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Morphometry of 150 Danish Lakes with some Considerations on Cartometry

Thorkild Høy

Høy, Thorkild: Morphometry of 150 Danish Lakes with some Considerations on Cartometry. Geografisk Tidsskrift 88:44-54. Copenhagen, 1988.

An overview of the charting of Danish lakes carried out by the author since 1957. Some results are given in a table summarizing the most important morphometric data for 150 Danish lakes. Further considerations are given on cartometry, dependability of figures, especially area figures, and accuracies. Finally a case story is told about the lake, Esrum Sø.

Keywords: *Lakes, Elements of charting, Cartometry, Lake morphometry, Esrum Sø.*

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Definition of lakes.

It is most common to define a lake as a body of water in hollows in the terrain. If this definition is accepted, lagoons, and possibly also reservoirs are left out. Nonetheless most handbooks e.g. Hutchinson (1975) also deal with what is termed "maritime coastal lakes". When the aim is to prepare a list of lakes inside a country (Denmark), this problem has to be solved. A broad definition is chosen which takes in lagoons and reservoirs and other kinds of artificial lakes. As lagoon lakes are considered those, which are not in open connection with the sea outside, be the hindrance a high water sluice, a sluice combined with pumps, locks, or a more or less permeable bar. This type of lakes will show all grades of salinity, sometimes changing rather rapidly, as most are subject to influx of sea water at stormy high water. Their water levels will, in most cases, oscillate around zero. Sometimes the sluices are rather derelict, leaving room for doubt whether this particular body of water conforms to the definition, v. what is said later about land-locked waters. A few lakes of that type are to be found in the main table: Selsø Sø, Nakskov Indrefjord, Gråsten Slotssø, and Kielstrup Sø. If lagoons are left out one runs into difficulties as will be seen later, when the lake list in "Danmarks Areal" 1968 (Areas of Denmark) is discussed.

If, after the definition chosen, a list of Danish lakes after size is made up, a question that might interest the general public, the largest will be Ringkøbing Fjord, and the next Nissum Fjord. Then will follow Arre Sø which is the lake most often deemed the largest. In fact Arre Sø also originated as a lagoon.

Next there is a type of water bodies which here shall be termed indvande (landlocked waters). These are bodies of water completely surrounded by land but in open connection with the sea. The mouths will always be narrow, sometimes riverlike, and they will very often be spanned by a bridge, a condition which often goes back to the Middle Ages. There is quite a lot of them, e.g. Stege Nor, Skelskør Nor, Kerteminde Fjord-Kertinge Nor, Hejls Nor, and some more. The definition rules out such waters as Basnæs Nor-Holsteinborg Nor, Karrebæk Fjord-Dybsø Fjord, Odense Fjord, Lindelse Nor, and others. It appears that the designation *Nor,* which is normally attributed to pretty landlocked waters, is not to be relied upon when making the selection. None of the waters classified as indvande are to be found in table 4.

Bodies of water larger than 10 hectares plus a number of smaller ones which by chance have been charted, altogether 361, are listed in a carto-bibliography compiled by the present writer: Danske Søer og Indvande. En oversigt over ældre og nyere kortlægning indtil marts 1987 (Danish Lakes and Landlocked Waters. A bibliography of charts up to March 1987). No distinction is made between the two groups. Halkjær Bredning is not listed (see below) as is not Hjarbæk Fjord because of its uncertain fate. Klovvig or Nørskov Vig on the island Venø might have been listed, a couple of others not.

Lake areas. In the important and indispensable collection of statistical tables already mentioned, "Danmarks Areal", there is a list of lakes (table IV) with their areas. The list contains 1008 lakes and ponds which carried a name on the map sheets in 1:20,000 used as base maps for the planimetration. This list meant an improvement in comparison with the 1906 publication with the same title which was more limited on that point. The figure 1008 could be added to by searching cadastral plans, plans from the Forest Administration, county and local administration reports etc. The list shows, undeniably, a considerable inconsistency with respect to which water bodies are incorporated and which not. Sebber Sund, or more correct Halkjær Bredning (a name, which appeared on the maps fairly recently) is to be found, an inlet the writer has hesitated to group under indvande (landlocked waters) although a dam and a bridge cross the mouth of it. Lately one more dam and bridge has been constructed, rendering its indvande-status more plausible, but it is impossible to count it as a lake. Hejls Nor or Hejlsminde Nor, not barred from the Lillebælt, is indicated, but not any other of the same kind: Korsør Nor, Skelskør Nor, Stege Nor etc. Hovvig near to Nykøbing Sjælland, Kilen at Struer, Ketting Nor on Als, Vejlen or Ulvedybet, Lønnerup Fjord, Østerild Fjord, all barred from the sea, are on the list, but not Nakskov Indrefjord which is practically fresh. A long row of smaller lagoons are listed, but not the two largest, Ringkøbing Fjord and Nissum Fjord.

As it has already been hinted, a grouping taking advice from the names of the water bodies, will not have much correlation with geographical realities. Quite a lot of lagoons carry the appellation: *Fjord* (Fiord) or *Nor* (Cove) while others situated in the same manner carry *Sø* (Lake).

Names of lakes. This leads on the next problem to be solved, that of proper or correct names. Naturally the maps issued by the Ordnance Survey of Denmark (Geodætisk Institut) will be the main source. There are in Denmark, however, quite a lot of Nørre- and Søndersøer (but remarkably few Øster- and Vestersøer), Møllesøer, Slotssøer, Langsøer, Sortesøer, and Klaresøer, Avnsøer, and Lillesøer. These names are quite sufficient locally, but when a nationwide list is to be compiled, they fall short. County water administrations often use a localizing element in the names they use, and if this is the case, such ones are adopted. Some examples may clarify the issue: *Ulstrup* Langsø, *Løvenholm* Langsø, *Rugård* Nørresø, in the Southern, Northern, and Eastern Djursland respectively. *Grærup* Langsø (in fact not a langsø, i.e. a glacial tunnel lake) in County Ribe. *Gråsten* Slotssø, and *Koldinghus* Slotssø in Southern Jutland, *Borbjerg* Møllesø, and *Gjorslev* Møllesø, situated in Harsyssel and on Stevns respectively, and many more. Some of these localizing elements have been in use for a long time, e.g. *Silkeborg* Langsø, *Salten* Langsø, *Viborg* Nørre- and Søndersø, *Maribo* Nørre- and Søndersø. Sometimes it is difficult or impossible to find an obvious and acceptable prename which, for instance, is the case with Langesø on Fyn (Funen). The Mansion standing on its shores carry unfortunately exactly the same name. There are several Søgård and Søby Lakes with the same problem. To reduce identification problems the lakes have been grouped after the geographical parts Denmark fall into: The main island groups separately, and Jutland. In some cases where it has been deemed advisable some localizing element has been put after the name in brackets.

There is a lake on Sjælland (Zealand) which is called Haraldsted Sø, and just as often Langesø, sometimes both names will be on the map, one of them in brackets. That particular lake has been placed in the table under the name Haraldsted Langesø. On the oldest (it is dated 1754) geometrically correct plan covering the Estate of Skjoldenæsholm to which the lake thence belonged, it carries precisely that name: Haraldsted Langesø.

Importance of sounding dates. The aforementioned problems settled, we turn our attention to the columns of figures in the main table. The first one gives the year or years when the sounding took place, an information more important than the year of issue of the chart, in most cases they are identical, however. It is further interesting to note the differing attitude against various groups of figures. It is generally accepted that years shall be correct. Historians will spare no pains to ensure correctness of dates. When it comes to areas and the like the attitude is much more relaxed, it seems. Maybe because it can be, and often is, a much more complex affair to accomplish congruence, as shall be demonstrated.

Planimetration. Already at an early stage of these studies an interest was taken in how figures for e.g. areas were produced, and what confidence could be put into them. The first editor of this journal Ed. Erslev, had some considerations on this subject in its fourth volume (1880): "Some Considerations on Figures in Geography". His wisdom, however, does not seem to have left an eternal mark as numbers are often given with many more significant figures or more decimal places, than the methods used to produce them leave room for. Further figures often seem to be accepted too readily. The following quotation from Haruko Kishimoto (1968) supports this: "In the course of research, we witness not infrequently what might be called an implicit belief in the accuracy of numerical data on the part of the investigator which may not always be fully justified". The discipline which delivers data on the basis of maps, plans, or charts is, as most readers will know, called cartometry. Derek H. Maling (1977) has pointed out that the methods used often are inferior and unsystematic, and carries on "how much credence can be put on such results? This ought to be important to the scientist. For example, he should be aware of the kind of precision which is likely to be obtained and the kind of errors arising from making only one or two measurements on one map".

Turning to Denmark the picture is much the same. The writer knows of only one printed (outside textbooks) important work of cartometrical substance, viz. Lund-Larssen's introduction to Danmarks Areal 1906 "Fremgangsmaaden ved den planimetriske Arealbestemmelse" (Determination of Areas by Planimeters). The next general planimetration of Denmark took place 1953-59 on planetable sheets in 1:20,000 which had a very variable status of revision. Some of them had their last revision as far back as 1900. The results were published by Danmarks Statistik in Statistiske Meddelelser 1968, 4. In the short preface some information is given about the maps used and on the revision of administrative boundaries, but nothing about how the figures were produced and what credence can be placed on them.

Turning our attention to the main table again, the next column contains *the scale of the chart* on which the cartometric measurements are made. The charts may have been issued in more than one scale. The scale is an important factor for the accuracy of the determination of areas and volumes. It can be mentioned that the standard error with respect to the determination of area is four times lower in the scale 1:5,000 than in 1:20,000 expressed in units of area.

Water level. The level of water from which the depths are determined is to be found in the following column. A small number of the earliest chartings lack this important figure. They are all small and isolated lakes. Without this information, comparison of one specific chart with a later one will be hampered. After maybe 50 years it might be of interest to determine the amount of sedimentation which has taken place in those years. Possibly it may be enough to repeat some of the echo-sounded profiles. It can be done by retrieving the working plans showing the tracks, but still knowledge of the water levels are imperative. It shall be noted in this context, that there are two different Datums to consider: System GM = GradMaalingen (Trigonometrical Survey), an earlier trigonometrical institute responsible for 1. and 2. order determinations, which is the older system, and still in use – so far – in Jutland, and System GI = Geodætisk Institut (Geodetic Institute) which is then the newer of the two and in use in insular Denmark outside Bornholm, an island which has its own Datum. System GI is, at the point of origin, 54 mm lower than System GM according to a study by O. Simonsen (1941). As to this general fact no further comments will be given in relation to table 4.

Coastline. In the older topographical maps from the Ordnance Survey of Denmark there will be found a figure in the middle of the lakes, indicating the height of the water level, mostly the level found, be it high or low water, when the plane-tabling happened to take place. These figures were believed by many map-users (also some who ought to have known better) to be "the depth" of the lake. For that reason, but also for some other reasons, this practice was abandoned. For quite a lot of lakes there are by-laws or agreements governing the water level, especially where the water has been used for generating power. Mostly, in such cases there will be summer and winter water marks, but with the diminishing use of water power in Denmark the level will very often not be kept up to the legal markers. Ideally the depths on the charts had to be related to a yearly mean, derived from a long period of readings or recordings. It has been possible to achieve this only in a few cases. It is evident that water level, area, volume of water and depth are interdependent which among other things means that the coastline at the time of the sounding should be the coastline drawn on the map or adjustments made to effect this. It is a state of affair not easily brought about. At the chartings made by the present writer before 1981 aerial photos generously were made available by Geodætisk Institut or procured from the archives of photogrammetric firms. The disadvantage of these pictures were, apart from the fact that they often had to undergo considerable enlargement, that nearly all of them were taken in the spring before leafing, when the water level is generally high and the edges of the reed swamp not very distinct. From 1981 and onwards special photographic missions were undertaken in summer at low level, the resulting photo scales being between ca. 1:5,000 and ca. 1:8,000. That kind of black and white photos has ever since served at the definition of the coastline and of the outer edges of the reed swamps, the latter being dominant features of Danish lakes, especially after eutrophication has set in. For control of scale an array of various sources was used: modern cadastral plans or large scale plans produced for community planning etc., photogrammetric manuscript maps from the Ordnance Survey (Geodætisk Institut) where they are available. The Southeastern part of Jutland and Sønderjylland (North Schleswig) are not covered as yet. In the last mentioned part of the country cadastral plans were always used. For some of the older charts, enlarged topographical maps (less satisfactory) were brought into use. These charts will be revised when time and money allow for it. For some of the oldest charts (from 1958 and 1959) sounded from ice, the coastline could be pinpointed along with the sounding work.

Where reed swamps are a prominent feature of a lake there will often be a very gradual transition to bog mires or quag mires and further on to real terra firma, and in such cases the definition of the coastline will be difficult. In most cases a part of the reed swamp will be limnic, and a part of the water area. The coast line looked for will then be somewhere inside the reed swamps. Large scale aerial photos compared with conditions in the field are of great help, but a certain amount of subjectivity will be unavoidable. For the 150 lakes in the table, however, there exists the rather unique situation that the same person has made the evaluation, and a somewhat higher degree of consistency should be expected. It is then evident, that the definition of the coastline is extremely important for the size of the lake, the area, somewhat less for the volume. Two independent chartings will in many cases generate differences in area which can be much larger than the differences emanating from the cartometric part of it.

Danish lakes with sharply defined coastlines are not very common. Peblingesø and Sct. Jørgens Sø in Copenhagen are examples, but rather special. Hammer Sø on Bornholm and Esrum Sø in Northern Sjælland have fairly distinct coastlines as have a number of lakes in Jutland, where in some parts cultural influence is less. Gundsømagle Sø, for instance, is at the other extreme. It is so indistinct with respect to shoreline, that any area figure will be disputable.

If comparisons between the areas given in the main table here and table IV in "Danmarks Areal" 1968 are made, considerable differences can be detected. One of the reasons already mentioned is, that a number of the 1:20,000 sheets were rather obsolete. Furthermore, the writer finds it undeniable that the delineation of the lakes was treated somewhat unfairly. Minor changes in coastline caused by minor regulations of water level, which took place in Denmark in abundance up to two or three decades ago, were registered slowly. A part of the sheets was based on reduced cadastral plans and put together like a jigsaw puzzle. As these cadastral plans differed much in age and had no common origin (they were "island maps") there would be discrepancies which very often were evened out

	"Danmarks Areal" ha	Forest Administr. ha	Th. Høy ha
Bondedammen	9.2	13.55	13.1
Bøgeholm Sø	18.6	29.91	32.2
Klare Sø	1.8	3.35	3.4
Sortesø	2.6	3.17	3.5

Table 1. Discrepancy of areas of 4 lakes in the Elsinore (Helsingør) Region.

at the expense of the lakes, as lakes would often border cadastral units. Because of this dislocations can sometimes be noticed when looking at lake sides opposing each other. Also quite a variation in quality can be noticed, which must be ascribed to the person who has actually worked in the field, even if some control and supervision took place. This is applicable to the cadastral plans and the topographical maps alike. When working with Gurre Sø in the Elsinore (Helsingør) Region (Thorkild Høy, 1965) the writer met with considerable discrepancies between the aerial photos and the map (enlarged from a 1:20,000 sheet) and the two small lakes, Sortesø and Klaresø, were not of proper size (table 1).

The main part of "Danmarks Areal" 1968, however, deals with administrative areas, and these are much less or not at all influenced by the deficiencies pointed at. The discrepancies with respect to the lakes have diminished dramatically with the new topographical maps based on photogrammetry. By now (1987) more than half of Denmark is covered.

Cartometry. As to the cartometric operations the planimeter is by far the most important instrument. On a part of the older charts a Coradi Rolling Disc Planimeter with a conventional read-out was put into action. The greatest part of the cartometry, however, has been made with a Lasico 1260D Rolling Disc Planimeter with digital readout. For both instruments the standard error of the mean of 2-4 tracings can easily be kept below 0.2 %. This figure is based on tests and on a long experience. Looking at the error on the planimetering solely, it becomes meaningless to give areas above 4-500 hectares with decimals. All sources of error taken into account, the shrinkage of the paper for instance, not to speak of the errors built into the chart might be dubious at 100 ha already. As a main rule areas between 100 and 200 ha are not given better than in half a hectare. Areas larger than about 200 ha are given without decimals. In the lake areas the adjoining bog mires are not taken into account but are given separately (not in the table). Islands, on the other hand, are included as a lake is looked at as a geographical entity. The areas of the islands, if any, are given in a separate column, making it rather easy to deduct from the total to get the water area.

Volumes. As it is known the calculations of volumes of water are brought about by planimetering the areas of the various depth contours. In the final result the accidental errors in these measurements will accumulate, somewhat moderated, according to the propagation of errors, moderated while the areas diminish downwards and thereby carry less weight. By the deeper lakes (20 meters and more) it should be reasonable to reckon with an error of about 1 % from this source. At the calculations of volumes the simple formula h/2 (A1+A2), where A1 and A2 are two consecutive contour areas and h the equidistance, which is 1 meter for a large part of the charts, has been used. This procedure is followed instead of applying Simpsons Formula or other similar formulas, as the part volumes are of interest if the construction of hypsographs are aimed at.

An intricate question is how near such calculated volumes come to the "true" volumes. The formula is exact only when all profiles in the basin are parables, which naturally is never the case in reality. It can be gathered, however, that the more regular the lake basin is, the closer is the result to the "true" figure. A way to go would be to reduce the distance between the sounded profiles, which by the charts treated here normally are, as a mean, 50 meters, and increase the number of the depth contours. An undertaking of that kind will for economical and practical reasons be difficult to embark upon.

To gain some knowledge in this direction the author has left out every second contour and re-calculated the volumes of the lakes Tystrup Sø and Bavelse Sø. Lake Tystrup Sø by itself offers two very distinct basins. For the same lakes calculations have also been made on a base map reduced to a scale of 1:33,600 to gain some idea of the effect of generalization (table 2).

	1:5000		1:33,600
	1 m cont.	every second cont.	2 m cont.
Tystrup Sø			
West basin	44,800	44,878	
East basin	20,902	20,947	
	65,702	65,825	65,515
Bavelse Sø	4,100	4,043	4,035

Table 2. Volume (in 1000 m^3) calculated on a chart in 1:5000 and on a chart in 1:33,600.

For Tystrup Sø the differences are in all cases within 0,3 %. That particular lake has a very uneven bottom topography, and a considerable depth, and accordingly many depth contours. The accidental errors can then have tended to go against each other. Bavelse Sø is much more even and the depth is moderate (maximum 8.8 m).

The results seem to conform to the idea, that where the basic material is large scale charts, constructed on the basis of a close net of profile lines, and the cartographical and cartometric operations in all parts made by experienced operators, the difference from the unknown "true" figure can safely be assumed to lay within 2 %.

	County Administr.	Th. Høy	Diff. %
Bue Sø	247	244	1.2
Kimmerslev Sø	1,268	1,265	0.2
Kornerup Sø	230	225	2.2
St.Kattinge Sø	1,966	1,900	3.4
Svogerslev Sø	381	380	0.3
Bryrup Langsø	1,730	1,745	0.9
Fussing Sø	27,300	27,000	1.1
Karl Sø	174	177	1.7
Kvind Sø	274	272	0.7
Kulsø	308	313	1.6
Stilling-Solbjerg Sø	29,420	29,700	1.0
Thorsø	2,910	2,930	1.1

Table 3. Determinations of volume (in 1000 m^3).

To get some idea about the effect also of the personal equation it might be of interest to look at what differences will occur, when comparing completely independent determinations, i.e. such made by other persons with other instruments, but on the same charts (table 3).

The differences are by no means alarming, but they lay stress on what is said about a certain amount of rounding off. Size and complexity of the lake basins do not seem to have any marked effect on the differences.

For the time being no more will be said about the problems of lake volume determination, although it is obvious that they have only been touched upon. Lars Håkanson (1977a) has some more sophisticated ideas about this subject.

Depths. Turning to the table 4 again: The mean depth is calculated quite simply from water area and volume.

The maximum depths also appear in the charts, but it must be added, that the bottoms charted are the surfaces of the bottom sediments which, in most cases, can be determined with an uncertainty of 1-2 decimeters.

All earlier lake charts were made by the lead and line method and in most cases they show too great depths as a – variable – amount of sediment went with the water depths.

Evidently it is possible to deduct many more morphometric parameters v. e.g. Lars Håkanson et al (1978), and Lars Håkanson (1981).

Lengths. In this connection it is reasonable to restrict oneself to comment upon some of them: the determination of the length of the shoreline leads to the general problem of determination of lengths of extremely winding

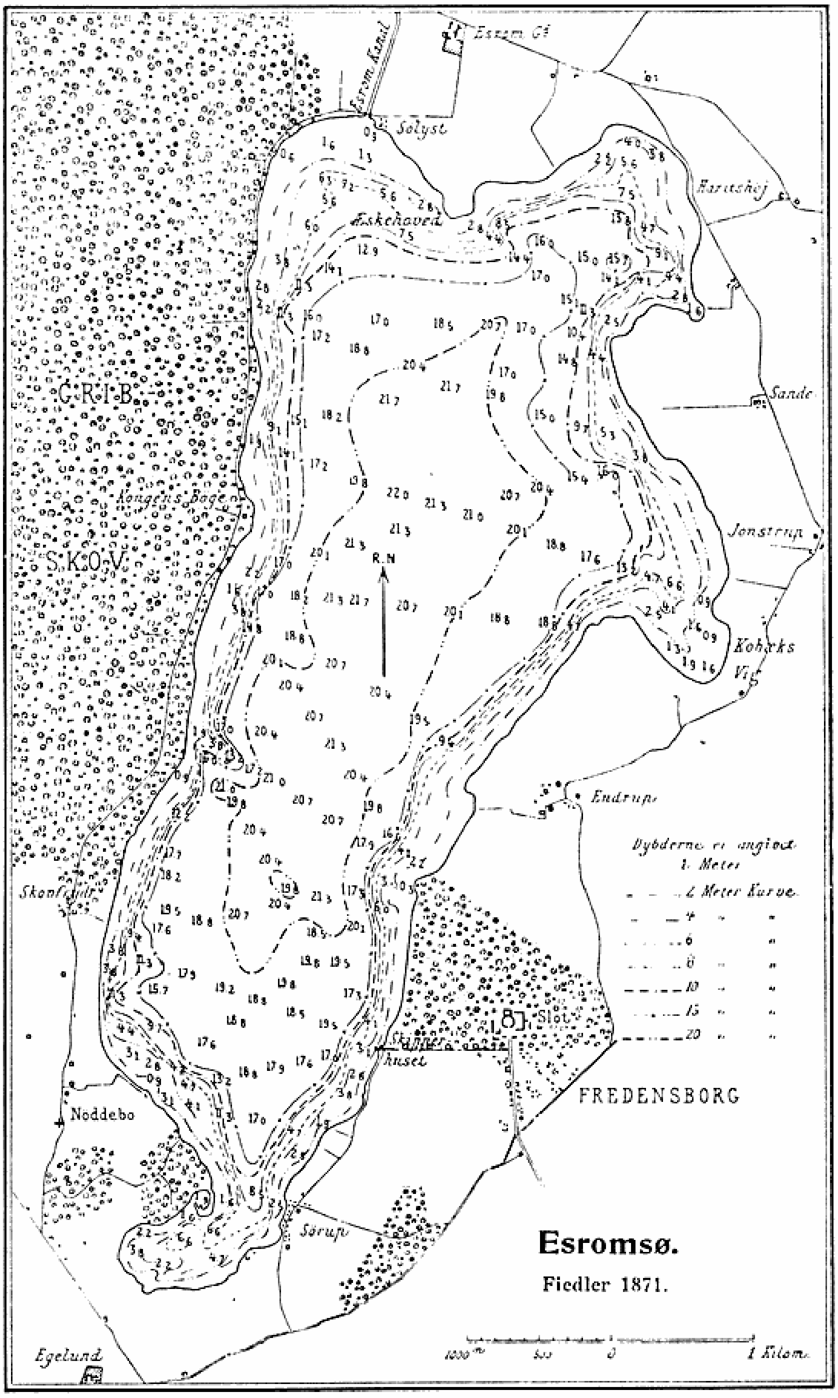

Fig. 1. Chart of Esrum Sø 1871.

lines on maps and charts. The authors already mentioned, D.H. Maling (1977), and H. Kishimoto (1968) deal with this problem at length. Up to recent times the methods of arriving at results in this direction were rather crude and the uncertainty great. Thus all figures given everywhere for the length of rivers and coastlines must be looked at with considerable scepticism. The appearance of digitizing tables can improve the accuracy of these determinations enormously, especially when the type of equipment is used, where intervals of time guides the input of coordinates. The cursor will be moved with variable speed when following very crooked lines in comparison to the straighter parts. So far the author is not aware of any results achieved by such equipment in this context. Ob-

viously, it will also be possible to determine areas by applying such instruments combined with computers. The manipulation of the cursor, however, is very much the same as with the tracer of the planimeter, consequently no great improvement on accuracy is to be expected, but it might be a little bit faster. Unfortunately, there is only a few independent treatises on this subject, in fact the present writer knows of only one, J. R. Rollin (1986), the British Ordnance Survey, Southampton.

Fetch. Another important parameter is the so called effective fetch, which is a determining factor for erosion of the shores, transport, wind generated imbalance in the water level, currents etc.

The median depth is defined as the depth where half the lake area is above it, the other half below. It is best determined on the hypsographic curve.

Sometimes it will be of interest to look at the area of a lake lying below Datum. The lakes where this occurs are easily singled out by comparing the figures for water level and maximum depth, and the maximum depth of the *crypto-depression* can then be deducted. Quite a lot of Danish lakes contain crypto-depressions.

The writer sometimes operates with what he terms the common depth, which is a figure or an interval more subjectively found by studying the chart.

The parameters already mentioned, and many more, e.g. maximum length and width, maximum effective length and width, slope, mean slope, and so on, it has not been found appropriate to calculate in conjunction with this overview paper, they might eventually appear in lake monographs.

Lake Vänern. Håkanson (1978b) relates that as an outcome of the extensive echo-soundings in Lake Vänern (Sweden) 1972-73, which in the first place resulted in a much better bathymetric chart, a new calculation of the water volume ended in a figure 13 cubic kilometers larger than earlier figures, not an insignificant amount of fresh water!

As a comparison the 150 Danish lakes appearing in table 4 together contain 626,555,000 cubic meters or a little more than 0.6 cubic kilometer. If knowledge from W. Halbfass (1922, 1937) and other sources, about the rest of the lakes, is accounted for, one can confidently say that the combined volumes of stagnant fresh water in Denmark do not exceed 2 cubic kilometers.

The name of W. Halbfass shall not be forgotten in this connection since his works were some of the early sources of inspiration to the present writer. The two works referred to were a heroic achievement, although it cannot be denied that at least for the Danish lakes, his figures are not to be used uncritically.

Lake Esrum. A report like the one on Vänern can be made about the Danish lake, Esrum Sø.

The writer was in 1983 in charge of a new survey of Esrum Sø on behalf of Hovedstadsrådet (The Greater Copenhagen Council). The final chart was published in 1:10,000 with 1 meter contours on the basis of echo-sounding tracks, 50 meters apart. A considerably reduced and generalized version is published here, and for comparison the chart, which for more than a hundred years has been the source of knowledge about the lake basin. This chart was provided by district judge H. V. Fiedler, 1871. He was a man who took a great interest in freshwater fisheries. The original was constructed in the scale 1:20,000. A re-drawn and metrified version was published by C. Wesenberg-Lund (1904), and this is the version reproduced here.

On the basis of the old chart Kaj Berg (1938) calculated the water volume to be 212,700,000 m^3. A calculation on the basis of the new chart resulted in a figure for the volume of 233,200,000 m^3, well over 20 million cubic meters more fresh water, nearly as much as the lakes Sorø Sø and Tuel Sø combined. Made out in per cent the increase in volume of fresh water was even larger for Esrum Sø than for Vänern, 9.6 % against 9.3.

In this overview paper it has been possible to publish one chart only. The publishing of charts for the remaining 149 lakes, either full size or reduced as the format directs, in atlas or book form, must wait for a later work, as map sheets they have been issued throughout the years.

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Many others could and should have been mentioned, but for the sake of space I have to thank them all sincerely and, I regret it, anonymously.

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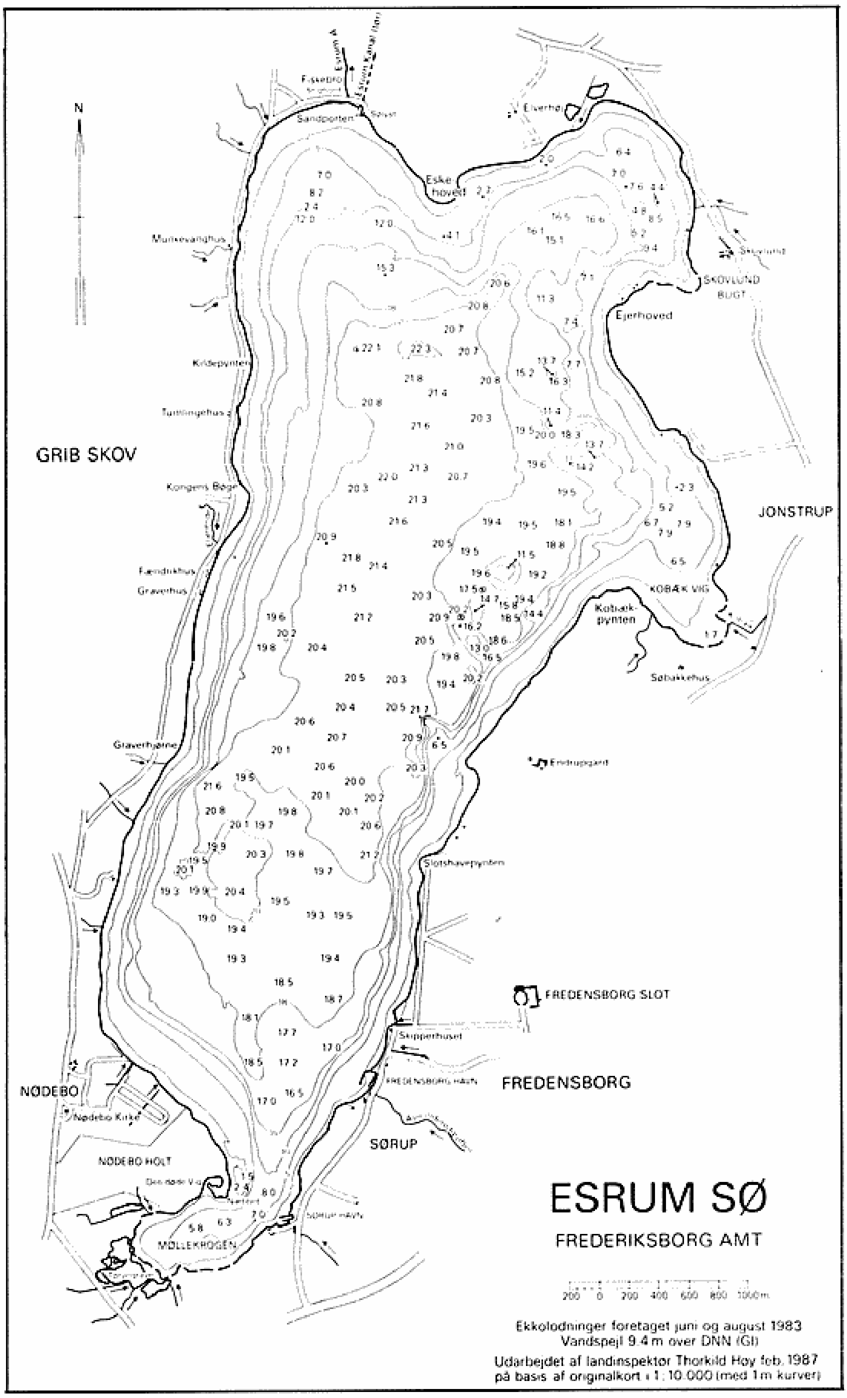

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Table 4.

SJÆLLAND	Year of sounding	Scale	Water level m	Maxi-mum depth m	Mean depth m	Area incl. islands ha	Islands ha	Volume of water 1000 m³
Agersø	1958	1:4000	53,0	6,2	3,3	3,5		116
Agesø	1964	1:2000	-	2,0	1,3	2,8		37
Avnsø	1981	1:4000	69,2	7,6	4,3	4,8		208
Bavelse Sø	1984	1:5000	6,8	8,8	4,6	89,5		4100
Bagsværd Sø	1976	1:5000	18,4	3,2	1,9	121,5	0,2	2335
Bastrup Sø	1976	1:4000	28,7	7,0	3,5	32,4		1140
Bondedam	1982	1:5000	21,0	2,9	1,4	13,1	0,5	183
Borup Sø	1973	1:5000	40,0	1,7	0,9	9,7		90
Bromme Lillesø	1985	1:5000	30,4	2,7	1,5	13,7		210
Bromme Maglesø	1966	1:5000	30,0	3,4	2,2	73,3	0,35	1572
Buesø	1971	1:5000	2,6	6,6	3,6	6,7		244
Buresø	1981	1:5000	26,5	10,8	6,7	76,1		5100
Bøgeholm Sø	1982	1:5000	25,3	1,9	1,1	32,2	1,9	322
Dalby Sø	1973	1:5000	31,3	1,8	1,2	15,2		180
Donse Storedam	1958	1:4000	-	2,9	1,5	20,9	2,2	280
Ejlemade Sø	1984	1:5000	50,5	2,5	1,3	22,1	0,2	280
Esrum Sø	1983	1:10.000	9,4	22,3	13,5	1729		233.200
Farum Sø	1976	1:5000	20,0	14,7	6,3	119,3	0,7	7444
Gjorslev Møllesø	1984	1:5000	9,3	6,6	2,7	23,6	0,35	620
Glumsø Sø	1978	1:5000	10,5	2,1	1,3	25,4		330
Gundsømagle Sø	1981	1:5000	3,9	1,9	1,2	ca.32		ca.375
Gurre Sø (inkl. Slotssøen)	1961-1962	1:5000	26,4	5,4	2,1	236	10,6	4660
Gyrstinge Sø	1985	1:5000	24,3	10,4	4,6	263,2	1,0	12.100
Haraldsted Langesø	1981	1:5000						
Reservoiret			22,0	11,1	4,9	201,5		9850
"Tivolisøen"			21,2	5,1	3,0	28,7		858
Hornbæk Sø	1981	1:5000	4,3	3,6	1,8	11,8		217
Hvidsø	1961	1:5000	59,9	9,2	4,8	5,6		270
Julmose	1958	1:4000	-	4,5	1,9	3,1		60

	Year of sounding	Scale	Water level m	Maxi-mum depth m	Mean depth m	Area incl. islands ha	Islands ha	Volume of water 1000 m³
Jystrup Sø	1986	1:5000	62,9	2,6	1,3	6,1		80
Kattinge-søerne	1967	1:5000						
Store Kattingesø			2,4	6,0	2,5	76,7		1900
Lille "			2,4	1,7	0,5	ca.18		ca. 90
Kimmerslev Sø	1973	1:5000	30,5	6,5	3,6	35,0		1265
Klaresø	1961	1:2000	-	4,0	1,6	3,4		53
Knapsø	1975	1:5000	51,4	1,6	1,1	6,5		70
Kornerup Sø	1970	1:5000	4,0	4,5	2,7	8,3		225
Lyngby Sø	1955/1976	1:4000	18,4	2,8	1,6	59,2	0,5	960
Løgsø	1958	1:4000	49,9	6,4	3,0	5,8	0,02	170
Madesø	1979	1:5000	1,7	5,5	2,3	30,4		708
Maglesø	1958	1:4000	-	5,6	3,2	15,1		480
Mortenstrup Sø	1986	1:5000	64,9	1,7	0,6	9,4		54
Nielstrup Sø	1978	1:5000	48,7	1,1	0,6	13,2		85
Pedersborg Sø	1985	1:5000	33,7	5,7	2,9	14,3		418
Selsø Sø	1981	1:5000	0,1	1,9	0,8	ca.77	2,0	ca.610
Skarresø	1984	1:5000	18,5	4,1	2,6	193,5	1,3	5050
Skjoldenæsholm Gårdsø	1986	1:5000	64,8	3,2	2,2	10,2		220
Skovrød Sø	1958	1:4000	-	1,7	1,0	3,8		37
Snesere Sø	1980	1:4000	36,6	5,2	2,0	7,0		139
Sortesø	1962	1:2000	-	6,0	2,0	3,5		70
Sorø Sø	1984	1:5000	34,7	12,8	5,0	210	0,1	10.400
Store Hulsø	1958	1:4000	18,8	4,3	2,3	2,5		58
Svogerslev Sø	1967	1:5000	2,4	4,4	1,6	23,8		380
Søgård(Luderup)Sø	1978	1:5000	8,2	2,8	1,2	8,8		107
Søndersø(Værløse)	1982	1:5000	12,5	7,8	3,3	125,4		4164
Søtorup Sø	1985	1:5000	56,2	23,0	10,0	68,4		6870
Tuel Sø	1985	1:5000	32,1	18,1	6,7	189,5		12.730
Tystrup Sø	1984	1:5000	6,8	21,7	9,9	662	1,0	65.700
Ulse Sø	1978	1:5000	52,9	20,5	8,8	50,9		4500
Valsølille Sø	1961	1:10.000	57,9	2,2	ca.0,3	ca.98	22,6	ca.260
Vejlesø	1960	1:4000	20,0	6,3	3,4	16,8	0,3	565

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As a comparison the 150 Danish lakes appearing in table 4 together contain 626,555,000 cubic meters or a little more than 0.6 cubic kilometer. If knowledge from W. Halbfass (1922, 1937) and other sources, about the rest of the lakes, is accounted for, one can confidently say that the combined volumes of stagnant fresh water in Denmark do not exceed 2 cubic kilometers.

The name of W. Halbfass shall not be forgotten in this connection since his works were some of the early sources of inspiration to the present writer. The two works referred to were a heroic achievement, although it cannot be denied that at least for the Danish lakes, his figures are not to be used uncritically.

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The writer was in 1983 in charge of a new survey of Esrum Sø on behalf of Hovedstadsrådet (The Greater Copenhagen Council). The final chart was published in 1:10,000 with 1 meter contours on the basis of echo-sounding tracks, 50 meters apart. A considerably reduced and generalized version is published here, and for comparison the chart, which for more than a hundred years has been the source of knowledge about the lake basin. This chart was provided by district judge H. V. Fiedler, 1871. He was a man who took a great interest in freshwater fisheries. The original was constructed in the scale 1:20,000. A re-drawn and metrified version was published by C. Wesenberg-Lund (1904), and this is the version reproduced here.

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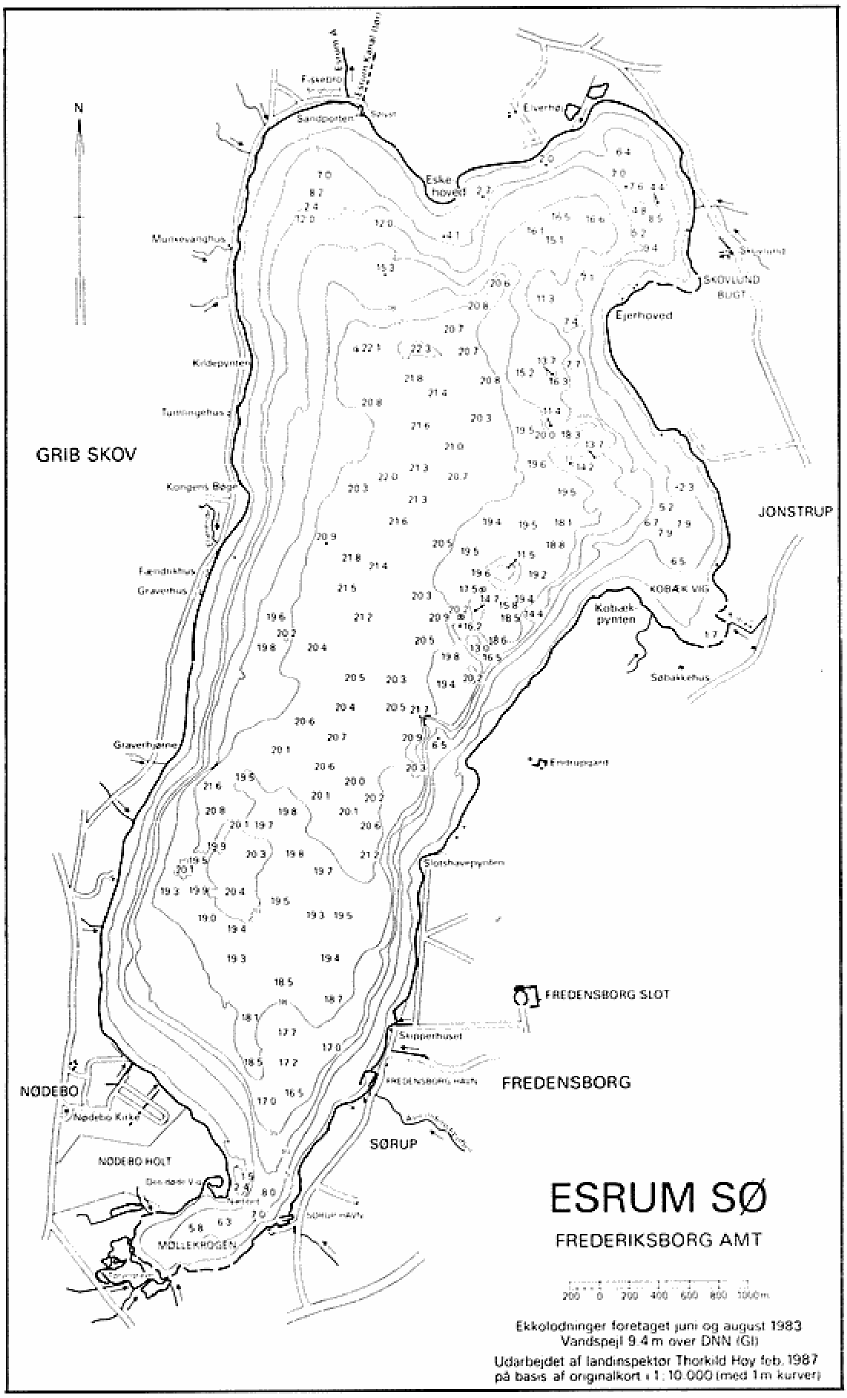

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