, 15 in the size range 0.1–5 ha and seven ponds (0.01–0.1 ha) are encompassed by the programme. This corresponds to 1.4% and 0.5%, respectively, of the total number of lakes in these two size categories.

Together with 19 other Danish lakes, Lake Arreskov Sø has been selected for intensive monitoring aimed at providing a detailed description of their ecological status in order to be able to detect both natural and anthropogenic changes in their status. In addition, the programme is intended to provide information for use in the impact assessment and scenario analyses for the other lakes.

Operational monitoring

There are six lakes larger than 5 ha in Odense River Basin that are not encompassed by NOVANA. As all six of these lakes are at risk of not achieving their environmental objectives by 2015, operational monitoring has to be undertaken – in principle every third year. This requirement is covered by the DEVANO programme, which currently includes four of the lakes on Funen. With these resources it is possible to monitor approximately one of the six lakes each year, which provides monitoring once every 6 years.

Of the approx. 2,600 ponds and small lakes in the river basin, the majority should in principle undergo operational monitoring because they fail to meet their environmental objectives. It will only be feasible to monitor a fraction of these, though. Pursuant to the Water Framework Directive, however, it is permissible to group them on the basis of their typology and the character of the catchments, whereafter monitoring can be performed on a subgroup of the lakes. No monitoring of these small lakes has yet been planned, though.

Investigative monitoring

Investigative monitoring is used when the reason for a water body failing to meet its environmental objective is unclear, or when the effect of a particular intervention needs to be clarified. Examples of investigative monitoring include: Calculation and source apportionment of loading from the catchment of selected lakes, investigation of special types of loading, e.g. from duck holdings, investigations of hazardous substance loading and concentration in sediment or the water phase, and determination of the effect of restoration work. In 2007, nutrient loading will be investigated in certain lakes by random sampling, and the effect of restoration of Lake Sønderby Sø will be investigated.

Measurement of lake transparency – Secchi depth – is a simple method for describing a lake's environmental state. Photo: Jette Christiansen.

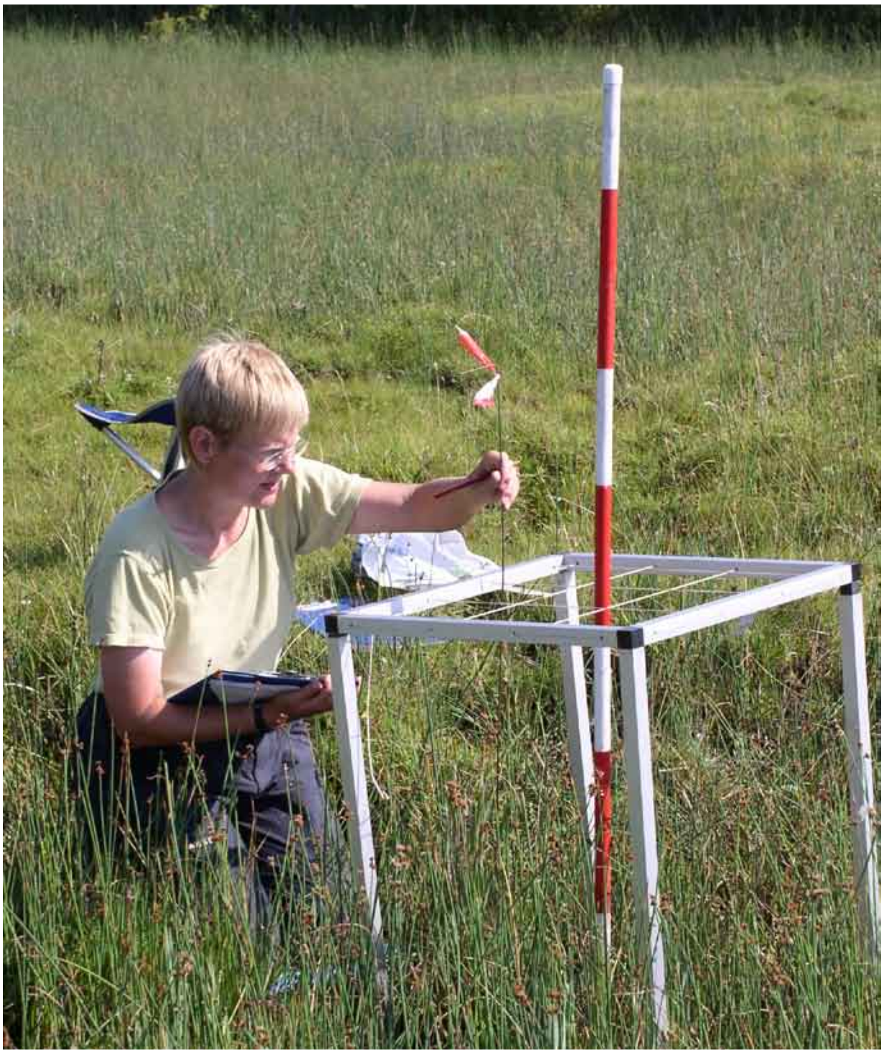
7.3 Wetlands

Watercourses, lakes and coastal waters together with adjacent wetlands comprise the planning units in the river basin management plans. Well-functioning wetlands with among other things a natural hydrology are often a prerequisite for the adjacent watercourses, lakes and coastal waters to be able to achieve the Water Framework Directive environmental objective of "good surface water status". Conversely, well-functioning watercourses, lakes and coastal waters are often of decisive importance for the status of the wetlands.

The wetlands must therefore be included as an integrated part of the surveillance, operational and investigative monitoring.

A wetland monitoring programme should be drawn up comprised of subelements of the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA) such that the results obtained with the various monitoring programmes are comparable and can be utilized in the overall monitoring. The wetland monitoring should therefore consist of one or more of the parameters mentioned in Table 7.3.

In addition, investigative monitoring should be carried out on the springs in the river basin because these are a very important part of the wetlands, and because knowledge of the springs is largely based on indirect knowledge obtained via botanical indicators and groundwater models. The monitoring should provide the necessary basis for including the springs in the coming river basin management plans and the statutory Natura 2000 plans (2007–2009) and improve the groundwater models so that they are more suitable than at present for assessing the effects of water abstraction on wetlands, lakes and watercourses.



The species composition of vegetation is determined using the pin-point method. By repeating the methods over a period of several years it is possible to obtain an impression of the trend in vegetation. The pin-point method is presently used in terrestrial habitat monitoring under the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA). Photo: Erik Vinther.

Table 7.3
Overview of the wetland monitoring.

Monitoring of wetlands
• Characterization of the individual wetlands by habitat type and category (cf. Technical instructions on the characterization of terrestrial habitat types) • Vegetation analyses (pin-point) in 1–20 50x50 cm analysis plots in each of the open natural habitat types (cf. Technical instructions on the monitoring of terrestrial habitat types) • Collection of supplementary data (species lists, coverage by woody plants) in 1–20 5-m radius circles laid out in each of the open habitat types (cf. Technical instructions on the monitoring of terrestrial habitat types) • Analysis of C/N ratio, phosphorus index and pH in 1–10 soil samples from each of the open habitat types. In springs, quaking bogs and raised bogs, 1–10 water samples are collected for determination of pH, conductivity, NO_x^- (cf. Technical instructions on the monitoring of terrestrial habitat types) • In alluvial forests, vegetation analyses and supplementary data collection are performed in 1–20 plots, and C/N ratio, phosphorus index and pH are measured in 1–10 soil samples (cf. Technical instructions on the monitoring of woodland habitat types) • Standard field report forms are completed to describe the species present, the structure and the presence of invasive species in the whole wetland (Field report form developed by the National Environmental Research Institute).

7.4 Groundwater

The groundwater monitoring programme is comprised of surveillance monitoring and operational monitoring. The surveillance monitoring is intended to follow the trend in groundwater quality in the aquifers at a frequency of once every sixth year. The operational monitoring aims to follow the trend in groundwater quality in groundwater bodies that are at risk of failing to achieve their environmental objective, and has to be carried out at least once a year.

The monitoring of groundwater bodies in Odense River Basin is comprised of routine monitoring of all waterworks wells and special monitoring in three national groundwater monitoring sites located partially or completely within the river basin.

There are a total of 255 waterworks wells in Odense River Basin, each of which is analysed at minimum every third, fourth or fifth year. By far the majority of the waterworks wells are analysed every third year. The analysis encompasses nutrients, trace elements and pesticides and other hazardous substances.

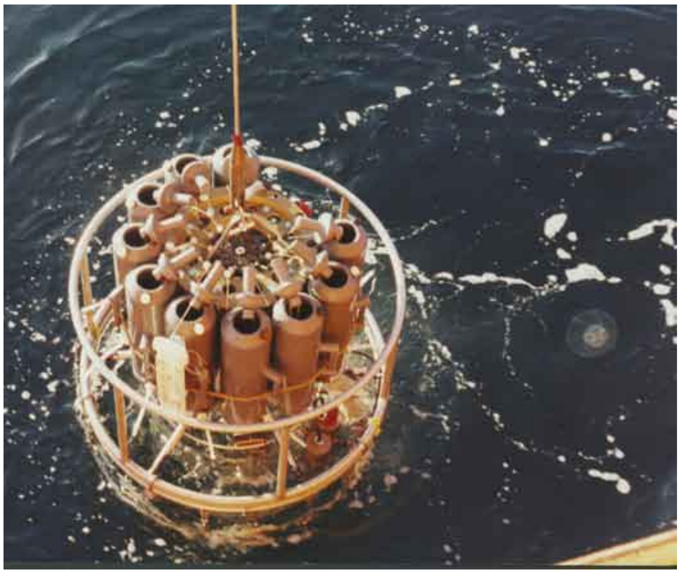
The monitoring programme in the three national groundwater monitoring sites encompasses 21 wells from which samples are collected every sixth year or every year depending on the trend in groundwater quality. The analysis encompasses nutrients, trace elements and hazardous substances, including pesticides.

The water that is abstracted by the waterworks is often rather old, i.e. at least 40 years old. As a consequence, monitoring is not a very suitable means of studying newly arisen contamination of the groundwater as contamination has been on its way for many years before it is detected in the groundwater. The national monitoring programme is to a greater extent directed at the newly formed groundwater closer to the surface so that initiatives can be taken at the national level to hinder contamination if the monitoring programme indicates that the upper groundwater is contaminated.

All in all, 275 wells are included in the monitoring. Given the analysis frequency used, approx. 90 wells are analysed for nutrients, trace elements and hazardous substances per year.

Sample collection at a soil water station. Photo: Bjarne Andresen.

7.5 Coastal waters



Sample collection in the sea using a CTD/rosette water sampler. Photo: Fyn County.

The coastal waters solely consist of Odense Fjord subdivided into an inner part, Seden Strand, and the large outer fjord. Three water bodies have been designated in the fjord, Seden Strand and two water bodies in the outer fjord. The reason for the latter subdivision is that the western part of the outer fjord has a high quality objective because it is designated as a scientific reference area (see Chapter 2 and 5). Comprehensive monitoring of Odense Fjord is carried out under the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA). This also includes nutrient and organic matter loading of the fjord (see Section 7.6) and dynamic 3-dimensional modelling of the fjord. In addition to the general aims of monitoring, the intention of the extended monitoring programme is to achieve a broader understanding of the fjord system, including cause and effect relationships, the continuation of long time series aimed for example at identifying climatic effects, and continued development of modelling tools, etc. With most quality elements the monitoring is therefore more comprehensive than the minimum requirements stipulated in the Water Framework Directive.

Surveillance monitoring

In principle, surveillance monitoring requirements are met by the NOVANA programme. However, as all three of the water bodies that comprise Odense Fjord are at risk of failing to meet their environmental objectives, they obviously have to be included in the operational monitoring (see below).

Operational monitoring

None of the three water bodies into which Odense Fjord is subdivided meet the environmental objectives of good surface water status (see Chapter 5), and therefore have to be included in the operational monitoring.

The frequency of the monitoring is shown in Table 7.1. The physico-chemical parameters and phytoplankton are monitored frequently because the water exchange conditions in the fjord are so dynamic that in addition to considerable spatial variation there is also considerable temporal variation. The pelagic monitoring is undertaken at two stations, one in the inner fjord and one in a deep, stratified area in the outer fjord. Due to the abovementioned marked variation, the monitoring should also include a pelagic station in the water body comprised by the western part of the outer fjord, which as explained in Chapter 5, has to achieve "high surface water status".

As Odense Fjord is encompassed by the NOVANA monitoring programme, monitoring of the biological quality elements such as benthic invertebrates and macrophytes (both large algae and angiosperms) is performed at a relatively large number of stations and transects.

Hazardous substances are monitored comprehensively, but not as frequently as specified in the Water Framework Directive. On the other hand, the monitoring not only encompasses concentrations in sediment and biota (mussels, fish) but also includes various measurements of the effects of hazardous substances on gastropods, mussels and fish.

Investigative monitoring

A major source of nutrients for algal and plant growth is turnover in and subsequent release (efflux) from the sediment. It is necessary to quantify this internal loading and consider it in relation to anthropogenic, land-based loading. This applies not least to the phosphorus pools that accumulated in the sediment before comprehensive wastewater treatment was introduced. The trend in internal phosphorus loading thus needs to be monitored.

It can be necessary to develop programmes that specifically focus on the physical pressures to which the fjord is exposed (shipping, dredging of shipping fairways, etc.).

Eelgrass has been on the decline in Odense Fjord in recent years despite certain improvements in water quality. As the reason for this is unclear, it is necessary to initiate investigative monitoring to clarify the issue.

The necessity can also arise to investigate physical and ecological effects of the invasive species that have been detected in Odense Fjord, for example the Chinese mitten crab (Eriocheir sinensis), which is known to be able to undermine dykes and dams, but which so far has only occasionally been registered in Odense Fjord, and the rhodophyte Dasya baillouviana, a red algal species that now seems to have become established in the fjord. In addition, algal blooms of potentially toxic algal species have occurred in Odense Fjord in recent years, occasionally leading to the death of fish in marine fish farms and of benthic invertebrates in marine waters around Funen. It will thus be necessary to investigate the effects on fish and benthic invertebrates in Odense Fjord during such algal blooms.

7.6 Pressures

Even though monitoring the environmental status of the individual types of water body can provide an indication of the types of pressure to which they are exposed, it is also necessary to directly monitor the individual pressures in order to be able to reliably and cost-effectively design environmental measures to deal with them and to follow the effects of these measures. It can also be necessary to monitor pressures in order to be able to take timely action and hinder deterioration in the environmental status of a water body as a result of changes in pressures, in particular in water bodies in which the effect of a pressure is not detected until many years after the pressure has changed. Examples of pressures are wastewater discharges, nutrient loss from agricultural production, and physical pressures such as watercourse regulation and maintenance (see Table 3.1). In order to be able to differentiate anthropogenic pressures from natural pressures it is necessary to also carry out monitoring aimed at identifying the magnitude of the natural pressures, e.g. the magnitude of background nutrient loading.

Among other reasons, monitoring of the individual pressures is important in investigative monitoring, where the aim is to clarify the relationship between pressure and environmental status, i.e. the effect of pressures on environmental status and changes in them. The monitoring can be carried out either by direct registration of the magnitude of the pressure, or by modelling of the pressure based on statistical and geographical information characterizing the pressure. In practice, resource constraints make it impossible to regularly monitor/record the magnitude of all pressures on each individual water body directly. Taking diffuse loss of nutrients from farmland as an example, this pressure would thus have to be monitored through a combination of direct measurements describing the pressure on specific localities and model calculations of the magnitude of the pressure based on statistical and geographical information on agricultural production in the locality. Direct measurements are always necessary in order to be able to regularly calibrate and verify the models employed to describe the pressure.

The monitoring programme for pressures on water bodies in Odense River Basin is summarized in Table 7.4. The programme encompasses monitoring of both pollutant pressures and physical pressures.

Table 7.4
Monitoring of pressures. In cases where data are collected by other than the Ministry of the Environment, this is indicated in parentheses.

Monitoring of pressures
Pollutants (nutrients, organic matter and hazardous substances)
Wastewater discharges • Measurement of discharges from municipal wastewater treatment plants (Municipality) • Geographical information on the location of discharges and precipitation catchment/source of discharges. Statistical information on catchment/source and discharge permit conditions (Municipality) • Model calculations of discharge from stormwater outfalls and sparsely built-up areas • Measurement of discharges from selected stormwater outfalls and discharges from sparsely built-up areas.
Nutrient loss from agriculture: • Measurement of diffuse nutrient runoff in watercourses draining farmland • Measurement of nutrient leaching and drainage runoff from fields • Measurement of nutrient content in upper aquifers in farmland • Measurement of nutrient deposition on aquatic and terrestrial surfaces in farmland • Statistical and geographical information on agricultural production/practice, including information on individual holdings and on the consumption of ancillary substances such as fertilizer, pesticides and imported fodder (from Statistics Denmark and Ministry of Food, Agriculture and Fisheries) • Statistical and geographical information on planned and approved changes in agricultural production/practice at holding level (Municipality)
Diffuse loss of pollutants • Diffuse runoff of organic matter, nutrients, etc. in watercourses draining natural/seminatural areas
Emission of pollutants from industry • Measurement of atmospheric emissions from industry (industry) • Statistical and geographical information on emissions from transport, power stations, households and industry/enterprises
Atmospheric deposition of pollutants on aquatic and terrestrial surfaces • Modelled deposition apportioned by various types of aquatic and terrestrial surfaces in the catchment • Measurement of deposition in urban and rural areas with local sources of various strengths.
Physical pressures
• Statistical and geographical information on watercourse regulation, drainage and maintenance (Municipality). In addition, information about completed restoration projects
• Registration of localities with erosion alongside water bodies
• Registration of physical pressures such as abstraction through synchronous measurements of discharge in watercourses during minimum runoff situations together with measurement of the groundwater table in wetlands. • Statistical and geographical information on abstraction (Municipality)
• Registration of the magnitude of hunting and fishery in lakes and Odense Fjord
• Pressure from navigation (recreational and commercial) and from maintenance of shipping fairways and harbours

Watercourses

As far as concerns watercourses, the main pressures are inputs of pollutants and physical disturbance of the watercourses and their immediate surroundings.

Discharges from municipal wastewater treatment plants are monitored by the Municipalities as part of their supervisory responsibilities. In addition, the Municipalities will have to monitor discharges from stormwater outfalls (magnitude and frequency) and discharges from properties (or at least selected properties) in sparsely built-up areas.

No programme presently exists for monitoring pesticide loading from agriculture, but models are being developed in connection with pesticide research projects financed by the Danish EPA. Models have been developed for calculating nitrogen loss from agriculture, however, and corresponding models are being developed for phosphorus.

In future, physical pressure in the form of watercourse maintenance has to be documented (frequency, date, extent and method) based on the municipal watercourse regulations and watercourse maintenance records. Moreover, all obstructions and any municipal restoration projects have to be documented for whole watercourse systems, especially the small watercourses (shape, height, etc.), and their location recorded on a map.. In addition, the magnitude and impact of water abstraction will also have to be documented, especially for the small watercourses (and associated springs). Finally, use of the riparian areas will have to be recorded in order to be able to assess the impact of this on the status of the watercourses and the potential for improvement.

Slurry tank. Photo: Bjarne Andresen.

Ejby Mølle Wastewater Treatment Plant. Photo: Nils Daell Kristensen.

Lakes

The main pressures hindering achievement of the environmental objectives for lakes are nitrogen and phosphorus loading from their catchments and to some extent also from the air. Loading from the catchment is presently only monitored in Lake Arreskov Sø, loading of the other lakes being calculated from models based among other things on land use in their catchments. With a number of the lakes, old measurements of water and nutrient transport are also utilized in the models. In order to verify the model findings, random determinations of water flow and nutrient transport are made in the lake inlets. If this approach proves to be inadequate, actual nutrient transport will have to be measured in the individual lakes.

As hazardous substance loading does not seem to hinder any of the lakes in achieving their environmental objectives, monitoring of hazardous substances is accorded low priority and is not presently carried out. At the national level, though, it is planned to screen for hazardous substances in certain watercourses and lakes, some of which could be located in Odense River Basin.

Coastal waters

It is vital to determine the magnitude of the factors that affect Odense Fjord, and this monitoring must necessarily be performed in parallel with the monitoring already mentioned. Monitoring of nutrient loading of the fjord has traditionally been well-developed, primarily via the intensively operated monitoring stations in the River Odense and the somewhat less intensively operated stations in three smaller watercourses. At these stations the transport of nitrogen, phosphorus and organic matter was monitored. All in all, this monitoring encompassed 80% of the nutrient and organic matter inputs to the fjord. At present, it is only carried out extensively. Intensive monitoring will have to be re-established and continued in the form of investigative monitoring.

Monitoring of hazardous substance inputs via the River Odense has ceased as an activity under the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA). It is necessary to re-establish and expand monitoring of hazardous substance inputs to Odense Fjord. Finally, it is necessary to establish monitoring of the physical pressures from shipping and maintenance of shipping fairways and harbours.

8. Public participation

8.1 Introduction

The Water Framework Directive requires that river basin management plans include a summary of public information and consultation regarding the planning process. This section describes the experience gained with public participation in the Odense Pilot River Basin project and draws parallels with the public participation process required by the Environmental Objectives Act.

The provisions of the Water Framework Directive are transposed into Danish law by the Environmental Objectives Act. The latter describes the work and planning process that has to be carried out to facilitate achievement of the Water Framework Directive objective of "good status" in all surface waters and groundwater. The Environmental Objectives Act prescribes a process whereby the public is afforded several opportunities to contribute suggestions and comments. Table 8.1 summarizes the possibilities for the public to contribute to achievement of the Water Framework Directive's objective.

As previously mentioned, the present river basin management plan has been prepared as a pilot project prior to the official timetable for implementation of the Water Framework Directive and the Danish Environmental Objectives Act. Thus it has not been possible – and in any case would not have been meaningful – to invite the public to participate in and contribute to the process as stipulated in the Environmental Objectives Act. In the pilot project it was therefore decided to involve the public in a somewhat different manner, both to ensure public input to the present pilot river basin management plan and to gain new experience with public participation in the planning process. The manner in which the public has been drawn into the process of developing the river basin management plan underway is described below together with the results of this participation.

Work programme and timetable for the process of preparing river basin management plans	To be published no later than 22 December 2006	Hearing period: 6 months
Idea phase initiated together with proposals for a summary of important water management tasks	Material to be published no later than 22 June 2007	Hearing period: 6 months
Draft river basin management plans	To be published no later than 22 December 2008	Hearing period: 6 months
Draft municipal action plans	To be published no later than 22 June 2010	Hearing period 8 weeks

Table 8.1.
Public participation in official implementation of the Danish Environmental Objectives Act.

8.2 Public information and consultation during the Pilot Project

In order to ensure successful implementation of a river basin management plan it is necessary to gain general acceptance of the plan, the proposed environmental objectives and the measures needed to achieve the environmental objectives in the river basin district in question. This necessitates early identification of all stakeholders, and their participation in the planning, something that the river basin district authority did from the start of the present project. The stakeholders in Odense River Basin are summarized in Table 8.2.

The important elements in the preparation of this river basin management plan have been the Provisional Article 5 Report and risk assessment, and the development of a cost-effective programme of measures. These reports have been prepared by the river basin district authority, and have been discussed with stakeholders in Odense River Basin.

All stakeholder organizations were invited to a series of meetings organized by the river basin district authority aimed at ensuring public participation in the various steps in the preparation of a river basin management plan.

The plan for public information and consultation is comprised of the following elements:

- Involvement of stakeholder groups through:
  A National Scientific Advisory Board
  A Regional Political Advisory Board
  An external technical expert group
  An environmental economics expert group
- A special theme in the 2005 Regional Plan for Funen
- Development of a project website.

The first two advisory boards – the National Scientific Advisory Board and the Regional Political Advisory Board – were formed in spring 2003 to ensure that the work and reports were of high professional quality and that local/regional politicians were informed about/in agreement with the decisions reached on the basis of the Provisional Article 5 Report and risk assessment and the cost-effective programme of measures. To further assure the quality of this comprehensive work an external technical expert group was established in spring 2004 to discuss the results and reports in a professional forum. Late in the process in spring 2006, an environmental economics expert group was formed to assure the quality of the cost-effectiveness analysis of the programme of measures.

As mentioned above, preparation of the pilot river basin management plan was designated as a special theme in the 2005 Regional Plan for Funen. In addition, a project website www.odenseprb.ose.mim.dk has been created to inform the public about the project and the pilot river basin management plan.

Table 8.2
Stakeholders in Odense River Basin.

Stakeholders				
Representation level	**Key actors**	**Other authorities**	**Business organizations, research, etc.**	**NGOs and associations**
Local and regional	Environment Centre Odense/Fyn County/	Municipalities	Local industry, agro-industrial companies	Danish Sports Fisher Association
			Representatives of private consultancy firms	Danish Hunters Association
			Danish Agriculture and 3 local farming associations: Funen Family Farmers´ Association, Funen Farming Unions, Patriotisk Selskab	
			Fyntour (Funen tourism organization)	
			Association of private waterworks on Funen	
National	Danish Forest and Nature Agency		The Confederation of Danish Industries, Danish Agriculture	Birdlife Denmark
	Danish Environmental Protection Agency	Ministry of Food, Agriculture and Fisheries	Danish Water and Waste Water Association	Danish Society for Nature Conservation
	Danish Ministry of the Environment	Danish Regions	Danish Horticulture	Danish Forestry Extension
		Institute of Food and Resource Economics	Universities and research institutions	Danish Outdoor Council

8.3 What types of comment have been received by the river basin district authority?

The project has benefited considerably from the two associated advisory boards, the external technical expert group and the environmental economics expert group. The technical advisory board has been particularly active in submitting comments. The comments received from the two advisory boards, the external technical expert group and the environmental economics expert group can be subdivided into the following categories:

1. Technical comments
2. Comments concerning the definition of environmental objectives and reference conditions
3. Political comments
4. Comments on the planning process

The types of comment in each category can be summarized as follows:

1. Technical comments
- Clarification of facts
- Concrete suggestions for improving characterization of water bodies
- Identification of tools considered to be lacking when preparing the Provisional Article 5 Report
- Suggestions pertaining to the definition of modified water bodies
- Suggestions for carrying out the cost-effectiveness analysis of the programme of measures

2. Comments concerning the definition of environmental objectives and reference conditions
- Input regarding the definition of environmental objectives
- Suggestions for tools for determining present status and defining environmental objectives
- Scientific support for the definition of environmental objectives
- Support regarding how far back in time the river basin district authority needs to go in order to be able to define reference conditions
- Suggestions for defining reference conditions
- Necessary coordination with other EU directives

3. Political comments
- Criticism of environmental objectives; some stakeholders wanted more stringent objectives and some wanted less stringent objectives
- Calls for the Provisional Article 5 Report not to be published
- Emphasis on the necessity for correct and up-to-date economic assessment (of the programme of measures)
- Views on the costs of implementing the river basin management plan

4. Comments on the planning process
- Calls for uniformity in selecting levels of ambition
- Awareness of the necessity for cooperation between involved parties
- Criticism of the work form during the first phase of the project
- Praise for the work form during the last phase of the project
- Calls for the submission of suggestions as to how environmental objectives and measures can be operationalized
- Support for technical solutions to deal with agricultural losses

8.4 What types of action have been taken regarding the comments?

The river basin district authority has dealt with the comments in different ways. As regards the technical comments, relevant necessary changes have been incorporated into the Provisional Article 5 Report, the risk analysis and the programme of measures. An overview of all comments can be seen in minutes of the meetings.

Comments concerning the definition of environmental objectives and reference conditions have been dealt with in three different ways. Questions about methodology have been responded to with concrete answers. Suggestions as to which elements should be included when defining environmental objectives and reference conditions have been evaluated. Finally, comments about coordination with other EU directives have been discussed internally in the river basin district authority as well as in other authorities.

Some of the more political comments have been answered directly by politicians from the former County Council. As regards comments on the planning process, these have drawn attention to the work process and the way stakeholders cooperate with each other and with the river basin district authority. During discussions about the Provisional Article 5 Report it became apparent that more room and time for mutual exchange of information and dialogue between stakeholders would have been desirable during the process. The level of information attained by stakeholders during preparation of the programme of measures was higher and the process smoother, although it was still time-consuming.

8.5 Future measures that should be initiated when the actual river basin management plan is to be implemented

In order to ensure a high level of participation and involvement in future it is necessary to establish a cooperation forum for the naturally delimited river basin districts or subdistricts for which a river basin management plan is to be drawn up. The Municipalities are only allowed six months from final adoption of the river basin management plans to draw up a draft of a municipal action plan. This necessitates involving the Municipalities in the work at an early point in time. The Municipalities' statutory groundwater protection responsibilities could beneficially be coordinated in these cooperation fora.

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Annexes

Annex 1.1. Macrophytes

Watercourse type	Group/species, vernacular	Group/species, Latin
1	Lesser Water-parsnip One-rowed Watercress Aquatic moss species	*Berula erecta* *Nasturtium microphyllum*
2	Lesser Water-parsnip One-rowed Watercress Blue Water Speedwell Spiked Water Milfoil Common Water Crowfoot Horned Pondweed Water Starwort species	*Berula erecta* *Nasturtium microphyllum* *Veronica anagallis-aquatica* *Myriophyllum spicatum* *Ranunculus aquatilis* *Zannichellia palustris* *Callitriche*
3	Flowering Rush Arrowhead Great Yellowcress Mare's-tail Greater Water-parsnip Fan-leaved Water Crowfoot Common Water Crowfoot Spiked Water Milfoil Yellow Water-lily Reddish Pondweed Shining Pondweed Long-stalked Pondweed Grasswrack Pondweed Flat-stalked Pondweed Blunt-leaved Pondweed Fennel Pondweed Perfoliate Pondweed Broad-leaved Pondweed Pondweed hybrids	*Butomus umbellatus* *Sagittaria sagittifolia* *Rorippa amphibia* *Hippuris vulgaris* *Sium latifolium* *Ranunculus circinatus* *Ranunculus aquatilis* *Myriophyllum spicatum* *Nuphar lutea* *Potamogeton alpinus* *Potamogeton lucens* *Potamogeton praelongus* *Potamogeton compressus* *Potamogeton friesii* *Potamogeton obtusifolius* *Potamogeton pectinatus* *Potamogeton perfoliatus* *Potamogeton natans* *Potamogeton* hybrids

Annex 1.2. Macroinvertebrates

Group/species	Watercourse type		
	1	2	3
TRICLADIDA (Planarians)			
Polycelis feline	•S		
Dugesia gonocephala	•	•	•
Bdellocephala punctata			•
CRUSTACEA (Crustaceans)			
Gammarus pulex	•	•	•
EPHEMEROPTERA (Mayflies)			
Baetis rhodani	•	•	
Baetis fuscatus			•
Centrotilum luteolum			•
Procloeon bifidum			•
Heptagenia sulphurea		•	•
Heptagenia fuscogrisea †			•
Ecdyonurus lateralis †			•
Ephemera danica	•	•	
Ephemera vulgate			•
Ephemerella ignite		•	•
Paraleptophlebia submarginata		•	
Siphlonurus aestivalis	•T		
Caenis rivulorum			•
ODONATA (Dragonflies/Damselflies)			
Calopteryx splendens			•
PLECOPTERA (Stoneflies)			
Nemurella picteti	•S		
Brachyptera risi	•T		
Taeniopteryx nebulosa		•	•
Capnia bifrons	•T		
Amphinemura standfussi	•T		
Isoperla grammatical		•	
Leuctra nigra	•S	•	
Leuctra hippopus	•	•	
Leuctra fusca	•	•	•
Nemoura avicularis			•
Nemoura flexuosa	•		
HETEROPTERA (True bugs))			
Aphelocheirus aestivalis †		•	•
MEGALOPTERA (Alderflies, etc.)			
Sialis fuliginosa		•	
Sialis nigripes †			•
TRICHOPTERA (Caddisflies)			
Rhyacophila fasciata	•	•	•
Agapetus fuscipes	•		
Agapetus ochripes		•	•
Hydroptila sparsa		•	•
Ithytrichia lamellaris †			•
Wormaldia occipitalis	•S		
Plectrocnemia conspersa	•	•	
Polycentropus flavomaculatus		•	•
Polycentropus irroratus			•
Neureclipsis bimaculata		•L	•L
Tinodes pallidulus	•	•	
Lype reducta	•		
Lype phaeopa		•	•
Hydropsyche angustipennis		•L	•L
Hydropsyche pellucidula		•	•
Hydropsyche saxonica		•	
Hydropsyche siltalai		•	•
Molanna angustata			•
Beraeodes minutus	•	•	•
Sericostoma personatum	•	•	
Notidobia ciliaris			•
Lepidostoma hirtum			•
Brachycentrus subnubilus			•
Goera pilosa		•	•
Lithax obscurus	•		
Silo pallipes	•	•	
Silo nigricornis		•	•
Ironoquia dubia	•T		
Anabolia nervosa		•	•
Limnephilus fuscicornis			•
Limnephilus lunatus		•	•
Potamophylax nigricornis	•S		
Potamophylax cingulatus	•	•	
Potamophylax latipennis			•
Potamophylax rotundipennis		•	
Halesus radiatus	•	•	•
Chaetopteryx villosa	•	•	•
Athripsodes albifrons		•	•
Athripsodes cinereus		•	•
Mystacides azurea			•
Ceraclea dissimilis			•
Ceraclea alboguttata		•	•
Ceraclea nigronervosa			•
Micropterna sequax	•T		
Micropterna lateralis	•		
COLEOPTERA (Beetles)			
Elodes minuta	•	•	
Elodes marginata	•S		
Elmis aenea		•	•
Limnius volckmari	•	•	•
Oulimnius tuberculatus		•	•
Orechtochilus villosus			•
GASTROPODA (Gastropods)			
Theodoxus fluviatilis		•	•
Ancylus fluviatilis	•	•	•
BIVALVIA (Mussels, clams, etc)			
Unio crassus		•	•

Notes:
- ● Must be present
- ○ May occur in some places
- † Extinct on Funen
- T Primarily present in drying-out watercourses
- S Primarily present in springbrooks
- L Primarily present in lake outlets

Annex 1.3. Fish

Watercourse type	Group/species: Vernacular name	Group/species: Latin name
1	Brown trout, especially fry (0+) [2–5/m^2] Brook lamprey	*Salmo trutta* *Lampetra planeri*
2	Brown trout Brook lamprey Eel Minnow	*Salmo trutta* *Lampetra planeri* *Anguilla anguilla* *Phoxinus phoxinus*
3	Brown trout Brook lamprey Sea lamprey Eel Pike Burbot Minnow Ide Roach Spined loach Gudgeon Perch	*Salmo trutta* *Lampetra planeri* *Petromyzon marinus* *Anguilla anguilla* *Esox lucius* *Lota lota* *Phoxinus phoxinus* *Leuciscus idus* *Rutilus rutilus* *Cobitis taenia* *Gobio gobio* *Perca fluviatilis*

Annex 2.1. Special Areas of Conservation (Habitats Directive)

* indicates priority habitat types that Denmark is required to provide special protection pursuant to the Statutory Order on Demarcation and Administration of International Nature Conservation Sites.

No. 94 Odense Fjord
1110 Sandbanks which are slightly covered by sea water all the time
1140 Mudflats and sandflats not covered by seawater at low tide
1160 Large shallow inlets and bays
1310 *Salicornia* and other annuals colonizing mud and sand
1330 Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)
3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*
3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
4010 Northern Atlantic wet heaths with *Erica tetralix*
6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
7220 *Petrifying springs with tufa formation (*Cratoneurion*)
7230 Alkaline fens

No. 97 The mires Urup Dam, Brabæk Mose, Birkende Mose and Illemose
1903 Fen orchid *Liparis loeselii*
3140 Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
6410 *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)
7210 *Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*
7230 Alkaline fens
91E0 *Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)

No. 98 River Odense with River Hågerup, River Sallinge and River Lindved
1016 Desmoulin's whorl snail *Vertigo moulinsiana*
1032 Common river mussel *Unio crassus*
1096 Brook lamprey *Lampetra planeri*
1149 Spined loach *Cobitis taenia*
3260 Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
7220 *Petrifying springs with tufa formation (*Cratoneurion*)
7230 Alkaline fens
91E0 *Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)

No. 103 Storelung
7120 Degraded raised bogs still capable of natural regeneration
91D0 *Bog woodland

No. 104 Forests and lakes south of Brahetrolleborg
1016 Desmoulin's whorl snail *Vertigo moulinsiana*
1166 Great crested newt *Triturus cristatus*
3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* - type vegetation
3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
7110 *Active raised bogs
7230 Alkaline fens
91D0 *Bog woodland
91E0 *Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)

No. 105 Lake Arreskov Sø

1016 Desmoulin's whorl snail *Vertigo moulinsiana*
3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* – type vegetation
3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
6410 *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)
6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
7230 Alkaline fens
91D0 *Bog woodland
91E0 *Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)

No. 106 Lake Store Øre Sø, Lake Sortesø and Lake Igle Sø

3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* – type vegetation
3160 Natural dystrophic lakes and ponds
7140 Transition mires and quaking bogs
7150 Depressions on peat substrates of the *Rhynchosporion*
7230 Alkaline fens

Annex 2.2. Special Protection Areas (Birds Directive)

No. 74 Lake Brændegård Sø, Lake Nørresø and forests at Brahetrolleborg

Cormorant (*Phalacrocorax carbo*)
Grey lag goose (*Anser anser*)
Common pochard (*Aythya farina)*
Tufted duck (*Aythya fuligula*)

No. 75 Odense Fjord

Arctic tern (*Sterna paradisea*)
Sandwich tern (*Sterna sandvicensis*)
Marsh harrier (*Circus aeruginosis*)
Avocet (*Recurvirostra avosetta*)
Mute swan (*Cygnus olor*)
Whooper swan (*Cygnus Cygnus*)
Red-breasted merganser (*Mergus serrator*)
Goosander (*Mergus merganser*)
Coot (*Fulica atra*)

No. 78 Lake Arreskov Sø

Bittern (*Botaurus stellaris)*
White-tailed eagle (*Haliaeetus albicilla)*
Honey Buzzard (*Pernis apivorus)*
Common tern (*Sterna hirundo*)
Grey lag goose (*Anser anser*)
Tufted duck (*Aythya fuligula)*
Shoveler (*Anas clypeata)*

Annex 3.1.

LAKE ARRESKOV SØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Arreskov Sø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	45.2 ha	0.63	0				13.2
5% higher utilization of the N content of manure	963 ha	0.38	0				29.9
EU agricultural reform (CAP) + improved utilization of the N content of fodder	963 ha	0.68	0				0
Structural development (reduction in area relative to 2003)	39.7 ha	0.53	0				0
Agri-environmental measures – buffer zones and wetlands	1.3 ha	0.12	0.001	+			8.9
Set-aside of land for afforestation (upland[1])	8.2 ha	0.09	0.001		+		28.1
Set-aside of land for wetlands (APAE II+III)	49 ha	10.63	0.049	+	+		199.7
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	55 properties	0.24	0.056			Reduced discharge of oxygen-consuming substances and ammonia	410.8
Wastewater treatment plants – improved wastewater treatment through optimization of operation	WWTPs						0
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	1 locality	0.04	0.01			Reduced discharge of oxygen-consuming substances and ammonia	558.1
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	1 locality	0.03	0.005			Reduced discharge of oil residues, precipitates, etc.	44.8
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-13.39**	**-0.12**				**1,293.4**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.2.

LAKE BRAHETROLLEBORG SLOTSSØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Brahetrolleborg Slotssø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establishment and improvement of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	30.2 ha	0.46	0				8.8
5% higher utilization of the N content of manure	643 ha	0.28	0				19.9
EU agricultural reform (CAP) + improved utilization of the N content of fodder	643 ha	0.5	0				0
Structural development (reduction in area relative to 2003)	26.6 ha	0.39	0				0
Agri-environmental measures – buffer zones and wetlands	1.1 ha	0.102	0.001	+			7.6
Set-aside of land for afforestation (upland[1])	5.5 ha	0.06	0.001		+		18.7
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		0
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	60 properties	0.13	0.033			Reduced discharge of oxygen-consuming substances and ammonia	448.1
Wastewater treatment plants – improved wastewater treatment through optimization of operation	0 WWTPs						
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	1 locality	0.03	0.008			Reduced discharge of oxygen-consuming substances and ammonia	306.1
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	1 locality	0	0			Reduced discharge of oil residues, precipitates, etc.	44.8
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-1.94**	**-0.04**				**854.2**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.3.

LAKE BRÆNDEGÅRD SØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Brændegård Sø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	Phosphorus Change in waterborne discharge to water bodies (tonnes/yr)	Reduced physical pressure	Natural habitats Re-establish-ment and improve-ment of quality	Other	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	16.8 ha	0.2	0				4.9
5% higher utilization of the N content of manure	358 ha	0.13	0				11.1
EU agricultural reform (CAP) + improved utilization of the N content of fodder	358 ha	0.23	0				0
Structural development (reduction in area relative to 2003)	14.8 ha	0.18	0				0
Agri-environmental measures – buffer zones and wetlands	0.5 ha	0.046	0.001	+			3.4
Set-aside of land for afforestation (upland[1])	3.5 ha	0.04	0		+		12.0
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		0
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	0 properties	0	0			Reduced discharge of oxygen-consuming substances and ammonia	
Wastewater treatment plants – improved wastewater treatment through optimization of operation	0 WWTPs						
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	0 localities	0	0			Reduced discharge of oxygen-consuming substances and ammonia	
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	0 localities	0	0			Reduced discharge of oil residues, precipitates, etc.	
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-0.826**	**-0.001**				**31.5**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.4.

LAKE NØRRESØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Nørresø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	1 ha	0.01	0				0.3
5% higher utilization of the N content of manure	21 ha	0.01	0				0.6
EU agricultural reform (CAP) + improved utilization of the N content of fodder	21 ha	0.01	0				0
Structural development (reduction in area relative to 2003)	0.9 ha	0.01	0				0
Agri-environmental measures – buffer zones and wetlands	0 ha	0	0	+			0
Set-aside of land for afforestation (upland[1])	0.2 ha	0	0		+		0.7
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		0
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	3 properties	0.01	0.002			Reduced discharge of oxygen-consuming substances and ammonia	22.4
Wastewater treatment plants – improved wastewater treatment through optimization of operation	WWTPs						
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	0 localities	0	0			Reduced discharge of oxygen-consuming substances and ammonia	
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	0 localities	0	0			Reduced discharge of oil residues, precipitates, etc.	
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-0.05**	**-0.002**				**24.0**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.5.

LAKE DALLUND SØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Dallund Sø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	3.2 ha	0.03	0				0.9
5% higher utilization of the N content of manure	68 ha	0.02	0				2.1
EU agricultural reform (CAP) + improved utilization of the N content of fodder	68 ha	0.03	0				0
Structural development (reduction in area relative to 2003)	2.8 ha	0.03	0				0
Agri-environmental measures – buffer zones and wetlands	0 ha	0	0	+			0
Set-aside of land for afforestation (upland[1])	0.6 ha	0.01	0		+		2.1
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		0
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	11 properties	0.03	0.006			Reduced discharge of oxygen-consuming substances and ammonia	82.2
Wastewater treatment plants – improved wastewater treatment through optimization of operation	0 WWTPs						
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	0 localities	0	0			Reduced discharge of oxygen-consuming substances and ammonia	
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	2 localities	0.04	0.007			Reduced discharge of oil residues, precipitates, etc.	89.5
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-0.19**	**-0.013**				**176.8**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.6.

LAKE FJELLERUP SØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Fjellerup Sø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	1.7 ha	0.02	0				0.5
5% higher utilization of the N content of manure	35 ha	0.01	0				1.9
EU agricultural reform (CAP) + improved utilization of the N content of fodder	35 ha	0.02	0				0
Structural development (reduction in area relative to 2003)	1.5 ha	0.01	0				0
Agri-environmental measures – buffer zones and wetlands	0 ha	0	0	+			0
Set-aside of land for afforestation (upland[1])	0.3 ha	0	0		+		1.0
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		0
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	0 properties					Reduced discharge of oxygen-consuming substances and ammonia	
Wastewater treatment plants – improved wastewater treatment through optimization of operation	0 WWTPs						0
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	0 localities					Reduced discharge of oxygen-consuming substances and ammonia	
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	0 localities					Reduced discharge of oil residues, precipitates, etc.	
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-0.06**	**-0**				**2.6**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.7.

LAKE LANGESØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchmnet of Lake Langesø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	14.7 ha	0.21	0				4.3
5% higher utilization of the N content of manure	314 ha	0.14	0				9.7
EU agricultural reform (CAP) + improved utilization of the N content of fodder	314 ha	0.23	0				0
Structural development (reduction in area relative to 2003)	13 ha	0.18	0				0
Agri-environmental measures – buffer zones and wetlands	0 ha	0	0	+			0
Set-aside of land for afforestation (upland[1])	2.7 ha	0.03	0		+		9.3
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		0
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	60 properties	0.17	0.041			Reduced discharge of oxygen-consuming substances and ammonia	448.1
Wastewater treatment plants – improved wastewater treatment through optimization of operation	0 WWTPs						0
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	0 localities					Reduced discharge of oxygen-consuming substances and ammonia	
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	0 localities					Reduced discharge of oil residues, precipitates, etc.	
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-0.96**	**-0.041**				**471.4**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.8.

LAKE NØRRE SØBY SØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Nørre Søby Sø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III							
Catch crops: Increased area	47.3 ha	0.71	0				13.9
5% higher utilization of the N content of manure	1007 ha	0.44	0				31.2
EU agricultural reform (CAP) + improved utilization of the N content of fodder	1007 ha	0.78	0				0
Structural development (reduction in area relative to 2003)	41.5 ha	0.61	0				0
Agri-environmental measures – buffer zones and wetlands	0 ha			+			0
Set-aside of land for afforestation (upland[1])	8.6 ha	0.09	0.001		+		29.5
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		0
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	126 properties	0.15	0.063			Reduced discharge of oxygen-consuming substances and ammonia	941.1
Wastewater treatment plants – improved wastewater treatment through optimization of operation	0 WWTPs						0
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	0 localities					Reduced discharge of oxygen-consuming substances and ammonia	
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	0 localities					Reduced discharge of oil residues, precipitates, etc.	
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-2.78**	**-0.064**				**1,015.7**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.9.

LAKE SØBO SØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Søbo Sø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	9.9 ha	0.11	0				2.9
5% higher utilization of the N content of manure	212 ha	0.07	0				6.6
EU agricultural reform (CAP) + improved utilization of the N content of fodder	212 ha	0.12	0				0
Structural development (reduction in area relative to 2003)	8.7 ha	0.1	0				0
Agri-environmental measures – buffer zones and wetlands	0 ha	0	0	+			0
Set-aside of land for afforestation (upland[1])	2 ha	0.02	0		+		6.9
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		0
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	33 properties	0	0.001			Reduced discharge of oxygen-consuming substances and ammonia	246.5
Wastewater treatment plants – improved wastewater treatment through optimization of operation	WWTPs						0
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	0 localities					Reduced discharge of oxygen-consuming substances and ammonia	
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	0 localities					Reduced discharge of oil residues, precipitates, etc.	
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-0.42**	**-0.001**				**262.8**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.10.

LAKE SORTESØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Sortesø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	Phosphorus Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	0 ha	0	0				
5% higher utilization of the N content of manure	0 ha	0	0				
EU agricultural reform (CAP) + improved utilization of the N content of fodder	0 ha	0	0				
Structural development (reduction in area relative to 2003)	0 ha	0	0				
Agri-environmental measures – buffer zones and wetlands	0 ha	0	0	+			
Set-aside of land for afforestation (upland[1])	0 ha	0	0		+		
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	0 properties					Reduced discharge of oxygen-consuming substances and ammonia	
Wastewater treatment plants – improved wastewater treatment through optimization of operation	0 WWTPs						0
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	0 localities					Reduced discharge of oxygen-consuming substances and ammonia	
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	0 localities					Reduced discharge of oil residues, precipitates, etc.	
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-0**	**-0**				**0**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.11.

LAKE STORE ØRESØ

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the catchment of Lake Store Øresø

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	5.1 ha	0.06	0				1.5
5% higher utilization of the N content of manure	109 ha	0.04	0				3.4
EU agricultural reform (CAP) + improved utilization of the N content of fodder	109 ha	0.06	0				0
Structural development (reduction in area relative to 2003)	4.5 ha	0.05	0				0
Agri-environmental measures – buffer zones and wetlands	0 ha	0	0	+			0
Set-aside of land for afforestation (upland[1])	1 ha	0.01	0		+		3.4
Set-aside of land for wetlands (APAE II+III)	0 ha	0	0	+	+		0
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	0 properties					Reduced discharge of oxygen-consuming substances and ammonia	
Wastewater treatment plants – improved wastewater treatment through optimization of operation	0 WWTPs						0
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	0 localities					Reduced discharge of oxygen-consuming substances and ammonia	
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	0 localities					Reduced discharge of oil residues, precipitates, etc.	
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	0 localities					Reduced temperature impact from cooling water	
Contaminated sites – remediation	0 localities					Hazardous substances – reduced loss to the environment	
COMBINED EFFECT AND COST		**-0.22**	**-0**				**8.3**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 3.12.

REMAINDER OF ODENSE RIVER BASIN

Baseline 2015 – assumptions

Adopted but not yet (2004) fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc. in the remainder of Odense River Basin

Initiated measures and assumptions	Dose	Effects					Economics
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Other**	Economic cost DKK 1,000 /yr
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III Catch crops: Increased area	3.040 ha	44.33	0				890.7
5% higher utilization of the N content of manure	64.691 ha	27.02	0				2.005.7
EU agricultural reform (CAP) + improved utilization of the N content of fodder	64.691 ha	48.43	0				0
Structural development (reduction in area relative to 2003)	2.670 ha	37.87	0				0
Agri-environmental measures – buffer zones and wetlands	87.1 ha	8.057	0.087	+			597.9
Set-aside of land for afforestation (upland[1])	553.1 ha	5.9	0.055		+		1,897.1
Set-aside of land for wetlands (APAE II+III)	554 ha	120.22	0.554	+	+		2,257.3
Gothenburg Protocol – reduced airborne nitrogen emissions Reduced N emission from agriculture, power stations, traffic, etc.	Whole DK	?	0		+	-3 kg N/ha deposition on water surfaces and -1.3 kg N/ha on terrestrial natural habitats	?
Livestock production – prognosis 2005–2015 20% increase in production (Prognosis by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.		0	0			No increase in ammonia emissions	?
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment	3,943 properties	7.2	1.83			Reduced discharge of oxygen-consuming substances and ammonia	29,450.3
Wastewater treatment plants – improved wastewater treatment through optimization of operation	13 WWTPs	2	0				0
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems	128 localities	5	1.6			Reduced discharge of oxygen-consuming substances and ammonia	40,499.2
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments	0 localities					Reduced discharge of oil residues, precipitates, etc.	
Disused waste depository – Stige Ø: Remedial measures to protect Odense Fjord	0 localities					Reduced discharge of hazardous substances	
Enterprises – Fynsværket CHP Plant: Reduction of pressure from cooling water discharge by re-routing the River Odense, etc.	1 localities	2.7	0.02			Reduced temperature impact from cooling water	15,179.0
Contaminated sites – remediation	107 localities					Hazardous substances – reduced loss to the environment	29,202.000
COMBINED EFFECT AND COST		**-308.727**	**-4.546**				**121,979.3**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 4.1.

LAKE ARRESKOV SØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Arreskov Sø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establishment and improvement of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	0 ha	-	-			-
2. Additional 5% higher utilization of the N content of manure	207 ha	0.1	0			3.1
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	153 ha	0	No loss increase			?
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	54 ha	0	Reduction not quantified			?
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	0 ha	-	-			
6. Additional 5% higher utilization of the N content of manure	150 ha	0.2	0			2.3
7. Reduced N fertilization norm (-10%)	0 ha	-	-			-
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	111 ha	0	No loss increase			?
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	39 ha	0	Reduction not quantified			?
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	310 ha	3.2	0.031		+	1,063.3
11. Permanent grassland	0 ha	-	-		+	-
12. Restrictions on cultivation of land potentially subject to erosion	180 ha	1.8	0.026	+	+	580.7
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	20 ha	2	0.02	+	++	83.1
14. Permanent grassland on farmland	0 ha	-	-	+	++	-
15. 5-m buffer zones alongside watercourses in lake catchments	3 ha	0.2	0.003	+	+	13.1
16. 10-m buffer zone around ponds in lake catchments	2 ha	0.1	0.002	+	+	9.8
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	23 ha	0.2	0.0005		++	73.4
18. Pesticide-free cultivation of farmland around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	-
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	5 localities	-	-	++		54.9
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	10 ha 6 km	1	0.01	++	++	33.3 -75.3
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	5 km	-	-	++		160.6
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	137 properties	0	0.052			1,023.3
23. Wastewater treatment plants - improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-	-	-	-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**8.8**	**0.137**			**3,025.5**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.2.

LAKE BRAHETROLLEBORG SLOTSSØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Brahetrolleborg Slotssø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	0 ha	-	-			-
2. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	0 ha	-	-			-
6. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
7. Reduced N fertilization norm (-10%)	0 ha	-	-			-
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	307 ha	3.1	0.031		+	1,053.0
11. Permanent grassland	91 ha	0.9	0.009		+	293.6
12. Restrictions on cultivation of land potentially subject to erosion	19 ha	0.2	0.002	+	+	61.3
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	19 ha	1.9	0.019	+	++	80.6
14. Permanent grassland on farmland	162 ha	4.3	0.016	+	++	522.6
15. 5-m buffer zones alongside watercourses in lake catchments	5 ha	0.2	0.005	+	+	19.1
16. 10-m buffer zone around ponds in lake catchments	2 ha	0.1	0.002	+	+	6.4
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	18 ha	0.2	0.0004		++	57.3
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	6 localities	-	-	++		65.9
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	15 ha 10 km	1.5	0.015	++	++	49.9 -111.8
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	4 km	-	-	++		114.7
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	60 properties	0.1	0.05			448.1
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-	-	-	-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**12.5**	**0.145**			**2,660.6**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.3.

LAKE BRÆNDEGÅRD SØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Brændegård Sø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establishment and improvement of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	0 ha	-	-			-
2. Additional 5% higher utilization of the N content of manure	41 ha	0	0			0.6
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	30 ha	0	No loss increase			?
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	11 ha	0	Reduction not quantified			?
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	0 ha	-	-			-
6. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
7. Reduced N fertilization norm (-10%)	0 ha	-	-			-
8 P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	173 ha	1.8	0.017		+	593.4
11. Permanent grassland	44 ha	0.5	0.004		+	141.9
12. Restrictions on cultivation of land potentially subject to erosion	44 ha	0.5	0.004	+	+	141.9
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	43 ha	4.3	0.043	+	++	182.3
14. Permanent grassland on farmland	4 ha	0.1	0.0004	+	++	12.9
15. 5-m buffer zones alongside watercourses in lake catchments	2 ha	0.1	0.002	+	+	8.9
16. 10-m buffer zone around ponds in lake catchments	1 ha	0.1	0.001	+	+	4.2
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	0 ha	-	-		++	-
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	-
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	4 localities	-	-	++		43.9
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	2 ha 9 km	0.2	0.002	++	++	6.7 -104.8
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	4 km	-	-	++		121.3
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	34 properties	0.1	0.04			253.9
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-	-	-	-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking,, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**7.5**	**0.112**			**1,407.3**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.4.

LAKE NØRRESØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Nørresø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	0 ha	-	-			
2. Additional 5% higher utilization of the N content of manure	0 ha	-	-			
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	0 ha	-	-			
6. Additional 5% higher utilization of the N content of manure	0 ha	-	-			
7. Reduced N fertilization norm (-10%)	0 ha	-	-			
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	1 ha	0	0.0001		+	3.4
11. Permanent grassland	9 ha	0.1	0.001		+	29.0
12. Restrictions on cultivation of land potentially subject to erosion	9 ha	0.1	0.001	+	+	29.0
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	1 ha	0.1	0.001	+	++	4.2
14. Permanent grassland on farmland	1 ha	0	0.0001	+	++	3.2
15. 5-m buffer zones alongside watercourses in lake catchments	0 ha	-	-	+	+	
16. 10-m buffer zone around ponds in lake catchments	0 ha	-	-	+	+	
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	0 ha	-	-		++	
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	2 localities	-	-	++		22.0
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	0 ha 3 km			++	++	- -35.3
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	1 km	-	-	++		39.3
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	0 properties	-	-			-
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-	-	-	-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**0.3**	**0.003**			**94.8**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.5.

LAKE DALLUND SØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Dallund Sø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	0 ha	-	-			-
2. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
3 P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	0 ha	-	-			-
6. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
7. Reduced N fertilization norm (-10%)	0 ha	-	-			-
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	59 ha	0.6	0.006		+	202.4
11. Permanent grassland	2 ha	0	0.0002		+	6.5
12. Restrictions on cultivation of land potentially subject to erosion	2 ha	0	0.0002	+	+	6.5
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	1 ha	0.1	0.001	+	++	4.2
14. Permanent grassland on farmland	2 ha	0.1	0.0002	+	++	6.5
15. 5-m buffer zones alongside watercourses in lake catchments	0,3 ha	0	0.0003	+	+	1.3
16. 10-m buffer zone around ponds in lake catchments	0,1 ha	0	0.0001	+	+	0.4
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	1 ha	0	0		++	4.0
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	-
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	1 locality	-	-	++		11
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	0 ha 0,4 km	-	-	++	++	0 -4.7
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	0,2 km	-	-	++		6.6
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	11 properties	0	0.006			82.2
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-	-	-	-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**0.8**	**0.0139**			**326.7**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.6.

LAKE FJELLERUP SØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Fjellerup Sø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	0 ha	-	-			-
2. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	0 ha	-	-			-
6. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
7. Reduced N fertilization norm (-10%)	0 ha	-	-			-
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	29 ha	0.3	0.003		+	99.5
11. Permanent grassland	0 ha	-	-		+	-
12. Restrictions on cultivation of land potentially subject to erosion	4 ha	0.04	0.0004	+	+	12.9
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	0 ha	-	-	+	++	-
14. Permanent grassland on farmland	1,5 ha	0.04	0.0002	+	++	4.8
15. 5-m buffer zones alongside watercourses in lake catchments	0 ha	-	-	+	+	-
16. 10-m buffer zone around ponds in lake catchments	0 ha	-	-	+	+	-
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	0 ha	-	-		++	-
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	-
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	0 localities	-	-	++		-
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	0 ha 0 km	-	-	++	++	- -
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	0 km	-	-	++		-
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	0 properties					-
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-	-	-	-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**0.4**	**0.0035**			**117.2**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.7.

LAKE LANGESØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Langesø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	0 ha	-	-			-
2. Additional 5% higher utilization of the N content of manure	133 ha	0.1	-			2.0
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	85 ha	0	No loss increase			?
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	48 ha	0	Reduction not quantified			?
Environmental optimization of crop production – lowland/river valleys . Catch crops: Increased area	0 ha	-	-			-
6. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
7. Reduced N fertilization norm (-10%)	0 ha	-	-			-
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	29 ha	0.3	0.003		+	99.5
11. Permanent grassland	60 ha	0.6	0.006		+	193.6
12. Restrictions on cultivation of land potentially subject to erosion	0 ha	-	-	+	+	-
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	9 ha	0.8	0.0082	+	++	34.8
14. Permanent grassland on farmland	73 ha	1.9	0.0073	+	++	235.5
15. 5-m buffer zones alongside watercourses in lake catchments	0 ha	-	-	+	+	-
16. 10-m buffer zone around ponds in lake catchments	2 ha	0.1	0.0018	+	+	7.6
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	6 ha	0.1	0.0001		++	18.5
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	-
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	3 localities	-	-	++		32.9
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	1 ha 1,2 km	0.1	0.001	++	++	3.3 -14.1
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	0,4 km	-	-	++		13.1
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	0 properties	-	-			-
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-	-	-	-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**4.0**	**0.0273**			**626.7**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.8.

LAKE NØRRE SØBY SØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Nørre Søby Sø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establishment and improvement of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	0 ha	-	-			-
2. Additional 5% higher utilization of the N content of manure	147 ha	0.1	0			2.2
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	109 ha	0	No loss increase			?
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	38 ha	0	Reduction not quantified			?
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	0 ha	-	-			-
6. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
7. Reduced N fertilization norm (-10%)	0 ha	-	-			-
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	530 ha	5.4	0.053		+	1.817.9
11. Permanent grassland	0 ha	-	-		+	-
12. Restrictions on cultivation of land potentially subject to erosion	0 ha	-	-	+	+	-
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	19 ha	1.9	0.019	+	++	80.1
14. Permanent grassland on farmland	286 ha	7.6	0.029	+	++	922.6
15. 5-m buffer zones alongside watercourses in lake catchments	7 ha	0.4	0.007	+	+	29.7
16. 10-m buffer zone around ponds in lake catchments	2 ha	0.1	0.0022	+	+	9.3
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	0 ha	-	-		++	-
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	-
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	4 localities	-	-	++		43.9
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	6 ha 5 km	0.6	0.006	++	++	20.0 -57.7
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	0 km	-	-	++		-
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	0 properties	-	-			-
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-			-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**16.1**	**0.116**			**2,868.1**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.9.

LAKE SØBO SØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Søbo Sø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
<u>*Environmental optimization of crop production – upland*</u>[1] 1. Catch crops: Increased area	0 ha	-	-			-
2. Additional 5% higher utilization of the N content of manure	0 ha	-	-			-
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	-	-			-
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	-	-			-
<u>*Environmental optimization of crop production – lowland/river valleys*</u> 5. Catch crops: Increased area	0 ha	-	-			-
6. Additional 5% higher utilization of the N content of manure	2 ha	0	0			0
7. Reduced N fertilization norm (-10%)	0 ha	-	-			-
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	1,5 ha	0	No loss increase			?
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0,5 ha	0	Reduction not quantified			?
<u>*Set-aside of farmland – upland*</u>[1] 10. Land for afforestation (broadleaf)	94 ha	1	0.0094		+	322.4
11. Permanent grassland	98 ha	1	0.0098		+	316.1
12. Restrictions on cultivation of land potentially subject to erosion	0 ha	-	-	+	+	-
<u>*Set-aside of farmland – lowland/river valleys*</u> 13. Land for re-establishment of wetlands	3 ha	0.3	0.003	+	++	12.7
14. Permanent grassland on farmland	11 ha	0.3	0.0011	+	++	35.5
15. 5-m buffer zones alongside watercourses in lake catchments	0 ha	-	-	+	+	-
16. 10-m buffer zone around ponds in lake catchments	0,4 ha	0	0.0004	+	+	1.7
<u>*Groundwater protection measures*</u> 17. Set-aside: Permanent grassland kept unfertilized	0 ha	-	-		++	-
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	-
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	0 localities	-	-	++		-
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	1 ha 0,2 km	0.1	0.001	++	++	3.3 -2.4
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	0,1 km	-	-	++		3.3
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	0 properties	-	-			-
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-	-	-	-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**2.7**	**0.025**			**692.8**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.10.

LAKE SORTESØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Sortesø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland[1] 1. Catch crops: Increased area	0 ha					
2. Additional 5% higher utilization of the N content of manure	0 ha					
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	0	No loss increase			
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	0	Reduction not quantified			
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	0 ha					
6. Additional 5% higher utilization of the N content of manure	0 ha					
7. Reduced N fertilization norm (-10%)	0 ha					
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	0 ha	0	No loss increase			
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	0 ha	0	Reduction not quantified			
Set-aside of farmland – upland[1] 10. Land for afforestation (broadleaf)	0 ha				+	
11. Permanent grassland	0 ha				+	
12. Restrictions on cultivation of land potentially subject to erosion	0 ha			+	+	
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	0 ha			+	++	
14. Permanent grassland on farmland	0 ha			+	++	
15. 5-m buffer zones alongside watercourses in lake catchments	0 ha			+	+	
16. 10-m buffer zone around ponds in lake catchments	0 ha			+	+	
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	0 ha				++	
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	0 localities	-	-	++		
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	0 ha 0 km			++	++	
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	0 km	-	-	++		
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	0 properties					
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	0	0	-	-	
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**0**	**0**			**0**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.11.

LAKE STORE ØRESØ

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the catchment of Lake Store Øresø

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establishment and improvement of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
<u>*Environmental optimization of crop production – upland*[1]</u> 1. Catch crops: Increased area	0 ha	-	-			-
2. Additional 5% higher utilization of the N content of manure	97 ha	0.04	0			1.5
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	72 ha	0	No loss increase			?
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	25 ha	0	Reduction not quantified			?
<u>*Environmental optimization of crop production – lowland/river valleys*</u> 5. Catch crops: Increased area	0 ha	-	-			-
6. Additional 5% higher utilization of the N content of manure	10 ha	0.01	0			0.2
7. Reduced N fertilization norm (-10%)	0 ha	-	-			-
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	7 ha	0	No loss increase			?
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	3 ha	0	Reduction not quantified			?
<u>*Set-aside of farmland – upland*[1]</u> 10. Land for afforestation (broadleaf)	0 ha	-	-		+	-
11. Permanent grassland	0 ha	-	-		+	-
12. Restrictions on cultivation of land potentially subject to erosion	0 ha	-	-	+	+	-
<u>*Set-aside of farmland – lowland/river valleys*</u> 13. Land for re-establishment of wetlands	0 ha	-	-	+	++	-
14. Permanent grassland on farmland	0 ha	-	-	+	++	-
15. 5-m buffer zones alongside watercourses in lake catchments	0 ha	-	-	+	+	-
16. 10-m buffer zone around ponds in lake catchments	1 ha	0.05	0.0009	+	+	3.8
<u>*Groundwater protection measures*</u> 17. Set-aside: Permanent grassland kept unfertilized	0 ha	-	-		++	-
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	-
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	0 localities	-	-	++		-
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	0 ha 0 km	-	-	++	++	-
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	0 km	-	-	++		-
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	15 properties	0.08	0.033			112.0
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	0 WWTPs	-	-	-	-	-
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**0.17**	**0.034**			**117.5**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 4.12.

REMAINDER OF ODENSE RIVER BASIN

WFD – Programme of measures

Cost-effective dosing of measures to meet the environmental objectives for water bodies and natural terrestrial habitats in the remainder of Odense River Basin

Measure	Dose	Effects				
		Nitrogen Change in waterborne discharge to water bodies (tonnes/yr)	**Phosphorus** Change in waterborne discharge to water bodies (tonnes/yr)	**Reduced physical pressure**	**Natural habitats** Re-establish-ment and improve-ment of quality	**Economics** Economic cost (DKK 1,000 /yr)
Diffuse nutrient and pesticide loading – agriculture						
Environmental optimization of crop production – upland1 1. Catch crops: Increased area	11,482 ha	114.7				3,358.4
2. Additional 5% higher utilization of the N content of manure	40,923 ha	16.6	0			622.4
3. P fertilization regulation: Balance between applied and removed phosphorus at field level	30,296 ha	0	No loss increase			
4. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	10,626 ha	0	Reduction not quantified			
Environmental optimization of crop production – lowland/river valleys 5. Catch crops: Increased area	4,565 ha	120.6				1,361.9
6. Additional 5% higher utilization of the N content of manure	12,953 ha	13.6				197.0
7. Reduced N fertilization norm (-10%)	12,953 ha	31.73				909.3
8. P fertilization regulation: Balance between applied and removed phosphorus at field level	9,586.5 ha	0	No loss increase			
9. P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)	3,367.5 ha	0	Reduction not quantified			
Set-aside of farmland – upland1 10. Land for afforestation (broadleaf)	0 ha				+	
11. Permanent grassland	0 ha				+	
12. Restrictions on cultivation of land potentially subject to erosion	0 ha			+	+	
Set-aside of farmland – lowland/river valleys 13. Land for re-establishment of wetlands	3,071 ha	307.1	3.071	+	++	13,021.0
14. Permanent grassland on farmland	0 ha			+	++	
15. 5-m buffer zones alongside watercourses in lake catchments	0 ha			+	+	
16. 10-m buffer zone around ponds in lake catchments	0 ha			+	+	
Groundwater protection measures 17. Set-aside: Permanent grassland kept unfertilized	4,550 ha	43.68			++	14,678.3
18. Pesticide-free cultivation of arable land around water supply wells (300-m zone) (no pesticide leaching)	? ha	-	-		+	
Reduction of physical pressure on watercourses						
19. Removal of obstructions for fish migration	195 localities	-	-	++		2,140.5
20. Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands corresponding to measure 13)	2,000 ha 499.6 km	200	2	++	++	6,656.0 -5,881.0
21. Remeandering of watercourses, laying out of spawning gravel, stones, etc.	212.9 km	-	-	++		6,979.0
Reduction of pressure from point sources						
22. Sparsely built-up areas – improved wastewater treatment	1,259 properties	7.54	2.77			9,403.6
23. Wastewater treatment plants – improved wastewater treatment (UV and ozone treatment) • Disinfection and removal of hazardous substances	7 WWTPs	0	0	-	-	28,581.1
Special measures – terrestrial natural habitats						
24. New terrestrial natural habitats (Coastal meadows, mires/freshwater meadows and dry grasslands) • Carried out integrated with measures 11–18	Coastal meadows: xx ha Mires/meadows: xx ha Dry grasslands: xx ha	+	+	+	++	
25. Reduced ammonia emission from livestock holdings >35 LU[2] • 50% reduction – 840 tonne reduction in NH_x emission	xx properties (2003)	++			++	
26. Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	xx ha				++	
27. Nature management – Clearance	xx ha				++	
28. Improved hydrological conditions (Decommissioning of ditches/drains)	xx km	+	+	+	++	
COMBINED EFFECT (Nutrients) AND COST WFD		**855.53**	**7.932**			**82,027.6**

[1] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.
[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.

Annex 5.1. Municipal-level river basin management reference

Pursuant to the Environmental Objectives Act, municipal councils are required to draw up a municipal action plan and a municipality-related programme of measures specifying how river basin management plans and the associated programmes of measures will be implemented within the boundaries of the municipality as far as concerns the terrestrial and coastal areas of the river basin.

The Environmental Objectives Act only specifies requirements as to river basin management plans and municipal action plans, however. Thus it does not specify any guidelines regarding how programmes of measures are to be subdivided geographically in accordance with municipal boundaries.

Odense River Basin is spread across seven municipalities and encompasses a markedly different proportion of each municipality. Each of these municipalities is required to draw up a municipal action plan containing measures directed at Odense River Basin. It is therefore necessary to develop a municipal-level river basin management reference based on municipal-level calculations for the measures so as to enable each municipality to draw up an appropriate action plan.

By way of example, the calculations for a municipal-level river basin management reference for Faaborg-Midtfyn Municipality are shown below.

The calculations for Odense River Basin are also shown subdivided among the catchments of the 11 largest lakes and the remainder of Odense River Basin in Annex 4. Subdivision of the programme of measures at the municipal level within each of these 12 subcatchments is performed according to the following principles:

- The area-related measures aimed at reducing diffuse nutrient loading from agriculture are distributed equally within the municipality's farmland in lowland areas (river valleys), farmland in upland areas where groundwater protection is needed and the remaining upland areas.

- Measures pertaining to physical conditions in rivers, obstructions, stormwater discharges, sparsely built-up areas, contaminated sites, etc. are dosed according to specific conditions within the individual municipality.

Figure: Municipalities in Odense River Basin.

Annex 5.2.

Baseline 2015 – Faaborg-Midtfyn Municipality

Adopted but not yet fully implemented measures pursuant to the Regional Plan, municipal wastewater disposal plans, Action Plan on the Aquatic Environment III, trend in livestock production, etc.

	Initiated measures and assumptions[1]	Dose	Effects				
			Nitrogen Change in waterborne discharge to water bodies (kg/yr)	**Phosphorus** Change in waterborne discharge to water bodies (kg/yr)	**Reduced physical pressure**	**Terrestrial natural habitats** Re-establishment and improvement of quality	**Other**
Diffuse nutrient and pesticide loading – agriculture							
Action Plan on the Aquatic Environment III	Catch crops: Increased area	1,217 ha	17,078	0			
	5% higher utilization of the N content of manure	25,877 ha	10,410	0			
	EU agricultural reform (CAP) + improved utilization of the N content of fodder	25,877 ha	18,658	0			
	Structural development (reduction in area relative to 2003)	1,068 ha	14,590	0			
	Agri-environmental measures – buffer zones and wetlands	3 ha	243	3	+		
	Set-aside of land for afforestation (upland[2])	231 ha	2,463	23		+	
	Set-aside of land for wetlands (APAE II+III)	221 ha	47,901	221	+	+	
Reduction of pressure from point sources							
Sparsely built-up areas – improved wastewater treatment		1,670 properties	12,027	3,675			
Wastewater treatment plants – improved wastewater treatment through optimization of operation		6 WWTPs	90	18			
Stormwater outfalls – overflow lagoons at outfalls from combined sewerage systems		41 localities	148	185			
Stormwater outfalls – overflow lagoons at outfalls from separate sewerage systems in lake catchments		2 localities					
Contaminated sites – remediation		18 localities					Hazardous substances – reduced loss to the environment
COMBINED EFFECT			**124,568**	**4,125**			

[1] As regards livestock production the prognosis for the period 2005–15 is for a 20% increase in production (prognosis made by Danish Agriculture). It is assumed that requirements will be imposed to ensure that the increase in production does not lead to increased emissions/discharges or attenuate the effect of the measures adopted to reduce the pressure from existing production.
[2] Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

Annex 5.3.

Programme of measures (supplementary measures) – Faaborg-Midtfyn Municipality

Cost-effective measures to meet the environmental objectives for water bodies and natural terrestrial habitats in Odense River Basin

	Measure		Dose	Effects: Nitrogen – Change in waterborne discharge to water bodies (kg/yr)	Effects: Phosphorus – Change in waterborne discharge to water bodies (kg/yr)	Effects: Reduced physical pressure	Effects: Natural habitats – Re-establishment and improvement of quality	Effects: Other
Diffuse nutrient and pesticide loading – agriculture								
Environmental optimization of crop production	Catch crops: Increased area	Upland[1]	4,248 ha	42,440	0			
	Additional 5% higher utilization of the N content of manure		15,622 ha	6,322	0			
	P fertilization regulation: Balance between applied and removed phosphorus at field level		11,560 ha	0	No loss increase			
	P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)		4,062 ha	0	Reduction not quantified			
	Catch crops: Increased area	Lowland / river valleys	1,443 ha	37,385	0			
	Additional 5% higher utilization of the N content of manure		4,177 ha	4,386	0			
	Reduced N fertilization norm (-10%)		4,015 ha	9,838	0			
	P fertilization regulation: Balance between applied and removed phosphorus at field level		3,091 ha	0	No loss increase			
	P fertilization regulation: Reduced P fertilization of soil with a high P index (26% of all farmland)		1,086 ha	0	Reduction not quantified			
Set-aside of farmland	Land for afforestation (broadleaf)	Upland[1]	1,318 ha	13,526	132		+	
	Permanent grassland		148 ha	1,516	15		+	
	Restrictions on cultivation of potentially erosive land		244 ha	2,505	24	+	+	
	Land for re-establishment of wetlands	Lowland / river valleys	1,031 ha	103,082	1.031	+	++	
	Permanent grassland on farmland		456 ha	12,125	46	+	++	
	5-m buffer zones alongside rivers in lake catchments		16 ha	777	16	+	+	
	10-m buffer zone around ponds in lake catchments		7 ha	374	7	+	+	
G.water protect.	Set-aside: Permanent grassland kept unfertilized	Upland[1]	1,588 ha	15,240	32		++	
	Pesticide-free cultivation of farmland around water supply wells			-	-		+	No pesticide leaching
Reduction of physical pressure on rivers								
	Removal of obstructions for fish migration		68 localities	-	-	++		
	Cessation of watercourse maintenance combined with extensification of cultivation in river valleys (incl. re-establishment of wetlands)		652 ha 225 km	65,222	652	++	+	
	Remeandering of rivers, laying out of spawning gravel, stones, etc		64 km	-	-	++		
Reduction of pressure from point sources								
	Sparsely built-up areas – improved wastewater treatment		705 properties	4,396	1,550			
	Wastewater treatment plants - improved wastewater treatment (UV and ozone treatment		1 WWTP	0	0	-	-	Disinfection and removal of hazardous substances

Annex 5.3.

Special measures – terrestrial natural habitats						
New terrestrial natural habitats (coastal meadows, mires/freshwater meadows and dry grasslands)	C. meadows: x ha Mires/meadows: x ha Dry grasslands: x ha	+	+	+	++	Integrated with agri-environmental measures No. 11-19 cf. Table 6.1
Reduced ammonia emission from livestock holdings >35 LU[2]	x properties (2003)	+			++	840 tonne reduction in NH_x emission
Nature management – Grazing down, haymaking, etc. on present natural terrestrial habitats	x ha				++	
Nature management – Clearance	x ha				++	
Improved hydrological conditions (decommissioning of ditches/drains)	x km	+	+	+	++	
COMBINED EFFECT (Nutrients)		**319,134**	**3,505**			

Upland farmland is defined as farmland lying more than one metre above the normal high water level in the adjacent watercourses into which the runoff takes place.

[2] LU: Livestock Unit: 1 LU = the quantity of livestock producing 100 kg nitrogen per year in manure measured ex store, e.g.1 Jersey dairy cow, 35 slaughter pigs, etc.