1.5 Lakes

1.5.1 Location of the lakes

There are 2 620 lakes larger than 100 m² in Odense River Basin. Their combined area is 1 106 ha, corresponding to 1% of the whole basin. Their location is apparent from Figure 1.5.1, and their size distribution from Table 1.5.1.

The WFD does not specify any lower size limit for the lakes it encompasses. The typology "System A" in Annex II of the WFD suggests a lower size limit of 0.5 km², but the horizontal Guidance Document "Indentification of Water Bodies" stresses that the WDF applies to all surface waters. Member States can decide that also smaller water bodies are so important that they should be individually identified." In Denmark, all lakes larger than 100 m² are protected by the Protection of Nature Act and are individually identified. This protection is partly due to the fact that many small lakes were disappearing, and partly because the many small lakes are important natural elements in the very culturally influenced Danish landscape. For example, the small lakes and ponds together contain more species of macroinvertebrates such as worms, snails, mussels, crustaceans and insects than both the large lakes and watercourses (Fog & Wiberg-Larsen, 2002).

As a consequence, all lakes larger than 100 m² have been identified as discrete water bodies.

This emphasizes that the protection offered by the WFD applies to all surface waters. If the small lakes are not discretely identified, there is the risk that this important habitat type could only be improved to the extent necessary to achieve good status in the water bodies with which they are in direct or indirect contact (cf. Section 3.5 of the horizontal guidance "Identification of water bodies").

It is not practicable to investigate each of the more than 2 600 lakes, however. According to the horizontal guidance "Identification of water bodies", it is permissible to aggregate lakes in relation to monitoring, reporting and management. The lakes are grouped on the basis of lake type and catchment (assessed from GIS), and monitoring is carried out for a randomly selected subgroup of the lakes. This aggregation and selection has not yet been carried out.

1.5.2 Physical modification

Many lakes have been physically modified over the years as a result of lowering of the water level, filling in, damming, etc. A very large proportion of the typically small, shallow lakes have completely disappeared over the past 100 years or so. For example, the number of lakes in the Lake Arreskov catchment area has decreased by 76% from 276 around the year 1890 to 65 in 1992.

Many of the existing lakes in Odense River Basin have arisen as a result of human activity, e.g. peat mining, clay, marl or gravel quarrying, or as a result of dams etc. especially for operating mills. Of 66 investigated lakes in the basin, nearly half (45%) arose as a result of peat mining, and only 18 (27%) are natural (Table 1.5.2). Of the larger lakes (>5 ha), however, nearly all are natural.

Heavily modified water bodies

Millponds derived from damming watercourses are classified as heavily modified water bodies. Thereafter a decision has to be made whether to preserve the dam, for example for cultural historical reasons. If it is decided to eventually remove the dam and re-create the watercourse, the reach is thereafter classified in the river basin management plan as a watercourse and not as a heavily modified water body.

Size	Number	Total area (ha)	Investigated	
			Number	%
>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 1.5.1
Number and total area of lakes of various size categories in Odense River Basin.

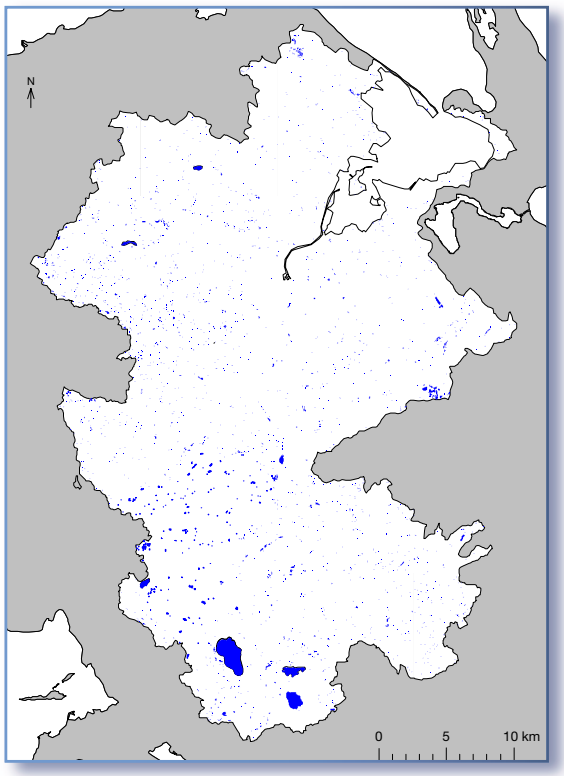

Figure 1.5.1
Location of the 2 620 lakes >100 m² in Odense River Basin.

Artificial water bodies

Lakes created through human activity in a location where there has not previously been a water body are classified as artificial water bodies. This particularly applies to peat mine, gravel quarry and marl/clay quarry lakes, duck ponds, and, to a certain extent, also to village ponds and fire reservoirs.

Unlike natural lakes, artificial and heavily modified lakes do not have to achieve good ecological status, but rather "good ecological potential". Correspondingly, reference conditions do not have to be established for these lakes, but rather a "maximum ecological potential".

Through the use of good ecological potential it is possible to impose just as stringent requirements regarding pressures, for example pollution. Moreover, good chemical status also has to be achieved. Thus relative to good ecological status, good ecological potential is only less stringent regarding the special physical conditions pertaining in connection with dams and the special physical nature of lakes originating from gravel quarries and peat mines.

The status of the water body thus has to be measured against the maximum ecological potential. This describes the closest approximation to the reference conditions in the natural ecosystem that can be achieved with the hydromorphological conditions pertaining. With the majority of peat mine and gravel quarry lakes, which only differ slightly from natural lakes (e.g. very steep banks), maximum ecological potential will correspond to the reference conditions.

Classification as artificial water bodies thus does not entail the imposition of less stringent requirements concerning, for example, pollution of the water body than if it had been natural in origin.

A special group consists of the lakes that have arisen in connection with Action Plan on the Aquatic Environment II. These have been formed with the main aim of enhancing retention and denitrification of the nitrogen leaching from agricultural land. Pursuant to the Danish EPA's current guidelines, quality objectives are not to be set for these lakes, and consideration for their ecological status cannot in itself justify measures in the catchment to reduce the pollution.

Table 1.5.2
Origin of 66 investigated lakes in Odense River Basin.

Origin	No. of lakes	%
Natural	18	27
Peat mine	30	45
Marl/clay quarry	7	11
Gravel quarry	4	6
Village pond, etc.	3	5
Dam/millpond	4	6
Total	66	100

Modification of natural lakes

The natural lakes are often also modified as a result of changes in water level. The changes are usually so slight, though, that the water body does not change type. This applies, for example, to Lake Arreskov, where the water level has been lowered in several steps such that large parts of the former lake surface are now freshwater meadows and mires. Despite the change, the lake can fulfil the criteria for good ecological status and hence does not need to be classified as a heavily modified water body. In Lake Langesø, among others, the water level has been raised relative to the natural level by a dam in the outlet. In this case too, the assessment is that this change in hydromorphology is so slight that it does not hinder achievement of good ecological status.

Characterization of the lakes

The lakes have to be characterized as either natural lakes, artificial water bodies or heavily modified water bodies. Based on the above remarks, Figure 1.5.2 shows the location and category of

the 66 investigated lakes. The lakes are shown subdivided by origin in Table 1.5.2. Of these, 18 are characterized as natural, 44 as artificial water bodies (peat mine and marl, clay and gravel quarry lakes, village ponds, fire reservoirs, etc.) and 4 as heavily modified water bodies (dams and millponds).

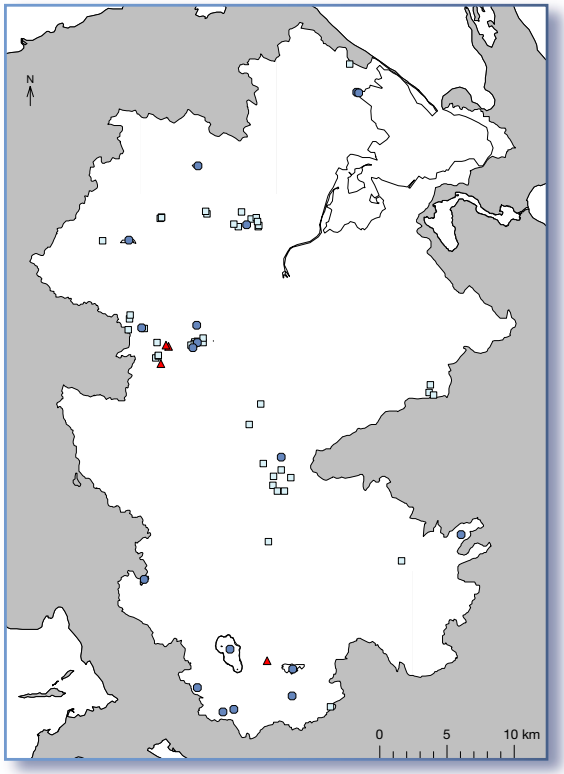

Figure 1.5.2
Category and location of 66 investigated lakes in Odense River Basin.

1.5.3 Typology

According to the WFD, Odense River Basin lies in ecoregion 14: Central plains. Differentiation of lake types can be done using the typology "System A" (altitude, mean depth, surface area and geology) or "System B" (obligatory and optional physico-chemical factors), cf. Annex II of the WFD.

For typology of lakes in Denmark it has been decided to use "System B", with lake type being determined from alkalinity, colour, salinity and mean depth (Table 1.5.3), cf. National Environmental Research Institute (in prep.).

This potentially gives 16 different lake types. In reality, though, only 11 of these exist in Denmark. The lake types refer mainly to lakes larger than 5 ha. It appears to be inappropriate, though, that lake size cannot be taken more into account. In very small lakes (devoid of fish), the biological conditions are very different from those in large lakes. In addition, it should also be possible to differentiate out lakes with high salinity.

This system should therefore be extended so as to also take into account lake size, and a special class should be introduced for lakes with high salinity (Table 1.5.4). It should thus be possible to differentiate between very small lakes (<0.1 ha), small lakes (0.1–1.0 ha) and lakes larger than 1 ha. In addition, consideration should be given to introducing a class for lakes with salinity exceeding 12‰ since biological conditions change dramatically with increasing salinity. For example, mussels become more widespread, and the zooplankton shifts at a salinity exceeding approx. 10–12‰. Unfortunately, little is presently known about the distribution of this type of lake.

This potentially gives 72 different types of lake. In practice, many of the possible combinations will not exist, and as is apparent from Table 1.5.3c, no more than 17 types exist in Odense River Basin.

Due to the lack of knowledge it will be difficult to establish reference conditions for many of the lake types. For this reason, the National Environmental Research Institute and the Danish Forest and Nature Agency are not presently prepared to propose more than the original 16

Parameter	Low	High
Alkalinity	<0.2 meq/l	≥0.2 meq/l.
Colour	<60 mg Pt/l	≥60 mg Pt/l
Salinity	<0.5‰	≥0.5‰
Mean depth	≤3.0 m	>3.0 m

Table 1.5.3
Typology of lakes >1 ha. After National Environmental Research Institute (in prep.).

Parameter	Low	Medium	High
Alkalinity	<0.2 meq/l		≥0.2 meq/l
Colour	<60 mg Pt/l		≥60 mg Pt/l
Salinity	<0.5‰	≥0.5‰ <12‰	≥12‰
Mean depth	≤3.0 m		>3.0 m
Area	<0.1 ha (≥0.001 ha)	≥0.1 ha <1.0 ha	>1 ha

Table 1.5.4
Alternative typology of lakes in Odense River Basin.

Table 1.5.5 Lake types in Odense River Basin according to the typology given in Table 1.5.4.

Type No.	Area	Alkalinity	Colour	Salinity	Depth	No. of lakes	Examples	
1	Small	Low	High	Low	Low	Few/none	Small brownwater lakes/ponds	Total of 1 577 lakes
2	Small	High	Low	Low	Low	Ca. 1 500	Most of the small freshwater lakes/ponds	
3	Small	High	Low	Medium	Low	Few/none	Freshwater-influenced coastal lagoons	
4	Small	High	Low	High	Low	Many	Coastal lagoons	
5	Medium	Low	High	Low	Low	Few/none	Small brownwater lakes	Total of 954 lakes
6	Medium	High	Low	Low	Low	Ca. 900	Most of the small freshwater lakes	
7	Medium	High	Low	Low	Deep	Some	Gravel quarrry lakes	
8	Medium	High	Low	Medium	Low	Few/none	Freshwater-influenced coastal lagoons	
9	Medium	High	Low	Medium	Deep	Few/none	Quarry lakes influenced by salt water	
10	Medium	High	Low	High	Low	Some	Coastal lagoons	
11	High	Low	High	Low	Low	1	Lake Sortesø	Total of 98 lakes
12	High	High	Low	Low	Low	Ca. 90	Most of the freshwater lakes	
13	High	High	Low	Low	Deep	>1	Lake Søbo, gravel quarry lakes	
14	High	High	Low	Medium	Low	Few/none	Freshwater-influenced coastal lagoons	
15	High	High	Low	Medium	Deep	Few/none	Quarry lakes influenced by salt water	
16	High	High	Low	High	Low	Some	Coastal lagoons	
17	High	High	Low	High	Deep	Few/none	Quarry lakes influenced by salt water	

Table 1.5.6 Proposed reference values for three lake types (>1 ha). Summer mean values. Depth refers to mean depth. After National Environmental Research Institute (in prep.).

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	0.08
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

types. The future monitoring work should aim to help improve knowledge of a number of the less well-known lake types, especially the small lakes, including small coastal lagoons.

1.5.4 Reference conditions

According to the WFD, the undisturbed ecological status – termed the reference conditions – is to serve as the basis for the ecological classification. Establishment of the reference conditions is therefore important, and there are several methods for doing this: 1) Current status in undisturbed Danish or foreign lakes, 2) Historical data 3) Modelling including palaeolimnological studies or 4) expert judgement.

None of the lakes in Fyn County can be said to hold reference conditions as they are all more or less affected by enhanced nutrient loading.

Palaeolimnological studies in Danish lakes show that the best proposal for reference conditions from the temporal point of view is the period around 1850–1900 (National Environmental Research Institute, in prep.).

Palaeolimnological studies have been undertaken in a few lakes in Odense River Basin. The results are summarized below. The phosphorus content back in time has been calculated from the composition of the diatoms in the sediment.

The concentrations are therefore subject to some degree of uncertainty, although the method is generally considered to be reliable.

Lake Dallund

The lake is described on the basis of an approx. 11 m drill core covering approx. 7 000 years. The results of the biological and physico-chemical measurements indicate that the lake was in a stable state up to the end of the Bronze Age (around 750 BC). The phosphorus concentration was around 0.020 mg/l. At this point changes took place due to increased agriculture. Greater changes took place in the Middle Ages after the introduction of the wheel plough and forest clearance, with a resultant marked increase in nutrient input. In that period, the phosphorus concentration reached as high as 0.175 mg/l. After a minor fall in phosphorus concentration in the 18th Century, the impact of human activity increased markedly again up to the beginning of the 1990s. After the cessation of wastewater discharge into the lake and restoration in the form of biomanipulation, the phosphorus concentration has again fallen to 0.059 mg/l in 2000 (average for the summer period).

Lake Langesø

The phosphorus concentration in Lake Langesø was already high in 1850 (0.135 mg/l) and increased considerably until around 1900 (to approx. 0.180 mg/l) and again after 1950 (to approx. 0.220 mg/l). The eutrophication that took place at the end of the 19th Century is probably attributable to a manor located near the lake. New investigations of a deeper drill core show that the phosphorus content was also high before 1850. The lake is apparently naturally eutrophic, probably as a result of the inflow of phosphorus-rich water from naturally phosphorus-rich soil layers. In 2002, the phosphorus concentration was 0.172 mg/l.

Lake Nørresø

Investigations of plant remains have shown that a well-developed submerged macrophyte vegetation formed at the end of the 18th Century, probably after lowering of the water level. The phosphorus concentration was approx. 0.030 mg/l around 1850 and increased to around 0.060 mg/l up to 1900. Around 1930, and after 1950, the concentration increased markedly, peaking at 0.120 mg/l around 1970. In 2002, the phosphorus concentration was 0.073 mg/l.

Lake Søby

An investigation of algal pigment residues in the lake sediment indicates that the composition of the algal community was relatively stable from the end of the 19th Century and up to around 1940, where after a marked increase in eutrophication took place over the period 1950–1977. The phosphorus concentration has not been reconstructed.

Establishment of reference conditions

The data material for establishing the reference conditions for the various lake types is rather weak. In addition, each lake has its own history, as related above. Based on data for the cleanest Danish lakes the National Environmental Research Institute has proposed reference values for water chemistry parameters for the three most common types of lake (Table 1.5.4). As is apparent from Table 1.5.5, by far the majority of the lakes in Odense River Basin belong to the alkaline, shallow type, with only a few lakes belonging to the other two types. None of the lakes are expected to have reference conditions according to these criteria.

Objective	No. of lakes	No. of lakes meeting objective	Lake name	Preliminary future objective
A1	6	1	Arreskov, Brændegård, Sortesø, Store Øresø, Nørresø, Fjordmarken	High ecological status
B	6	0	Søbo, Langesø, Nr. Søby, Dallund, Fjellerup, Brahetrolleborg Slotssø	Good ecological status
No specific objective set, but generally status should meet objective B	2 608	?		Good/high ecological status

Table 1.5.7 Current objectives and preliminary future objectives for lakes in Odense River Basin.

Phosphorus content (mg/l)	High	Good	Moderate	Poor	Bad
Shallow, alkaline	0–0.025	0.025–0.050	0.050–0.100	0.100–0.200	>0.200
Deep, alkaline	0–0.0125	0.0125–0.0250	0.025–0.050	0.050–0.100	>0.100

Table 1.5.8 Proposed classification in ecological status classes based on phosphorus content (summer mean). After National Environmental Research Institute (in prep.).

In order to be able to establish reference conditions for the other lake types, further data and possibly also expert judgements are needed.

1.5.5 Provisional establishment of objectives

Current objectives

Fyn County's Regional Plan operates with two quality objectives for the lakes in Odense River Basin: A1 – reference area for scientific studies, and B – fish waters for angling and fishery. Both objectives entail that the lakes have to have a natural and divers flora and fauna that may only be slightly affected by pollution. The system of quality objectives also encompasses an eased objective – C, but this is not employed in Fyn County. In lakes with quality objective A1, the flora and fauna must be accorded special protection. Lakes for which a specific quality objective has not been set are encompassed by the general requirement to meet quality objective B. Six lakes in Odense River Basin have the specific quality objective A1, and six have quality objective B (Table 1.5.7) All the other lakes larger than 100 m^2 are encompassed by the general requirement to meet quality objective B.

No specific requirements have been established for the lakes for which a quality objective has been set, but they are subject to a number of general requirements concerning the input of polluting discharges. For example, wastewater discharges should as far as possible be avoided.

At present, only 1 of the lakes for which a specific quality objective has been set, Lake Øresø, meets its objective.

Lake Arreskov. *Photo: Kjeld Sandby Hansen, Fyn County*

WFD objectives

The WFD operates with five classes of ecological status: High, good, moderate, poor and bad. With high ecological status, no or little deviation is permitted from undisturbed status (reference conditions). With good ecological status, slight deviation is permitted. With moderate ecological status, moderate deviation from reference conditions is permitted. The aim is that all surface water bodies should achieve good status no later than 2015. The National Environmental Research Institute (in prep.) has proposed criteria for the individual ecological classes for the most common lake types found in Denmark. The proposal encompasses both water chemistry and biological parameters. One of the fundamental parameters is phosphorus content. Even though this does not in itself comprise a classification element under the WFD, phosphorus availability determines the status of the majority of lakes. The proposed classes are shown in Table 1.5.8.

The current basic objective, B, requires a natural and diverse flora and fauna. This is fundamentally similar to the WFD's good ecological status, which has to be achieved by all lakes by 2015. Pursuant to the WFD, the status of the lakes may not deteriorate, i.e. lakes that currently have high ecological status must also preserve this high ecological status in future. In a few gravel quarry lakes the phosphorus concentration is less than 0.025 mg/l, and there is thus the potential to achieve high ecological status. In contrast, by far the majority of natural lakes are assessed as having moderate to poor status.

When establishing the future objective it is reasonable that lakes currently designated as "reference areas for scientific studies", quality objective A, should be assigned the environmental objective "high ecological status" pursuant to the WFD. However, this requires closer assessment of every individual lake, which will be carried out in connection with preparation of the first river basin management plan.

A number of the lakes are also encompassed by international protection, EC Habitat sites and EC Bird protection sites (see Section 2). Among others, this applies to Lake Arreskov, Lake Brændegaard, Lake Nørresø, Lake Sortesø, Lake Øresø and Lake Fjordmarken. In these areas, "favourable conservation status" has to be achieved for the species and habitat types for which the areas have been designated. In the case of the lakes, this typically entails certain species of aquatic plants and birds. The environmental objectives established pursuant to the WFD shall also help ensure that favourable conservation status can be achieved for these species.